AUTOMATED DRIVING AND PRODUCT LIABILITY

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INTRODUCTION 1
WHO CARES? 3
CRASHES, INJURIES, AND FATALITIES 7
CRASH COST 21
PRODUCT FAILURE 27
INDUSTRY LIABILITY 32
CONSUMER COST 57
CONSUMER ADOPTION 64
CONCLUSION 71

INTRODUCTION

Cyberphysical systems—computers that act in and on the physical world—are proliferating rapidly. These systems have the potential to address some of today's dangers, deprivations, and desires, and to create opportunities unimagined. Occasionally, however, they will cause injuries that otherwise would not have occurred. The inevitability of injury invites speculation about how product liability law will address these cases and impact these systems.

In one sense, this is a problem: "a question raised for inquiry, consideration, or solution."[1] It deserves and perhaps demands

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thoughtful analysis. Descriptively, how are the evolving rules of product liability law likely to apply to these systems? Normatively, how should they apply? A problem of this kind is to be initially "solved," if at all, through exploration rather than legislation.

Often, however, the "liability problem" means something different. It is an obstacle to be removed, the object of consternation rather than contemplation.[2] In the case of automated driving systems, liability apparently must be "solved" before these systems can be deployed to the public.[3] On this view, the focus rapidly jumps from understanding the problem to enacting the solution.

Product liability law may pose particular functional challenges for the development and deployment of cyberphysical systems. Likewise, cyberphysical systems may pose particular functional challenges for the operation of product liability law. But neither exists to promote the other. Rather, these challenges should be identified and evaluated with reference to broader societal goals, including safety and welfare.

This Article focuses on one cyberphysical domain—automated driving—to methodically analyze the so-called liability problem. It considers how automated driving could affect product liability, how product liability could affect automated driving, and how each could advance or impede the prevention of injury and the compensation of victims.

The Article concludes that the current product liability regime, while imperfect, is probably compatible with the adoption of automated driving systems. These systems, when introduced, are likely to be substantially safer than human-driven vehicles. Because driving decisions will shift from human drivers to automated systems (and their designers), a larger share of the crashes that nonetheless occur will implicate product liability law. This means that, in comparison to the automotive industry today, the automated driving industry will likely bear a bigger slice of a smaller pie of total crash costs. Under conservative assumptions, these costs are large—but not extraordinarily so.

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1. *Problem*, MERRIAM-WEBSTER (2016), http://www.merriam-webster.com/dictionary/problem [https://perma.cc/B7KG-WCB6] (last visited Nov. 16, 2016); *cf.* Robert D. Hursh, *The Products Liability Problem*, 27 J. MARKETING 9 (1963).

2. *See Problem*, *supra* note 1 ("a source of perplexity, distress, or vexation").

3. *See, e.g.*, AUTONOMOUS VEHICLES, NAVIGANT RESEARCH (2013), https://www.navigantresearch.com/wp-content/uploads/2013/08/ASDV-13-Brochure.pdf [https://perma.cc/5NRX-ADJH].

Introducing automated driving as a service rather than as a product may be a more effective way of passing these costs to the motorists who, along with victims and the broader public, already pay for the costs of crashes today. Service models such as driverless taxis and delivery robots would help consumers avoid paying large upfront costs and would provide manufacturers with a flexible revenue stream that could help them better manage inevitable uncertainty about their liability exposure.

This analysis is a sketch to be critiqued and completed. It relies heavily on numbers that are imprecise and assumptions that are arbitrary. The results are presented with a minimum of significant digits and should be viewed as order-of-magnitude estimates. Experts from other domains and with access to other (likely proprietary) data can play an important role in refining these estimates. In short, the Article does not claim to be definitive, but it does try to be deliberate.

WHO CARES?

Many people seem to care about the question of liability in the context of automated driving. It is the subject of countless news articles,[4] multiple academic articles,[5] and at least two publicly funded reports.[6] The question of "who is liable" is frequently posed at public events, though more recently it has been eclipsed somewhat by ruminations on runaway trolleys.[7]

The public focus on liability may reflect some combination of fear and fascination. Perhaps those who wonder about it are essentially asking how law can bring order to an uncertain future; or perhaps liability is an indirect way of talking about death and destruction—a respectable veneer on an evolutionarily useful preoccupation with the macabre. Such speculation runs beyond this Article.

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4. *See, e.g.*, GOOGLE.COM, https://www.google.com/#q=autonomous+cars+liability [https://perma.cc/B5XJ-LL59] (last visited Nov. 16, 2016) (search "autonomous cars liability").

5. *See infra* notes 120, 146, 213, 214, 246, 280.

6. *See infra* notes 17, 293.

7. Unfortunately. *See* Bryant Walker Smith, *Slow Down That Runaway Ethical Trolley*, CTR. INTERNET & SOC'Y (Jan. 12, 2015, 3:42 PM), https://cyberlaw.stanford.edu/blog/2015/01/slow-down-runaway-ethical-trolley [https://perma.cc/CRU8-U73N]; Bryant Walker Smith, *The Trolley and the Pinto: Cost-Benefit Analysis in Automated Driving and Other Cyberphysical Systems*, TEX. A&M L. REV. (forthcoming 2017).

But who *should* care—and why? Developers and manufacturers of automated driving systems should care because they will be defendants in injury cases. The lawyers who will litigate these cases should also care. Liability should also matter to people who will actually be harmed in automated driving crashes and to people who could be injured in crashes of any kind. This last statement tracks two principal goals of civil liability: compensation and safety.[8]

These goals are common to both vehicular negligence and product liability. As used in this Article, vehicular negligence refers primarily to personal injury claims against individual motorists or their principals, while product liability includes claims against companies that allegedly made or sold a defective product.[9] This Article focuses on the shift from a compensation regime for conventional driving that is largely premised on vehicular negligence[10] to a compensation regime for automated driving that increasingly implicates product liability.

The compensatory function of product liability is intended to make victims of product defects whole again by returning them to the condition they were in before the relevant injuries. Similarly, tort law's compensatory function is intended to restore victims of wrongful acts more generally, including negligent driving. As explored below, crashes can impose tremendous costs on those who are injured in them. Shifting from a regime premised on vehicular negligence to one premised on product liability will advance this compensatory function if and only if that shift makes more of these costs recoverable.

The safety function of product liability is intended to incentivize manufacturers and consumers to take reasonable safety precautions. Ideally, product liability will deter manufacturers from selling products that are not reasonably safe without deterring these manufacturers from selling useful products that are reasonably safe.[11]

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8. *See* John C.P. Goldberg & Benjamin C. Zipursky, *The Easy Case for Products Liability Law: A Response to Professors Polinsky and Shavell*, 123 HARV. L. REV. 1919, 1919 (2010); Richard W. Wright, *The Principles of Product Liability*, *in Symposium, Products Liability: Litigation Trends on the 10th Anniversary of the Third Restatement*, 26 REV. LITIG. 1067, 1067 (2007).

9. *See infra* notes 11-14. Product liability can encompass other claims as well.

10. This also includes states with no-fault crash regimes.

11. *See* Goldberg & Zipursky, *supra* note 8, at 1919. *But see* Richard C. Ausness, *"Danger Is My Business": The Right to Manufacture Unsafe Products*, 67

The regime's actual impacts on safety and innovation, unfortunately, are unclear and contested.[12] In simplistic terms, some may view product liability as a potential impediment to the development and adoption of automated driving systems that could save lives, while others may view product liability as a tool to ensure that these systems are responsibly deployed and continually improved. On either view, product liability's impacts result from a combination of exposure to liability and uncertainty about the extent of that exposure.[13]

Liability exposure refers to the actual product liability costs that a company will incur. In theory, if a manufacturer can confidently predict these costs, then it can pass them onto its customers through the prices that it charges. The same is true for the insurer to which that manufacturer may turn. In this way, product liability helps to internalize some of the costs of injuries. Between two otherwise identical products, the safer one should be less expensive and hence more attractive to buyers.

Differences between vehicular negligence and product liability could distort the relative economics of automated driving and conventional driving.[14] Imagine that a conventional vehicle and a vehicle with an automated driving system cost the same to actually manufacture and market. Further assume, subject to the discussion below,[15] that the manufacturer's liability exposure is greater for the vehicle with the automated driving system than for the one without. In that case, the more advanced vehicle will cost more upfront, even if it is substantially safer.

In this example, the higher purchase price of the vehicle with the automated driving system might theoretically be offset by increased safety, especially as reflected by lower automotive insurance premiums. However, a purchaser may not compare the overall cost of ownership. Moreover, to the extent that more crash

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ARK. L. REV. 827, 827 (2014) (explaining how and why product liability law sometimes tolerates unsafe products).

12. *See, e.g.*, THE LIABILITY MAZE: THE IMPACT OF LIABILITY LAW ON SAFETY AND INNOVATION (Peter W. Huber & Robert E. Litan eds., 1991).

13. *Cf.* Mark A. Geistfeld, *Legal Ambiguity, Liability Insurance, and Tort Reform*, 60 DEPAUL L. REV. 539, 540-41 (2011) (discussing "Frank Knight's renowned distinction between 'risk' and 'uncertainty'").

14. *See infra* notes 118-19, 186-90, 278-83.

15. *See infra* Figure 9.

costs are internalized under product liability than under vehicular negligence,[16] the conventional vehicle may still appear to be cheaper.

In short, liability exposure could conceivably lead to higher prices for automated driving systems, which could lead to slower adoption of these systems, which could lead to crash injuries that could have been prevented by these systems.

In contrast to exposure, liability uncertainty refers to lack of confidence about the actual product liability costs that a company will incur. If an automated driving developer is unable to confidently predict its liability costs, it may either delay deployment of its system or conservatively price that system to account for the possibility of high liability costs. Similarly, insurers may decline to cover that developer or the would-be buyers of its system, or they may demand higher premiums to do so.

In those cases, liability uncertainty could lead to slower deployment of or higher prices for automated driving systems, which could lead to slower adoption of these systems, which could lead to crash injuries that could have been prevented by these systems.

These scenarios are possibilities, not predictions. The majority of this Article develops a foundation for evaluating these possibilities by examining the relationship of both automated and conventional driving to (1) crashes, injuries, and fatalities; (2) the societal cost of crashes; (3) the technical failure of vehicles and their components; (4) the product liability of developers, manufacturers, and operators; and (5) the availability and adoption of products and services.

One prominent simplifying assumption throughout this analysis requires upfront explanation. Many of the numbers that follow stipulate or assume 100% automated driving across all vehicles and all trips. This assumption is pure fantasy. However, this assumption facilitates straightforward comparison with current driving statistics without distorting those comparisons. The National Highway Traffic Safety Administration's (NHTSA) analysis of the safety benefits of vehicle-to-vehicle communication likewise assumed universal adoption.[17]

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16. *See infra* notes 111-15 (low minimum requirements for third-party liability insurance); *see also* Bryant Walker Smith, *How Governments Can Promote Automated Driving*, 46 N.M. L. REV. (forthcoming 2016), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2749375 [https://perma.cc/7D59-V9FB] (discussing strategies to internalize the costs of travel).

17. JOHN HARDING ET AL., NHTSA., DOT HS 812 014, VEHICLE-TO-VEHICLE COMMUNICATIONS: READINESS OF V2V TECHNOLOGY FOR APPLICATION, at

In reality, there are multiple pathways to fully automated driving, including advanced driver assistance systems that assume an increasing share of the driving task, automated emergency intervention systems that intervene in increasingly assertive ways, and truly driverless systems that operate in increasingly challenging environments.[18] Each of these systems will need to interact with human drivers, bicyclists, pedestrians, and other conventional road users. These interactions may be especially challenging, and the crashes that result from them will raise particular questions within product liability law.[19]

CRASHES, INJURIES, AND FATALITIES

> Two Bay Area families suffered a devastating loss after two mothers and their four children were killed in a fiery minivan accident on Interstate 5 near the community of Gorman in Los Angeles Tuesday morning. Officials had to hold back two hysterical fathers from the flames as they tried to rescue their family. ABC7 News learned the children were ages 2, 3, 4 and 5 years old. The minivan was partially in the right-hand lane after a minor wreck on Interstate 5 near the community of Gorman, about 65 miles north of downtown Los Angeles. A semi-truck going about 55 mph slammed into the van from behind, sending it off the road and down an embankment, where it quickly caught fire, CHP Officer Frank Romero said. The two fathers, who were in the driver's and passenger seats at the time of the crash, suffered burns trying to save their wives and four children, Romero said.[20]

This is a recent crash report selected at random. There are many more like it because some 35,000 people die on U.S. roads every year.[21] This is roughly one hundred deaths every day and, as many others have observed, equivalent to two large commercial airplanes colliding every week.[22] Motor vehicle crashes are a leading

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xiv (2014), http://www.nhtsa.gov/staticfiles/rulemaking/pdf/V2V/Readiness-of-V2V-Technology-for-Application-812014.pdf.

18. Walker Smith, *supra* note 16.

19. *See infra* notes 213-15 and accompanying text.

20. Katie Marzullo, *2 Bay Area Mothers, 4 Kids Killed in Fiery Los Angeles Crash*, ABC 7 NEWS (June 29, 2016), http://abc7news.com/news/2-bay-area-mothers-4-kids-killed-in-fiery-la-crash/1404831/ [https://perma.cc/69WZ-YAKQ].

21. NAT'L CTR. FOR STATS. & ANALYSIS, NHTSA, DOT HS 812 269, EARLY ESTIMATE OF MOTOR VEHICLE TRAFFIC FATALITIES IN 2014 (2015), https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812160 [https://perma.cc/3PRS-XE27] [hereinafter 2014 TRAFFIC FATALITIES].

22. For reference, a common commercial airplane, the Boeing 747-8, carries a maximum of roughly 467 passengers. *See* BOEING, 747-8 AIRPLANE CHARACTERISTICS FOR AIRPORT PLANNING 13 (2012), http://www.boeing.com/assets/

cause of death by injury, and for Americans between fifteen and twenty-four, *the* leading cause of death.[23] More than 15% of those killed in crashes are bicyclists and pedestrians.[24]

Fatalities are just one measure of the destruction on U.S. roads.[25] Crashes also injure nearly four million Americans every year.[26] Approximately six million crashes are reported to the police every year,[27] and at least as many less severe crashes likely go unreported.[28]

At the same time, roadways are significantly safer than in the past. In the late 1960s and early 1970s, crashes annually claimed more than 50,000 lives[29] even though Americans were cumulatively driving less than half the three *trillion* miles that they currently travel each year.[30] Fatalities have declined from this peak both in absolute

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pdf/commercial/airports/acaps/747_8.pdf [https://perma.cc/CZ2Y-PTEN] (last visited Nov. 16, 2016).

23. Motor vehicle crashes account for nearly a quarter of fatalities in this age group—more than suicide, homicide, poisoning, or any single medical condition. *See* CTR. FOR DISEASE CONTROL & PREVENTION, TEN LEADING CAUSES OF DEATH AND INJURY, http://www.cdc.gov/injury/wisqars/leadingcauses.html [https://perma.cc/6Z4E-T2CQ] (last updated Feb. 25, 2016) [hereinafter CDC TEN LEADING CAUSES]; Jiaquan Xu et al., *Deaths: Final Data for 2013*, 64 NAT'L VITAL STATS. REPS. 1, 84-85 (2016), http://www.cdc.gov/nchs/data/nvsr/nvsr64/nvsr64_02.pdf [https://perma.cc/MYC3-K32Y] (last visited Nov 16, 2016).

24. NAT'L CTR. FOR STATS. & ANALYSIS, NHTSA, DOT HS 812 270, TRAFFIC SAFETY FACTS, 2014 DATA: PEDESTRIANS 1 (2016), https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812270 [https://perma.cc/LLC9-YHQZ]; NAT'L CTR. FOR STATS. & ANALYSIS, NHTSA, DOT HS 812 151, TRAFFIC SAFETY FACTS, 2013 DATA: BICYCLISTS AND OTHER CYCLISTS 1 (2015), https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812151 [https://perma.cc/YN6M-94EX].

25. There is also a difference between fatal crashes and crash fatalities, since a single crash may involve multiple fatalities. Similarly, injury crashes can—and often do—involve more than one injury. For simplicity, this Article generally references fatalities and injuries as well as police-reported crashes.

26. LAWRENCE J. BLINCOE ET AL., NHTSA, DOT HS 812 013, THE ECONOMIC AND SOCIETAL IMPACT OF MOTOR VEHICLE CRASHES, 2010 (REVISED), at 1 (2015), http://www-nrd.nhtsa.dot.gov/Pubs/812013.pdf [https://perma.cc/MN4X-FCQC].

27. *Id.* at 13.

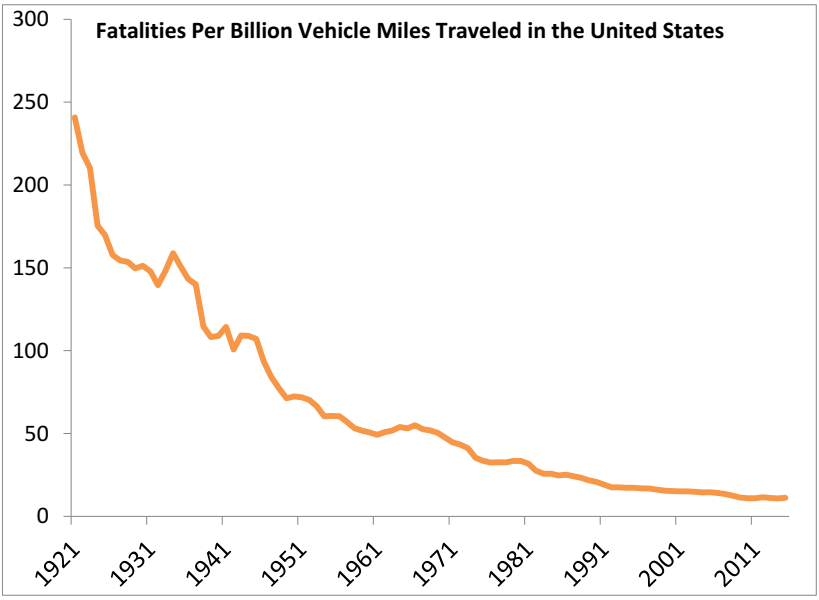
28. *Id.*

29. ANCESTRY.COM, MOTOR VEHICLE TRAFFIC FATALITIES & FATALITY RATE: 1899-2003, http://www.rootsweb.ancestry.com/~pawashin/military/TrafficFatalities_1899-2003.pdf [https://perma.cc/M8D7-7ZK3] (last visited Nov. 16, 2016) [hereinafter TRAFFIC FATALITIES].

30. FED. HIGHWAY ADMIN., TRAVEL MONITORING ANALYSIS SYSTEM (TMAS) HISTORICAL VMT REPORT (2012), http://www.fhwa.dot.gov/policyinformation/travel/tvt/history/historicvmt.pdf [https://perma.cc/PK33-4NGJ] [hereinafter HISTORICAL VMT REPORT].

terms and much more dramatically relative to vehicle miles traveled. Figure 1 shows this relative change.[31]

Figure 1



A focus on fatalities, however, can obscure as much as it can reveal. An annual fatality count does not indicate whether, in comparison to years past, a vehicle today is less likely to crash (or crash severely), the individuals involved are less likely to sustain injuries, or those injuries are less likely to be fatal—and, if so, why. More recent data on nonfatal crashes, while far from precise or consistent, suggest some combination of these factors. Figure 1, for example, shows the declines in rates of fatalities, injuries, and police-reported crashes[32] relative to 1994.

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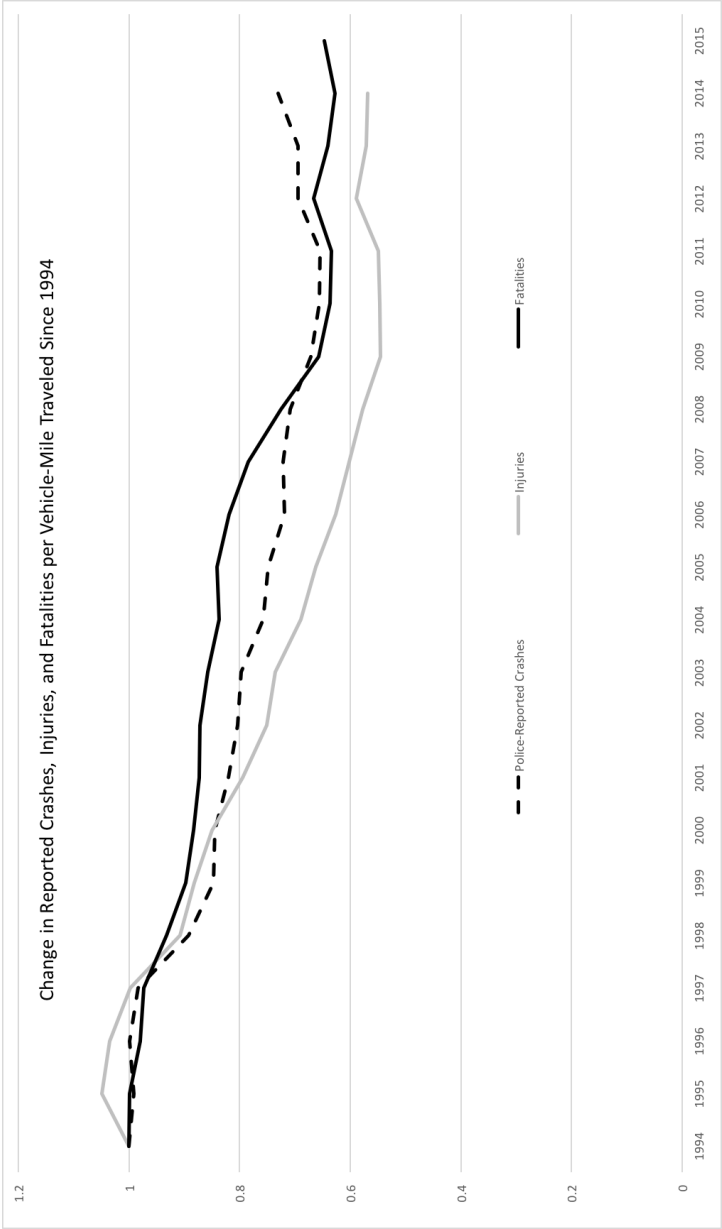
31. TRAFFIC FATALITIES, *supra* note 29; HISTORICAL VMT REPORT, *supra* note 30.

32. While not shown on this graph, the rate of fatal crashes has decreased more slowly than the rate of fatalities, and the rate of injury crashes has likewise decreased more slowly than the rate of injuries. *See supra* note 25; NAT'L CTR. FOR STATISTICS & ANALYSIS, NHTSA, DOT HS 812 246, 2014 MOTOR VEHICLE CRASHES: OVERVIEW 2 (2016), https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812246 [https://perma.cc/SGL9-V7DM] (comparing the decreasing rate of injuries to that of fatalities over the past 20 years).

