The Reasonable Computer: Disrupting the Paradigm of Tort Liability

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Abstract

Artificial intelligence is part of our daily lives. Whether working as chauffeurs, accountants, or police, computers are taking over a growing number of tasks once performed by people. As this occurs, computers will also cause the injuries inevitably associated with these activities. Accidents happen, and now computer-generated accidents happen. The recent fatality involving Tesla's autonomous driving software is just one example in a long series of "computer-generated torts."

Yet hysteria over such injuries is misplaced. In fact, machines are, or at least have the potential to be, substantially safer than people. Self-driving cars will cause accidents, but they will cause fewer accidents than human drivers. Because automation will result in substantial safety benefits, tort law should encourage its adoption as a means of accident prevention.

Under current legal frameworks, suppliers of computer tortfeasors are likely strictly responsible for their harms. This Article argues that where a supplier can show that an autonomous computer, robot, or machine is safer than a reasonable person, the supplier should be liable in negligence rather than strict liability. The negligence test would focus on the computer's act instead of its design, and in a sense, it would treat a computer tortfeasor as a person rather than a product. Negligence-based liability would incentivize automation when doing so would reduce accidents, and it would continue to reward suppliers for improving safety.

More importantly, principles of harm avoidance suggest that once computers become safer than people, human tortfeasors should no longer be measured against the standard of the hypothetical reasonable person that has been employed for hundreds of years. Rather, individuals should be judged against computers. To appropriate the immortal words of Justice Holmes, we are all "hasty and awkward" compared to the reasonable computer.

Table of Contents

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January 2018 Vol. 86 No. 1

INTRODUCTION

An automation revolution is coming, and it is going to be hugely disruptive.[1] Ever cheaper, faster, and more sophisticated computers are able to do the work of people in a wide variety of fields and on an unprecedented scale. They may do this at a fraction of the cost of existing workers, and in some instances, they already outperform their human competition.[2] Today's automation is not limited to manual labor; modern machines are already diagnosing disease,[3] conducting le-

1 *See generally* JAMES MANYIKA ET AL., MCKINSEY & CO., DISRUPTIVE TECHNOLOGIES: ADVANCES THAT WILL TRANSFORM LIFE, BUSINESS, AND THE GLOBAL ECONOMY (2013).

2 *See, e.g.*, Carl Benedikt Frey & Michael A. Osborne, *The Future of Employment: How Susceptible Are Jobs to Computerisation?*, 114 TECHNOLOGICAL FORECASTING & SOC. CHANGE 254, 265–66 (2017) (reporting in a seminal paper that "47 percent of total US employment is [at] high risk" of automation, and stating that "recent developments in [machine learning] will put a substantial share of employment, across a wide range of occupations, at risk in the near future").

3 *See* Roger Parloff, *Why Deep Learning Is Suddenly Changing Your Life*, FORTUNE (Sept. 28, 2016, 5:00 PM), http://fortune.com/ai-artificial-intelligence-deep-machine-learning [https://perma.cc/E3UA-N2TZ]. Several artificial intelligence systems are already capable of automating medical diagnoses. *See id.* For instance, Freenome has a system for diagnosing cancer from blood samples that is competitive with pathologists. *See id.*; *see also* FREENOME, http://www.freenome.com (last visited Jan. 4, 2018).

gal due diligence,[4] and providing translation services.[5] For better or worse, automation is the way of the future—the economics are simply too compelling for any other outcome.[6] But what of the injuries these automatons will inevitably cause? What happens when a machine fails to diagnose a cancer, ignores an incriminating email, or inadvertently starts a war?[7] How should the law respond to computer-generated torts?

Tort law has answers to these questions based on a system of common law that has evolved over centuries to deal with unintended harms.[8] The goals of this body of law are many: to reduce accidents, promote fairness, provide a peaceful means of dispute resolution, reallocate and spread losses, promote positive social values, and so forth.[9] Whether tort law is the best means for achieving all of these goals is debatable, but jurists are united in considering accident reduction as one of the central, if not the primary, aims of tort law.[10] By creating a framework for loss shifting from injured victims to tortfeasors, tort law deters unsafe conduct.[11] A purely financially motivated rational

4 *See* Jane Croft, *Legal Firms Unleash Office Automatons*, FIN. TIMES (May 16, 2016), https://www.ft.com/content/19807d3e-1765-11e6-9d98-00386a18e39d (discussing various software programs that can outperform attorneys and paralegals in document review); *cf.* Dana Remus & Frank S. Levy, Can Robots Be Lawyers? Computers, Lawyers, and the Practice of Law (Nov. 27, 2016), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2701092 (unpublished manuscript) (arguing that artificial intelligence will refocus rather than replace attorneys).

5 *See* Yonghui Wu et al., Google's Neural Machine Translation System: Bridging the Gap Between Human and Machine Translation (Sept. 26, 2016), https://arxiv.org/pdf/1609.08144.pdf (unpublished manuscript). Google now claims its Google Neural Machine Translation system is approaching human-level translation accuracy. *Id.* at 2.

6 *See, e.g.*, DELOITTE, FROM BRAWN TO BRAINS: THE IMPACT OF TECHNOLOGY ON JOBS IN THE UK 4 (2015), https://www2.deloitte.com/content/dam/Deloitte/uk/Documents/Growth/deloitte-uk-insights-from-brawns-to-brain.pdf (suggesting that every nation and region of the U.K. has benefitted from automation and that automation has resulted in £140 billion to the U.K.'s economy in new wages).

7 *See, e.g.*, Fiona Macdonald, *The Greatest Mistranslations Ever*, BBC (Feb. 2, 2015), http://www.bbc.co.uk/culture/story/20150202-the-greatest-mistranslations-ever (describing some of the unfortunate outcomes associated with mistranslation).

8 *See generally* MORTON J. HORWITZ, THE TRANSFORMATION OF AMERICAN LAW, 1780–1860 (1977) [hereinafter HORWITZ, 1780–1860]; MORTON J. HORWITZ, THE TRANSFORMATION OF AMERICAN LAW 1870–1960 (1992).

9 *See* George L. Priest, *Satisfying the Multiple Goals of Tort Law*, 22 VAL. U. L. REV. 643, 648 (1988).

10 *See, e.g.*, George L. Priest, *The Invention of Enterprise Liability: A Critical History of the Intellectual Foundations of Modern Tort Law*, 14 J. LEGAL STUD. 461 (1985); *see also* Robert F. Blomquist, *Goals, Means, and Problems for Modern Tort Law: A Reply to Professor Priest*, 22 VAL. U. L. REV. 621 (1988) (arguing that economic theory and moral philosophy both require accident reduction to be the primary aim of tort law).

11 *See* George L. Priest, *Modern Tort Law and Its Reform*, 22 VAL. U. L. REV. 1, 7 (1987).

actor will reduce potentially harmful activity to the extent that the cost of accidents exceeds the benefits of the activity.[12] This liability framework has far-reaching and sometimes complex impacts on behavior. It can either accelerate or impede the introduction of new technologies.[13]

Most injuries people cause are evaluated under a negligence standard where unreasonable conduct establishes liability.[14] When computers cause the same injuries, however, a strict liability standard applies.[15] This distinction has financial consequences and a corresponding impact on the rate of technology adoption.[16] It discourages automation, because machines incur greater liability than people. It also means that in cases where automation will improve safety, the current framework to prevent accidents now has the opposite effect.

This Article argues that the acts of autonomous computer tortfeasors should be evaluated under a negligence standard, rather than a strict liability standard, in cases where an autonomous computer is occupying the position of a reasonable person in the traditional negligence paradigm and where automation is likely to improve safety. For the purposes of ultimate financial liability, the computer's supplier (e.g., manufacturers and retailers) should still be responsible for satisfying judgments under standard principles of product liability law.

This Article employs a functional approach to distinguish an autonomous computer, robot, or machine from an ordinary product.[17]

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12 *See* United States v. Carroll Towing Co., 159 F.2d 169, 173 (2d Cir. 1947) (applying rule that balances the burden of additional protections on the actor with the probability and gravity of an injury).

13 *See* Helling v. Carey, 519 P.2d 981, 983 (Wash. 1974) (holding that the standard of care in the profession of ophthalmology should not insulate providers from failure to test for glaucoma); Gideon Parchomovsky & Alex Stein, *Torts and Innovation*, 107 MICH. L. REV. 285, 286 (2008) (discussing how the role of custom in tort law impedes innovation). Nor is the idea that tort liability is a barrier to developments in machine intelligence new. *See* Steven J. Frank, *Tort Adjudication and the Emergence of Artificial Intelligence Software*, 21 SUFFOLK U. L. REV. 623, 639 (1987).