Figure 2


Change in Reported Crashes, Injuries, and Fatalities per Vehicle-Mile Traveled Since 1994
1.2
1
0.8
0.6
0.4
0.2
0
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Police-Reported Crashes
Injuries
Fatalities

Historically, improvements in vehicle design have reduced the rates of some kinds of crashes and increased the survivability of the crashes that nonetheless occur.[33] About a dozen automotive safety features covered by the Federal Motor Vehicle Safety Standards—including seatbelts, air bags, and energy-absorbing steering assemblies—are estimated to have saved nearly 28,000 lives in 2012 alone.[34]

Unfortunately, the current model of individual vehicle ownership means that new technologies can take decades to be prevalent in the nationwide fleet.[35] The average age of a motor vehicle is about eleven years.[36] If this ownership model persists, then electronic stability control, for example, will be in less than 90% of registered vehicles until the late 2020s.[37] This technology saved over 1,000 lives in 2012[38] even though it was then on less than half of all registered vehicles.[39]

Seatbelts are an earlier success story involving both vehicle design and occupant behavior. Three-point seatbelts were introduced into the United States by Volvo in the early 1960s[40] and are now used by nearly nine out of ten drivers nationwide (with substantial

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33. *See, e.g.*, CHARLES J. KAHANE, NHTSA, DOT HS 812 069, LIVES SAVED BY VEHICLE SAFETY TECHNOLOGIES AND ASSOCIATED FEDERAL MOTOR VEHICLE SAFETY STANDARDS, 1960 TO 2012: PASSENGER CARS AND LTVS (2015), https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812069 [https://perma.cc/UJ24-55N8].

34. *Id.* at 227.

35. *See* ADRIAN LUND, INS. INST. FOR HIGHWAY SAFETY, HIGHWAY SAFETY: PAST, PRESENT AND FUTURE 53-54 (2016), http://www.iihs.org/media/e79d686a-514d-4671-84c4-a946200a295b/-1172843725/Presentations/2016_04_03%20LifesaversLund_FULLtimeline.pdf [https://perma.cc/JPJ3-CE59].

36. U.S. DEP'T OF TRANSP., TABLE 1-26: AVERAGE AGE OF AUTOMOBILES AND TRUCKS IN OPERATION IN THE UNITED STATES (2016), http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/html/table_01_26.html_mfd [https://perma.cc/VRG4-Y3AA].

37. *See* LUND, *supra* note 35, at 53-54.

38. NAT'L CTR. FOR STATISTICS & ANALYSIS, NHTSA, DOT HS 812 042, ESTIMATING LIVES SAVED BY ELECTRONIC STABILITY CONTROL, 2008-2012, at 3 (2014), https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812042 [https://perma.cc/ RF3Z-PNNC].

39. *See* LUND, *supra* note 35, at 54.

40. Michelle Krebs, *The Man Who Buckled Up the World*, N.Y. TIMES, (Jan. 24, 1999), http://www.nytimes.com/1999/01/24/automobiles/the-man-who-buckled-up-the-world.html [https://perma.cc/6YH3-4H7N].

variation among the states).[41] In 2014, unrestrained occupants accounted for only 13% of travelers[42] but nearly 50% of fatalities.[43] In other words, wearing a seatbelt is one of the best ways to survive a crash.

Driver behavior remains the most significant determinant of whether a crash actually occurs.[44] (This fact, unfortunately, is often lost in news about the latest vehicle defects.)[45] Driver error plays a role in some 94% of motor vehicle crashes today.[46] These errors include inattention, distraction, inadequate surveillance, excessive speed, incorrect assumptions, misjudgments, illegal maneuvers, overcompensation, poor directional control, and simply falling asleep.[47] Three overlapping factors—alcohol impairment, speeding, and driver distraction—are particularly noteworthy.

In 2014, 31% of roadway fatalities involved alcohol impairment.[48] In contrast, a roadside survey conducted by NHTSA detected illegal levels of alcohol on the breath of 0.4% of drivers during weekday daytime hours and 1.5% of drivers during weekend

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41. *See* YUAN YAN CHEN, NHTSA, DOT HS 812 149, SEAT BELT USE IN 2014—USE RATES IN THE STATES AND TERRITORIES (2015), https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812149 [https://perma.cc/3BVX-W7AV].

42. *Id.*

43. 2014 MOTOR VEHICLE CRASHES, *supra* note 32, at 3-4. In 2007, when average usage was 82%, about 5,000 people died because they were not properly belted. CHEN, *supra* note 41, at 2; *see also* NHTSA, DOT HS 811 105, LIVES SAVED FAQS 13 (2009), https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/811105 [https://perma.cc/47L6-2TN3].

44. *See* SANTOKH SINGH, NHTSA, DOT HS 812 115, CRITICAL REASONS FOR CRASHES INVESTIGATED IN THE NATIONAL MOTOR VEHICLE CRASH CAUSATION SURVEY 1 (2015), http://www-nrd.nhtsa.dot.gov/pubs/812115.pdf [https://perma.cc/28J3-J8CD].

45. *Cf.* NHTSA, DOT HS 808 795, MOTOR VEHICLE SAFETY DEFECTS AND RECALLS: WHAT EVERY VEHICLE OWNER SHOULD KNOW (2011), http://www-odi.nhtsa.dot.gov/recalls/recallprocess.cfm [https://perma.cc/7AQQ-Q9PY] ("In 2009, approximately 30,000 lives were lost on our Nation's highways. . . . Clearly, there is a need for dramatic improvement in motor vehicle safety. Getting unsafe vehicles off the road is integral to improving safety and saving lives.").

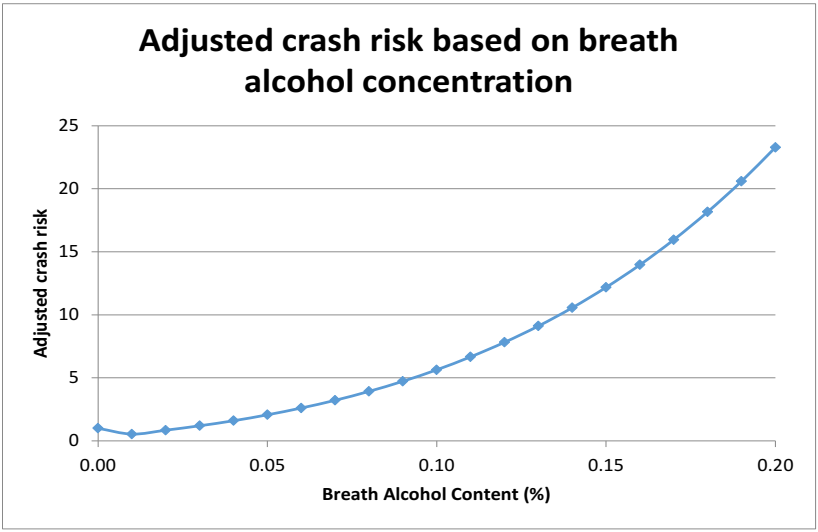
46. SINGH, *supra* note 44, at 1; *see also* Bryant Walker Smith, *Human Error as a Cause of Vehicle Crashes*, CTR. INTERNET & SOC'Y (Dec. 18, 2013, 3:15 PM), https://cyberlaw.stanford.edu/blog/2013/12/human-error-cause-vehicle-crashes [https://perma.cc/6H7Y-XR7P].

47. *See* SINGH, *supra* note 44, at 2.

48. NHTSA, DOT HS 812 219, 2014 CRASH DATA KEY FINDINGS (2015), https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812219 [https://perma.cc/FXL7-TB8M] [hereinafter 2014 CRASH KEY FINDINGS].

nighttime hours.[49] (Approximately 15% of drivers declined to provide breath samples.)[50] As Figure 3 shows, higher alcohol levels are associated (except at very low levels) with significantly higher crash probabilities.[51] A driver at the legal limit of 0.08% is nearly four times more likely to crash than a driver with no detectable alcohol, and a driver at twice the legal limit is nearly fourteen times more likely to crash.

Figure 3



49. AMY BERNING, RICHARD COMPTON & KATHRYN WOCHINGER, NHTSA, DOT HS 812 118, RESULTS OF THE 2013-2014 NATIONAL ROADSIDE SURVEY OF ALCOHOL AND DRUG USE BY DRIVERS 1-2 (2015), http://www.nhtsa.gov/staticfiles/nti/pdf/812118-Roadside_Survey_2014.pdf [https://perma.cc/7AJ4-CGY6]. This apparently represents a significant decline from previous decades. *Id.*

50. *Id.* at 4. For more discussion of drivers avoiding the test site or refusing to be tested, see Robert B. Voas et al., *Drinking and Driving in the United States: The 1996 National Roadside Survey*, 30 ACCIDENT ANALYSIS & PREVENTION 267, 267 (1998) (explaining the methodologies of earlier surveys).

51. *See* RICHARD P. COMPTON & AMY BERNING, NHTSA, DOT HS 812 117, DRUG AND ALCOHOL CRASH RISK 6 (2015), http://www.nhtsa.gov/staticfiles/nti/pdf/812117-Drug_and_Alcohol_Crash_Risk.pdf [https://perma.cc/K6K7-C836] (using data to create Figure 3).

Speeding likely played a role in at least 28% of roadway fatalities.[52] "NHTSA considers a crash to be speeding-related if the driver was charged with a speeding-related offense or if an officer indicated that racing, driving too fast for conditions, or exceeding the posted speed limit was a contributing factor in the crash."[53] Speeding is routine,[54] and while it may be merely incidental to some crashes, it probably plays an unacknowledged role in far more. Regardless, higher speed is both theoretically and empirically associated with more severe injury in those crashes that do occur.[55]

Driver distraction was present in 10% of roadway fatalities.[56] Distraction associated with electronic devices is of rising concern.[57] Preliminary roadway fatality data for 2015 suggest that fatalities increased by approximately 7% over 2014, which is more than twice the rate at which vehicle miles traveled increased.[58] Notably, as

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52. 2014 CRASH KEY FINDINGS, *supra* note 48, at 1. *See also* NHTSA, DOT HS 812 021, SPEEDING: 2012 DATA 1, 4 (2014), https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812021 [hereinafter 2012 SPEEDING].

53. 2012 SPEEDING, *supra* note 52, at 1.

54. *See* KAY FITZPATRICK ET AL., NAT'L COOP. HIGHWAY RESEARCH PROGRAM, NCHRP REPORT 504, DESIGN SPEED, OPERATING SPEED, AND POSTED SPEED PRACTICES 82 (2003), http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_504.pdf [https://perma.cc/L2F9-F6DC]; PAUL SCHROEDER, LIDIA KOSTYNIUK & MARY MACK, NHTSA, DOT HS 811 865, 2011 NATIONAL SURVEY OF SPEEDING ATTITUDES AND BEHAVIORS 39 (2013), http://www.nhtsa.gov/staticfiles/communications/pdf/2011_N_Survey_of_Speeding_Attitudes_and_Behaviors_811865.pdf [https://perma.cc/D7AH-ZA89]; *see also* Bryant Walker Smith, *Lawyers and Engineers Should Speak the Same Robot Language*, *in* ROBOT LAW 78, 93 (Ryan Calo, A. Michael Froomkin & Ian Kerr eds., 2016).

55. *See, e.g.*, Chris Jurewicz et al., *Exploration of Vehicle Impact Speed—Injury Severity Relationships for Application in Safer Road Design*, 14 TRANSP. RESEARCH PROCEDIA 4247, 4248 (2016); Colleen Peterson et al., *Addressing Key Concerns Regarding Automated Speed Enforcement via Interactive Survey* (forthcoming 2017) (describing the dangers of speeding); DAVID RICHARDS & RICHARD CUERDEN, DEPT. FOR TRANSP.: LONDON, ROAD SAFETY WEB PUBLICATION NO. 9: THE RELATIONSHIP BETWEEN SPEED AND CAR DRIVER INJURY SEVERITY 9 (2009), http://webarchive.nationalarchives.gov.uk/20090417002224/http:/www.dft.gov.uk/pgr/roadsafety/research/rsrr/theme5/rsrr9.pdf [https://perma.cc/6HGM-WWCQ]; DAVID C. RICHARDS, DEPT. OF TRANSP.: LONDON, ROAD SAFETY WEB PUBLICATION NO. 16, RELATIONSHIP BETWEEN SPEED AND RISK OF FATAL INJURY: PEDESTRIANS AND CAR OCCUPANTS 10 (2010), http://nacto.org/docs/usdg/relationship_between_speed_risk_fatal_injury_pedestrians_and_car_occupants_richards.pdf [https://perma.cc/EP4N-V7MP].

56. 2014 CRASH KEY FINDINGS, *supra* note 48, at 1.

57. DISTRACTION.GOV, http://www.distraction.gov/ [https://perma.cc/2YLD-FDH7] (last visited Nov. 16, 2016).

58. 2014 TRAFFIC FATALITIES, *supra* note 21, at 1.

shown in Figure 2 above, the rate of police-reported crashes began trending upward sooner than fatalities and injuries, which would be consistent with riskier driving in safer vehicles.

These factors, and others, are important to understanding the future of roadway safety, for which automated driving holds tremendous promise. When automated driving systems are eventually deployed, they are likely to be significantly safer than conventional vehicles for at least five reasons.

The first reason is practical: Safer performance is likely to be a social if not a legal prerequisite to market introduction. In informal comments, NHTSA's administrator has suggested that automated driving should be at least twice as safe as conventional driving.[59] The U.S. Secretary of Transportation, in the context of emphasizing safety, has cited a prediction that automated driving could reduce fatalities by 80%.[60] If these sentiments reflect the eventual expectations of regulators, developers, and consumers, then automated driving will not be a commercial reality unless and until it is in fact safer than conventional driving. (This, of course, does not mean that an automated driving system is safer merely because it has been introduced.)

Second, there is hope that automated driving systems will reduce crash rates by reducing the opportunity for and impact of driver error (more than they increase the opportunity for and impact of other kinds of error such as component malfunction). Automated driving systems may avoid many of the errors, described above, that contribute to some 94% of crashes.[61] At a minimum, they will not be literally drunk. Moreover, they are unlikely to operate at unreasonably high speeds (even if they exceed posted speed limits under some circumstances).

Third, the combination of remote data collection and over-the-air software updates will allow developers to quickly identify and correct some kinds of performance issues. Today's drivers are largely unable to share the situational expertise and locational

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59. Keith Naughton, *Regulator Says Self-Driving Cars Must Be Twice as Safe*, BLOOMBERG (June 8, 2016, 12:00 PM), https://www.bloomberg.com/news/articles/2016-06-08/u-s-auto-regulator-says-self-driving-cars-must-be-twice-as-safe [https://perma.cc/4HMH-99B4] (I moderated this panel).

60. Pete Bigelow, *Anthony Foxx: Coolness Aside, Self-Driving Focus Should Be on Safety*, CAR & DRIVER (July 20, 2016, 10:00 AM), http://blog.caranddriver.com/anthony-foxx-coolness-aside-self-driving-focus-should-be-on-safety [https://perma.cc/5727-TXJ8].

61. *See* SINGH, *supra* note 44, at 1.

knowledge that they develop. In contrast, the automated driving systems deployed by a particular developer will act less like 200 million individual drivers and more like a single driver.[62] Vehicle recalls today, which typically involve driving to a repair shop, generally achieve only a 75% completion rate.[63] In contrast, many over-the-air software updates are likely to be fast and universal.

Fourth, vehicles with automated driving systems are likely to be operated either in fleets or with the ongoing involvement of their developers.[64] Consistently maintaining and regularly replacing these vehicles could improve the overall safety performance.[65]

Fifth, automated driving systems may be designed in ways that reduce the severity of crashes that nonetheless occur. Slower speeds mean less crash energy. In addition, at least two automated driving developers have suggested informally in conversations with me that their systems will operate only if every vehicle occupant is wearing a seatbelt. As the numbers above suggest, making seatbelt use a condition of operation could improve crash survival.[66]

Projections of these potential safety benefits are still preliminary.[67] One analysis estimated that a combination of just

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62. U.S. DEP'T OF TRANSP., OUR NATION'S HIGHWAYS 2011 25-36 (2010), https://www.fhwa.dot.gov/policyinformation/pubs/hf/pl11028/onh2011.pdf [https://perma.cc/9W4M-AZZM].

63. *New Survey Identifies Factors Influencing Recall Completion Rate*, ALLIANCE OF AUTO. MFRS. (Oct. 7, 2015), http://www.autoalliance.org/index.cfm?objectid=FADB8130-6D32-11E5-997E000C296BA163 [https://perma.cc/JZQ5-8JRZ].

64. *See, e.g.*, Rob Matheson, *Startup Bringing Driverless Taxi Service to Singapore*, MIT NEWS (Mar. 24, 2016), https://news.mit.edu/2016/startup-nutonomy-driverless-taxi-service-singapore-0324 [https://perma.cc/U4A9-2BEY]; *see also infra* discussion at notes 280-90 (discussing service models).

65. NHTSA, DOT HS 811 825, HOW VEHICLE AGE AND MODEL YEAR RELATE TO DRIVER INJURY SEVERITY IN FATAL CRASHES 2 (2013), https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/811825 [https://perma.cc/UP6H-U2AL].

66. *See supra* note 43 and accompanying text.

67. *Cf., e.g.*, MYRA BLANCO ET AL., VA. TECH TRANSP. INST., AUTOMATED VEHICLE CRASH RATE COMPARISON USING NATURALISTIC DATA 1, 72 (2016), http://www.vtti.vt.edu/PDFs/Automated%20Vehicle%20Crash%20Rate%20Comparison%20Using%20Naturalistic%20Data_Final%20Report_20160107.pdf [https://perma.cc/6JGE-2WNV] ("The currently low amount of miles driven from [Google's] Self-Driving Car project makes it difficult to draw firm conclusions on the potential safety impact of self-driving cars."); SCOTT SMITH ET AL., U.S. DEP'T OF TRANSP., BENEFITS ESTIMATION FRAMEWORK FOR AUTOMATED VEHICLE OPERATIONS 53 (2015), http://ntl.bts.gov/lib/55000/55400/55443/AVBenefitFrameworkFinalReport082615_Cover1.pdf [https://perma.cc/5EQG-RWBT] (describing the safety impact methodology framework to be applied to automated driving safety estimates); Memorandum from Nathaniel Beuse, Assoc. Adm'r for Vehicle Safety Research, to

blind-spot monitoring, lane departure warning, and forward collision warning could, with total adoption and effectiveness, "prevent or reduce the severity of as many as 1.3 million [U.S.] crashes annually, including 133,000 injury crashes and 10,100 fatal crashes."[68] NHTSA estimated that a "fully mature" vehicle-to-vehicle (V2V) communications system "could potentially address" about 80% of crashes today.[69] Although V2V communications are distinct from automated driving,[70] many of the crash types that NHTSA examined involved perception failures that automated systems may also be able to address.

The common suggestion that "driverless cars" are "already safer" than conventional vehicles remains premature. With the exception of low-speed applications in limited environments,[71] truly driverless motor vehicles do not yet exist in a commercial sense. Advanced driver assistance systems like Tesla's Autopilot[72] are at most "partial automation" that operate with the expectation that human drivers will actively monitor the roadway and intervene as

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Docket Number NHTSA 2014-0070 (June 2, 2015), http://www.regulations.gov/document?D=NHTSA-2014-0070-0002 [https://perma.cc/2H3G-HEWX] (noting NHTSA's current work on "the potential incremental safety benefits for automated vehicle functions/concepts"). For a thorough assessment of potential safety benefits in the distinct but nonetheless relevant context of vehicle-to-vehicle communications, see HARDING ET AL., *supra* note 17, at xiv.

68. Corey D. Harper, Chris T. Hendrickson & Constantine Samaras, *Cost and Benefit Estimates of Partially-Automated Vehicle Collision Avoidance Technologies*, 95 ACCIDENT ANALYSIS & PREVENTION 104, 108 (2016).

69. HARDING ET AL., *supra* note 17, at 18.

70. *See* Bryant Walker Smith, *A Legal Perspective on Three Misconceptions in Vehicle Automation*, *in* LECTURE NOTES IN MOBILITY: ROAD VEHICLE AUTOMATION 85, 89 (Gereon Meyer & Sven Beiker eds., 2014).

71. *E.g.*, CITYMOBIL2, http://www.citymobil2.eu/en/ [https://perma.cc/37U8-PFFU] (last visited Nov. 16, 2016); *Heathrow Pod: Self Guided Tour Instructions*, ULTRA GLOBAL PRT, http://www.ultraglobalprt.com/wp-content/uploads/2011/10/Ultra_SelfTour2.pdf [https://perma.cc/3DUW-3J5S] (last visited Nov. 16, 2016); *Mine of the Future*, RIO TINTO, http://www.riotinto.com/australia/pilbara/mine-of-the-future-9603.aspx [https://perma.cc/NQC3-R7B7] (last visited Nov. 16, 2016).

72. *Model S Software Version 7.0*, TESLA, https://www.tesla.com/presskit/autopilot [https://perma.cc/7CQA-N45K] (last visited Nov. 16, 2016).

needed.[73] Even Google's research vehicles are closely supervised by professional safety drivers when on public roads.[74]

Moreover, just because an automated system should be safer than humans does not necessarily mean that it will be safer; surprises abound on roads as well as in software. No company has logged the hundreds of millions of miles that might provide a statistical comparison of actual crash and injury rates,[75] and early empirical claims are necessarily limited. A study commissioned by Google compared conventional driving to *supervised* automated driving.[76] Tesla's statements about the relative performance of its Autopilot are lacking.[77]

Even the prediction that automated driving will be safer than conventional driving requires some important caveats. First, this superior safety will be broadly statistical; given everything that happens in the three trillion vehicle miles traveled annually in the United States,[78] there will be individual incidents of diminished safety.[79] Second, early automated driving systems may have limited

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73. SAE INT'L, J3106, TAXONOMY AND DEFINITIONS FOR TERMS RELATED TO ON-ROAD MOTOR VEHICLE AUTOMATED DRIVING SYSTEMS (2014) [hereinafter SAE J3016] (defining six levels of driving automation).

74. *On The Road*, GOOGLE SELF-DRIVING CAR PROJECT, https://www.google.com/selfdrivingcar/where/ [https://perma.cc/8DF4-9F57] (last visited Nov. 16, 2016) ("There are test drivers aboard all vehicles for now.").

75. Bryant Walker Smith, *Driving at Perfection*, CTR. INTERNET & SOC'Y (Mar. 11, 2012, 3:20 PM), https://cyberlaw.stanford.edu/blog/2012/03/driving-perfection [https://perma.cc/CV7X-AKQX]; NIDHI KALRA & SUSAN M. PADDOCK, RAND CORP., DRIVING TO SAFETY: HOW MANY MILES OF DRIVING WOULD IT TAKE TO DEMONSTRATE AUTONOMOUS VEHICLE RELIABILITY? (2016), https://www.rand.org/content/dam/rand/pubs/research_reports/RR1400/RR1478/RAND_RR1478.pdf [https://perma.cc/SUG5-PRQ4]. Other approaches to the question of demonstrating safety are also possible. *See infra* notes 146-47 and accompanying text.

76. *See* BLANCO ET AL., *supra* note 67.

77. *See* Nick Lum & Edward Niedermeyer, *How Tesla and Elon Musk Exaggerated Safety Claims About Autopilot and Cars*, THE DAILY BEAST (July 14, 2016, 1:00 AM.), http://www.thedailybeast.com/articles/2016/07/14/why-tesla-s-cars-and-autopilot-aren-t-as-safe-as-elon-musk-claims.html [https://perma.cc/D5F7-GLLD]; Tom Simonite, *Tesla's Dubious Claims About Autopilot's Safety Record*, MIT TECH. REV. (July 6, 2016), https://www.technologyreview.com/s/601849/teslas-dubious-claims-about-autopilots-safety-record/ [https://perma.cc/4BPL-TMPF].