14 *See infra* text accompanying notes 62–71.

15 *See infra* text accompanying notes 93–100.

16 *See, e.g.*, Amy Finkelstein, *Static and Dynamic Effects of Health Policy: Evidence from the Vaccine Industry*, 119 Q.J. ECON. 527, 535 (2004) (explaining that establishment of the Vaccine Injury Compensation Fund encouraged vaccine development by indemnifying manufacturers from liability).

17 Terms such as "robot," "machine," "artificial intelligence," "machine intelligence," and even "computer" are not used consistently even in the scientific literature. *See, e.g.*, NEIL JOHNSON ET AL., ABRUPT RISE OF NEW MACHINE ECOLOGY BEYOND HUMAN RESPONSE TIME 2 (2013), https://www.nature.com/articles/srep02627.pdf (discussing autonomy in the context of artificial intelligence); Matthew U. Scherer, *Regulating Artificial Intelligence Systems: Risks, Chal-*

Society's relationship with technology has changed. Computers are no longer just inert tools directed by individuals. Rather, in at least some instances, computers are given tasks to complete and determine for themselves how to complete those tasks. For instance, a person could instruct a self-driving car to take them from point A to point B, but would not control how the machine does so. By contrast, a person driving a conventional vehicle from point A to point B controls how the machine travels. This distinction is analogous to the distinction between employees and independent contractors, which centers on the degree of control and independence.[18] As this Article uses such terms, autonomous machines or computer tortfeasors control the *means* of completing tasks, regardless of their programming.[19]

The most important implication of this line of reasoning is that just as computer tortfeasors should be compared to human tortfeasors, so too should humans be compared to computers. Once computers become safer than people and practical to substitute, computers should set the baseline for the new standard of care. This means that human defendants would no longer have their liability based on what a hypothetical, reasonable person would have done in their situation, but what a computer would have done. In time, as computers come to increasingly outperform people, this rule would mean that someone's best efforts would no longer be sufficient to avoid liability. It would not mandate automation in the interests of freedom and autonomy,[20] but people would engage in certain activities at their own peril. Such a rule is entirely consistent with the rationale for the objective standard of the reasonable person, and it would benefit the general welfare. Eventually, the continually improving

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lenges, Competencies, and Strategies, 29 HARV. J.L. & TECH. 353, 359–61 (2016) (discussing difficulties with defining artificial intelligence); John McCarthy, What Is Artificial Intelligence? 2–3 (Nov. 12, 2007), http://jmc.stanford.edu/articles/whatisai/whatisai.pdf (discussing the lack of a standardized definition of artificial intelligence by the scientist who coined the term).

18 *See* Yewens v. Noakes [1880] 6 QB 530 at 532–33 (Eng.) ("A servant is a person subject to the command of his master as to the manner in which he shall do his work."). Also see *O'Connor v. Uber Technologies, Inc.*, No. 14-16078 (9th Cir. argued Sept. 20, 2017), for one of the many ongoing lawsuits against Uber highlighting modern challenges distinguishing between employees and independent contractors.

19 *See, e.g.*, Ryan Abbott, *I Think, Therefore I Invent: Creative Computers and the Future of Patent Law*, 57 B.C. L. REV. 1079, 1083–91 (2016) (discussing types of machine architectures, including conventional knowledge-based systems with expert rules as well as types of machine intelligence algorithms that result in unexpected machine behavior).

20 *See generally* Richard M. Ryan & Edward L. Deci, *Overview of Self-Determination Theory: An Organismic Dialectical Perspective*, *in* HANDBOOK OF SELF-DETERMINATION RESEARCH 3, 6 (Edward L. Deci & Richard M. Ryan eds., 2002) (arguing that people have three basic psychological needs: connectedness, autonomy, and feeling competent).

"reasonable computer" standard should even apply to computer tortfeasors, such that computers will be held to the standard of other computers. By this time, computers will cause so little harm that the primary effect of the standard would be to make human tortfeasors essentially strictly liable for their harms.

This Article uses self-driving cars as a case study to demonstrate the need for a new torts paradigm.[21] There is public concern over the safety of self-driving cars, but a staggering *ninety-four percent* of crashes involve human error.[22] These contribute to over 37,000 fatalities a year in the United States at a cost of about $242 billion.[23] Automated vehicles may already be safer than human drivers, but if not, they will be soon.[24] Shifting to negligence would accelerate the adoption of driverless technologies, which, according to a report by the consulting firm McKinsey & Company, may otherwise not be widespread until the middle of the century.[25]

Automated vehicles may be the most prominent and disruptive upcoming example of robots changing society, but this analysis applies to any context with computer tortfeasors. For instance, IBM's flagship artificial intelligence system, Watson, is working with clinicians at Memorial Sloan Kettering to analyze patient medical records and provide

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21 Others have written about tort liability and self-driving vehicles, although primarily dealing with how existing law deals with accidents involving autonomous vehicles. *See, e.g.*, Jeffrey K. Gurney, *Sue My Car Not Me: Products Liability and Accidents Involving Autonomous Vehicles*, 2013 U. ILL. J.L. TECH. & POL'Y 247; F. Patrick Hubbard, *"Sophisticated Robots": Balancing Liability, Regulation, and Innovation*, 66 FLA. L. REV. 1803, 1803 (2014) (arguing, using the example of self-driving vehicles, that the current framework "provides an appropriate balance of innovation and liability for personal injury"); Gary E. Marchant & Rachel A. Lindor, *The Coming Collision Between Autonomous Vehicles and the Liability System*, 52 SANTA CLARA L. REV. 1321 (2012).

22 *See* NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., U.S. DEP'T OF TRANSP., DOT HS 812 115, CRITICAL REASONS FOR CRASHES INVESTIGATED IN THE NATIONAL MOTOR VEHICLE CRASH CAUSATION SURVEY 1 (2015), https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812115.

23 *General Statistics*, INS. INST. FOR HIGHWAY SAFETY (Dec. 2017), http://www.iihs.org/iihs/topics/t/general-statistics/fatalityfacts/overview-of-fatality-facts [https://perma.cc/2J5P-Y27C]; *see* NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., U.S. DEP'T OF TRANSP., DOT HS 812 013, THE ECONOMIC AND SOCIETAL IMPACT OF MOTOR VEHICLE CRASHES, 2010 (REVISED) 1 (2015), https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812013.

24 *See* Cadie Thompson, *Why Driverless Cars Will Be Safer Than Human Drivers*, BUS. INSIDER (Nov. 16, 2016, 9:24 PM), http://www.businessinsider.com/why-driverless-cars-will-be-safer-than-human-drivers-2016-11.

25 Michele Bertoncello & Dominik Wee, *Ten Ways Autonomous Driving Could Redefine the Automotive World*, MCKINSEY & CO. (June 2015), http://www.mckinsey.com/industries/automotive-and-assembly/our-insights/ten-ways-autonomous-driving-could-redefine-the-automotive-world.

evidence-based cancer treatment options.[26] It even provides supporting literature to human physicians to support its recommendations.[27] Like self-driving cars, Watson does not need to be perfect to improve safety—it just needs to be better than people. In that respect, the bar is unfortunately low. Medical error is one of the leading causes of death.[28] A 2016 study in the *British Medical Journal* reported that it is the *third* leading cause of death in the United States, ranking just behind cardiovascular disease and cancer.[29] Some companies already claim their artificial intelligence systems outperform doctors, and that claim is not hard to swallow.[30] Why should a computer not be able to outperform doctors when the computer can access the entire wealth of medical literature with perfect recall, benefit from the experience of directly having treated millions of patients, and be immune to fatigue?[31]

This Article is divided into three Parts. Part I provides background on the historical development of injuries caused by machines and how the law has evolved to address these harms. It discusses the role of tort law in injury prevention and the development of negligence and strict product liability. Part II argues that while some forms of automation should prevent accidents, tort law may act as a deterrent to adopting safer technologies. To encourage automation and improve safety, this Part proposes a new categorization of "computer-generated torts" for a subset of machine injuries. This would apply to cases in which an autonomous computer, robot, or machine is occupying the position of a reasonable person in the traditional negligence paradigm and where automation is likely to improve safety. This Part contends that the acts of computer tortfeasors should be evaluated under a negligence standard rather than under principles of product liability, and it goes on to propose rules for implementing the system.

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26 *Oncology and Genomics*, IBM, https://www.ibm.com/watson/health/oncology-and-genomics [https://perma.cc/Z6H7-S5W4].