78. U.S. DEP'T OF TRANSP., OFFICE HIGHWAY POL'Y INFO., TRAFFIC VOLUME TRENDS: DECEMBER 2015 (2016), https://www.fhwa.dot.gov/policyinformation/travel_monitoring/15dectvt/15dectvt.pdf [https://perma.cc/H4RZ-Z93L] [hereinafter 2015 TRAFFIC VOLUME TRENDS].

79. *Cf., e.g.*, *Preliminary Report, Highway HWY16FH018*, NAT'L TRANSP. SAFETY BD., (July 26, 2016), http://www.ntsb.gov/investigations/AccidentReports/

operational design domains; for example, they may not initially operate in snow or other challenging environments. Third, unlikely systemic risks—of which cyberattacks are the most prominent—could affect this overall safety performance if they are realized on a massive scale. Fourth, automated driving could conceivably increase the rate of minor crashes even while decreasing the rate of more serious crashes.[80]

A comparison between automated driving and conventional driving also misses the potential contribution of active safety systems intended to assist rather than replace a human driver.[81] In terms of safety performance, an automated driving system could be compared not only to a human driver but also to that driver as assisted by lane departure warnings, automatic braking, and even more advanced forms of automated emergency intervention. This is discussed more below.

Finally, a substantial increase in vehicle miles traveled could negate some of these potential safety gains. Automation could conceivably induce additional travel by making that travel less stressful, less expensive, or more productive.[82] Some vehicles may even deliver goods, circulate while waiting for passengers, return home or seek parking after completing a drop off, collect neighborhood data, or display advertising—all without any human on board.[83] Consider a hypothetical illustration: If automated driving halves the crash rate while doubling the number of vehicle miles traveled, the total number of crashes would stay the same.

For the reasons discussed above, automating every motor vehicle trip could reduce total crash magnitude. In short: Automated driving systems may crash less frequently and less severely, and

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Pages/HWY16FH018-preliminary.aspx [https://perma.cc/NL6T-S4PZ] [hereinafter HWY16FH018].

80. *Cf.* BLANCO ET AL., *supra* note 67; *Signalized Intersections: An Informational Guide*, FED. HIGHWAY ADMIN., http://safety.fhwa.dot.gov/intersection/conventional/signalized/fhwasa13027/ch1.cfm [https://perma.cc/QD4Q-362T] (last visited Nov. 16, 2016) (describing how traffic signals can increase the frequency but reduce the severity of crashes).

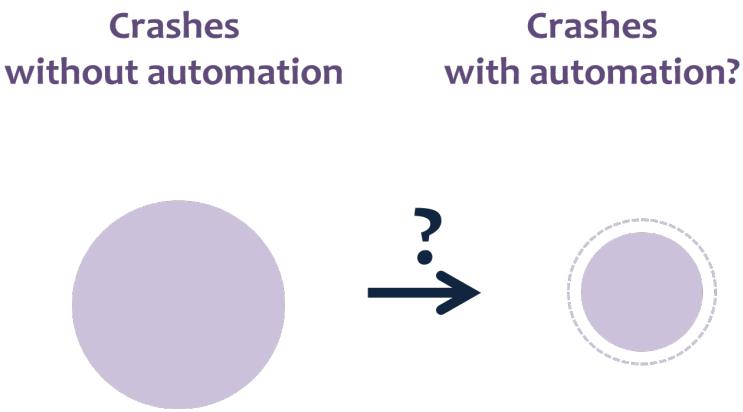
81. *See* Bryant Walker Smith, Presentation at the 2012 Road Vehicle Automation Workshop: Autolaw 3.0 (July 24-26, 2012), http://onlinepubs.trb.org/onlinepubs/conferences/2012/Automation/presentations/WalkerSmith.pdf [https://perma.cc/QF43-VZBQ]; *see also* Walker Smith, *supra* note 16.

82. *See* Bryant Walker Smith, *Managing Autonomous Transportation Demand*, 52 SANTA CLARA L. REV. 1401, 1401-02 (2012).

83. A crash involving a vehicle making zero-occupancy trips might still injure (only) those outside that vehicle.

those who are involved in these crashes may be better protected. Figure 4 illustrates this broad prediction: The pie on the left (representing crash magnitude today) is larger than the pie on the right (representing crash magnitude if every motor vehicle trip were automated).

Figure 4



Crash magnitude here means the total number of crashes weighted by their severity.[84] As a practical matter, such weighting is difficult: How many severe injuries, for example, is equivalent to a fatality? Although valuation matters for the subsequent liability analysis, this initial comparison of crash magnitude requires no further granularity or equivalence.

The dotted circle around the right pie illustrates how an increase in vehicle miles traveled could complicate this comparison. However, this potential complication is less relevant to this Article's focus on managing product liability. There is some relationship between vehicle miles traveled and automaker revenue (as more miles traveled may lead to more frequent vehicle turnover) and an even stronger relationship between vehicle miles traveled and operator revenue (as ride services often charge at least in part by distance traveled). This means that more miles traveled could mean both more crashes and more revenue to offset that potential liability.

84. A thousand injury-free crashes may be preferable to a single fatal crash. At the same time, the costs associated with a severe injury (such as lifetime medical care) may be more recoverable than those associated with a fatality. *See infra* discussion at notes 87-100.

CRASH COST

In 2010, motor vehicle crashes in the United States imposed societal costs of some $836 billion.[85] This figure—$836,000,000,000—is the most recent to come from NHTSA's multi-decade effort to understand the costs of driving.[86] That complex undertaking is the focus of this section.

About one-third of the $836 billion accounts for "the value of resources that are used or that would be required to restore crash victims, to the extent possible, to their pre-crash physical and financial status."[87] These economic costs include $23 billion in medical expenses, $76 billion in property damage, $77 billion in lost productivity, $28 billion in congestion impacts, and $37 billion in additional economic costs.[88] They can be "estimated in a fairly direct manner through empirical measurements."[89]

The remaining two-thirds represents both loss of life and diminished quality of life. "In the case of death, victims are deprived of their entire remaining lifespan. In the case of serious injury, the impact on the lives of crash victims can involve extended or even lifelong impairment or physical pain, which can interfere with or prevent even the most basic living functions."[90] The value of a statistical life (VSL) can be used to represent the cost of a fatality and scaled for a nonfatal injures.[91] VSL is inferred from how much consumers will either pay to avoid a risk of death or demand to accept a risk of death.[92] The $836 billion is based on a VSL of just under $9 million;[93] using other established values produces total costs ranging from about $500 billion to over $1 trillion.[94]

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85. BLINCOE ET AL., *supra* note 26, at 5 (in 2010 dollars). In 2010, there were "32,999 fatalities, 3.9 million non-fatal injuries, and 24 million damages vehicles." *Id.* at 1.

86. *Id.*

87. *Id.* at 113.

88. *Id.* at 5.

89. *Id.* at 113.

90. *Id.*

91. *Id.* at 116. Because some costs that are explicit in the economic calculations are implicit in the VSL measure, "combining measures of economic costs and lost quality-of-life requires an adjustment to avoid double counting these components." *Id.* at 117.

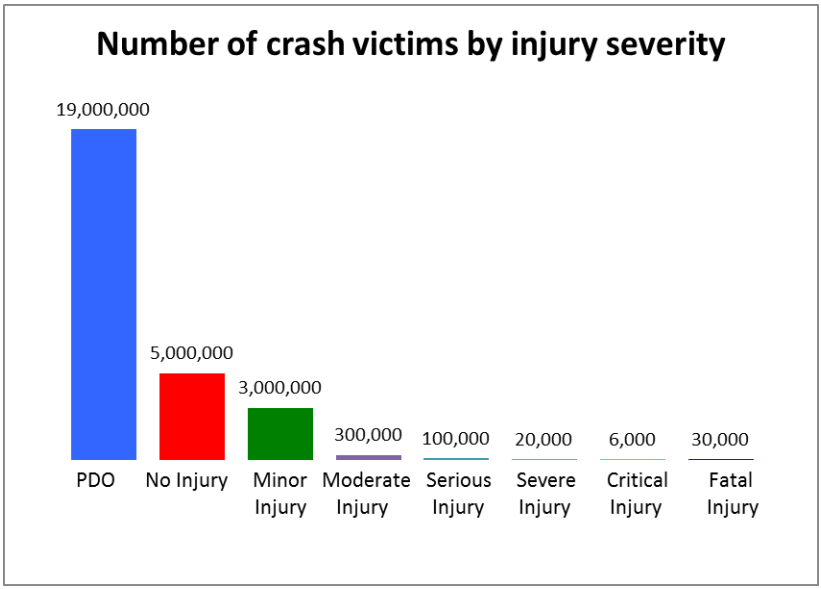
92. *Id.* at 113-14. For example, "'willingness to pay' studies (WTP) are most frequently based on wage rate differentials for risky jobs, or on studies of the prices consumers pay for products that reduce their risk of being fatally injured." *Id.* at 113.

93. *Id.* at 114 (2010 dollars based on 2012 dollars).

94. *Id.* at 10.

As Figures 1, 2, and 3 illustrate,[95] crash injuries vary widely in severity and hence in cost. Crashes involving property damage only (PDO) account for a vast majority of total crashes but less than 10% of total crash costs.[96] In contrast, fatal crashes account for less than half of 1% of all crashes but over a third of total crash costs.[97] This is because of the high costs of each fatality.[98] Depending on the severity, injuries can also cost millions of dollars.[99] These costs are only averages, and "in individual cases they can be exceeded by a factor of three or more."[100]

Figure 5



95. *See id.* at 13, 16, 17 (2010 numbers). For simplicity, the paragraph above references crashes. In contrast, the figures reference crash victims and, in the case of property-damage only (PDO) crashes, crash vehicles. A single crash can involve multiple victims with different levels of severity. The "no injury" category on the figures (and in the NHTSA report on which they are based) refers to uninjured participants of crashes in which others were injured. *Id.*

96. *Id.*

97. NHTSA, DOT HS 811 552, 2010 MOTOR VEHICLE CRASHES: OVERVIEW (2012), https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/811552 [https://perma.cc/T4PK-NVTU]; NHTSA, DOT HS 811 659, TRAFFIC SAFETY FACTS 2010 (2011), https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/811659 [https://perma.cc/87L4-K2R6].

98. BLINCOE ET AL., *supra* note 26, at 4.

99. *See id.* at 26.

100. *Id.* at 8.

Figure 6

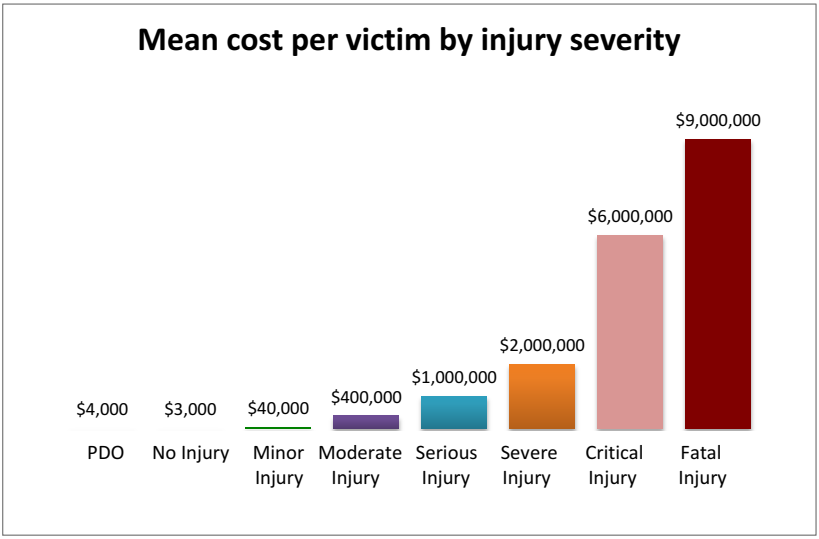
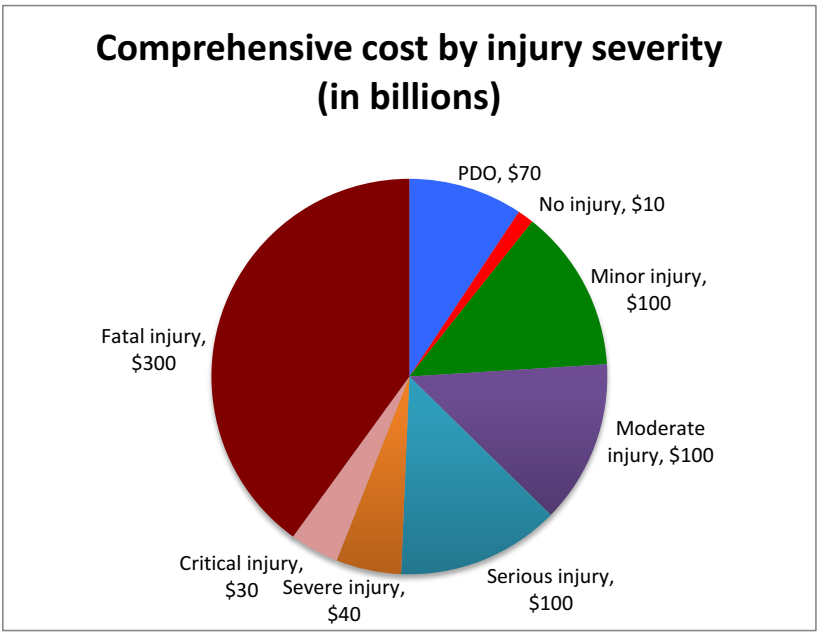


Figure 7



Who actually pays these costs?

Most of the total burden falls on the direct and indirect victims of tragic crashes. The child who never reaches adulthood loses something of intrinsic value even though that something cannot be transacted. So do her parents and siblings. The same is true for the adult who never reaches old age—as well as for her family, friends, colleagues, and larger community. The marathon runner whose leg is amputated also loses something, even if she ultimately competes in different ways or discovers new perspectives and abilities as a result of that loss.[101] These costs are real even if they are not transactional, and failing to reimburse them does not make them disappear.

Individual crash victims also bear roughly one-quarter of the explicitly economic costs of their crashes.[102] These victims "pay a modest portion of medical care, and absorb significant portions of both market and household productivity losses, as well as property damage."[103] The unreimbursed costs can be substantial. "Depending on the financial ability and insurance coverage of the individual crash victims," these costs "can be catastrophic to the victim's economic wellbeing in addition to their physical and emotional condition."[104] In a 1999 study of bankruptcy petitioners, one out of four respondents cited illness or injury as a reason for their bankruptcy filing.[105]

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101. This is fraught. *See, e.g.*, Trude Arnesen & Erik Nord, *The Value of DALY Life: Problems with Ethics and Validity of Disability Adjusted Life Years*, 319 BMJ 1423 (1999), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1117148/ [https://perma.cc/a3M7T-3PM6]; Tom Shakespeare & Bryan Vernon, *Disability Rights and Resuscitation: Do Not Attempt Reconciliation?*, *in* DISABLED PEOPLE AND THE RIGHT TO LIFE: THE PROTECTION AND VIOLATION OF DISABLED PEOPLE'S MOST BASIC HUMAN RIGHTS 99-101 (Luke Clements & Janet Read eds., 2008).

102. BLINCOE ET AL., *supra* note 26, at 238-40.

103. *Id.* at 238. For more background on these cost estimates, see *id.* at 38-48.

104. *Id.* at 8.

105. Elizabeth Warren, Teresa Sullivan & Melissa Jacoby, *Medical Problems and Bankruptcy Filings* 4 (Harvard Law Sch. Law and Legal Theory Working Paper Series, Working Paper No. 009, 2000), http://papers.ssrn.com/sol3/papers.cfm?abstract_id=224581 [https://perma.cc/H5UR-QJX2]. *But see* Edward R. Morrison et al., *Health and Financial Fragility: Evidence from Car Crashes and Consumer Bankruptcy* 24 (U of Chi. Law Sch. Coase-Sandor Inst. for Law & Econ., Working Paper No. 655, 2013), http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2353328 [https://perma.cc/569K-3MTC] (finding no causal connection between vehicle crashes and bankruptcy filings). Bankruptcy transfers some costs from an individual to society.

Society at large bears the remaining three-quarters of the economic cost.[106] Private insurers cover 54% largely by charging policyholders.[107] People who travel, shop, and breathe pay for 12% in the form of longer travel times, additional fuel purchases, higher shipping prices, and impacts associated with increased pollution.[108] Governments at all levels cover 8% by taxing current and future taxpayers.[109] In 2010, these economic costs alone came to $784 annually for every person in the United States.[110]

Nearly every state requires motorists to carry third-party liability insurance (or to otherwise demonstrate financial responsibility),[111] and many states further require motorists to purchase insurance for injuries caused by uninsured or underinsured motorists.[112] (In 2012, 12.6% of motorists were uninsured.)[113] These required minimums, however, are manifestly inadequate for any serious injury. Most states require coverage of only $25,000 per fatality.[114] To protect their assets, many drivers carry liability insurance above the legal minimum—but median household net

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106. BLINCOE ET AL., *supra* note 26, at 240.

107. *Id.*

108. *Id.* at 2, 50, 239. *$28,027,000,000 / $241,988,000,000 = 11.6%. Id.* at 11.

109. *Id.* at 6.

110. *Id.* at 5.

111. *Compulsory Auto/Uninsured Motorists*, INS. INFO. INST. (Sept. 2016), http://www.iii.org/issue-update/compulsory-auto-uninsured-motorists [https://perma.cc/AT9F-TB36]. New Hampshire is the exception. *Id.*

112. *Id.*

113. *Id.*

114. *Id.* In contrast, German law requires at least €1 million in third-party liability coverage for personal injury. BEWACHUNGSVERORDNUNG [BEWACHV] [Regulation on the Security Industry] Haftpflichtversicherung [liability insurance], Oct. 7, 2013, BGBL. I at 1378, § 6 (Ger.); *see also* GESETZ ÜBER DIE PFLICHTVERSICHERUNG FÜR KRAFTFAHRZEUGHALTER [PflVG] [Law on Compulsory Insurance of Vehicle Owners], Aug. 31, 2015, BGBL. I at 1474, § 4 (Ger.); Walker Smith, *supra* note 16, at 35-36 (advocating a substantial increase in the amount of third-party liability insurance required).

worth was only $69,000 in 2011.[115] The average societal cost of a fatality is more than *100 times* these numbers.[116]

If automated driving reduces the magnitude of crashes, then it should also reduce the societal costs of crashes. A 15% across-the-board decline in crashes, for example, would reduce annual crash costs by some $125 billion.[117] Replacing 10,000 fatal injuries with 10,000 minor injuries would reduce costs by some $90 billion.[118] Even replacing those fatalities with 100,000 minor injuries would still save some $86 billion.[119]

Once again, there are numerous caveats. Some costly elements of the crash infrastructure, such as trauma centers, may need to exist regardless of how much crashes decline. Because organ donations often come from motor vehicle crash victims, fewer fatal crashes could mean fewer organs donated to others in need.[120] Vehicles with automated driving systems may be more expensive to repair than conventional vehicles, which could raise the average cost of even minor crashes.[121] If automated driving increases the number of these minor crashes, the aggregate economic effect could be large. And automated driving could conceivably increase total vehicle miles traveled, which could countervail improvements in per-mile safety.[122]

Generally, however, most of these issues probably fall into the category of "good problems to have." Serious motor vehicle crashes dramatically upend lives—often young lives[123]—in ways that cannot

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115. Marina Vornovitsky, Alfred Gottschalck & Adam Smith, *Distribution of Household Wealth in the U.S.: 2000 to 2011*, U.S. CENSUS BUREAU (2013), https://www.census.gov/people/wealth/files/Wealth%20distribution%202000%20to%202011.pdf [https://perma.cc/9TUR-X6KX]. Moreover, much of this wealth may be sheltered by law from tort liability. Stephen G. Gilles, *The Judgment-Proof Society*, 63 WASH. & LEE L. REV. 603, 623 (2006); *See* Bert I. Huang, *Surprisingly Punitive Damages*, 100 VA. L. REV. 1027, 1034–35 (2014).

116. *See also* Walker Smith, *supra* note 16, at 35.

117. *See id.* at 30-32.

118. *$90 billion − $400 million = $90 billion* (calculated to one significant figure).

119. *$90 billion − $4 billion = $86 billion*.

120. *See* Justine Hofherr, *What Do Driverless Cars Have to Do With Organ Donors?*, BOSTON.COM (Jan. 23, 2015), https://www.boston.com/cars/news-and-reviews/2015/01/23/what-driverless-cars-have-with-organ-donors/nhSxw0YRrC0XiNUjUuXwNP/story.html [https://perma.cc/DC6J-R2KQ]; *see also* Stacy Dickert-Conlin, Todd Elder & Brian Moore, *Donorcycles: Motorcycle Helmet Laws and the Supply of Organ Donors*, 54 J. L. & ECON. 907, 908 (2011).

121. *Self-Driving Cars and Insurance*, INS. INFO. INST. (July 2016), http://www.iii.org/issue-update/self-driving-cars-and-insurance [https://perma.cc/58L8-9JQD].

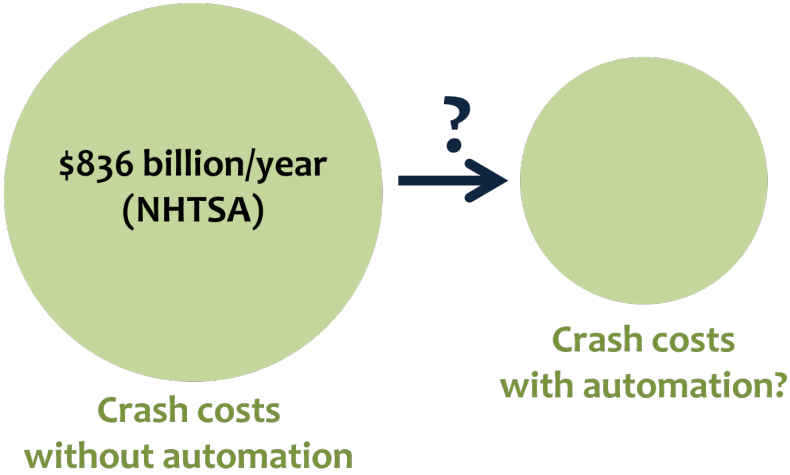
122. *See supra* discussion at notes 78-80.

123. *See supra* discussion at notes 45-58.

be fully expressed in financial terms, even though these are the terms on which this Article is based.

Figure 8 illustrates the potential change in societal crash costs if automated driving substantially increases motor vehicle safety: The pie on the left (representing total crash costs today) is larger than the pie on the right (representing total crash costs if every motor vehicle trip were automated).

Figure 8



PRODUCT FAILURE

This section considers those crashes to which the failure of a vehicle or a component thereof contributes. Narrowly construed, this category might include only those crashes in which a vehicle component breaks or malfunctions. More broadly construed, however, this category could include a wide range of suboptimal interactions between a vehicle and the humans who operate, use, or otherwise interact with it.