27 *Id.*

28 *See* INST. OF MED., TO ERR IS HUMAN: BUILDING A SAFER HEALTH SYSTEM (Linda T. Kohn et al. eds., 2000); Martin A. Makary & Michael Daniel, *Medical Error—The Third Leading Cause of Death in the US*, 353 BMJ 2139, 2139 (2016). The landmark report published by the Institute of Medicine in 2000 was a wake-up call to the medical profession about the harmful effects of medical error. *See* INST. OF MED., *supra*. Yet the report was based on studies conducted in 1984 and 1992. *See id.*

29 Makary & Daniel, *supra* note 28, at 2143 fig.1.

30 Parloff, *supra* note 3. For example, Enlitic has a program for detecting and classifying lung cancers which the company claims has already outperformed human radiologists. *Id.*

31 *See, e.g.*, Saul N. Weingart et al., *Epidemiology of Medical Error*, 320 BMJ 774, 775 (2010) (discussing some of the causes of human medical error).

Finally, Part III argues that once computer operators become safer than people and automation is practical, the "reasonable computer" should become the new standard of care. It explains how this standard would work, argues the reasonable computer standard works better than a reasonable person using an autonomous machine, and considers when the standard should apply to computer tortfeasors. At some point, computers will be so safe that the standard's most significant effect would be to internalize the cost of accidents on human tortfeasors.

This Article is focused on the effects of automation on accidents, but automation implicates a host of social concerns. It is important that policymakers act to ensure that automation benefits everyone. Automation may increase productivity and wealth, but it may also contribute to unemployment, financial disparities, and decreased social mobility. These and other concerns are certainly important to consider in the automation discussion, but tort liability may not be the best mechanism to address every issue related to automation.[32]

I. Liability for Machine Injuries

A. A Brief History

Injuries caused by machines are nothing new. For as long as people have used machines, injuries have resulted—and machines have been with us for quite some time. The earliest evidence of simple machines—tools that redirect force to make work easier, like axes—dates back millions of years to the beginning of the Stone Age.[33] In fact, the Stone Age is so named because it was characterized by the use of stone to make simple machines such as hand axes.[34] The primary function of these tools was to hunt and cut meat,[35] but they were also used to facilitate violence against people.[36] Machines used in the furtherance of intentional torts were likely used negligently as well.

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32 *See, e.g.*, Ryan Abbott & Bret Bogenschneider, *Should Robots Pay Taxes? Tax Policy in the Age of Automation*, 12 Harv. L. & Pol'y Rev. 145 (2018) (arguing that the tax system incentivizes automation even in cases where it is not otherwise efficient and that automation decreases government tax revenue, and proposing changes to existing tax policies as a solution).

33 Kate Wong, *Ancient Cut Marks Reveal Far Earlier Origin of Butchery*, Sci. Am. (Aug. 11, 2010), https://www.scientificamerican.com/article/ancient-cutmarks-reveal-butchery/.

34 *See Stone Age*, Merriam-Webster, https://www.merriam-webster.com/dictionary/Stone%20Age [https://perma.cc/U6W4-M4M8]. *See generally* Sonia Harmand et al., *3.3-Million-Year-Old Stone Tools from Lomekwi 3, West Turkana, Kenya*, 521 Nature 310 (2015).

35 Wong, *supra* note 33.

36 M. Mirazón Lahr et al., *Inter-group Violence Among Early Holocene Hunter-Gatherers of West Turkana, Kenya*, 529 Nature 394, 396 (2016).

Given that home knife accidents led to about a third of a million emergency room visits in the United States in 2011 alone, it is not difficult to imagine that during the Stone Age these simple machines caused accidents.[37]

As history progressed, and the use and complexity of simple machines grew, so too did the resultant injuries[38]: Mesopotamian surgeons botched procedures,[39] Greek construction zones were so dangerous they required physicians on site,[40] and Egyptian embalmers accidently left instruments in their subjects.[41] Such injuries continued unabated from the time complex machines were invented by the ancient Chinese and Greeks to the time of the first modern industrial machines.[42]

The Industrial Revolution marked a turning point in the role of machines in society.[43] Major technological advances occurred during

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37 *See* Joe Yonan, *Knife Injuries and Other Kitchen Mishaps Afflict Both Top Chefs and Everyday Cooks*, WASH. POST (Jan. 7, 2013), https://www.washingtonpost.com/national/health-science/knife-injuries-and-other-kitchen-mishaps-afflict-both-top-chefs-and-everyday-cooks/2013/01/07/92e191f8-4af0-11e2-b709-667035ff9029_story.html.

38 *See generally* Y.C. CHIU, AN INTRODUCTION TO THE HISTORY OF PROJECT MANAGEMENT 19–115 (2010) (discussing the use of technology in industrial activities). For example, almost half a million people died building the Great Wall of China, although the number of these deaths due to machine injuries is unknown. *Great Wall of China*, HISTORY.COM, http://www.history.com/topics/great-wall-of-china [https://perma.cc/7MP5-FJX5]. So common were machine and industrial injuries in the ancient world that ancient Greek, Roman, Arab, and Chinese laws provided for compensation schedules for accidents. *See* Gregory P. Guyton, *A Brief History of Workers' Compensation*, 19 IOWA ORTHOPAEDIC J. 106, 106 (1999). Under ancient Arab law, "loss of a joint of the thumb was worth one-half the value of a finger. The loss of a penis was compensated by the amount of length lost, and the value an ear was based on its surface area." *Id.*

39 *See* Emily K. Teall, *Medicine and Doctoring in Ancient Mesopotamia*, 3 GRAND VALLEY J. HIST. 1, 5 (2014). Unfortunately for these doctors, medical malpractice in Babylon was corporally punishable. Allen D. Spiegel & Christopher R. Springer, *Babylonian Medicine, Managed Care and Codex Hammurabi, Circa 1700 B.C.*, 22 J. COMMUNITY HEALTH 69, 81 (1997); *see also* GUIDO MAJNO, THE HEALING HAND: MAN AND WOUND IN THE ANCIENT WORLD 53 (1975).

40 DAVID MATZ, VOICES OF ANCIENT GREECE AND ROME: CONTEMPORARY ACCOUNTS OF DAILY LIFE 58 (2012).

41 Granted, this example involves cadavers rather than living patients, or so one hopes. Owen Jarus, *Oops! Brain-Removal Tool Left in Mummy's Skull*, LIVE SCI. (Dec. 14, 2012, 8:03 AM), http://www.livescience.com/25536-mummy-brain-removal-tool.html/. It certainly portends modern medical malpractice cases involving retained surgical instruments. *See, e.g.*, Atul A. Gawande et al., *Risk Factors for Retained Instruments and Sponges After Surgery*, 348 NEW ENG. J. MED. 229, 230 (2003).

42 Peter J. Lu, *Early Precision Compound Machine from Ancient China*, 304 SCIENCE 1638 (2004); *cf.* Russell Fowler, *The Deep Roots of Workers' Comp*, 49 TENN. B.J. 10, 10–12 (2013) (discussing historical development of workers' compensation schemes from the medieval through the modern era).

43 Economists have argued the Industrial Revolution was "certainly the most important

this period in textiles, transportation, and iron making, which resulted in the development of machines for shaping materials and the rise of the factory system.[44] It also resulted in a dramatic increase in the number and severity of machine injuries.[45] Working in industrial settings was a dangerous business, in part because employers often had minimal liability for employee harms.[46] These dangerous working conditions persisted well into the twentieth century before the U.S. government began collecting data on work-related injuries in a systematic way.[47] In 1913, the Bureau of Labor estimated that 23,000 workers died from work-related injuries (albeit an imperfect proxy for machine injuries) out of a workforce of 38 million, which works out to a rate of 61 deaths per 100,000 workers.[48]

In the modern era, the rate of work-related injuries has declined significantly. In 2016, for example, the U.S. Bureau of Labor reported 5190 fatal work injuries, a rate of 3.6 per 100,000 workers.[49] The reason for this decline is multifactorial: changes to tort liability, evolved societal and ethics norms that place a greater priority on human welfare, a modern system of regulations and criminal liability that protects worker wellbeing, as well as improvements in safety technology. Yet despite significant progress in workplace safety, accidents are still a serious societal concern. Workplace accidents were responsible for

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event in the history of humanity since the domestication of animals and plants, perhaps the most important since the invention of language. It bids fair to free us all, eventually." Deirdre McCloskey, *Review of* The Cambridge Economic History of Modern Britain, PRUDENTIA (Jan. 15, 2004), http://www.deirdremccloskey.com/articles/floud.php [https://perma.cc/UAP4-6ZZ3].

44 *See generally History of Technology: The Industrial Revolution (1750–1900)*, ENCYCLOPÆDIA BRITANNICA, https://www.britannica.com/technology/history-of-technology/The-Industrial-Revolution-1750-1900 [https://perma.cc/QV7K-LKLK].