Although vehicle condition in the narrow sense contributes to crashes, the contribution is far less than that of human error.[124] A 1985 study estimated that vehicle issues are the sole cause of 2% of

124. For a discussion of human error, see *supra* note 46 and accompanying text.

crashes and a partial cause of another 10% of crashes.[125] A NHTSA analysis of the single "last event in the crash causal chain" identified "a vehicle component's failure or degradation" in 2% of crashes.[126] This number, however, may not fully account for "internal vehicle related problems that might have led to the crash," but were not readily apparent to crash investigators.[127]

The incredible sophistication of modern motor vehicles means that concerns about automotive electronics are not limited to automated driving.[128] "Electronic systems have become critical to the functioning of the modern automobile."[129] These "increasingly interconnected . . . systems are creating opportunities to improve vehicle safety and reliability as well as demands for addressing new system safety and cybersecurity risks."[130] In the early 2000s, highly publicized incidents of unintended acceleration in Toyota vehicles prompted widespread speculation about the electronic throttles in these vehicles.[131] While both NHTSA and NASA ultimately found no evidence of an electronic cause of unintended acceleration in real-world use,[132] at least one jury may have believed otherwise.[133]

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125. Harry Lum & Jerry A. Reagan, *Interactive Highway Safety Design Model: Accident Predictive Module*, 59 PUB. ROADS (1995), http://www.fhwa.dot.gov/publications/publicroads/95winter/p95wi14.cfm [https://perma.cc/JZ92-CJN2]. The roadway was the sole cause of 3% of crashes and a partial cause of 31% of crashes. *Id.*

126. SINGH, *supra* note 44, at 1. The driving environment was the critical reason in 2% of crashes. *Id.*

127. *Id.* at 2.

128. *See* TRANSP. RESEARCH BD., NAT'L ACAD. OF SCI., SPECIAL REPORT 308: THE SAFETY PROMISE AND CHALLENGE OF AUTOMOTIVE ELECTRONICS: INSIGHTS FROM UNINTENDED ACCELERATION (2012), http://www.nap.edu/catalog/13342/trb-special-report-308-the-safety-challenge-and-promise-of-automotive-electronics [https://perma.cc/JYN2-CV8U]; NHTSA, REPORT TO CONGRESS: "ELECTRONIC SYSTEMS PERFORMANCE IN PASSENGER MOTOR VEHICLES" (2015); VAN EIKEMA HOMMES, NHTSA, DOT HS 812 285, ASSESSMENT OF SAFETY STANDARDS FOR AUTOMOTIVE ELECTRONIC CONTROL SYSTEMS (2016).

129. SPECIAL REPORT 308, *supra* note 128 at 2.

130. *Id.* at 68.

131. *See* Jaclyn Trop, *Toyota Seeks a Settlement for Sudden Acceleration Cases*, N.Y. TIMES (Dec. 13, 2013), http://www.nytimes.com/2013/12/14/business/toyota-seeks-settlement-for-lawsuits.html?_r=0 [https://perma.cc/Z8PZ-QS9E].

132. NHTSA, TECHNICAL ASSESSMENT OF TOYOTA ELECTRONIC THROTTLE CONTROL (ETC) SYSTEMS 62 (2011), http://www.nhtsa.gov/staticfiles/nvs/pdf/NHTSA-UA_report.pdf [https://perma.cc/XT86-ZWHW] [hereinafter TOYOTA ASSESSMENT]; NASA ENGINEERING & SAFETY CTR., NHTSA, TECHNICAL SUPPORT TO THE NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION (NHTSA) ON THE REPORTED TOYOTA MOTOR CORPORATION (TMC) UNINTENDED ACCELERATION (UA)

Even when every component performs as intended, design issues may still contribute to crashes. In these situations, the line between design failure and driver failure is often blurry. For example, NHTSA attributed many instances of unintended acceleration to pedal misapplication by the driver.[134] But even in these cases, a design decision—whether the close placement of the brake and accelerator pedals or merely the traditional placement of these two input devices in a position that is out of sight and operable only by foot—may have contributed to that misapplication.[135] Other design decisions, including the operation of the emergency off switch, may have exacerbated some occurrences of unintended acceleration.[136]

More broadly, design issues related to "human factors" or "human-machine interaction" reflect the fact that humans drive motor vehicles.[137] When a vehicle crashes at 120 miles per hour, excessive speed is likely to be a contributing factor. In general, however, such a speed is reached only because a human decides to drive a vehicle that fast and the vehicle is actually capable of that speed. Similarly, drunk driving generally occurs only when a human decides to drive a vehicle while drunk and that vehicle has no alcohol ignition interlock that would preclude operation by an intoxicated driver. By no means are these examples intended to diminish the driver's role. Rather, they merely show that many crashes are actually complex products of numerous design and driving decisions.[138]

Regardless, as discussed above, driver error is widely accepted as the key factor in the vast majority of today's crashes. This is in part because human drivers continue to make almost all of the real-time decisions necessary for driving, from the tactical (such as travel speed) to the operational (such as how to avoid a vehicle swerving into the travel lane).[139] Electronic systems may inform those

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INVESTIGATION (2011), http://www.nhtsa.gov/staticfiles/nvs/pdf/NASA-UA_report.pdf [https://perma.cc/7C5X-P7E4].

133. *See* Margaret Cronin Fisk, *Toyota Settles Oklahoma Acceleration Case After Verdict*, BLOOMBERG (Oct. 25, 2013, 12:46 PM), https://www.bloomberg.com/news/articles/2013-10-25/toyota-settles-oklahoma-acceleration-case-after-jury-verdict [https://perma.cc/KBR3-WP8V].

134. TOYOTA ASSESSMENT, *supra* note 132, at viii.

135. *Id.* at 52.

136. *Id.* at 51-52.

137. *See id.* at 30 n.58.

138. *See id.* at 66.

139. SAE J3016, *supra* note 73.

decisions (in the case of blind-spot warnings), implement those decisions (in the case of cruise control), or optimize those decisions (in the case of electronic stability control), but humans remain the drivers for all practical purposes.

In many ways, automated driving systems will essentially drive tomorrow's vehicles. NHTSA has even suggested as much in the context of the Federal Motor Vehicle Safety Standards (FMVSS).[140] Because these systems will make many if not all of the real-time decisions necessary for driving, it is widely accepted that design issues will play a much greater role in automated driving crashes than in today's conventional driving crashes.[141]

These systems will eliminate some forms of driver error while introducing new opportunities for other forms of error. These new errors may involve the physical failure of a relevant component, the provision or use of flawed data, a reliance on buggy code, the execution of an unreasonable driving decision, suboptimal interaction among system components, or inadequate communication with other road users, to name just a few. Designing an automated driving system that minimizes, manages, and mitigates these errors is an immense technical challenge.

The complex world in which these systems will eventually operate poses further challenges. Drivers in the United States travel three trillion vehicle miles every year[142] on some four million miles of road.[143] These roads may have potholes, black ice, roadway debris,

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140. Letter from NHTSA to Chris Urmson, Dir. of Google, Inc.'s Self-Driving Car Project (Feb. 4, 2016), http://isearch.nhtsa.gov/files/Google%20--%20compiled%20response%20to%2012%20Nov%20%2015%20interp%20request%20--%204%20Feb%2016%20final.htm [https://perma.cc/LU7R-QMAM] ("As a foundational starting point for the interpretations below, NHTSA will interpret 'driver' in the context of Google's described motor vehicle design as referring to [Google's self-driving system (SDS)]. . . . In this instance, an item of motor vehicle equipment, the SDS, is actually driving the vehicle."). NHTSA's conclusion is limited to the FMVSS. "Driver" has a distinct and likely broader meaning in many state vehicle codes. *See* Bryant Walker Smith, *Automated Vehicles Are Probably Legal in the United States*, 1 TEX. A&M L. REV. 411, 433 (2014). Moreover, in contrast to the FMVSS, these codes generally treat a driver or operator as a legal person. *Id.* at 477.

141. *See* Walker Smith, *supra* note 140, at 419.

142. 2015 TRAFFIC VOLUME TRENDS, *supra* note 78.

143. BUREAU OF TRANSP. STATISTICS, U.S. DEP'T OF TRANSP., TABLE 1-6: ESTIMATED U.S. ROADWAY LANE-MILES BY FUNCTIONAL SYSTEM, http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/html/table_01_06.html) [https://perma.cc/ZF82-DMUX] (last visited Nov. 16, 2016).

crossing animals, falling animals, stalled vehicles, maintenance or construction crews, emergency responders, and wrong-way "ghost drivers," if not actual ghosts.[144] Publicly available videos from dashboard-mounted cameras illustrate the wide variety of unusual, dangerous, and tragic situations that human drivers today cause or confront.[145] Anything that could conceivably happen on the road will eventually happen—as well as many things that cannot be conceived in advance.

Even demonstrating the safety of automated driving may be daunting. The level of safety assurance demanded of aircraft systems would require at least a billion hours of testing.[146] A statistical comparison between automated and conventional driving could require hundreds of millions of miles of representative driving—and probably much more.[147] There are many views on, and little consensus about, demonstrating reasonable safety.[148] I have argued that developers of automated driving systems should have the opportunity and even the obligation to make public safety cases that evidence a lifecycle approach to defining, measuring, monitoring, and ensuring reasonable safety.[149]

Figure 9 illustrates the increased contribution of product failure to motor vehicle crashes. This figure is based on the initial figure showing crash magnitude. As the pie on the left shows, vehicle failure, as generally conceived, contributes to only a small portion of today's crashes. As the pie on the right shows, the shift in real-time decision-making from human driver to automated driving system

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144. *See* Nick Kurczewski, *Creepy, Cursed, and Curvy: New Jersey's Clinton Road is the Most Frightening Road in America.*, N.Y. DAILY NEWS (May 23, 2014, 1:02 PM), http://www.nydailynews.com/autos/creepy-cursed-curvy-new-jersey-clinton-road-frightening-road-america-article-1.1803331 [https://perma.cc/6L6P-6SET].

145. *See, e.g.*, YOUTUBE.COM, https://www.youtube.com/results?search_query=dash+cam+compilation [https://perma.cc/L8CU-CLTP] (last visited Nov. 16, 2016) (searching for "dash cam compilation").

146. *See* Philip Koopman & Michael Wagner, *Challenges in Autonomous Vehicle Testing and Validation*, 4 SAE INT'L J. TRANSP. SAFETY 15, 15-16 (2016); INT'L ORG. FOR STANDARDIZATION [ISO], ISO 26262-1:2011, ROAD VEHICLES—FUNCTIONAL SAFETY (2011), http://www.iso.org/iso/catalogue_detail?csnumber=43464 [https://perma.cc/DSP7-56BE]; INT'L ELECTROTECHNICAL COMM'N [IEC], FUNCTIONAL SAFETY AND IEC 61508 (2016), http://www.iec.ch/functionalsafety/ [https://perma.cc/SN3L-5QQP].

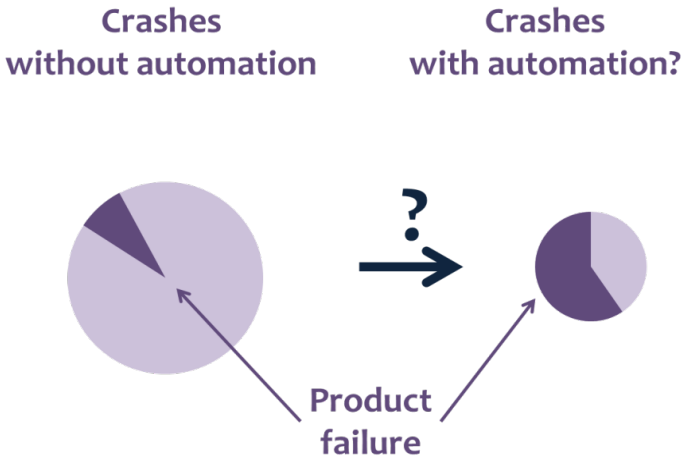
147. *See* Walker Smith, *supra* note 75; KALRA & PADDOCK, *supra* note 75, at 2.

148. *See generally* KALRA & PADDOCK, *supra* note 75.

149. Bryant Walker Smith, *Regulation and the Risk of Inaction*, *in* AUTONOMES FAHREN 593, 597 (Markus Maurer et al. eds., 2015) [hereinafter *Regulation and the Risk of Inaction*].

means that vehicle failure is likely to explain a far greater proportion of the crashes that still occur.

Figure 9



INDUSTRY LIABILITY

The abstract question of "who is responsible in a crash" is as unhelpful as it is popular.[150] At the outset, responsibility is not necessarily legal in nature; it can also be moral or technical. Even within the legal domain, responsibility as a concept can contemplate prospective obligations or authorities as well as retrospective liabilities.[151] These retrospective liabilities can be criminal, administrative, or civil in nature. Asking who is civilly liable in the event of a crash is therefore more precise—but not necessarily any more helpful.

Courts and legislatures have spent the last century developing, disrupting, and refining the rules of civil liability in the realms of tort, contract, insurance, property, and product liability law. An individual injured in a crash may sue multiple natural or legal persons[152] and may ultimately recover from all, some, or none of

150. *See, e.g.*, Brian Fung, *The Big Question About Driverless Cars No One Seems Able to Answer*, WASH. POST (Feb. 17, 2016), https://www.washingtonpost.com/news/the-switch/wp/2016/02/17/the-big-question-about-driverless-cars-no-one-seems-to-have-an-answer-to/ [https://perma.cc/T6W6-MCFD].

151. *See Regulation and the Risk of Inaction*, *supra* note 149, at 596.

152. A corporation is a legal person.

them. If a plaintiff successfully recovers damages from a defendant, that defendant may in turn be able to recover some or all of these damages from another natural or legal person. The outcome depends in part on how the specific laws of the particular jurisdiction align with the specific facts of the particular crash.

Insurers play many roles in this process. A crash victim who has automotive, health, or life insurance might seek payment directly from the provider of that insurance. The victim may additionally or alternatively seek payment from an insurer that provides liability coverage to a would-be defendant. In the event of litigation, that insurer may defend its insured and ultimately pay some or all of the costs incurred in that litigation. Any of these insurers may seek to collect some of its costs from another liable party through subrogation of its insured's claim. Finally, these insurers may themselves rely on a variety of risk-spreading mechanisms, including reinsurance, to which they may turn for recovery. These functions are similar even in states with limited no-fault automotive insurance regimes.[153]

Largely because of automotive insurance, the vast majority of crashes are handled without any litigation.[154] Accordingly, legal costs represent only 1.3% of total societal crash costs.[155] Even when a lawsuit is filed, it is highly unlikely to proceed all the way to a verdict by a judge or jury. Of the roughly 4,000 motor vehicle personal injury cases that terminated in U.S. district courts in 2015, only 3% actually reached trial.[156]

Westlaw's Case Evaluator, which aggregates verdicts from multiple jurisdictions, also points to an absolute decline in the

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153. *Auto Insurance*, INS. INFO. INST., http://www.iii.org/fact-statistic/auto-insurance [https://perma.cc/D677-ME4L] (last visited Nov. 16, 2016) [hereinafter *Auto Insurance*].

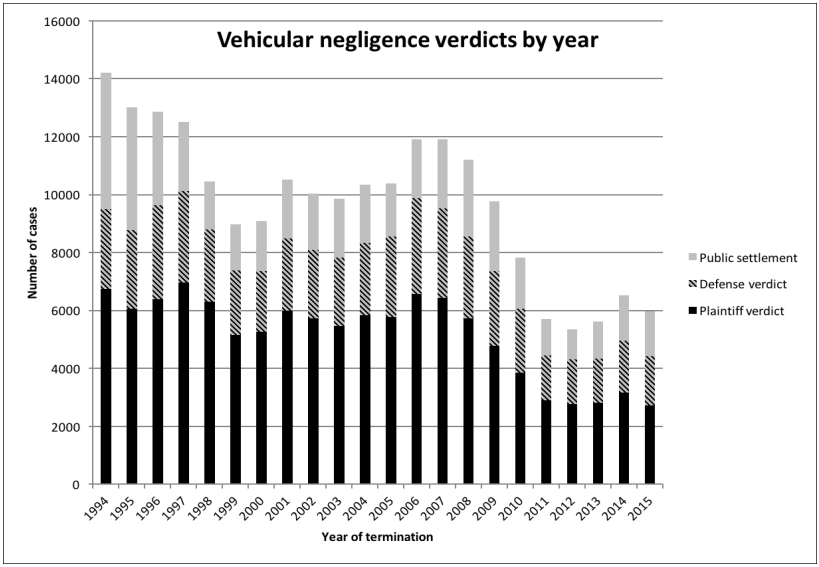
154. *Cf. id.* (showing a claim frequency for collision coverage of 5.95 claims per 100 car years).

155. BLINCOE ET AL., *supra* note 26, at 16.

156. U.S. DISTRICT COURTS–CIVIL CASES TERMINATED, BY NATURE OF SUIT, AND ACTION TAKEN, DURING THE 12-MONTH PERIOD ENDING DECEMBER 31, 2015 (2015), http://www.uscourts.gov/statistics/table/c-4/statistical-tables-federal-judiciary/2015/12/31 [https://perma.cc/FL5S-JG7M]. This figure includes both cases in which the United States was a defendant and private cases in which there was diversity of citizenship among the parties. *Id.* Three percent is actually higher than many other kinds of claims. *See, e.g.*, *id.*; Marc Galanter, *The Vanishing Trial: An Examination of Trials and Related Matters in Federal and State Courts*, 1 J. EMPIRICAL LEGAL STUD. 459 (2004); Xavier Rodriguez, *The Decline of Civil Jury Trials: A Positive Development, Myth, or the End of Justice as We Now Know It?*, 45 ST. MARY'S L.J. 333 (2014).

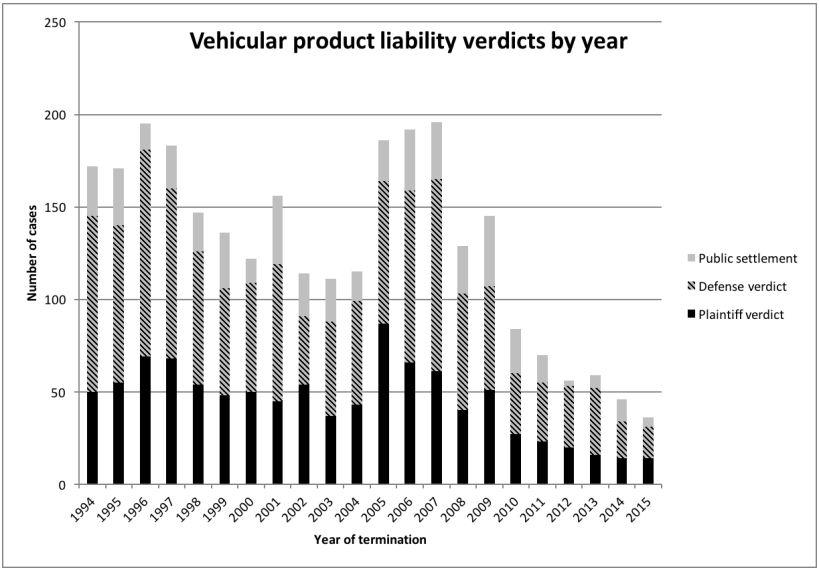
number of verdicts.[157] Figure 10 shows how the number of recorded verdicts in motor vehicle-related negligence claims has fallen since the mid-2000s. Similarly, Figure 11 shows how the number of recorded verdicts in motor vehicle-related product liability claims has declined even more dramatically.[158] Public settlements, which are also shown on the figures, represent only a small portion of all settlements.

Figure 10



157. *See infra* Figure 10.
158. *See infra* Figure 11.

Figure 11



Even settlements and other case dispositions, however, occur against the backdrop of those relatively few cases that do reach a verdict. Those verdicts provide external benchmarks for the standard of reasonable care to which a defendant may be held and the amount of compensation, if any, to which a plaintiff may be entitled. These verdicts also clarify the relevant legal rules, particularly when a losing party appeals to a higher court.

Most personal injury cases involve claims of negligence. This includes 99% of the 80,000 relevant verdicts in Westlaw's Case Evaluator from 2006 through 2015.[159] The plaintiff asserting a negligence claim must show that the defendant breached a legal duty by acting unreasonably in a way that proximately caused legally recognized harm to the plaintiff.[160] Defendants are frequently individual motorists, and this Article uses the term vehicular negligence to refer to negligence claims against these individuals or

159. *See supra* Figure 10.

160. Or, more specifically, that the defendant breached a legal duty by acting unreasonably in a way that proximately caused legally recognized harm to the plaintiff.

their principals.[161] However, defendants may also include manufacturers, sellers, and other companies.[162]

In contrast, defendants in a product liability case are generally the entities that make, distribute, or sell the product or product component that allegedly harmed the plaintiff.[163] In its broad sense (and as used in this Article), product liability law encompasses a variety of claims, including negligence. This area of the law varies tremendously in both time and space: It has evolved dramatically over the last 100 years, and this evolution has produced strikingly different rules in different states.[164] About 6% of the relevant verdicts in Westlaw's Case Evaluator involve a product liability claim,[165] which is comparable to estimates of the percent of crashes that are caused at least in part by a vehicle failure.[166]

Defect in a legal sense, however, is not necessarily coterminous with failure in a technical sense.[167] The failure or degradation of a vehicle component does not necessarily mean that the component was defective. Vehicles that are reasonably safe when sold may be—and in fact often are[168]—poorly maintained, and they may otherwise reach the end of their functional life. Tire condition, for example, is a particularly obvious factor in some crashes,[169] but a tire is not necessarily defective merely because it explodes. Conversely, a design may be defective even if a component does not physically fail

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161. Under some circumstances, employers and vehicle owners that were not themselves negligent can nonetheless be vicariously liable for the negligent acts of their employees and permissive drivers.

162. *See* Samuel R. Gross & Kent D. Syverud, *Don't Try: Civil Jury Verdicts in a System Geared to Settlement*, 44 UCLA L. REV. 1, 19 (1996).

163. *See id.*

164. *See generally* Richard C. Henke, *Comparative Fault in Products Liability: Comparing California and New Jersey*, 19 T.M. COOLEY L. REV. 301 (2002); David G. Owen, *The Evolution of Products Liability Law*, 26 REV. LITIG. 955 (2007).

165. Many of these cases also include negligence claims.

166. *See infra* note 305 and accompanying text.

167. *See supra* PRODUCT FAILURE (previous Part) (discussing product failure in this technical sense).

168. *See* NHTSA, DOT HS 809 316, TIRE PRESSURE SPECIAL STUDY: INTERVIEW DATA (2001), http://www-nrd.nhtsa.dot.gov/Pubs/809316.pdf [https://perma.cc/5ZNF-FJHM].

169. *See* SINGH, *supra* note 44, at 2 ("Of the small percentage (2%) of the crashes in which the critical reason was assigned to the vehicle, [a] tire problem accounted for about 35 percent (±11.4%) of the crashes.").

or degrade. For example, a plaintiff may allege that she was not adequately instructed on the proper use of a product.[170]

Crashworthiness claims—also known as enhanced injury or second collision claims[171]—are an especially important example. Because "[c]ollisions with or without fault of the user are clearly foreseeable by the manufacturer and are statistically inevitable," that manufacturer has "a duty to use reasonable care in the design of its vehicle to avoid subjecting the user to an unreasonable risk of injury in the event of a collision."[172] These claims can involve, for example, the absence of a particular safety device,[173] a fuel tank fire,[174] or a second collision between the plaintiff's body and some part of the vehicle.[175] Although numbers are not readily available, the attention paid to these claims by practicing attorneys,[176] high courts,[177] scholars,[178] and at least one legislature[179] suggests they are a significant part of contemporary automotive product liability.