45 *See generally* HENRY ROGERS SEAGER, SOCIAL INSURANCE: A PROGRAM OF SOCIAL REFORM 24–52 (1910) (including a chapter on industrial accidents in a classic exposition of the philosophical movement for social insurance).

46 John S. Haller, Jr., *Industrial Accidents—Worker Compensation Laws and the Medical Response*, 148 WEST J. MED. 341–48 (1988); *see also* HORWITZ, 1780–1860, *supra* note 8, at 90.

47 *See Progressive Era Investigations*, U.S. DEP'T LAB., https://www.dol.gov/dol/aboutdol/history/mono-regsafepart05.htm [https://perma.cc/HUT4-5WQE]. The first systematic U.S. survey of workplace fatalities found that 526 workers died in "work accidents" in Allegheny County from July 1906 to June 1907. *Improvements in Workplace Safety—United States, 1900–1999*, 48 CDC MORBIDITY & MORTALITY WKLY. REP. 461, 461 (1999). Of those fatalities, 195 were steelworkers. *Id.* Contrast that with 17 national steelworker fatalities in 1997. *Id.*

48 *Improvements in Workplace Safety—United States, 1900–1999*, *supra* note 47, at 461. The National Safety Council estimated that 18,000–21,000 workers died from work-related injuries in 1912. *Id.*

49 BUREAU OF LABOR STATISTICS, U.S. DEP'T OF LABOR, NATIONAL CENSUS OF FATAL OCCUPATIONAL INJURIES IN 2016, at 1 (2017), http://www.bls.gov/news.release/pdf/cfoi.pdf [https://perma.cc/2YMS-RA8F].

approximately 4000 deaths in the United States in 2014 and a total cost of about $140 billion.[50] More broadly, there were a total of almost 200,000 injury-related deaths in 2014 in the United States, with all unintentional injuries costing some $850 billion.[51] Unintentional injuries are the fourth leading cause of death.[52]

B. Tort Law as a Mechanism for Accident Prevention

Part of the reason for the decline in workplace injuries is that tort law now provides a stronger financial incentive for safer conduct. The law has evolved from a system designed to insulate employers and manufacturers from liability to one with greater regard for worker and consumer health.[53]

A tort is a harmful civil act, other than under contract, where one person is damaged by another, and it gives way to a right to sue.[54] A variety of goals have been proposed for tort law: to reduce accidents, promote fairness, provide a peaceful means of dispute resolution, reallocate and spread losses, promote positive social values, and so forth.[55] Whether tort law is the best means for achieving all of these goals is a matter of endless dispute.[56] Jurists are united, however, in considering accident reduction as one of the central goals of tort law, if not the primary goal.[57] By creating a framework for loss shifting from injured

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50 Nat'l Safety Council, Injury Facts: 2016 Edition 3, 8 (2016).

51 *Id.* Lost quality of life from those injuries is valued at an additional $3345.5 billion. *Id.* at 8.

52 *Id.* at 2.

53 Tort law primarily grew out of a focus on bodily injury and physical property damage, but protection in modern times has been extended beyond the physical to include harm to emotional well-being, and economic loss.

> The range of torts is as broad as human experience and includes such wrongful conduct as negligence (personal injury law for unintentional harm), intentional torts (e.g., assault, battery, trespass to land), products liability (defective products), abnormally dangerous activities liability (e.g., blasting, aerial pesticide spraying), nuisance (e.g., air, water, and noise pollution), defamation (libel and slander), privacy invasion (private area intrusion and personal autonomy interference), and fraud (misrepresentation). Tort law study also includes consideration of legislative measures related to torts and alternatives to tort liability, for example, automobile no-fault compensation systems.

Dominick Vetri et al., Tort Law and Practice 3 (5th ed. 2016).

54 *See id.* at 2. A tort governs loss shifting from injured victims to tortfeasors, and it dictates who can sue and what they can sue for. *See id.* It is "the set of legal rules establishing liability and compensation for personal injury and death caused by the intentional or careless conduct of a third party." *Id.*

55 *See, e.g.*, Priest, *supra* note 9, at 645 n.23, 648.

56 *See, e.g.*, Priest, *supra* note 10.

57 *See* Blomquist, *supra* note 10, at 628–29 (arguing that economic theory and moral philosophy both require accident reduction to be the primary aim of tort law).

victims to tortfeasors, tort law deters unsafe conduct.[58] A purely financially motivated rational actor will reduce potentially harmful activity to the extent that the cost of accidents exceeds the benefits of the activity.[59]

On a broader level, the law of torts is one of the primary ways in which society choses to allocate liability. And allocating liability has far-reaching and sometimes complex impacts on behavior. In its quest to reduce accidents, tort law can either accelerate the introduction of new technologies, as was the case with the use of glaucoma testing and pulse oximeters, or it can discourage the use of new technologies, as is usually the case where the standard of care is based on custom.[60]

Torts are typically categorized based on the level of fault they require (or based on the interests they protect). On one end of the spectrum are intentional torts involving intent to harm or malice; on the other are strict liability torts which do not require fault.[61] Covering the "great mass of cases" in the middle are harms involving negligence.[62]

C. Negligence

The concept of negligence is the primary theory through which courts deal with accidents and unintended harms.[63] In practice, to prevail in most personal injury cases, a plaintiff must prove by a preponderance of the evidence that the defendant owed the plaintiff a duty of reasonable care, the defendant breached that duty, the breach caused the plaintiff's damages, and the plaintiff suffered compensable damages.[64] This generally requires proof that the defendant acted negligently, which is to say, acted unreasonably considering foreseeable risks. This standard is premised on what an objective and hypothetical "reasonable" person would have done under the same circum-

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58 *See* Priest, *supra* note 9, at 648.

59 *See* United States v. Carroll Towing Co., 159 F.2d 169, 173 (2d Cir. 1947) (stating that liability calculations should consider whether the probability of injury times potential damages is lower than the burden imposed).

60 *See* Helling v. Carey, 519 P.2d 981, 983 (Wash. 1974) (holding that the standard of care in the profession of ophthalmology should not insulate providers from failure to test for glaucoma); Parchomovsky & Stein, *supra* note 13, at 306 (discussing how the role of custom in tort law impedes innovation).

61 Oliver Wendell Holmes, Jr., *The Theory of Torts*, 7 AM. L. REV 652, 653 (1873).

62 *Id.*

63 *See* Thomas C. Grey, *Accidental Torts*, 54 VAND. L. REV. 1225, 1283–84 (2001).

64 *See* RESTATEMENT (SECOND) OF TORTS § 281 (AM. LAW INST. 1965).

stances.[65] Thus, if the courts determined that a reasonable person would not have headed out to sea without a radio to warn of storm conditions,[66] manufactured a ginger beer with a snail inside,[67] or dropped heavy objects off the side of a building,[68] then these activities could expose a defendant to liability.

Negligence strikes a balance between the interests of plaintiffs and defendants. Society has interests in reducing injuries and compensating victims as well as encouraging economic growth and progress.[69] One way that tort law attempts to achieve this balance is by permitting recovery in negligence only where there has been socially blameworthy conduct.[70] Thus, where a defendant has acted reasonably, even if the defendant has caused serious injury to a plaintiff, there will generally be no liability. Juries play a key role in determining the reasonable person standard as applied to the facts of a case.[71]

D. Strict and Product Liability

While negligence governs virtually all accidents, there are exceptions. For instance, defendants may be strictly liable for harms they cause as a result of certain types of activities such as hazardous waste disposal or blasting.[72] Strict liability is a theory of liability without fault; it is essentially based on causation without regard to whether a defendant's conduct is socially blameworthy.[73] Thus, a defendant cor-

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65 The idea that negligence involves conduct that falls below an objective standard was first articulated by Baron Alderson in the case of *Blyth v. Birmingham Waterworks Co.*:

> Negligence is the omission to do something which a reasonable man, guided upon those considerations which ordinarily regulate the conduct of human affairs, would do, or doing something which a prudent and reasonable man would not do. The defendants might have been liable for negligence, if, unintentionally, they omitted to do that which a reasonable person would have done, or did that which a person taking reasonable precautions would not have done.

(1856) 156 Eng. Rep. 1047, 1049; 11 Ex. 781, 784.

66 *See* The T.J. Hooper, 53 F.2d 107 (S.D.N.Y. 1931).

67 *See* Donoghue v. Stevenson [1932] AC 562 (HL) (appeal taken from Scot.).

68 *See* Byrne v. Boadle (1863) 159 Eng. Rep. 299.