More broadly, the plaintiff in a product liability case must typically demonstrate that she was harmed by a product defect—that is, a dangerous characteristic of a product. If this defect is the result of an imperfect production process, then the plaintiff may be able to recover from the manufacturer even if the production process was

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170. *See* William A. Weiler, *Punitive Damages—Strict Products Liability—* Erie *Doctrine*, 25 DUQ. L. REV. 365, 382 (1987) (citing Incollingo v. Ewing, 282 A.2d 206 (Pa. 1971)).

171. *See* Michael Hoenig, *Resolution of "Crashworthiness" Design Claims*, 55 ST. JOHN'S L. REV. 633, 633 (1981).

172. Larsen v. Gen. Motors Corp., 391 F.2d 495, 502 (8th Cir. 1968).

173. *See, e.g.*, Williamson v. Mazda Motor of Am., Inc., 562 U.S. 323 (2011); Geier v. Am. Honda Motor Co., 529 U.S. 861 (2000).

174. *See, e.g.*, Linert v. Foutz, 20 N.E.3d 1047 (Ohio Ct. App. 2014).

175. *See, e.g.*, Parr v. Ford Motor Co., 109 A.3d 682, 692 (Pa. Super. Ct. 2014) ("validat[ing] 'roof crush' as the cause of head and neck injuries sustained by belted occupants in rollover motor vehicle accidents").

176. *See, e.g.*, *Crashworthiness Lawsuit*, AM. INJURY ATTORNEY GRP., https://attorneygroup.com/lawsuits/products-liability/crashworthiness-lawsuit/ [https://perma.cc/HT2V-7R22] (last visited Nov. 16, 2016).

177. *See, e.g.*, *Williamson*, 562 U.S. 323; *Geier*, 529 U.S. 861; D'Amario v. Ford Motor Co., 806 So. 2d 424 (Fla. 2001), *superseded by statute*, FLA. STAT. § 768.81.

178. *See, e.g.*, Ellen M. Bublick, *The Tort-Proof Plaintiff: The Drunk in the Automobile, Crashworthiness Claims, and the Restatement (Third) of Torts*, 74 BROOK. L. REV. 707 (2009).

179. *See, e.g.*, Fla. S.B. 142, 1st Sess. (Fla. 2011); *see also*, Larry M. Roth, *Florida's Motor Vehicle Crashworthiness Enhanced Injury Doctrine: "Wanted Dead Or . . ."*, 18 BARRY L. REV. 389 (2013).

reasonable.[180] However, if this defect is an aspect of the product's design, then the plaintiff generally must show that the design itself was unreasonable, often by reference to a reasonable alternative design.[181] Similarly, if the defect consists of incorrect or incomplete instructions for or warnings about the product, then the plaintiff must show that the information actually provided was unreasonable.[182]

Proving both that a product was defective and that this defect caused the plaintiff's injuries can be difficult and expensive, particularly when expert witnesses are required. (Defending such a claim can also be expensive.) These costs can deter injured individuals from pursuing, attorneys from accepting, and parties from fully pursuing claims that are complicated, uncertain, or comparatively low in damages.[183] The combination of litigation expenses and the contingent fee system also means that even successful plaintiffs will only see a portion of the actual settlement or award.[184]

Because they are public, jury awards can provide some insight into how injuries are valued. However, because of post-judgment appeals and settlements, these initial amounts do not necessarily reflect what the plaintiffs are ultimately awarded.[185]

Westlaw's Case Evaluator provides rough data on awards by claim and injury type. The table below shows data for vehicular negligence and product liability cases involving death, paraplegia, and quadriplegia; significant case variations reduce the utility of

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180. RESTATEMENT (THIRD) OF TORTS: PRODUCTS LIABILITY § 2 cmt. a (AM. LAW INST. 1998).

181. *Id.* at § 2(b).

182. *Id.* at § 2(c).

183. *See generally* Herbert M. Kritzer, *Contingency Fee Lawyers as Gatekeepers in the Civil Justice System*, 81 JUDICATURE 22 (1997).

184. *See, e.g.*, Derek H. Swanson & Lin Wei, *United States Automotive Products Liability Law: A Corporate Approach to Preventive Management, Risk Reduction, and Case Coordination for Chinese Automakers*, MCGUIRE WOODS 1, 16 (2009), https://www.mcguirewoods.com/news-resources/publications/us-automotive-products-liability.pdf [https://perma.cc/GWA2-B375].

185. A 1989 GAO report found that, for the cases examined,

> Appeals and posttrial settlement negotiations resulted in final payments different from the initial verdicts in 30 percent of all cases, and reduced total award amounts by 43 percent. Reductions occurred in 50 percent of the cases won by plaintiffs and in 71 percent of the cases with awards of $1 million or more.

U.S. Gen. Accounting Off., GAO-89-99, PRODUCT LIABILITY: VERDICTS AND CASE RESOLUTION IN FIVE STATES 3-4 (1989), http://www.gao.gov/assets/150/148313.pdf [https://perma.cc/S937-DMNG].

aggregate data on less severe injuries. For each, it indicates the percent of cases in which the verdict favored the defendant, the median award for cases in which the verdict favored the plaintiff, and the median settlement amount in cases in which that amount was publicly disclosed. These awards are generally rounded to one significant figure, because any more specificity would merely mock precision.[186]

Figure 12

Injury, Type, and Theory	Cases in dataset	Defense verdicts	Median public settlement	Median plaintiff verdict
Death - MV Negligence	2670	38%	$400,000	$2,000,000
Death - MV Prod Liability	230	64%	$700,000	$5,000,000
Death - All Prod Liability	738	48%	$400,000	$5,000,000
Paraplegia - MV Negligence	123	30%	$6,000,000	$9,000,000
Paraplegia - All Prod Liability	63	72%	$2,000,000	$10,000,000
Quadriplegia - MV Negligence	102	26%	$3,000,000	$15,000,000
Quadriplegia - All Prod Liability	91	51%	$3,000,000	$14,000,000
All injuries - MV Negligence	81842	35%	$50,000	$30,000
All injuries - MV Prod Liability	4706	53%	$400,000	$2,000,000
All injuries - All Prod Liability	1013	59%	$400,000	$3,000,000

Recall that each fatality costs society about $9 million and each critical injury costs society about $6 million.[187] (Paraplegia and quadriplegia are particularly critical injuries.) The median public settlements for fatal injuries are an order of magnitude lower than these estimates. The median awards for plaintiff verdicts, while more

186. These numbers are drawn from a decade of verdicts from a variety of jurisdictions involving a variety of disparate facts. The dataset almost certainly includes some miscoded or otherwise inappropriate cases. To provide a meaningful number of cases, the product liability data used in this Article sometimes relate to all product types rather than to motor vehicles only.

187. *See* BLINCOE ET AL., *supra* note 26, at 4.

comparable, are not necessarily final. Moreover, these medians exclude all the cases in which the verdict favors the defendant. Whereas most vehicular negligence verdicts in the dataset favor plaintiffs, most product liability verdicts favor defendants. That means that the median award across all product liability claims is actually $0.[188]

There are additional differences between the vehicular negligence and product liability awards in the dataset. For those motor vehicle-related injury cases that do result in a verdict for the plaintiff, the median product liability award is many times higher than the median vehicular negligence award. One explanation for this discrepancy may be the cost of litigating a complex product liability claim, which may discourage plaintiffs (or their attorneys) from fully pursuing these claims for less-than-severe injuries.[189]

The statistical picture with respect to specific injury types is more mixed. For fatal-injury cases with verdicts in favor of the plaintiff, median awards are more than twice as large in product liability as in vehicular negligence; a different analysis by Westlaw's parent company suggests a similar conclusion albeit with lower numbers.[190] However, for paraplegia and quadriplegia, these awards are comparable between vehicular negligence and product liability. Moreover, median public settlements for paraplegia are actually much higher in vehicular negligence than in product liability.

Characteristics of the defendant may also affect jury verdicts and awards, though both the empirical and the theoretical research on this point are mixed. A 1992 study found that juries are more likely to find for corporate defendants than for individual defendants but also to award somewhat higher damages against those corporate defendants that they do hold liable.[191] This is broadly consistent with the numbers above, although the inclusion of some vehicular negligence cases against corporate defendants may obscure a larger difference. Other empirical investigations of jury behavior have

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188. Means are not used here because they tend to be distorted by a few massive awards that either reflect additional injuries or largely comprise punitive damages.

189. *See* Kritzer, *supra* note 183.

190. According to *Current Award Trends in Personal Injury*, the median plaintiff award across all death cases analyzed from 2008 through 2014 is about $900,000, while the equivalent across only product liability cases is $1.9 million. CURRENT AWARD TRENDS IN PERSONAL INJURY 6, 19 (55th ed.).

191. *See* Brian Ostrom, David Rottman & Roger Hanson, *What are Tort Awards Really Like? The Untold Story from the State Courts*, 14 L. & POL'Y 77, 95 (1992).

found evidence of a jury preference for individual defendants over corporate defendants.[192] Juries may distrust companies, sympathize less with these companies, or hold these companies to a higher standard[193]—or not.[194] Regardless, the greater perceived wealth of corporate defendants apparently did explain this differential treatment.[195]

A comparatively wealthy company, however, is more likely to actually be able to pay a large judgment than an individual driver with minimum insurance and minimal reachable assets.[196] This means that even if a plaintiff prevails against an individual defendant who is uninsured or underinsured, she may not be able to collect in part or in full. In more practical terms, this means that many legally viable claims are never brought solely because they are not financially viable.[197]

The experience—or at least the rhetoric—of companies that rent or lease motor vehicles also suggests that the aggregate recovery for vehicular negligence would be higher if individual driver defendants had more reachable assets. "In 2005, Congress passed, and the President signed, a multi-billion dollar transportation act that contained the Graves Amendment, which prohibits any state from holding those in the business of renting or leasing cars liable for injuries caused by those cars, absent any negligence on their part."[198]

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192. *See, e.g.*, Robert J. MacCoun, *Differential Treatment of Corporate Defendants by Juries: An Examination of the "Deep-Pockets" Hypothesis*, 30 L. & SOC'Y REV. 121, 140 (1996).

193. *Id.* at 140-41.

194. *See* Valerie P. Hans, *The Illusions and Realities of Jurors' Treatment of Corporate Defendants*, 48 DEPAUL L. REV. 327, 342 (1998).

195. *Compare* MacCoun, *supra* note 192, *with* Edith Greene, William Douglas Woody & Ryan Winter, *Compensating Plaintiffs and Punishing Defendants: Is Bifurcation Necessary?*, 24 L. & HUM. BEHAV. 187, 197 (2000), *and* Neil Vidmar, *Empirical Evidence on the Deep Pockets Hypothesis: Jury Awards for Pain and Suffering in Medical Malpractice Cases*, 43 DUKE L.J. 217, 258 (1993).

196. *See* Gilles, *supra* note 115, at 606; Huang, *supra* note 115, at 1034-35.

197. *See* Gilles, *supra* note 115, at 606; *see also* Walker Smith, *supra* note 16, at 36 (advocating a substantial increase in the amount of third-party liability insurance required).

198. Susan Lorde Martin, *Commerce Clause Jurisprudence and the Graves Amendment: Implications for the Vicarious Liability of Car Leasing Companies*, 18 U. FLA. J. L. & PUB. POL'Y 153, 154 (2007). A contemporaneous article in *Auto Rental News* predicted that the day this bill was signed "will go down in history as one of the most significant dates in the vehicle rental industry." Michael LaPlaca, *What Does the End of Vicarious Liability Mean?*, AUTO RENTAL NEWS. (Sept./Oct. 2005), http://www.autorentalnews.com/channel/fleet-insurance/article/story/2005/09/what-does-the-end-of-vicarious-liability-mean.aspx [https://perma.cc/TCK6-TZR5].

The intent and effect of this provision was to preempt laws in perhaps a dozen states,[199] especially New York, that imposed some form of vicarious liability on these companies for the negligence of the individuals who drove their vehicles.[200] Various industry representatives asserted at the time that this vicarious liability cost car rental companies over $100 million annually in judgments and settlements.[201] In other words, in the states with vicarious liability, these corporate defendants may have paid $100 million annually that likely could not have been collected from the individual negligent drivers.[202]

The discussion so far has focused on the compensatory damages that are intended to make the victim whole. Punitive damages, in contrast, are intended in part to punish the defendant for morally culpable behavior.[203] Analyses of punitive damages reach divergent conclusions about their frequency and size. A study by Westlaw's parent notes that "punitive damages accompanied compensatory awards in" between 4% and 27% of the cases examined from 2008 through 2014,[204] which is significantly higher

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199. *See, e.g.*, H.R. REP. NO. 106-774, at 13 (2000), https://www.gpo.gov/fdsys/pkg/CRPT-106hrpt774/html/CRPT-106hrpt774-pt1.htm [https://perma.cc/NP94-NAR7] (mentioning eleven states); *Rental Fairness Act of 1999: Hearing Before the Subcomm. on Fin. & Hazardous Materials of the Comm. on Commerce*, 106th Cong. (1999) (statement of Richard H. Middleton, Jr.), https://www.gpo.gov/fdsys/pkg/CHRG-106hhrg60357/html/CHRG-106hhrg60357.htm [https://perma.cc/WQN2-TYKE] [hereinafter *1999 Finance and Hazardous Materials Hearing*] (referencing that 12 states have some form of vicarious liability and five states have full vicarious liability).

200. *See* Martin, *supra* note 198, at 157-58.

201. *See 1999 Finance and Hazardous Materials Hearing*, *supra* note 199 (statement of Sharon Faulkner, Area Manager, Premier Car Rental Company). This number was also identified in H.R. 1954, which was a precursor to the Graves Amendment. H.R. REP. NO. 106-774, at 5. Another witness suggested that this liability "amounts to over $200 million per year for this industry." *1999 Finance and Hazardous Materials Hearing*, *supra* note 199, (statement of Raymond T. Wagner, Vice President of Enterprise Rent-A-Car Corp.). Opponents of preemption noted that the "entire industry had only $100 million in accident costs in 1996," *id.* (statement of Richard H. Middleton, Jr., President, Ass'n of Trial Lawyers of Am.), although this may have referred only to "collision damages," *id.* (statement of Raymond T. Wagner).

202. An opponent of preemption did note that, "the auto rental industry has decided that they are going to not pursue 40 percent of the claims which they could, in fact, pursue for third-party liability. They have made no effort to do so," though it is not clear from this characterization whether these defendants had assets from which to recover. *Id.* (statement of Richard H. Middleton, Jr.).

203. *See* Huang, *supra* note 115, at 1028, 1035.

204. CURRENT AWARD TRENDS, *supra* note 190, at 20.

than in vehicular negligence cases (1%) and all cases (between 2% and 5%).[205] A study of state court cases in 2005, however, found that plaintiffs were awarded punitive damages in only 1% of the product liability cases in which they prevailed.[206] As a matter of constitutional law, punitive damage awards that are many times higher than the underlying compensatory award engender particular scrutiny from courts.[207] Like compensatory awards, punitive awards may also be reduced by trial and appeals courts.[208]

In addition to personal injury, product liability law also encompasses some claims on behalf of purchasers of a product who were economically but not physically harmed, typically because the product fails to conform to explicit or implicit representations made about it by its manufacturer or downstream seller.[209] In these cases, the harm to each individual purchaser may be small, but the aggregate injury is much more substantial. Because these purchasers are generally similarly situated, they (or an enterprising attorney) may litigate collectively through a class action. For example, in 2013 Toyota agreed to pay over $1 billion to settle a class action alleging that the economic value of vehicles had decreased as a result of sudden unintended acceleration concerns that had undermined Toyota's claims about safety.[210]

A more recent (and even more recently dismissed) putative class action alleged that several automakers had known "for years" that their vehicles "have been (and currently are) susceptible to hacking," that they did not disclose this, and that buyers therefore

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205. *Id.* at 7, 9.

206. THOMAS H. COHEN & KYLE HARBACEK, U.S. DOJ, BUREAU OF JUSTICE STATISTICS, PUNITIVE DAMAGE AWARDS IN STATE COURTS, 2005, at 4 tbl. 5 (2011), https://www.bjs.gov/content/pub/pdf/pdasc05.pdf [https://perma.cc/6PV8-F9JD].

207. *See* State Farm Mut. Auto. Ins. Co. v. Campbell, 538 U.S. 408, 425 (2003) ("[F]ew awards exceeding a single-digit ratio between punitive and compensatory damages . . . will satisfy due process.").

208. *See* Laura J. Hines & N. William Hines, *Constitutional Constraints on Punitive Damages: Clarity, Consistency, and the Outlier Dilemma*, 66 HASTINGS L.J. 1257, 1285-86 (2015) (examining 18 product liability opinions, finding a reduction in median punitive damages from about $16 million to $10 million, and noting that these amounts are higher than those found in empirical studies).

209. *See* Larry E. Ribstein, *Guidelines for Deciding Product Economic Loss Cases*, 29 MERCER L. REV. 493, 519 (1978).

210. *Toyota Economic Loss Settlement*, TOYOTA MOTOR CORP., https://www.toyotaelsettlement.com [https://perma.cc/WR5S-E9EZ] (last visited Nov. 16, 2016); Bill Vlasic, *Toyota Agrees to Settle Lawsuit Tied to Accelerations*, N.Y. TIMES (Dec. 26, 2012), http://www.nytimes.com/2012/12/27/business/toyota-settles-lawsuit-over-accelerator-recalls-impact.html [https://perma.cc/6L5A-LAM7].

paid more than those vehicles are worth.[211] In this case, the federal judge concluded that these claims were unsupported by any evidence of personal injury.[212] Nonetheless, these claims foreshadow some of the technical and legal issues that could accompany the combination of increasing automation and increasing connectivity.

Scholars have examined the product liability implications of automated driving for more than two decades.[213] Broadly, they recognize that shifting the real-time decisions necessary for driving

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211. Compl. & Demand for Jury Trial, Cahen v. Toyota Motor Corp., No. 3:15-cv-01104 (N.D. Cal. Mar. 10, 2015). *See also* Annie Hunt, *Judge Dismisses Car Hacking Lawsuit Against Automakers*, LEGAL NEWSLINE (Jan. 7, 2016, 10:11 AM), http://legalnewsline.com/stories/510656596-judge-dismisses-car-hacking-lawsuit-against-automakers [https://perma.cc/35BB-J43J].

212. *See* Hunt, *supra* note 211.

213. *See, e.g.*, Sophia H. Duffy & Jamie Patrick Hopkins, *Sit, Stay, Drive: The Future of Autonomous Car Liability*, 16 SMU SCI. & TECH. L. REV. 453 (2013); Kevin Funkhouser, *Paving the Road Ahead: Autonomous Vehicles, Products Liability, and the Need for a New Approach*, 2013 UTAH L. REV. 437 (2013); Andrew P. Garza, *"Look Ma, No Hands!": Wrinkles and Wrecks in the Age of Autonomous Vehicles*, 46 NEW ENG. L. REV. 581 (2012); Dorothy J. Glancy, Robert W. Peterson & Kyle F. Graham, *A Look at the Legal Environment for Driverless Vehicles*, 69 LEGAL RES. DIGEST 1, 3 (2016); Kyle Graham, *Of Frightened Horses and Autonomous Vehicles: Tort Law and Its Assimilation of Innovations*, 52 SANTA CLARA L. REV. 1241 (2012) [hereinafter Graham, *Of Frightened Horses*]; Jeffrey K. Gurney, *Sue My Car Not Me: Products Liability and Accidents Involving Autonomous Vehicles*, 2013 U. ILL. J. L. TECH. & POL'Y 247 (2013); F. Patrick Hubbard, *"Sophisticated Robots": Balancing Liability, Regulation, and Innovation*, 66 FLA. L. REV. 1803 (2014); Gary E. Marchant & Rachel A. Lindor, *The Coming Collision Between Autonomous Vehicles and the Liability System*, 52 SANTA CLARA L. REV. 1321 (2012); Dana M. Mele, *The Quasi-Autonomous Car as an Assistive Device for Blind Drivers: Overcoming Liability and Regulatory Barriers*, 28 SYRACUSE SCI. & TECH. L. REV. 26 (2013); Andrew R. Swanson, Comment, *"Somebody Grab the Wheel!": State Autonomous Vehicle Legislation and the Road to a National Regime*, 97 MARQ. L. REV. 1085 (2014); David C. Vladeck, *Machines Without Principles: Liability Rules and Artificial Intelligence*, 89 WASH. L. REV. 117 (2014); Bryant Walker Smith, *Proximity-Driven Liability*, 102 GEO. L.J. 1777 (2014) [hereinafter *Proximity-Driven Liability*]; Stephen S. Wu, *Product Liability Issues in the U.S. and Associated Risk Management*, *in* AUTONOMOUS FAHREN 575, 576 (2015); JAMES M. ANDERSON ET AL., RAND CORP., AUTONOMOUS VEHICLE TECHNOLOGY: A GUIDE FOR POLICYMAKERS (2016), http://www.rand.org/pubs/research_reports/RR443-2.html [https://perma.cc/S8BT-AG2U]; TOM M. GASSER ET AL., BAST-BERICHT, RECHTSFOLGEN ZUNEHMENDER FAHRZEUGAUTOMATISIERUNG, F 83, at 4 (2012); NIDHI KALRA, JAMES ANDERSON, MARTIN WACHS, RAND CORP., LIABILITY AND REGULATION OF AUTONOMOUS VEHICLE TECHNOLOGIES 17 (2009); STEPHEN N. ROBERTS ET AL., ADVANCED VEHICLE CONTROL SYSTEMS: POTENTIAL TORT LIABILITY FOR DEVELOPERS 1 (1993); JOHN VILLASENOR, BROOKINGS INST. PRODUCTS LIABILITY AND DRIVERLESS CARS: ISSUES AND GUIDING PRINCIPLES FOR LEGISLATION 2 (2014).

from human drivers to automated driving systems (or their human designers) means that automotive companies could be liable in a much greater share of crashes involving these systems.[214] These potential defendants could include automotive manufacturers, component suppliers, software providers, data providers, fleet operators, and infrastructure managers, among others that will make up the automated driving industry.[215] (This Article often refers to "manufacturers" or "developers" as synecdoches for this larger set of potential defendants.)

This decisional shift from human driver to automated driving system will significantly increase the importance of product liability relative to vehicular negligence. Whereas today's crash liability regime is based largely on the liability of individual drivers under negligence,[216] tomorrow's may be premised on the liability of manufacturers under product liability broadly. This shift will also create new issues for the judges and juries evaluating the resulting crash claims—as well as for the lawyers negotiating to avoid such trials.

Some of these issues will be threshold questions. The software that operates an automated driving system as well as the data used or produced by such a system may or may not be products for the purposes of product liability law.[217] The operator of an automated shuttle fleet may or may not be a common carrier subject to a higher standard of care.[218] Complex business relationships, product interactions, and informational supply chains may lead courts to expand or limit the duties of some potential defendants.[219]

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214. *See, e.g.*, Glancy, Peterson & Graham, *supra* note 213, at 39 ("[T]he principal locus of liability for accidents is expected to [eventually] transition away from people using these vehicles for transportation and toward the manufacturers of these devices and the software used in them.").

215. *See* Dorothy J. Glancy, *Autonomous and Automated and Connected Cars—Oh My! First Generation Autonomous Cars in the Legal Ecosystem*, 16 MINN. J. L. SCI. & TECH. 619, 657 (2015).

216. States with no-fault insurance regimes have adopted these regimes against a background rule of negligence. *See* Glancy, Peterson & Graham, *supra* note 213, at 11.

217. *See* Michael C. Gemignani, *Product Liability and Software*, 8 RUTGERS COMPUTER & TECH. L.J. 173, 199 (1981).

218. *See, e.g.*, Paul Stephen Dempsey, *Taxi Industry Regulation, Deregulation & Reregulation: The Paradox of Market Failure*, 24 TRANSP. L.J. 73, 85 (1996).

219. *See, e.g.*, *Proximity-Driven Liability*, *supra* note 213, at 1797-99.

Regardless of the particular theories invoked or the particular language used, the argument that the automated driving system in question performed unreasonably will be central to many personal injury claims. This question of unreasonable performance is likely to have two independent prongs: An automated driving system has performed unreasonably if either (a) a human driver or (b) a comparable automated driving system could have done better under the same circumstances.

This first prong—involving a comparison with a human driver—seems to fit most naturally with the consumer expectations test still used by some jurisdictions to determine defect under strict product liability. After all, a consumer is likely to expect that her automated driving system will perform at least as well as she would in any given situation.

This human comparison also matters to the more common risk-utility test. Under this test, a plaintiff may argue that an automated driving system that supplants rather than merely supplements the human driver is unreasonable. For the specific type of crash at issue, the reasonable alternative design would involve human and machine rather than just machine alone. A negligence claim would look similar: The occurrence of a crash that a human driver could have prevented would be used to suggest that the manufacturer acted unreasonably in prematurely marketing an automated driving system that operates without human supervision.

Because manufacturers are likely to imply that their systems are at least as safe as human drivers, a contradictory crash may also give rise to a misrepresentation claim. Many ex ante arguments about safety are likely to be statistical: Crash data, for example, may suggest that automated driving is safer overall than conventional driving.[220] Although the assumption that automated driving is also safer in every single situation does not logically follow from such a statistical comparison, manufacturers are unlikely to parse this difference in their representations. These representations could also motivate claims on behalf of entire classes of consumers alleging financial rather than physical injury.[221]

The second prong—involving a comparison with another actual or hypothetical automated driving system—will also focus narrowly on the particular crash at issue. Here, the risk-utility test for strict product liability will ask whether a reasonable change could have

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220. *See* BLANCO ET AL., *supra* note 67, at 40-41.
221. *See* Vlasic, *supra* note 210.

prevented the injury and not whether the automated driving system is safer than a human driver on the whole. In other words, whether an automated driving system has prevented tens of thousands of injuries in other situations will generally be irrelevant to whether that system caused the one injury in question.

New (and old) issues may arise in applying the risk-utility test to automated driving systems. The cost of a reasonable alternative design that involves changing only a few lines of code may be close to zero.[222] Probabilistic decision-making and machine learning may involve the explicit or implicit weighting of decisional criteria, such as the risk of a crash relative to the risk of a travel delay.[223] A jury may be sympathetic to a plaintiff's argument that an automated driving system (or its developer) should have assigned even higher values to safety-relevant inputs.[224] Outrage over these values could conceivably motivate some juries to impose punitive damages. At the same time, for probabilistic systems, the plaintiff may struggle to causally connect these values to the actual harm.

A minor crash between one of Google's research cars and a public bus in February 2016 illustrates these potential challenges.[225] While attempting to merge back into a travel lane, the car "detected the approaching bus, but predicted that it would yield to us because we were ahead of it."[226] Google's test driver predicted the same and therefore did not intervene.[227] However, the bus did not yield.[228] Following the crash, Google updated its software so that its "cars will more deeply understand that buses and other large vehicles are less likely to yield to us than other types of vehicles."[229] In other words, the updated version of Google's software is less likely to initiate a similar maneuver—but it might still do so.

The risk-utility test may also demand even better performance as automated driving technologies improve. For example, consider a

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222. *See Proximity-Driven Liability*, *supra* note 213, at 1801.

223. *See* Walker Smith, *supra* note 16, at 36-37.

224. *Id.*; *see also* Gary T. Schwartz, *The Myth of the Ford Pinto Case*, 43 RUTGERS L. REV. 1013, 1043 (1991).

225. *See Report of Traffic Accident Involving an Autonomous Vehicle*, Cal. DMV, http://docs.dpaq.de/10437-googleautocrashreportfeb2016.pdf ([https://perma.cc/X3CF-R7TQ] (last visited Nov. 16, 2016).

226. *Monthly Report: February 2016*, GOOGLE SELF-DRIVING CAR PROJECT (Feb. 29, 2016) https://static.googleusercontent.com/media/www.google.com/en//selfdrivingcar/files/reports/report-0216.pdf [https://perma.cc/9W67-UA5M].

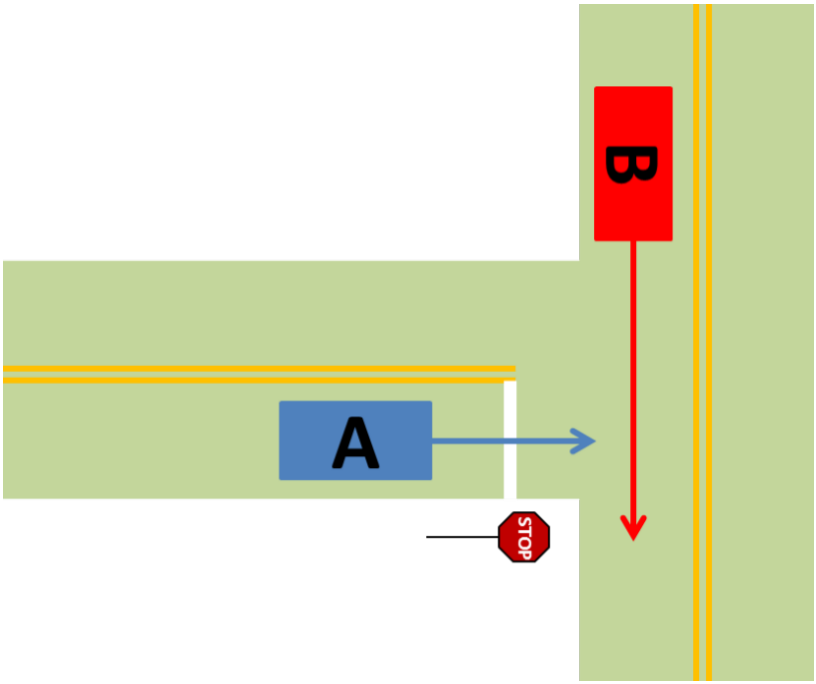
227. *Id.*

228. *Id.*

229. *Id.*

crash at a rural intersection in which the driver of vehicle A carelessly runs a stop sign and strikes vehicle B, seriously injuring its occupants:

Figure 13



Under these facts, the driver of vehicle A has clearly acted negligently, and the injured occupants of vehicle B should prevail in a personal injury claim against her. This driver, however, may have minimal liability insurance and minimal assets, in which case the injured occupants would likely be unable to actually collect their full damages. For this reason (and the other reasons noted above), they may look to other potential defendants.

First imagine that vehicle B had a conventional driver. Provided that this driver was behaving responsibly, she is unlikely to face any civil liability. Her vehicle was struck by a careless driver who failed to yield the right of way. She was not negligent, and her fellow occupants would be unlikely to even include her as a defendant, much less successfully recover from her.

But now imagine that vehicle B was operating in a highly automated mode. In this case the injured occupants may argue that

the automated driving system could and should have recognized that vehicle A was not slowing down, predicted that vehicle A would run the stop sign, and taken immediate evasive actions. A jury that would not expect this kind of expert defensive driving from a human driver may nonetheless expect it from an automated driving system.

Such a conclusion might support a finding that the automated driving system was defective. In that case, even if the jury still assigns most of the fault to the driver of vehicle A, the injured plaintiffs might nonetheless collect some or even all of their damages from the manufacturer of vehicle B (or from its relevant suppliers). This is similar to crashworthiness claims today in which automakers may be liable for injuries caused by the unreasonable performance of safety systems in crashes precipitated entirely by driver error.[230]

A high-profile fatal crash involving Tesla's so-called autopilot system is strikingly similar to this hypothetical.[231] In that crash, the driver of a truck pulling a trailer apparently turned across a divided highway, the Tesla car struck the trailer, and the Tesla driver was killed.[232] Potential but-for causes may include, among others, a failure by the truck driver to yield the right of way, a failure by the Tesla driver to brake to avoid striking the trailer, and failures by both the autopilot system and a separate automatic braking system to recognize the trailer as an obstacle. The presence of these two systems has created potential liability for Tesla and its supplier where otherwise there may have been none.

At some point, however, the *lack* of active safety systems like automatic braking may also give rise to product liability for the manufacturer. Indeed, NHTSA recently announced that major automakers had agreed to make automatic braking standard on their vehicles by 2022;[233] certainly at and possibly even before this point, a jury may conclude that a new vehicle without this feature is defective because of the omission.

It is important to emphasize again that automated emergency intervention systems are conceptually distinct from automated driving systems.[234] This means that the argument that a vehicle

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230. *See* Hoenig, *supra* note 171, at 633-35.

231. HWY16FH018, *supra* note 79.

232. *Id.*

233. Press Release, NHTSA, U.S. DOT and IIHS Announce Historic Commitment of 20 Automakers to Make Automatic Emergency Braking Standard on New Vehicles (Mar. 17, 2016), http://www.nhtsa.gov/About-NHTSA/Press-Releases/nhtsa_iihs_commitment_on_aeb_03172016 [https://perma.cc/65NX-5WTJ].

234. *See supra* notes 17-20 and accompanying text.

should be equipped with automatic braking is different than the argument that a vehicle should be equipped with automated driving functionality. If these were the same, then the liability comparison would be simpler: Given a choice between facing liability for every crash that automation could have prevented and facing liability for only a fraction of such crashes (when that automation actually failed), automakers would rationally choose the latter. However, in any case in which a human driver could have prevented a crash that an automated driving system did not, injured plaintiffs may argue that the combination of human driver and active safety system is a more reasonable design than automated driving without human supervision.

Even so, the complexities of human behavior may actually justify greater automation. Active safety systems that merely support human driving present difficult human factor issues. A human driver who learns that her vehicle's automatic braking system prevents many common crashes may over-rely on that system. Or a driver may perceive an imminent crash and, in a panic, fight with her vehicle's automatic emergency steering system in a way that exacerbates the situation. At some point, then, removing the human entirely from active driving may be safer than managing the "mushy middle" of shared human-machine operation.

This shift could also negate product liability claims that a manufacturer did not adequately instruct a driver on how to use an active safety system, misrepresented the performance of that system, failed to guard against foreseeable misuse of that system, or designed that system without reasonably addressing a particular problem with human-machine interaction. Active safety and driver assistance systems that have already reached the market, including crash-imminent braking, may eventually give rise to some of these claims.

Automation could also help automakers reduce their exposure to crashworthiness claims.[235] Avoiding a "first collision" can prevent a "second collision" between the would-be victim and some part of the vehicle.[236] This will not always be the case; for example, a vehicle occupant may still be injured if an automated driving system brakes or maneuvers quickly to avoid a crash. However, if automated

235. S*ee generally* Hoenig, *supra* note 171 (discussing crashworthiness).
236. *Id.* at 634 n.2.

driving systems operate only when all occupants are belted,[237] then those occupants are less likely to come into contact with other parts of the vehicle even in crashes or other instances of sudden deceleration.

Independent of automation, the increasing connectivity of modern motor vehicles could also give rise to new claims.[238] Automakers and other companies are increasing their "proximity" to their products—through technical means such as remote monitoring, over-the-air updates, and digital rights management technologies as well as legal means such as end user license agreements, subscription agreements, and copyright assertions.[239] With this greater power may come greater responsibility,[240] including expanded tort duties and higher standards of reasonable care.[241] Cybersecurity vulnerabilities may be a particularly important driver of new or expanded post-sale duties to warn or update. Increased data collection may also give rise to obligations and liabilities related to the unauthorized dissemination of those data. However, because these potential sources of liability depend primarily on connectivity rather than automation, they should be included on *both* sides of a liability comparison.

The mechanics of proving an automated driving-related product liability claim may also differ from the mechanics of proving a vehicular negligence claim or even a contemporary product liability claim. Whether this change favors the plaintiff or defendant in a particular case will depend on the particular facts of the crash and the particular law of the jurisdiction. On one hand, requiring the plaintiff to specifically demonstrate how and why an automated driving system performed poorly and should have performed better could impose technical and financial barriers to many claims, especially those involving comparatively minor injuries. On the other hand, permitting the plaintiff to use the consumer expectations test,[242]

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237. *See* Bryant Walker Smith, *Tesla and Liability*, CTR. FOR INTERNET & SOC'Y (May 20, 2015, 9:42 AM), https://cyberlaw.stanford.edu/blog/2015/05/tesla-and-liability [https://perma.cc/T3LF-BUVF].

238. *See generally Proximity-Driven Liability*, *supra* note 213, 1779-80.

239. *See id.* at 1779-86.

240. *See With Great Power Comes Great Responsibility*, QUOTE INVESTIGATOR (July 23, 2015), http://quoteinvestigator.com/2015/07/23/great-power/ [https://perma.cc/5NA3-NKLR] (last visited Nov. 16, 2016).

241. *Proximity-Driven Liability*, *supra* note 213, at 1779.

242. *See supra* notes 219-20 and accompanying text.

the malfunction doctrine,[243] or res ipsa loquitur[244] could make it easier to attribute undesirable outcomes to something within the automated driving system. In that case, the defendant automaker, rather than the plaintiff, might offer a more detailed explanation of the automated driving system's performance in order to shift some costs to other parties.

Data will be essential to many of these claims. Specific information about the crash may be stored in components of the automated driving system that are on the vehicle, in other systems on board the vehicle, in other vehicles or devices, or in offboard systems accessible to entities that may or may not be party to the case. Collecting, processing, and interpreting these data may be expensive. In some cases, these data provide unprecedented clarity about the actual causes of a particular crash. Indeed, a jury may be able to simply watch a complete recreation of the crash—although such cases would be highly unlikely to actually reach a jury on any question other than damages. In other cases, however, these data could actually produce more ambiguity and argumentation. For example, in one case a defendant automaker argued that its own data event recorder was not reliable—and it won.[245]

Because of all the theoretical and practical considerations discussed in this section, predictions about the effect on aggregate damages are largely speculative. If recovery rates and damage awards remain constant, then a shift from driver liability to product liability would mean that plaintiffs would generally pursue only claims involving significant injuries, that they would recover at a lower rate, and that those who did prevail would receive somewhat higher damages. Eventually, a larger body of settlements would come to reflect these benchmarks trials.[246]

Developers of automated driving systems and automotive insurance companies will play early and important roles in establishing expectations regarding recovery. Some developers may readily recognize instances of clear product failure and quickly

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243. *See* David Owen, *Products Liability Law Restated*, 49 S.C. L. REV. 273, 282 (1998).

244. *See id.* at 280.

245. *See, e.g.*, McAlonan v. Tracy, No. L-487-05, 2011 WL 6125, at *6-8 (N.J. Super. Ct. App. Div. Mar. 16, 2010) (accepting the defendant automaker's argument that the data from its own data recorder are not reliable).

246. *See* Glancy, Peterson & Graham, *supra* note 213, at 40 (describing stage three of personal injury litigation); Graham, *Of Frightened Horses*, *supra* note 213, at 1269-70.

compensate those who suffer physical harm or property damage. (Others may not.[247]) Automotive insurers, as well as others that cover crash losses,[248] will face decisions about how to treat early automated driving claims and, in the event of payment, whether to subrogate those claims against potential defendants.[249] Proactive developers and insurers may even partner with each other to fully utilize the existing claims processing infrastructure[250] and to capture the savings realized by avoiding product liability litigation.[251]

Figure 14 illustrates how the role of product liability in compensating the victims of motor vehicle crashes may expand in the future. As the pie on the left shows, motor vehicle manufacturers and associated companies pay only a small proportion of the costs associated with crashes. In the future, however, companies associated with automated driving are likely to be liable for a much greater share of the costs of crashes involving automated driving systems. As discussed previously, however, the hope is that total crash costs will decrease as crash magnitude decreases.[252]

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247. *See, e.g.*, Jeff S. Bartlett & Michelle Naranjo, *Guide to the Volkswagen Emissions Recall*, CONSUMER REPORTS, (July 25, 2016), http://www.consumerreports.org/cro/cars/guide-to-the-volkswagen-dieselgate-emissions-recall [https://perma. cc/UC46-J9JP] (describing Volkswagen's emissions control system fraud); Jennifer Chu, *Study: Volkswagen's Emissions Cheat to Cause 60 Premature Deaths in U.S.*, MIT NEWS (Oct. 28, 2015), https://news.mit.edu/2015/volkswagen-emissions-cheat-cause-60-premature-deaths-1029 [https://perma.cc/X4U7-8VZQ] (describing the continued threat to public health caused by this fraud); Anton R. Valukas, *Report to Board of Directors of General Motors Company Regarding Ignition Switch Recalls*, JENNER & BLOCK (May 29, 2014), https://s3.amazonaws.com/s3.documentcloud.org/documents/1183508/g-m-internal-investigation-report.pdf [https://perma.cc/2YL5-NMBE] (describing GM's evolving legal position toward victims of crashes involving fault ignition switches).

248. *See, e.g.*, Alexa Laborda Nelson, *Lien & Mean: Changes in Medicaid Subrogation Law Greatly Expand the Government's Right to Settlement Proceeds*, POST & SCHELL: E-FLASH (Jan. 16, 2014), http://www.postschell.com/publications/781-lien-mean-changes-medicaid-subrogation-law-greatly-expand-governments [https://perma.cc/CT68-CZ52].

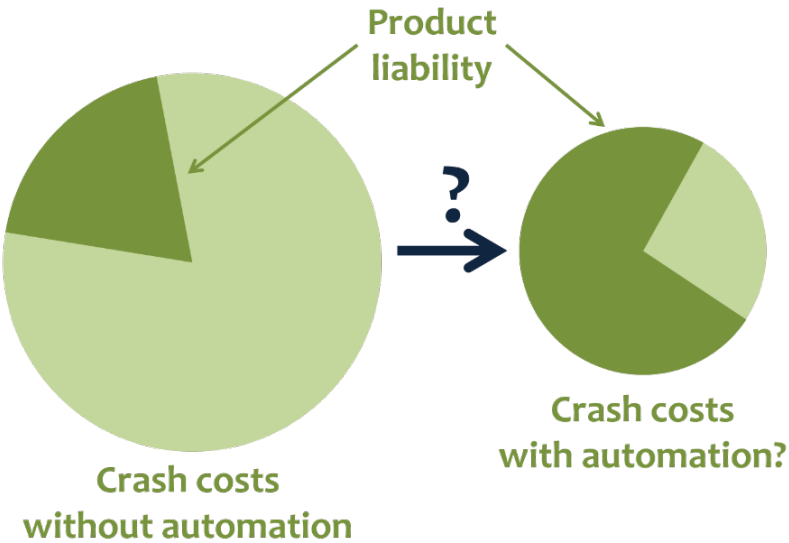
249. *See generally, e.g.*, Glancy, Peterson & Graham, *supra* note 213, at 47; Robert Peterson, *New Technology—Old Law: Autonomous Vehicles and California's Insurance Framework*, 52 SANTA CLARA L. REV. 1341, 1343 (2012).

250. Volvo Cars already markets automotive insurance to consumers in the United Kingdom. *Volvo Car Insurance*, VOLVO CARS UK, http://www.volvocars.com/uk/buy/sales/volvo-car-insurance [https://perma.cc/4PM7-WQRJ] (last visited Nov. 16, 2016).

251. *See* Kritzer, *supra* note 183, at 27-28 (describing the high costs of litigation).

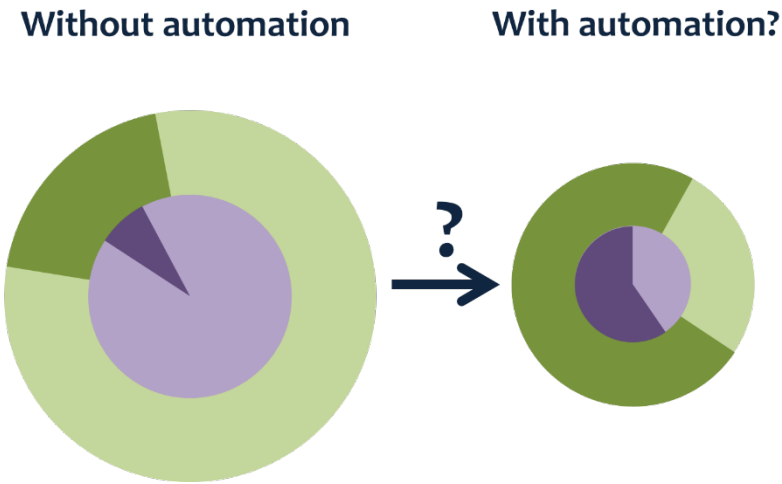
252. *See supra* notes 81-84 and accompanying text.

Figure 14



In short, the companies that develop and deploy automated driving systems are likely to have a bigger slice of what will hopefully be a smaller pie of total crash liability. For the reasons discussed above, this slice could be disproportionately larger than the actual contribution of these systems to crashes, particularly when interactions between automated driving systems and conventional drivers are routine. Figure 15 illustrates this possibility by juxtaposing the pie charts for crash magnitude (Figure 9) and crash cost (Figure 14):

Figure 15

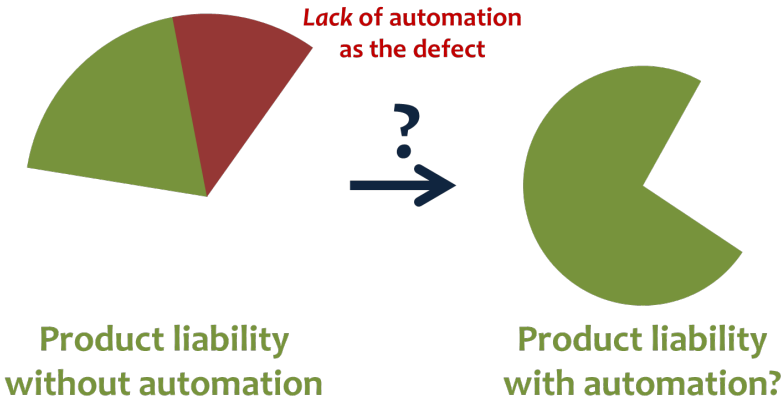


The smaller pies in the foreground represent crash magnitude (with the darker slices representing product failure),[253] while the larger pies in the background represent crash costs (with the darker slices representing product liability).