69 VETRI ET AL., *supra* note 53, at 12.

70 *See* James Barr Ames, *Law and Morals*, 22 HARV. L. REV. 97, 99 (1908).

71 VETRI ET AL., *supra* note 53, at 10.

72 *Id.* at 11.

73 *See* Frederick Pollock, *Duties of Insuring Safety: The Rule in* Rylands v. Fletcher, 2 L.Q. REV. 52, 53 (1886). While early English common law imposed strict liability for certain wrongs such as trespass, *Rylands v. Fletcher* (1868) 3 LRE & I App. 330 (HL), was the progenitor of the doctrine of strict liability for abnormally dangerous activities, and its ruling had a major impact on the development of tort law. Pollock, *supra*, at 52, 59. In the case, Fletcher's reservoir burst and flooded a neighboring mine run by Rylands through no fault of Fletcher. *Id.* at 53. This court held that "the person who for his own purposes brings on his lands and collects and keeps there,

poration that takes every reasonable care to prevent injury before dusting crops may nevertheless find itself liable for injuries it causes to a bystander.

One of the most important modern applications of strict liability is to product liability. Product liability refers to responsibility for the commercial transfer of a product that causes harm because it is defective or because its properties are falsely represented.[74] Product injuries cause upwards of 200 million injuries a year in the United States.[75] In most instances, members of the supply chain (e.g., manufacturers and retailers) are strictly liable for defective products.[76] The bulk of product liability cases involve claims for damages against a manufacturer or retailer by a person injured while using a product.[77] Typically, a plaintiff will try to prove that an injury was the result of some inherent defect of a product or its marketing and that the product was flawed or falsely advertised.[78] Defendants, in turn, attempt to prove that their products were reasonably designed, properly made, and accurately marketed.[79] Defendants may argue that plaintiff injuries were the result of improper and unforeseeable use of the product or that something other than the product caused the harm.[80]

Product liability was not always governed by strict liability. Originally, American courts followed the English doctrine of *caveat emptor* (let the buyer beware) for product liability claims, reflecting a national philosophy embracing individualism and free enterprise.[81] Toward the end of the nineteenth century, however, states began increasingly employing the doctrine of *caveat venditor* and an implied warranty of merchantable quality.[82] Under this doctrine, "[s]elling for a sound price raises an implied warranty that the thing sold is free from de-

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anything likely to do mischief if it escapes, must keep it in at his peril, and, if he does not do so, is *prima facie* answerable for all the damage which is the natural consequence of its escape." *Id.* at 54. Critics of the case objected to its potential impact on economic activity. *See, e.g.*, THOMAS C. GREY, FORMALISM AND PRAGMATISM IN AMERICAN LAW 248 (2014) (noting that many "prestigious judges and commentators" repudiated *Rylands* on the basis that "liberal principles of formal equality and economic freedom, or a devotion to economic development, required rejection of tort liability without fault").

74 DAVID G. OWEN, PRODUCTS LIABILITY LAW 1 (3d ed. 2014).

75 *Id.* at 1.

76 *Id.* at 3.

77 *Id.*

78 *Id.*

79 *Id.*

80 *Id.*

81 *Id.* at 17–18.

82 *Id.* at 18.

fects, known and unknown (to the seller)."[83] Ultimately, the doctrine of implied warranty of merchantable quality was reduced to statutory form in the Uniform Sales Act of 1906.[84] Yet even so, manufacturers were in large part able to avoid liability for defective products by arguing they lacked privity of contract with consumers.[85] This was possible because in most cases consumers purchased products from third-party retailers rather than directly from manufacturers.[86]

That changed in 1916 with the New York Court of Appeals decision in *MacPherson v. Buick Motor Co.*[87] The case involved a motorist who was injured when one of the wooden wheels of his Buick collapsed.[88] He subsequently attempted to sue the manufacturer (Buick) rather than the dealership from which he purchased the vehicle. In rejecting a defense based on privity of contact, the court held that if the manufacturer of such a foreseeably dangerous product knows that it "will be used by persons other than the purchaser, and used without new tests, then, irrespective of contract, the manufacturer of this thing of danger is under a duty to make it carefully."[89] *MacPherson* spurred negligence claims against manufacturers across the country as state courts one-by-one adopted *MacPherson*'s holding.[90] This shift was accompanied by growing public support for consumer protection together with the understanding that liability would not unduly burden economic activity.[91] Businesses are often in the best position to prevent product injuries and can distribute liability through insurance.[92]

In 1963, the Supreme Court of California decided *Greenman v. Yuba Power Products, Inc.*,[93] which held that manufacturers of defective products are strictly liable for injuries caused by such products.[94]

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83 *Id.* (quoting S. Iron & Equip. Co. v. Bamberg, E. & W. Ry. Co., 149 S.E. 271, 278 (S.C. 1929)).

84 *Id.*; *see* U.C.C. § 2-314 (Am. Law Inst. & Unif. Law Comm'n 2014). *See generally* Friedrich Kessler, *The Protection of the Consumer Under Modern Sales Law, Part 1*, 74 Yale L.J. 262 (1964).

85 Owen, *supra* note 74, at 18.

86 *Id.*

87 111 N.E. 1050 (N.Y. 1916).

88 *Id.* at 1051.

89 *Id.* at 1053.

90 Owen, *supra* note 74, at 22. Maine was the last state to abolish the privity requirement in negligence actions in 1982. *Id.*

91 *See id.* at 22–23.

92 *See id.*

93 377 P.2d 897 (Cal. 1963) (in bank).

94 *Id.* at 900. Of note, Justice Roger Traynor, who wrote the majority opinion in the case, had suggested this strict liability rule nineteen years earlier in a concurring opinion in *Escola v. Coca Cola Bottling Co. of Fresno*, 150 P.2d 436 (Cal. 1944). He argued responsibility should "be

This case represents the birth of modern products liability law in America.[95] After this decision, the doctrine of strict product liability spread rapidly across the nation in the 1960s, with the American Law Institute memorializing the rule in Section 402A of the Restatement (Second) of Torts.[96]

Of course, today's products liability law is not as simple as this brief narrative suggests.[97] It combines tort law (e.g., negligence, strict liability, and deceit), contract law (e.g., warranty), both common and statutory law (e.g., statutory sales law under Article 2 of the Uniform Commercial Code), and a hodgepodge of state "reform" acts.[98] Since the 1960s, a variety of state statutes have attempted to reform products liability law, often to limit the rights of consumers in order to protect manufacturers.[99] For our purposes, however, it suffices to say that as a general matter, manufacturers and retailers are strictly liable for injuries caused by defective products.[100]

II. Computer-Generated Torts

A. Automation Will Prevent Accidents

On May 7, 2016, a Tesla driver was killed in the first known fatal crash of a self-driving car.[101] Tesla reported that the autopilot system

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fixed wherever it will most effectively reduce the hazards to life and health inherent in defective products that reach the market." *Id.* at 440 (Traynor, J., concurring). A few years before this case, the Supreme Court of New Jersey found manufacturers strictly liable in warrantee to remote consumers in *Henningsen v. Bloomfield Motors, Inc.*, 161 A.2d 69, 77, 84 (N.J. 1960).

95 Owen, *supra* note 74, at 23.

96 Restatement (Second) of Torts § 402A (Am. Law Inst. 1965); *see* Owen, *supra* note 74, at 23.

97 For a more comprehensive view on products liability, the American Law Institute published a Restatement specifically on products liability in 1998. Restatement (Third) of Torts: Products Liability (Am. Law Inst. 1998).

98 Owen, s*upra* note 74, at 4.

99 *Id.* at 23.

100 *See* Vandermark v. Ford Motor Co., 391 P.2d 168, 171–72 (Cal. 1964) (in bank) ("Retailers like manufacturers are engaged in the business of distributing goods to the public. They are an integral part of the overall producing and marketing enterprise that should bear the cost of injuries resulting from defective products. In some cases the retailer may be the only member of that enterprise reasonably available to the injured plaintiff. In other cases the retailer himself may play a substantial part in insuring that the product is safe or may be in a position to exert pressure on the manufacturer to that end; the retailer's strict liability thus serves as an added incentive to safety. Strict liability on the manufacturer and retailer alike affords maximum protection to the injured plaintiff and works no injustice to the defendants, for they can adjust the costs of such protection between them in the course of their continuing business relationship." (citation omitted)).