In addition, manufacturers of conventional motor vehicles may eventually incur liability for crashes that are caused by the lack of active safety systems or by the interaction of these systems with human drivers. Figure 16 shows this possibility through the addition of a red slice on the left:

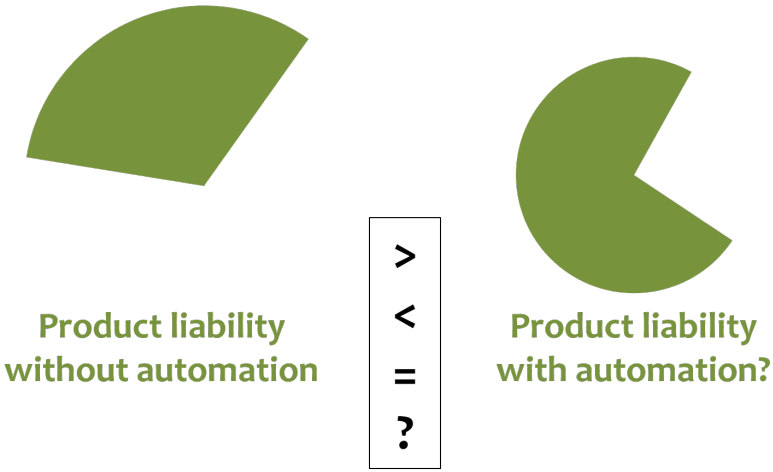
253. *See supra* Parts on PRODUCT FAILURE and CRASHES, INJURIES, AND FATALITIES.

Figure 16



As Figure 17 illustrates, it is unclear at this point how total product liability will compare as between conventional and automated driving. A small slice of a big pie (as is the case for conventional driving) may be smaller or larger than a big slice of a small pie (as may be true in the case of automated driving).

Figure 17



As the next section discusses, it is important to distinguish this uncertainty about liability from the actual exposure to liability.

CONSUMER COST

Driving is expensive. The average price of a new motor vehicle today is nearly $35,000.[254] The annual total cost of owning an average is about $0.57 per mile, which is equivalent to $8,600 per year.[255] In comparison, a typical UberX ride in Atlanta might cost $1.13 per mile,[256] which is equivalent to $12,000 per year.[257] The cost of ownership includes average automotive insurance costs of $840[258] to $1,200.[259] The same survey that produced this lower figure found average annual expenditures of $520 on third-party liability coverage and $300 on collision coverage.[260]

The price of automated driving products and services will reflect the product liability exposure of that industry. An extremely rough estimation exercise can offer an order-of-magnitude sense of this added cost in the United States. The exercise explicitly (and crudely) assumes that:

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254. The "average transaction price" for light vehicle sales in December 2015 was $34,428. Press Release, Kelly Blue Book, Record New-Car Transaction Prices Reported in December 2015, According to Kelly Bluebook (Jan. 5, 2016), http://mediaroom.kbb.com/record-new-car-transaction-prices-reported-december-2015 [https://perma.cc/8575-MG4T].

255. Press Release, AAA, Your Driving Costs (Apr. 7, 2016), http://newsroom.aaa.com/auto/your-driving-costs [https://perma.cc/3ME5-6MJ9] [hereinafter AAA Driving Costs 2016]. Similarly, the Internal Revenue Service's standard mileage rate for business miles driven is 57.5 cents for 2015 and 54 cents for 2016. Press Release, IRS, 2016 Standard Mileage Rates for Business, Medical and Moving Announced (Dec. 17, 2015), https://www.irs.gov/uac/newsroom/2016-standard-mileage-rates-for-business-medical-and-moving-announced [https://perma.cc/XG2T-QF7A].

256. *Atlanta Uber Prices*, UBERESTIMATE.COM, http://uberestimate.com/prices/Atlanta/ [https://perma.cc/SM7X-ARJC] (last visited Nov. 16, 2016) (noting fees of about $2.75 and charges of $0.12 per minute and $0.75 per mile). *Cf.* Press Release, AAA, New Study Reveals When, Where and How Much Motorists Drive (Apr. 16, 2015), http://newsroom.aaa.com/2015/04/new-study-reveals-much-motorists-drive/ [https://perma.cc/2RAE-BM5P] [hereinafter AAA Study] ("On average, Americans drive 29.2 miles per day, making two trips with an average total duration of 46 minutes.").

240. "Motorists age 16 years and older drive, on average, 29.2 miles per day or 10,658 miles per year." AAA Study, *supra* note 256.

258. *Auto Insurance*, *supra* note 153.

259. AAA Driving Costs 2016, *supra* note 255.

260. *Auto Insurance*, *supra* note 153.

(1) Developers, manufacturers, suppliers, and operators of automated driving systems pay 54% of total societal crash costs. (Insurers currently cover 54% of the $242 billion in economic costs.[261] Using total costs rather than just economic costs allows for the possibility that crash victims and the entities that insure them will recover far more of their damages, particularly for pain and suffering, in a product liability-based regime than in the current vehicular negligence-based regime.)

(2) These costs would equal $975 billion annually without automated driving. (This higher figure[262] represents a rough attempt to account for the increase in crash deaths[263] and the change in the value of a dollar between 2010 and 2015.[264])

(3) Legal expenses continue to account for only 1.3% of these costs.[265] (In other words, recovery through a product liability-based regime is no more expensive than recovery through a vehicular negligence-based regime.)

(4) Automakers sell 17,500,000 light-duty vehicles annually,[266] 100% of which have permanently engaged automated driving systems.[267] (In other words, vehicle sales do not change even if most vehicles are sold or transferred to fleets rather than to individuals.)

(5) There are 260,000,000 total registered vehicles,[268] 100% of which have permanently engaged automated driving

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261. BLINCOE ET AL., *supra* note 26, at 1, 13.

262. *See supra* discussion at note 103.

263. There were about 7% more crash deaths in 2015 than in 2010. *See supra* note 55 and accompanying text.

264. On the basis of purchasing power parity, $1 in 2010 is equivalent to about $1.09 in 2015, though other bases give a range of $1.09 to $1.21. Samuel H. Williamson, *Seven Ways to Compute the Relative Value of a U.S. Dollar Amount, 1774 to Present*, MEASURING WORTH, https://www.measuringworth.com/uscompare/ [https://perma.cc/8KYD-XVKH] (last visited Nov. 16, 2016).

265. BLINCOE ET AL., *supra* note 26, at 16.

266. Mike Spector, Jeff Bennett & John D. Stoll, *U.S. Car Sales Set Record in 2015*, WALL ST. J. (Jan. 5, 2016), http://www.wsj.com/articles/u-s-car-sales-poised-for-their-best-month-ever-1451999939 [https://perma.cc/3QHG-LSVC].

267. *See supra* INTRODUCTION.

268. U.S. DEP'T OF TRANSP., TABLE 1-11: NUMBER OF U.S. AIRCRAFT, VEHICLES, VESSELS, AND OTHER CONVEYANCES, http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/html/table_01_11.html [https://perma.cc/FPJ3-QZN4] (last visited Nov. 16, 2016).

systems.[269] (In other words, the total fleet size does not change.)

(6) These vehicles travel 3.15 trillion vehicle miles annually,[270] which is equivalent to 11,300 miles per light-duty vehicle.[271] (In other words, total vehicle miles traveled do not change.)

(7) These assumptions are independent of the business models identified below.

These assumptions are extremely rough and subject to significant criticism. The assignment of 54% of total societal crash costs to automotive companies, for example, is essentially arbitrary. Moreover, if only economic costs were used rather than total societal costs, the resulting cost estimates would be just one third as large. However, the larger numbers are used to reflect the possibility of greater compensation under a product liability-based regime.[272]

The exercise further posits four safety scenarios:

(1) Baseline: Automated driving does not reduce total crash costs.

(2) Moderate: Automated driving reduces total crash costs by 20%.

(3) Ambitious: Automated driving reduces total crash costs by 50%.

(4) Exceptional: Automated driving reduces total crash costs by 80%.

Finally, this exercise identifies four potential business models:

(1) Sale: A manufacturer sells its vehicles at a price that covers all of the liability costs that it incurs that year. (In other words, the manufacturer relies on new sales to cover existing liabilities.)

(2) Lease: A manufacturer leases its vehicles at a price that, over five years, covers all of the liability costs that it incurs that first year.[273]

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269. *See supra* INTRODUCTION.

270. *See* 2015 TRAFFIC VOLUME TRENDS, *supra* note 78.

271. AAA uses 15,000 miles per vehicle per year. AAA Driving Costs 2016, *supra* note 255.

272. *See supra* notes 186, 190 and accompanying text.

273. The average lease term is about thirty-six months, and the average loan term is about sixty-seven months. *See* Melinda Zabritski, *State of the Automotive Finance Market: First Quarter 2015*, EXPERIAN, at 13, 27 (2015), https://

(3) Subscription: A manufacturer makes its automated driving system available to users for a monthly or yearly fee that covers all of the liability costs that it incurs over that period.[274]

(4) Service: A manufacturer makes its vehicles available to users for a charge per vehicle mile traveled (VMT) that covers all of the liability costs that it incurs over that mile.[275]

Figure 18 shows the rough resulting product liability cost estimates for these four models.

Figure 18

Model	Unit	Baseline (-0%)	Moderate (-20%)	Ambitious (-50%)	Exceptional (-80%)
Sale	Per vehicle sold	$30,000	$24,000	$15,000	$6,000
Lease	Per vehicle per year for 5 years	$7,000	$5,500	$3,500	$1,400
Subscription	Per vehicle per year	$2,000	$1,600	$1,000	$400
Service	Per year (based on VMT)	$1,900	$1,500	$950	$380
	Per VMT	$0.17	$0.13	$0.08	$0.03

Many of these numbers are large, but not extraordinarily so. Under the ambitious safety scenario, the product liability costs range from about 11% of annual vehicle ownership costs (with the service

www.experian.com/assets/automotive/white-papers/experian-auto-2015-q1.pdf [https://perma.cc/7ZTU-GT4U].

274. *See, e.g.*, *Proximity-Driven Liability*, *supra* note 213, at 1817.

275. *See id.*

model) to about 40% of annual vehicle ownership costs (with the lease model).[276]

The numbers appear most dramatic for the sales model, because that model spreads hundreds of billions of dollars of crash costs among the relatively few consumers who purchase a new vehicle in any given year. The lease model also spreads these costs among new vehicle buyers, but it reflects the reality that the vast majority of these buyers actually rely on financing, including both loans and leases.[277] Incidentally, automakers already tend to rely at least in part on the sale of their new vehicles to cover the liability costs associated with their old vehicles,[278] which means that liability and other legacy costs related to vehicles sold years prior could conceivably disadvantage these companies as they compete with new entrants to the automotive or transportation markets.[279]

The subscription and service models further spread these costs, and, because of the assumptions used, are roughly equivalent. If automated driving enables current trips to be serviced by fewer total

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276. *See* AAA Driving Costs 2016, *supra* note 255. AAA's annual vehicle costs assume 15,000 miles per vehicle per year, *id.*, which is somewhat higher than the 11,300 miles per year used for the annual cost of the service model.

277. *See* Zabritski, *supra* note 273, at 6-7. Nearly 85% of new vehicle purchases in the first quarter of 2015 involved financing. *Id.* at 6.

278. *Compare, e.g.*, Ford Motor Co., Annual Report (Form 10-K), at FS-70 (Feb. 3, 2015), https://corporate.ford.com/microsites/sustainability-report-2014-15/doc/sr14-form-10-k.pdf [https://perma.cc/6CPR-YBMR] ("We accrue for [litigation] matters when losses are deemed probable and reasonably estimable . . . [taking] into consideration factors such as our historical experience with matters of a similar nature, the specific facts and circumstances asserted, the likelihood that we will prevail, and the severity of any potential loss. We reevaluate and update our accruals as matters progress over time. For the majority of matters, which generally arise out of alleged defects in our products, we establish an accrual based on our extensive historical experience with similar matters."), *with id.* at FS-71 ("We accrue obligations for warranty costs and field service actions (i.e., safety recalls, emission recalls, and other product campaigns) at the time of sale. We establish estimates for warranty and field service action obligations using a patterned estimation model using historical information regarding the nature, frequency, and average cost of claims for each vehicle line by model year.").

279. *Cf.* Matthias Holweg, *The Evolution of Competition in the Automotive Industry*, *in* BUILD TO ORDER: THE ROAD TO THE 5-DAY CAR 13, at 21-22 (Glenn Parry & Andrew Peter Graves eds., 2008) (discussing legacy costs related principally to pension obligations); A. Joseph Warburton, *Understanding the Bankruptcies of Chrysler and General Motors: A Primer*, 60 SYRACUSE L. REV. 531, 563 (2010) (describing how the Chrysler and GM bankruptcies addressed these obligations).

vehicles,[280] then the per-vehicle cost of the subscription model may be higher than estimated. Unlike that model, the service model can charge liability costs to each vehicle mile traveled, and the charge for a particular mile could even reflect the crash risk of that mile.

When the average annual expenditure for automotive liability insurance is subtracted from the estimates in Figure 18, these numbers become even more interesting. In 2013, this expenditure was about $520 per vehicle.[281] Figure 19 shows the resulting estimates. (The upfront cost of the pure sale model, which is essentially unchanged, does not reflect the present value of the lifetime insurance savings.)

Figure 19

Model	**Baseline**	**Moderate**	**Ambitious**	**Exceptional**
	(-0%)	**(-20%)**	**(-50%)**	**(-80%)**
Sale	$29,500	$23,500	$14,500	$5,500
Lease	$6,500	$5,000	$3,000	$900
Subscription	$1,500	$1,100	$500	**($100)**
Service	$1,400	$1,000	$400	**($150)**
	$0.12	$0.09	$0.04	**($0.01)**

Under the ambitious safety scenario, the product liability costs range from about 5% of annual vehicle ownership costs (with the service model) to about 34% of annual vehicle ownership costs (with the lease model). Strikingly, under the exceptional safety scenario, the subscription and service models may even product a net cost *savings*.

Automated driving may have other benefits that reduce its cost relative to conventional driving. A particularly significant example relates to the value of time. If automated driving allows vehicle users to reallocate 80% of their travel time at $18 per hour,[282] these users

280. UNIV. OF MICH. TRANSP. RES. INST., *Driverless Vehicles: Fewer Cars, More Miles* (Feb. 11, 2015), http://www.umtri.umich.edu/what-were-doing/news/driverless-vehicles-fewer-cars-more-miles [https://perma.cc/3V9U-2NBF].

281. *Auto Insurance*, *supra* note 153.

282. TEX. A&M TRANS. INST., *2015 Urban Mobility Scorecard*, at app. A-14 (2015), https://d2dtl5nnlpfr0r.cloudfront.net/tti.tamu.edu/documents/mobility-scorecard-2015-appx-a.pdf [https://perma.cc/Y44A-ZX8M] (using $17.67 per person-hour in

could potentially "save" $4,000 per year,[283] which is equivalent to $0.38 per mile.[284] The potential consumer savings are much more tangible in the case of an automated taxi or ridesharing system. Recall that a typical UberX ride in Atlanta might cost $1.13 per mile.[285] An UberX driver might earn about 75% of this fare.[286] This means that automating that driver's job could result in a cost savings of $0.85 per mile.[287]

These additional consumer savings (as well as any additional consumer costs) are relevant to the practical impact of product liability but not to the theoretical impact of product liability. If these savings are significant, then automated driving could be cheaper and hence more attractive than conventional driving even if product liability costs are higher. In that case, however, automated driving would be even cheaper and hence even more attractive without those higher liability costs. From a safety perspective, this may be an important distinction.

Of course, all of these numbers are incredibly rough estimates, and the actual consumer costs of product liability could be many times higher or lower. This uncertainty provides another argument for the subscription and service models. As the developer of an automated driving system learns more about the technical performance and liability implications of that system, it can adjust

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2014 dollars); Memorandum from Carlos Monje, Assistant Secretary for Transportation Policy, to Secretarial Officers & Modal Administrators (2015), at tbl. 4, https://www.transportation.gov/sites/dot.gov/files/docs/Revised%20Departmental%20Guidance%20on%20Valuation%20of%20Travel%20Time%20in%20Economic%20Analysis.pdf [https://perma.cc/AYA3-8KMB] (recommending values ranging from $12.50 per person-hour for local personal automotive travel to $24.40 for business automotive travel of any type in 2013 dollars).

283. "On average, Americans drive 29.2 miles per day [or 10,658 miles per year], making two trips with an average total duration of 46 minutes." AAA Study, *supra* note 256. *46 minutes/day * 365 days * 80% * $18/hour = $4,029.60*.

284. *$4,029.60 / 10,658 miles/year = $0.37808/mile*.

285. *Atlanta Uber Prices*, *supra* note 256 (noting fees of about $2 and charges of $0.12 per minute and $0.75 per mile). The calculation assumes a ten-mile trip that lasts fifteen minutes for an average speed of 40 miles per hour. *Cf.* AAA Study, *supra* note 256 ("On average, Americans drive 29.2 miles per day, making two trips with an average total duration of 46 minutes."). *$2 + ($0.75 * 10) + ($0.12 * 15) / 10 = $1.13* per mile.

286. Ellen Huet, *Uber Now Taking Its Biggest UberX Commission Ever—25 Percent*, FORBES (Sept. 22, 2014, 1:40 PM), http://www.forbes.com/sites/ellenhuet/2014/09/22/uber-now-taking-its-biggest-uberx-commission-ever-25-percent/.

287. *$1.13/mile * 75% = $0.8475*. Of course, this also means that this driver will have lost her job.

what it charges per month or per mile.[288] In this way, uncertainty need not mean inaction.[289]

Several key companies—including traditional automakers like Ford and General Motors—are already pursuing the service model.[290] Reasons for this may include a desire for more control over the automated driving systems, greater price flexibility, lower perceived consumer cost, and increased access to the users. The service model, particularly its per-mile cost, is the focus of the remaining analysis.

CONSUMER ADOPTION

This section considers the impact of a shift from a driver negligence-based personal injury regime to a product liability-based personal injury regime on consumer adoption of automated driving systems. To the extent that automated driving is safer than conventional driving, this adoption will presumably advance the societal goal of safety.[291]

At the outset, it is important to recognize that compensation is also a societal goal that could be affected by automated driving. As summarized earlier, this regime shift might mean that plaintiffs would generally pursue only claims involving significant injuries, that they would recover at a lower rate, and that those who did prevail would receive somewhat higher damages.[292]

The question explored here, however, is whether product liability exposure or uncertainty could delay or diminish widespread adoption of automated driving systems. There are at least three steps to this adoption: Companies need to develop and then market these systems, after which consumers to buy or otherwise use them.

Dire predictions that product liability will thwart innovation should—and can—be put in perspective. In 1993, the Federal

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288. *See Proximity-Driven Liability*, *supra* note 213, at 1817-19.

289. *Id.*

290. *See, e.g.*, Lisa Eadicicco, *Uber's First Self-Driving Car Is Hitting the Streets*, TIME (May 19, 2016), http://time.com/4341517/uber-first-self-driving-car/ [https://perma.cc/T69J-BTMD]; Mike Ramsey & Gautham Nagesh, *GM, Lyft to Test Self-Driving Electric Taxis*, WALL ST. J. (May 5, 2016, 10:54 AM), http://www.wsj.com/articles/gm-lyft-to-test-self-driving-electric-taxis-1462460094 [https://perma.cc/P366-ABDC]; Hope Reese, *Ford Plans to Mass Produce a 'No Driver Required' Autonomous Vehicle by 2021*, TECHREPUBLIC (Aug. 16, 2016, 12:10 PM), http://www.techrepublic.com/article/ford-plans-to-mass-produce-a-no-driver-required-autonomous-vehicle-by-2021/ [https://perma.cc/QT4J-AD53].

291. *See supra* notes 59-61 and accompanying text.

292. *See supra* notes 188-89 and accompanying text.

Highway Administration commissioned a report on tort liability faced by developers of "advanced vehicle control systems" (AVCS).[293] The report concluded that "[t]he prospect of liability for catastrophic accidents resulting from a failure of AVCS will likely deter entities from becoming involved with AVCS and impede its development unless the federal government adopts some or all of the legislative" limits on liability discussed in the report.[294] These limits ranged from restricting damages to eliminating some or even all tort claims.[295]

At the time,[296] the prediction that product liability would deter companies from releasing advanced driver assistance systems and from researching even more advanced forms of driving automation was understandable—and difficult to disprove. In the intervening two decades, however, traditional automotive manufacturers have widely released many of these systems,[297] while they and others have invested heavily in automated driving.[298] These companies have done so without receiving special exemptions from the generally applicable product liability regimes of each state. (Product liability law has changed over the last two decades, including in many ways more favorable to product sellers.[299] However, few of these changes are as dramatic as the liability limitations discussed in the 1993 report.[300])

In other words, remarkable innovation in the automotive industry seems to have refuted this prediction. Moreover, because of the tremendous progress in automated driving, the assertion that

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293. ROBERTS ET AL., *supra* note 213, at 1.

294. *Id.* at 57.

295. *Id.* at 48-57.

296. Notably, the 1990s were a peak of the "tort reform" movement. *See, e.g.*, F. Patrick Hubbard, *The Nature and Impact of the "Tort Reform"* Movement, 35 HOFSTRA L. REV. 437, 469-70 (2006); John T. Nockleby & Shannon Curreri, *100 Years of Conflict: The Past and Future of Tort Retrenchment*, 38 LOY. L.A. L. REV. 1021, 1022 (2005) ("The 1994 Republican 'Contract with America' promised Americans that, if Republicans took control of Congress, one of ten key agenda items would be changing the civil justice system.").

297. *See* MYCARDOESWHAT.ORG, https://mycardoeswhat.org/ [https://perma.cc/FKS4-YMB9] (last visited Nov. 16, 2016).

298. *See, e.g.*, Reese, *supra* note 290; Rob Toews, *Investment Opportunities in the Autonomous Vehicle Space*, TECHCRUNCH (June 11, 2016), https://techcrunch.com/2016/06/11/investment-opportunities-in-the-autonomous-vehicle-space/ [https://perma.cc/RH6E-NFC7].

299. *See, e.g.*, *supra* notes 204-06 and accompanying text (discussing punitive damages).

300. *See generally* ROBERTS ET AL., *supra* note 213.

liability will deter the introduction of highly automated driving systems can be tested in a way that was not possible twenty years ago: If a developer of such a system is reluctant to release it, that developer can simply point to its production-ready system and promise to release it if and only if particular rules of liability are changed.

Rather than demand such changes, several prominent companies have publicly "accepted" current product liability law. Volvo Cars has stated in a press release that it "will accept full liability whenever one of its cars is in autonomous mode."[301] Google and Daimler have both accepted that they will be liable if their respective technologies are at fault.[302] These statements are not revolutionary declarations as much as they simple acknowledgements of existing law.[303] They also do not necessarily resolve difficult questions of fault, causation, and damages. And to the extent that these statements function as product representations, they also raise a fascinating product liability question in their own right.[304] Regardless, such acknowledgments implicitly refute the notion that current product liability law is an absolute bar to automated driving.

The experience—or merely the continued existence—of the larger transportation industry is also instructive. In tort law, a person who causes a crash by negligently driving a vehicle is generally liable to the victim of that crash. Under some circumstances, however, the employer of that driver or the owner of that vehicle may also be vicariously liable to the victim even if the driver was the

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301. Press Release, Volvo Car Group, US Urged to Establish Nationwide Federal Guidelines for Autonomous Driving (Oct. 7, 2015), https://www.media.volvocars.com/global/en-gb/media/pressreleases/167975/us-urged-to-establish-nationwide-federal-guidelines-for-autonomous-driving [https://perma.cc/WT72-9ZL7] (last visited Nov. 16, 2016).