101 Sam Levin & Nicky Woolf, *Tesla Driver Killed While Using Autopilot Was Watching Harry Potter, Witness Says*, Guardian (July 1, 2016, 1:43 PM), https://www.theguardian.com/

did not apply the brakes after the car's sensor system failed to detect an eighteen-wheel truck and trailer.[102] The car attempted to drive full speed under the trailer and the bottom of the trailer impacted the car's windshield.[103] The driver, whom Tesla claims should have remained alert and who also failed to apply the brakes, may have been watching a Harry Potter movie at the time.[104]

Surveys of attitudes toward self-driving cars have produced mixed results, but they have often uncovered negative opinions.[105] A survey by the American Automobile Association in March 2016 reported that three out of four U.S. drivers surveyed said they would feel "afraid" to ride in a self-driving car.[106] Only one in five said they would trust a driverless car to drive itself while they were inside.[107] Another recent survey found that most U.K. citizens would feel uncomfortable with self-driving vehicles on the road, and more than

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technology/2016/jul/01/tesla-driver-killed-autopilot-self-driving-car-harry-potter; *see* Anjali Singhvi & Karl Russell, *Inside the Self-Driving Tesla Fatal Accident*, N.Y. TIMES (July 12, 2016), http://www.nytimes.com/interactive/2016/07/01/business/inside-tesla-accident.html?_r=0. This has been the first reported fatality, but not the only reported crash for which a self-driving vehicle has been at fault. *See, e.g.*, Tan Weizhen, *Self-Driving Car in Accident with Lorry at One-North*, TODAY (Oct. 18, 2016), http://www.todayonline.com/singapore/self-driving-car-involved-accident-one-north. Other, nonfatal accidents have been attributed to self-driving vehicles. *See* Dave Lee, *Google Self-Driving Car Hits a Bus*, BBC NEWS (Feb. 29, 2016), http://www.bbc.co.uk/news/technology-35692845. The National Highway Traffic Safety Administration ("NHTSA") investigated this accident and issued a report in January 2017 stating that "[a] safety-related defect trend has not been identified at this time and further examination of this issue does not appear to be warranted." NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., U.S. DEP'T OF TRANSP., INVESTIGATION PE 16-007 (2017), https://static.nhtsa.gov/odi/inv/2016/INCLA-PE16007-7876.PDF. The NHTSA found the accident was beyond the capabilities of the vehicle's Autopilot and Automatic Emergency Breaking systems. *Id.* The report went on to state that overall crash rates decreased by nearly forty percent after installation of Tesla's Autosteer technology. *Id.* at 10.

102 Levin & Woolf, *supra* note 101.

103 *Id.*

104 *Id.*

105 Similarly, a poll of 1869 registered voters in January 2016 by Morning Consult found that forty-three percent of registered voters said self-driving cars were unsafe, while only thirty-two percent said they were safe. Amir Nasr & Fawn Johnson, *Voters Aren't Ready for Driverless Cars, Poll Shows*, MORNING CONSULT (Feb. 8, 2016), https://morningconsult.com/2016/02/08/voters-arent-ready-for-driverless-cars-poll-shows/. Fifty-one percent of respondents said they would not ride in a driverless car, while twenty-five percent said they would. *Id.*; *see* Paul Lienert, *Tesla Crash Does Little to Sway Public Opinion on Self-Driving Cars*, AUTOMOTIVE NEWS (July 29, 2016, 2:21 PM), http://www.autonews.com/article/20160729/OEM06/160729812/tesla-crash-does-little-to-sway-public-opinion-on-self-driving-cars (discussing the results of other surveys).

106 Erin Stepp, *Three-Quarters of Americans "Afraid" to Ride in Self-Driving Vehicle*, AAA NEWSROOM (Mar. 1, 2016), http://newsroom.aaa.com/2016/03/three-quarters-of-americans-afraid-to-ride-in-a-self-driving-vehicle/.

107 *Id.*

three-quarters would want to retain a steering wheel.[108] Regulators are more optimistic than the public, but they are still cautious.[109] Until very recently, California required human drivers to be present in all self-driving cars being tested on public roads.[110] Two laws passed in 2016, however, now permit unmanned vehicles to operate on public roads under certain circumstances.[111]

Yet much of the public discourse on self-driving cars is misguided. The critical issue is not whether computers are perfect (they are not), but whether they are safer than people (they are). Nearly all crashes involve human error.[112] A human driver causes a fatality about every 100 million miles, resulting in tremendous human and financial costs.[113] The U.S. Department of Transportation reports that more than 35,000 people died from motor vehicle accidents in the United States in 2015.[114] It estimates the economic costs of those accidents at over $240 billion.[115]

By contrast, the Tesla fatality was the first known autopilot death in about 130 million miles driven by the system.[116] It is also important to note that driverless technologies are in their infancy. Imagine how improved such technologies will be in ten years. One academic expert predicted in September 2016 that self-driving cars will be ten times safer than human drivers in three years, and one hundred times safer in ten years.[117] At the point where automated cars are ten times safer

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108 David Neal, *Over Half of Brits Won't Feel Safe Using the Streets with Driverless Cars*, INQUIRER (Oct. 17, 2016), http://www.theinquirer.net/inquirer/news/2474351/over-half-of-brits-wont-feel-safe-using-the-streets-with-driverless-cars.

109 This caution is reflected, for example, in guidelines released in September 2016 by the Department of Transportation for safe design, development, and testing of self-driving cars. NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., U.S. DEP'T OF TRANSP., FEDERAL AUTOMATED VEHICLES POLICY: ACCELERATING THE NEXT REVOLUTION IN ROADWAY SAFETY 5–7 (2016), https://www.transportation.gov/sites/dot.gov/files/docs/AV%20policy%20guidance%20PDF.pdf.

110 Susmita Baral, *Driverless Car Laws in California Get Major Changes in September*, INT'L BUS. TIMES (Oct. 3, 2016, 5:40 PM), http://www.ibtimes.com/driverless-car-laws-california-get-major-changes-september-2425689.

111 *Id.*

112 NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., *supra* note 109, at 5.

113 ALEXANDER HARS, TOP MISCONCEPTIONS OF AUTONOMOUS CARS AND SELF-DRIVING VEHICLES 1, 6 (2016), http://www.inventivio.com/innovationbriefs/2016-09/Top-misconceptions-of-self-driving-cars.pdf.

114 *General Statistics*, *supra* note 23.

115 *Id.*

116 *A Tragic Loss*, TESLA (June 30, 2016), https://www.tesla.com/en_GB/blog/tragic-loss [https://perma.cc/LZ8X-UW2F].

117 Michael Belfiore, *Self-Driving Cars Will Be 10x Safer Than Human Drivers in 3 Years*, MICHAEL BELFIORE BLOG (Sept. 20, 2016), http://michaelbelfiore.com/2016/09/20/self-driving-cars-will-be-10x-safer-than-human-drivers-in-3-years/ [https://perma.cc/4T78-CEWD]. Similarly,

than human drivers, that could reduce the annual number of motor vehicle fatalities to about 3500. That was the conclusion of a report from the consulting firm McKinsey & Company, which predicted autonomous vehicles would reduce the number of auto deaths by about 30,000 a year.[118] However, the report estimated that self-driving technologies would not be adopted widely enough to permit this outcome until the middle of the century.[119]

B. Tort Liability Discourages Automation

To see why tort law discourages automation, it is important to look at the question of when it makes economic sense for a business to replace a human operator with a machine operator. In practice, it might be complex to calculate the cost of each operator. Human employees have costs in excess of their salaries and wages, such as tax liability for employer portions of Social Security tax, Medicare tax, state and federal unemployment tax, and workers' compensation; employer portions of health insurance; paid holidays, vacations, and sick days; contributions toward retirement, pension, savings, and profit-sharing plans, etc.[120] Computer costs may be simpler to estimate, but they may also be uncertain. In addition to purchase or license costs and taxes, there may be costs associated with repair, maintenance, and operation.

Added to the direct financial costs associated with employing an operator, there may be indirect financial and nonfinancial costs, known and unknown, that guide a decision.[121] For example, a person may require vocational training or be unable to work due to sickness; a computer may require software updates or be unable to work due to malfunction. Human operators may result in greater expenses for legal fees, administrative and overhead costs, as well as compliance with regulatory and employment requirements.[122] Automation may provide

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Bob Lutz, former General Motors ("GM") vice chairman, predicted that GM's first autonomous cars would have an accident rate about ten percent of those of human drivers. Michelle Fox, *Self-Driving Cars Safer than Those Driven by Humans: Bob Lutz*, CNBC (Sept. 8, 2014, 3:30 PM), http://www.cnbc.com/2014/09/08/self-driving-cars-safer-than-those-driven-by-humans-bob-lutz.html.

118 Bertoncello & Wee, *supra* note 25.

119 *Id.*

120 *See* Bret N. Bogenschneider, *The Effective Tax Rate of U.S. Persons by Income Level*, 145 TAX NOTES 117, 118 (2014); *see also* WAYNE F. CASCIO, COSTING HUMAN RESOURCES (4th ed. 2000).

121 *See* ALFRED MARSHALL, PRINCIPLES OF ECONOMICS 368, 376 (8th ed. 1920).

122 *See Cost of Small Business Employment*, CTR. FOR ECON. & BUS. RES., www.cebr.com/reports/cost-of-small-business-employment/ [https://perma.cc/V3F6-USE6].

tax benefits,[123] but may infringe patents or result in negative publicity.[124] Whether to staff with a person or a machine may also take into account broader social policies. For instance, automation may promote income inequality and unemployment. But businesses are required to act in the best interests of shareholders, and most businesses interpret this duty as a mandate to maximize profit rather than to promote social responsibility.[125]

The decision of whether to employ a computer or human operator, even where the two are capable of functioning interchangeably, may therefore be a complex one. Nevertheless, these are precisely the sorts of decisions that businesses are skilled at making—estimating uncertain future costs relatively accurately and making decisions as rational economic actors.[126] Tort liability will only be one factor to consider when deciding whether to employ a computer or human operator. But, in the aggregate, tort liability will influence automation.

As with some of these other factors, the costs of tort liability may not be straightforward. For instance, businesses may not be directly liable for harms caused by autonomous computers.[127] The computer's manufacturer and other members of the supply chain will generally be liable. By contrast, businesses will generally be liable for negligent harms caused by their employees, although businesses can attempt to limit this liability, for instance, by relying on independent contrac-

123 *See* Abbott & Bogenschneider, *supra* note 32.

124 *See, e.g.*, Kate Taylor, *McDonald's Ex-CEO Just Revealed a Terrifying Reality for Fast-Food Workers*, BUS. INSIDER (May 25, 2016, 10:05 AM), http://www.businessinsider.com/mcdonalds-ex-ceo-takes-on-minimum-wage-2016-5 (discussing criticism of McDonald's for replacing workers with machines).

125 *See generally* Dodge v. Ford Motor Co., 170 N.W. 668, 682–84 (Mich. 1919). Of course, many companies argue they promote corporate social responsibility, and in some circumstances, there may be a business case for doing so. *See, e.g.*, Archie B. Carroll & Kareem M. Shabana, *The Business Case for Corporate Social Responsibility: A Review of Concepts, Research and Practice*, 12 INT'L J. MGMT. REVS. 85 (2010).

126 *See, e.g.*, Hugh Courtney, Jane Kirkland & Patrick Viguerie, *Strategy Under Uncertainty*, HARV. BUS. REV., Nov.–Dec. 1997.

127 *See* Mark A. Chinen, *The Co-Evolution of Autonomous Machines and Legal Responsibility*, 20 VA. J.L. & TECH. 338, 347–48 (2016).

tors.[128] Businesses are not usually liable for negligent harms caused by their independent contractors.[129]

Yet even in cases where liability rests with a business's supplier or an independent contractor, such liability may indirectly impact a business. A manufacturer or retailer may pass along its costs in the form of higher prices, or a business may need to pay an independent contractor more than an employee to have the contractor assume risk. The percentage of cost passed on to the business or consumer will depend on the market and price elasticity for that product.[130] Yet the fact that tort liability may be indirect and complex or that firms may purchase insurance to manage risk does not change the fact that tort liability has a financial cost which influences behavior.

Leaving aside tort liability, if both operators cost a business the same amount to employ, the decision of whether to utilize a person or computer should be neutral. If a business introduces the variable of tort liability into the decision, a human operator would be preferred. Harms caused by a person will be evaluated in negligence, but the same harms caused by a computer will be evaluated in strict liability. It is easier to establish strict liability than negligence.[131] Strict liability does not require careless manufacturer behavior, only that a defect be present in a product.[132] At least with regard to tort liability, the law

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128 *See, e.g.*, Kleeman v. Rheingold, 614 N.E.2d 712, 715 (N.Y. 1993). There are, however, limits on the extent to which businesses can rely on independent contractors or attempt to classify employees as independent contractors. *See, e.g.*, *In re* Morton, 30 N.E.2d 369, 371 (N.Y. 1940). As another example of how business can avoid tort liability for the actions of human operators, employers are not generally liable for intentional torts committed by employees. *See, e.g.*, Ocana v. Am. Furniture Co., 91 P.3d 58, 70–71 (N.M. 2004).

129 *See Kleeman*, 614 N.E.2d at 715.

130 *See generally* RBB Economics, Cost Pass-Through: Theory, Measurement, and Potential Policy Implications (2014).

131 *See* Cronin v. J.B.E. Olson Corp., 501 P.2d 1153, 1162 (Cal. 1972) (in bank) ("[T]he very purpose of our pioneering efforts in [strict product liability] was to relieve the plaintiff from problems of proof inherent in pursuing negligence and warranty remedies, and thereby 'to insure that the costs of injuries resulting from defective products are borne by the manufacturers . . . .'" (ellipsis in original) (citations omitted) (quoting Greenman v. Yuba Power Prods., Inc., 377 P.2d 897, 901 (Cal. 1963))); *see also* Escola v. Coca Cola Bottling Co. of Fresno, 150 P.2d 436, 441 (Cal. 1944) (Traynor, J., concurring) ("It is to the public interest to discourage the marketing of products having defects that are a menace to the public. If such products nevertheless find their way into the market it is to the public interest to place the responsibility for whatever injury they may cause upon the manufacturer, who, even if he is not negligent in the manufacture of the product, is responsible for its reaching the market. However intermittently such injuries may occur and however haphazardly they may strike, the risk of their occurrence is a constant risk and a general one. Against such a risk there should be general and constant protection and the manufacturer is best situated to afford such protection.").

132 *See Cronin*, 501 P.2d at 1162.

thus favors people over machines. This will hold true as long as computers are treated as "ordinary products" as to which strict liability is the default rule.

C. Computer-Generated Torts Should Be Negligence Based

Holding computer-generated torts to a negligence standard will result in an improved outcome: it will accelerate the adoption of automation where doing so would reduce accidents. Of course, moving from a strict liability to a negligence standard would have some drawbacks. As mentioned earlier, strict liability creates a stronger incentive for manufacturers to make safer products, and manufacturers may be better positioned than consumers to insure against loss. Indeed, this is why courts initially adopted strict product liability.[133] Computer-generated torts, however, differ from other product harms in that—once machines become safer than people—automation will result in net safety gains.

To illustrate this, imagine that with current technology a computer driver would be ten times safer than a human driver. In this case, it would be better that *one* human driver is replaced by a machine than that the same machine becomes *100 times* safer than a human driver. To see why that is so, assume a closed system with only two vehicles, where the risk of injury for a human driver is one fatality per 100 million miles driven and the risk of injury for a computer driver (model C-A) is one fatality per 1 billion miles driven. C-A is ten times safer than a person. Over the course of ten billion miles driven by the person and C-A, there will be an average of 110 fatalities.

Now imagine that we are able to improve C-A an additional tenfold such that its risk of causing injury is reduced to one fatality per 10 billion miles (C-A+). Then, over the course of 10 billion miles driven by the person and C-A+, there will be a total of 101 fatalities. If, however, instead of focusing our efforts on improving C-A we simply replace the human driver with another C-A, then over the course of 10 billion miles driven by C-A & C-A there will be a total of 20 fatalities. Once computers become safer than people, and particularly once computers become substantially safer than people, very significant reductions in accident rates will be gained by automation. Therefore—at some point—it is preferable to weaken the incentive to gain incremen-

133 *See, e.g.*, *Greenman*, 377 P.2d at 901.

tal improvements in product safety to increase the adoption of safer technologies.

Also, even under a negligence standard, manufacturers will be incentivized to improve the safety of their computer systems because they may still be liable for accidents. Manufacturers will likely have the best information available to determine whether it would be better to pay to further reduce accident risks, e.g., whether an additional $10,000 per vehicle is worth a one percent reduction in accident risk, or whether to pay claims for additional accidents. Higher safety levels are not always better; inefficiently high safety levels may result in prohibitively high prices for consumers.[134] To the extent that society is not satisfied with a manufacturer's risk-benefit analysis on optimum safety levels, non-tort mechanisms could be brought to bear, such as regulatory mandates for minimum safety standards. Finally, to the extent that risk spreading is a concern, even though businesses may be better positioned to acquire insurance, consumers also have options to purchase insurance, particularly in the automobile context.[135]

There is further justification for separating out harms caused by ordinary products like MacPherson's Buick and "computer tortfeasors" like Tesla's autonomous driving software. Society's relationship with technology has changed. Computers are no longer just inert tools directed by individuals. Rather, in at least some instances, computers are taking over activities once performed by people and causing the same sorts of harm these activities generate. In other words, computers are stepping into the shoes of a reasonable person.