302. *See* Bill Whitaker, *Hands Off the Wheel*, CBS NEWS 60 MINUTES (Oct. 4, 2015), http://www.cbsnews.com/news/self-driving-cars-google-mercedes-benz-60-minutes/ [https://perma.cc/BG7T-Q3J2].

303. These companies are essentially saying that they will be liable when they are liable. Future plaintiffs may disagree with these companies, however, on the specifics of the particular incident, including the meaning of defect, the existence of causation, and the extent of damages. *See infra* notes 307-10 and accompanying text.

304. In short: Might a consumer purchase or use an automated driving system in reliance on a promise by the developer that it will assume liability in the event of a crash? If so, the developer's refusal to promptly compensate a crash victim might give rise to an argument of equitable estoppel and a separate claim for misrepresentation—by the crash victim and, conceivably, the entire class of buyers.

only negligent actor.[305] This vicarious liability is at least as "strict" as product liability.[306]

As noted earlier, the automotive leasing and rental industry successfully sought federal preemption of their vicarious liability for the negligence of individuals driving those vehicles.[307] At the time, this industry characterized vicarious liability as an existential threat—one which "has put literally hundreds of small operators out of business in States such as New York and other States across the country."[308] This argument seems extreme: A decade earlier, one major rental company noted that its cost for all liability settlements, including those for vicarious liability, "amounted to 8 to 11 percent of [its] annual revenues in the last few years,"[309] which is comparable to what the average motorist pays for liability insurance as a percentage of the total cost of vehicle ownership.[310]

Vicarious liability persists in other contexts. Notwithstanding the Graves Amendment,[311] motor carriers[312] and taxicab companies[313]

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305. The employer or vehicle owner can also be liable for negligently maintaining the vehicle or negligently entrusting it to the driver. In these cases, however, the employer or vehicle owner is actually negligent itself.

306. *See* James Fleming, Jr., *Vicarious Liability*, 28 TUL. L. REV. 161, 172 (1954).

307. *See supra* notes 196-202 and accompanying text; *see also*, *e.g.*, Martin, *supra* note 198, at 162; William Sprouse, *Grave Danger? Concerns and Possible Solutions for Individuals Injured by Drivers of Leased Vehicles*, 15 SUFFOLK J. TRIAL & APP. ADVOC. 209, 226-27 (2010); Brent Steinberg, *The Graves Amendment: Putting to Death Florida's Strict Vicarious Liability Law*, 62 FLA. L. REV. 795, 799 (2010).

308. *1999 Finance and Hazardous Materials Hearing*, *supra* note 199.

309. Matthew L. Wald, *Further Limits on Car Renters*, N.Y. TIMES (July 11, 1992), http://www.nytimes.com/1992/07/11/business/further-limits-on-car-renters.html [https://perma.cc/T9XG-HWKB]. In a potential victory for safety, vicarious liability had apparently also persuaded that company to ask its renters if they had been convicted of drunk driving before giving them the keys. *Id.*

310. In 2013, the average expenditure for liability insurance was $518.49, and the average cost of ownership for a medium sedan was $5,987. *See Auto Insurance*, *supra* note 153; YOUR DRIVING COSTS, AAA 6-7 (2013 ed.), http://exchange.aaa.com/wp-content/uploads/2013/04/Your-Driving-Costs-2013.pdf [https://perma.cc/9F6X-Y6LS] (*$518.49/$5,987 = 8.7%*).

311. 49 U.S.C. § 30106 (2012) ("An owner of a motor vehicle that rents or leases the vehicle to a person (or an affiliate of the owner) shall not be liable under the law of any State or political subdivision thereof, by reason of being the owner of the vehicle (or an affiliate of the owner), for harm to persons or property that results or arises out of the use, operation, or possession of the vehicle during the period of the rental or lease, if—(1) the owner (or an affiliate of the owner) is engaged in the trade or business of renting or leasing motor vehicles; and (2) there is no negligence

can be liable for the negligence of the drivers to whom they lease their equipment. Delivery companies can also be liable for the negligence of their drivers[314]—or even their lessors' drivers.[315] As a general matter, companies are liable for the negligence of their employees while acting within the scope of employment.[316] The questions of who is an employee[317] and what is within the scope of employment[318] can require fact-specific determinations, and courts may reach different conclusions.

For companies that are in the business of using public roads, vicarious liability for the crashes negligently caused by their drivers is often part of that business. They pass the cost of this liability onto their customers through the prices charged for rides or packages or pizzas. Nonetheless, people continue to buy rides, packages, and pizzas.

A service model for automated driving would likewise pass the costs of product liability onto the users of that automated driving service. Recall that, for the ambitious safety scenario (which assumes a 50% reduction in crash costs), the resulting product liability cost was very roughly estimated at between four and eight cents per mile.[319]

Fuel prices provide another point of reference for liability costs under the service model. Figure 20 shows that the fuel cost to travel one mile has, when adjusted for both inflation and changes in

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or criminal wrongdoing on the part of the owner (or an affiliate of the owner)."); *see also* Vargas v. FMI, Inc., 182 Cal. Rptr. 3d 803, 804-05 (2015).

312. *See generally* R. Clay Porter & Elenore Cotter Klingler, *The Mythology of Logo Liability: An Analysis of Competing Paradigms of Lease Liability for Motor Carriers*, 33 TRANSP. L.J. 1 (2006).

313. Kindard-Jennings v. Yellow Cab Co., Inc., No. CV126037331, 2013 WL 4046584, at *1 (Conn. Super. Ct. July 19, 2013).

314. *See, e.g.*, Arenas v. United Parcel Service, Inc., No. 34201000070698, 2012 WL 1418637 (Cal. App. Dep't Super. Ct. Apr. 3, 2012) (Verdict and Summary Settlement) ("Defendants UPS conceded vicarious liability for the accident."); Studer v. DHL Exp. (USA), Inc., 767 N.W.2d 420 (Iowa Ct. App. 2009); Morris v. JTM Materials, Inc., 78 S.W.3d 28, 35 (Tex. App. 2002).

315. *See, e.g.*, Horner v. FedEx Ground Package Sys. Inc., 258 S.W.3d 532 (Mo. Ct. App. 2008).

316. *See* Fleming, *supra* note 306, at 178.

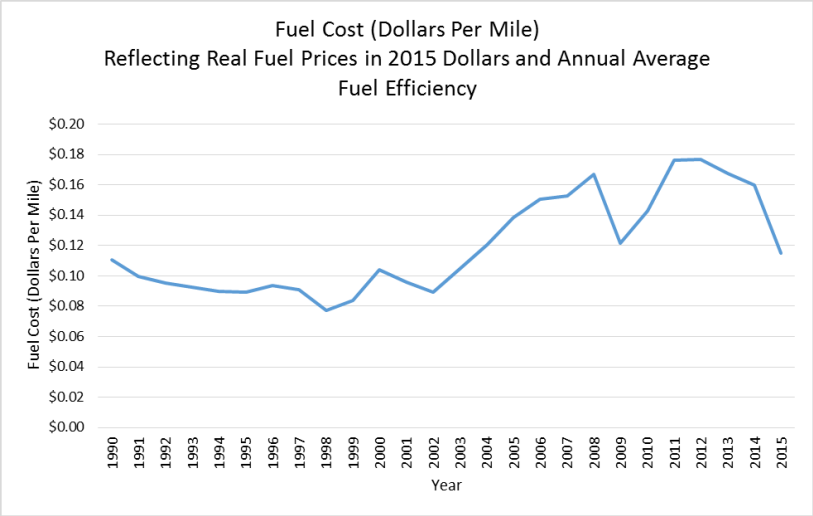
317. *See, e.g.*, Viado v. Domino's Pizza, LLC, 217 P.3d 199 (Or. Ct. App. 2009).

318. *See, e.g.*, Carlson v. Porter, 861 N.Y.S.2d 907 (N.Y. App. Div. 2008).

319. *See supra* notes 273-82 and accompanying text. Four cents per mile excludes the current average cost of liability insurance. Eight miles includes it.

average fuel economy, varied between eight cents and eighteen cents since 1990.[320]

Figure 20



Even if this price variation affects other spending decisions, it seems to have had little effect on vehicle miles actually traveled.[321] Figure 21 shows the relationship between real fuel cost and VMT per capita on an annual basis between 1990 and 2015.[322]

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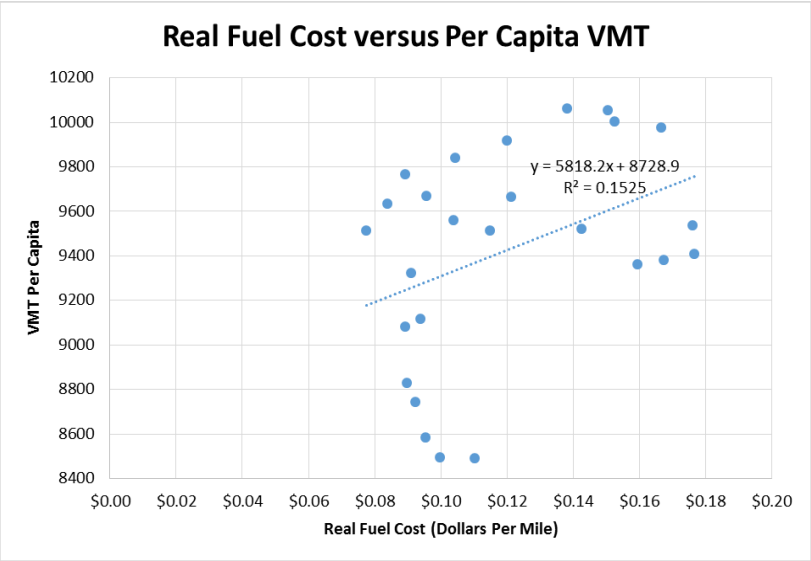
320. *See* SHORT-TERM ENERGY OUTLOOK, U.S. ENERGY INFO. ADMIN. (Sept. 7, 2016), https://www.eia.gov/forecasts/steo/realprices/ [https://perma.cc/MDX5-2PZ7] [hereinafter EIA GAS PRICES] (depicting gas prices); TABLE 4-23: AVERAGE FUEL EFFICIENCY OF U.S. LIGHT DUTY VEHICLES, U.S. DEP'T OF TRANSP., http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/html/table_04_23.html [https://perma.cc/VX5L-34YV] (last visited Nov. 16, 2016) (average fuel efficiency) (showing that fuel efficiency in 2015 is assumed to be equal to fuel efficiency in 2014).

321. *See also* Michael Morris, *Gasoline Prices Tend to Have Little Effect on Demand for Car Travel*, U.S. ENERGY INFO. ADMIN. (Dec. 5, 2014), https://www.eia.gov/todayinenergy/detail.cfm?id=19191 [https://perma.cc/HU9K-PVDK]. *Cf.* LISA ECOLA & MARTIN WACHS, RAND CORP., EXPLORING THE RELATIONSHIP BETWEEN TRAVEL DEMAND AND ECONOMIC GROWTH (2012), http://www.fhwa.dot.gov/policy/otps/pubs/vmt_gdp/ [https://perma.cc/GD59-ABAJ] (report prepared for the Federal Highway Administration).

322. *See* U.S. DEP'T OF ENERGY, ALTERNATIVE FUELS DATA CTR., ANNUAL VEHICLE MILES TRAVELED IN THE U.S. (2015), http://www.afdc.energy.gov/data/10315 (VMT); U.S. CENSUS BUREAU, POPULATION ESTIMATES: HISTORICAL DATA,

Figure 21



This comparison both requires and contains some caution. The choice between traveling and not traveling is different from the choice between driving and riding: An employee who needs to commute to her office probably does not need to do so in an automated taxi.[323] Furthermore, swings in the price of fuel hardly go unnoticed, and an increase in the cost of travel of eight cents per mile (before any offsetting savings) is equivalent to a rise of about $1.70 in the price of gasoline.[324] But this has precedent: It is roughly what occurred between 2002 and 2008.[325]

Again, the consumer costs under all four business models are large, but not extraordinarily so. And that is an important point. This exercise suggests that large—but not extraordinarily large—charges might directly cover more than 50% of total societal crash costs. In a hypothetical world with only automated driving, a charge of pennies

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https://www.census.gov/popest/data/historical/index.html [https://perma.cc/UU46-PRMW] (last visited Nov. 16, 2016). The coefficient of determination is 0.1525.

323. *Cf.* Morris, *supra* note 321 (discussing the relative inelasticity of motor vehicle travel in the United States).

324. *$0.08/mile * 21.4 miles/gallon = $1.712/gallon.*

325. *See* EIA GAS PRICES, *supra* note 320.

per mile might reimburse losses twice as large as those covered by the entire automotive insurance industry in 2010.[326]

CONCLUSION

The foregoing analysis suggests that automated driving and product liability can coexist. In comparison to the automotive industry today, the automated driving industry will likely bear a bigger slice of a smaller pie of total crash costs. Given substantial uncertainty about the size of that slice, this industry may be inclined toward service-based business models that provide more flexibility. Under such a model, liability exposure could conceivably add several cents per mile to travel costs.

This analysis is a sketch that should be refined as automated driving becomes real and, ultimately, routine. As companies move their automated driving systems closer to deployment, they will learn more about the actual performance of those systems both in absolute terms and relative to human drivers. As automotive insurers negotiate with manufacturers over subrogated claims involving advanced driver assistance systems, both sides will learn more about expected litigation and settlement costs. In many cases, unfortunately, this information will not reach the public.[327]

One entity is particularly well positioned to contribute to public analysis of these questions. With 215,000 vehicles[328] traveling over 1.2 billion miles annually,[329] the United States Postal Service (USPS) operates "one of the largest civilian fleets in the world."[330] A USPS employee who is injured on the job generally obtains workers compensation under the Federal Employees' Compensation Act,[331]

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326. *Auto Insurance*, *supra* note 153 (Incurred Losses for Auto Insurance, 2011-2015).

327. Greater transparency in other domains would also be useful to understanding these issues. High-speed electronic trading, for example, could already offer valuable insight into the legal, technical, and business strategies that companies use to manage massive financial risks associated with automated systems that operate in complex environments at speeds that preclude effective human supervision.

328. SIZE AND SCOPE, U.S. POSTAL SERV., http://about.usps.com/who-we-are/postal-facts/size-scope.htm [https://perma.cc/F9DZ-TPYY] (last visited Nov. 16, 2016) [hereinafter SIZE AND SCOPE].

329. 2012 USPS SUSTAINABILITY REPORT: FLEET AND TRANSPORTATION MANAGEMENT, U.S. POSTAL SERV., http://about.usps.com/what-we-are-doing/green/report/2012/14.html [https://perma.cc/6MM6-7TCG] (last visited Sept. 15, 2016).

330. SIZE AND SCOPE, *supra* note 328.

331. 5 U.S.C. § 8101 (2012).

and a member of the public who is injured by the on-the-job negligence of one of those 625,000 employees[332] generally obtains compensation under the Federal Tort Claims Act.[333] Just as USPS's vast logistics operation could provide insight into the driving environment, its legal operation could provide insight into personal injury negotiations and settlements. Although USPS is authorized to withhold its attorneys' work product under the Freedom of Information Act,[334] that statute does not obligate it to do so.[335]

A clearer public understanding of the state of personal injury litigation may be instructive for other cyberphysical systems as well. Roadways are far from the only imperfect environment. In addition to the 35,000 roadway fatalities, each year there are some 5,000 deaths from workplace injuries,[336] 20,000 deaths from home injuries,[337] and somewhere between 100,000 and 440,000 deaths from medical errors.[338] In 2014, unintentional poisonings killed 42,000 people, unintentional falls killed 32,000 people, homicide by firearm killed nearly 11,000 people, and suicide by firearm killed nearly twice that number.[339]

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332. SIZE AND SCOPE, *supra* note 328. Although USPS also uses contractors, its employees service "the vast majority of postal carrier routes." KEVIN R. KOSAR, CONG. RESEARCH SERV., R42549, THE U.S. POSTAL SERVICE'S USE OF CONTRACTORS TO DELIVER MAIL: BACKGROUND AND RECENT DEVELOPMENTS 5 (May 29, 2012), https://www.fas.org/sgp/crs/misc/R42549.pdf [https://perma.cc/527F-AY6D].

333. *See* 39 U.S.C. § 409 (1970); General Counsel, TORT CLAIMS, U.S. POSTAL SERV. (PB 22170) (Dec. 22, 2005), https://about.usps.com/postal-bulletin/2005/html/pb22170/a-c4_002.html [https://perma.cc/2NFA-2VRS].

334. 5 U.S.C. § 552(b)(5) (1994) ("[I]nter-agency or intra-agency memorandums or letters which would not be available by law to a party other than an agency in litigation with the agency . . . ."); *see also* 110 AM. JUR. *Trials* 367 § 21 (2008).

335. *See* 110 AM. JUR. *Trials* 367 § 16 (2008).

336. NUMBER OF FATAL WORK INJURIES, 1992-2014, U.S. BUREAU OF LABOR STATS. (2016), http://www.bls.gov/iif/oshwc/cfoi/cfch0013.pdf [https://perma.cc/5EDB-R8GK].

337. THE STATE OF HOME SAFETY IN AMERICA: FACTS ABOUT UNINTENTIONAL INJURIES IN THE HOME 8 (Carol W. Runyan & Cari Casteel eds., 2d ed. 2004), http://www.iccsafe.org/cs/CTC/Documents/guards/resource/guards_Moss_SOHSIA-2004report.pdf [https://perma.cc/9H7D-8RKA].

338. Marshall Allen, *How Many Die From Medical Mistakes in U.S. Hospitals?*, PROPUBLICA (Sept. 19, 2013, 10:03 AM), https://www.propublica.org/article/how-many-die-from-medical-mistakes-in-us-hospitals [https://perma.cc/Q74P-VSRP].

339. CDC TEN LEADING CAUSES, *supra* note 23; *see also* Melonie Heron, *Deaths: Leading Causes for 2013*, 65 NAT'L VITAL STATS. REP. 1, 2 (2016), http://www.cdc.gov/nchs/data/nvsr/nvsr65/nvsr65_02.pdf [https://perma.cc/F6R3-6LBF].

Whereas deaths and injuries can be recorded and tracked, the panoply of unmet needs in society is harder to inventory. From sustenance and survival[340] to care and companionship,[341] many people need more. Beyond basic needs, opportunities for (at least arguable) improvement also abound. From the body to the home to the sky, cyberphysical systems may address or affect these needs and opportunities.[342] Even some of the 74 million housecats in the United States[343] may be able to look forward to food,[344] water,[345] litter,[346] medical monitoring,[347] and entertainment[348] on demand.

In contrast to automated driving systems, the safety argument for some of these cyberphysical systems may be more difficult to discern—if there is one. Small unmanned aerial vehicles, for example, are not a replacement for particularly dangerous humans with wings. But they might substitute for light aircrafts,[349] motor

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340. *See* HUNGER IN AMERICA: 2016 UNITED STATES HUNGER AND POVERTY FACTS, WORLD HUNGER (Oct. 9 2016), http://www.worldhunger.org/hunger-in-america-2015-united-states-hunger-and-poverty-facts [https://perma.cc/6Q3X-V3M2].

341. *See* SELECTED LONG-TERM CARE STATISTICS, FAMILY CAREGIVER ALLIANCE (Jan. 31, 2015), https://www.caregiver.org/selected-long-term-care-statistics [https://perma.cc/FPY6-G9U5]; *see also* Janice Shaw Crouse, *The Loneliness of American Society*, AM. SPECTATOR (May 18, 2014, 8:00 AM), http://spectator.org/59230_loneliness-american-society [https://perma.cc/YNK7-DUXA].

342. *See* CYBER-PHYSICAL SYSTEMS: ENABLING A SMART AND CONNECTED WORLD, NAT'L SCI. FOUND., https://www.nsf.gov/news/special_reports/cyber-physical [https://perma.cc/K9JQ-7SY9] (last visited Nov. 16, 2016).

343. U.S. PET OWNERSHIP STATISTICS, AM. VETERINARY MED. ASS'N (2012), https://www.avma.org/KB/Resources/Statistics/Pages/Market-research-statistics-US-pet-ownership.aspx [https://perma.cc/7NHU-LQ9S].

344. *See* PETNET, http://www.petnet.io [https://perma.cc/5AUM-THUD] (last visited Nov. 16, 2016).

345. *See* Liwei Wu, *Pura: A Smart Water Fountain for Cats*, INDIEGOGO, https://www.indiegogo.com/projects/pura-a-smart-water-fountain-for-cats# [https://perma.cc/6TBN-SFXX] (last visited Nov. 16, 2016).

346. *See* LITTER-ROBOT, https://www.litter-robot.com [https://perma.cc/5S3V-D2YH] (last visited Nov. 16, 2016).

347. *See* TAILIO SMART HEALTH MONITOR, TAILIO, https://tailio.myshopify.com/products/talio-smart-health-monitor [https://perma.cc/N8NC-Z52H] (last visited Sept. 15, 2016).

348. *See* MOUSR, PETRONICS, http://www.petronics.io/#landing [https://perma.cc/637P-CHNS] (last visited Nov. 16, 2016).

349. *See* Jie Ma & Yuki Hagiwara, *Will Drones Become the Toast of Napa?*, BLOOMBERG BUSINESSWEEK (Feb. 18, 2016, 12:33 PM), https://www.bloomberg.com/news/articles/2016-02-18/in-napa-crop-dusting-drones-are-ready-for-takeoff [https://perma.cc/5GMH-3LS4].

vehicles,[350] or ladders[351]—all of which do pose dangers. Identifying appropriate analytic boundaries[352] is an important step toward understanding product liability's effects on the societal costs and benefits of a particular technology.

Like the world in which it operates, product liability law is far from perfect. These imperfections could advantage or disadvantage new technologies vis-à-vis their conventional counterparts. And these technologies, in turn, could mitigate or exacerbate those imperfections. These are problems to be explored.

Those who conclude that these are also problems to be solved should proceed deliberately. They should assess whether the underlying challenges relate to liability exposure or to liability uncertainty; distinguish between reducing the costs of injury and merely shifting those costs; identify the negative externalities of today's systems before assuming the positive externalities of tomorrow's systems; and be wary of inadvertently placing new technologies on one side of old battle lines. Long after automated driving is a reality, these are the kinds of issues that humans will still be navigating.

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350. *See* David Morgan, *Google Aims to Begin Drone Package Deliveries in 2017*, REUTERS (Nov. 3, 2015, 4:06 AM), http://www.reuters.com/article/us-usa-drones-alphabet-idUSKCN0SR20520151103 [https://perma.cc/G3QM-DEL7].

351. *See* Bart Jansen, *Insurers Adopt Drones for Airborne Inspections*, USA TODAY (Mar. 31, 2016, 9:33 AM), http://www.usatoday.com/story/news/2016/03/31/insurers-adopt-drones-airborne-inspections/82434322/ [https://perma.cc/EU3Q-XGK4].

352. *See Lawyers and Engineers Should Speak the Same Robot Language*, *supra* note 54, at 78.