What distinguishes an ordinary product from a computer tortfeasor in this system are the concepts of independence and control. Autonomous computers, robots, or machines are given tasks to complete, but they determine for themselves the means of completing those tasks.[136] In some instances, machine learning can generate unpredictable behavior such that the means are not predictable either by those giving tasks to computers or even by the computer's original programmers.[137] But the difference between ordinary products and

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134 David G. Owen, *Rethinking the Policies of Strict Products Liability*, 33 VAND. L. REV. 681, 710 (1980).

135 *Id.* at 694.

136 Curtis E.A. Karnow, *The Application of Traditional Tort Theory to Embodied Machine Intelligence*, *in* ROBOT LAW 51, 52 (Ryan Calo et al. eds., 2016).

137 *Id.* Unlike Karnow, the author does not agree that the relevant distinction between autonomous and nonautonomous machines should be the degree to which they are unpredictable. *See id.* at 55. Tort law should pursue functional solutions, and for the purposes of accident reduction, it should not matter whether a self-driving car operates per expert rules or per unpre-

autonomous computers should not be based on predictability, only on social and practical outcomes.[138] It makes no difference to a person run over by a self-driving car what type of computer was operating the vehicle. Whether a computer acts according to fixed or expert rules created by a programmer or more complex machine-learning algorithms such as neural networks that generate new and sometimes unforeseen behaviors, the physical outcome is the same.[139] Leaving aside difficulties with courts attempting to distinguish between different types of computer architecture, ultimately, the goals of tort law should be functional. Tort law should aspire to lower accident rates, not to create a formalistically pure theory of autonomy.

D. Computer-Generated Torts as a Type of Machine Injury

Not all machine injuries would be computer-generated torts. To illustrate, consider two hypothetical accidents:

> 1) A crane operator drops a steel frame on a passerby after incorrectly identifying the location for drop off.
> 2) A crane operator is manipulating a crane under normal conditions when it tips over and lands on a passerby.

In the first example, as between the machine and the operator, it seems obvious (and one may assume) that the operator is at fault (although a creative plaintiff's attorney might argue the crane was negligently designed to allow such an outcome). While the accident could not have occurred without the machine's involvement, making it a factual cause of the injury in torts vernacular, the machine did not interrupt a direct and foreseeable chain of events set in motion by the operator's action. The machine is essentially functioning as an extension of the operator, in the same way that the operator could commit a battery by throwing a rock at another person.[140] In the second hypothetical, allocating fault is once again intuitively obvious. The machine

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dictable machine-learning algorithms. *See* Abbott, *supra* note 19, at 1109 (arguing in the patent context that it would be impossible or impractical to distinguish between different computer architectures for determining whether a computer qualifies as an inventor and that the distinction is irrelevant to promoting innovation).

138 *Cf., e.g.*, David C. Vladeck, *Machines Without Principals: Liability Rules and Artificial Intelligence*, 89 WASH. L. REV. 117, 127 (2014) (arguing different liability rules may need to apply to injuries caused by computers that cannot be traced to a "design, manufacturing, or programming defect").

139 *See, e.g.*, Jack M. Balkin, *The Path of Robotics Law*, 6 CALIF. L. REV. CIR. 45, 45–46 (2015) (arguing against a focus on formalism and essentialism in the law).

140 *See, e.g.*, R v. Day (1845) 1 Cox 207, 208 (holding that slashing a victim's clothing with a knife constitutes battery).

is at fault rather than the operator. The operator acted with reasonable care, and the injury was due to (one may assume) a flawed crane.

These two scenarios would result in very different liability outcomes. In the first, the operator, and possibly the operator's employer, would be liable to the passerby in negligence because the operator failed to exercise reasonable care. In the second, the manufacturer and retailer of the crane would be strictly liable to the passerby even if the manufacturer had exercised the utmost care in the design and construction of the crane.

In both scenarios, an operator is using a crane in much the same way cranes have been used in construction for thousands of years. Granted, today's cranes utilize more sophisticated designs, are built from sturdier materials, and have electric power, but the basic dynamic between person and machine has not changed much. The cranes used to build skyscrapers, the pulleys used to build the Giza Pyramids, and the cranes used to build the Parthenon all involved human operators controlling the movements of a simple or complex machine to redirect and amplify force.[141]

Now imagine a third scenario:

> 3) A computer-operated, unmanned crane drops a steel frame on a passerby after incorrectly identifying the location for drop off.

The law now treats Examples 2 and 3 the same way because they both involve defective products. Yet in important respects, Examples 1 and 3 are more closely related. Both Examples 1 and 3 involve the same sort of action and the same physical result. In Example 2, a machine is being used as a tool. In Example 3, a computer has stepped into the shoes of the worker; it has replaced a person, and it is performing in essentially the same manner as a person. If the computer were a person, the computer would be liable in negligence and held to the standard of a reasonable person.[142]

Holding computer tortfeasors to a negligence standard requires rules for distinguishing between computer-generated torts and other

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141 *See* J.J. Coulton, *Lifting in Early Greek Architecture*, 94 J. Hellenic Stud. 1, 1, 12, 15–17 (1974).

142 The author has previously argued for a similar rule in the intellectual property context, where he proposed that computers should be recognized as authors and inventors if they independently perform creative acts. *See* Ryan Abbott, *Hal the Inventor: Big Data and Its Use by Artificial Intelligence*, *in* Big Data Is Not a Monolith 187, 187 (Cassidy R. Sugimoto et al. eds., 2016); Abbott, *supra* note 19, at 1081. This rule would generate innovation by creating financial incentives for developing creative computers. *See* Abbott, *supra*; Abbott, *supra* note 19, at 1081.

harms. The goal is to distinguish between cases in which a machine is used as a mere instrument and a person is at fault (Example 1), cases in which an ordinary product is at fault (Example 2), and cases in which there is a "computer tortfeasor" (Example 3).

Computer-generated torts could be those cases in which an autonomous computer occupies the position of a reasonable person in the negligence calculus and where automating promotes safety. It is only beneficial to encourage automation when doing so would reduce accidents. It would be harmful to encourage automation while human drivers outperform self-driving cars (though, it might still be beneficial to encourage automation for a subset of cases, for instance, the class of bad drivers). To shift from strict liability to negligence, manufacturers should have the burden to show by a preponderance of the evidence that a computer tortfeasor is safer on average than a person.

E. Implementation

Automation may occur on a more or less permanent basis, or it may be situational. For example, an autonomous vehicle may only permit machine control, or it may allow a person to switch between human and machine control. Where automation is all-or-nothing, the relevant inquiry should be whether a specific instance of automation would be expected to result in a net reduction in accidents, rather than to reduce the risk of the specific harm that occurred. For instance, if self-driving cars were better than people at avoiding collisions with other vehicles, but worse at avoiding collisions specifically with white cars, a computer driver might decrease the overall risk of accidents but increase the risk of colliding with white cars. In a case involving a collision with a white car, a negligence standard should still apply. Better that there should be more collisions with white cars so long as there are fewer collisions in total (assuming collisions with white cars do not result in disproportionate harm).

Even where automation is situational, it makes sense to apply a negligence standard. Hypothetically, if a self-driving car is on average ten times safer than a person, but only half as safe as a person in rainy conditions, a person should rely on autonomous driving software most of the time but operate the vehicle conventionally in the rain. If someone instead uses self-driving software in the rain, the computer should still be evaluated under a negligence standard. It may be difficult for a user to know in advance what circumstances an autonomous computer is likely to encounter as well as when an autonomous computer will outperform a person. In addition, the manufacturer—as the liable

party—may not have input into how its computers are used situationally. Manufacturers could utilize non-tort mechanisms to prevent unsafe uses, such as by warning users that self-driving cars may not be operated in the rain or by building in technological safeguards to prevent self-driving cars from operating in the rain. If self-driving cars prove to be less safe than human drivers in the rain, it is likely manufacturers would still be liable for accidents in negligence.

Similarly, software used to diagnose disease based on medical imaging may outperform physicians generally, but underperform at detecting *certain* diseases. Ideally, this might result in human-machine collaborative review of imaging. If a machine were to underperform detecting lung cancer, for example, it should still be evaluated in negligence for its failures. The computer will likely be liable if a physician should have detected the lung cancer. In instances where a computer is generally safer than a person but underperforms in a certain area, it is likely to be liable in negligence when underperforming. This retains the ex ante incentive to improve an autonomous computer to reduce accidents and still allows victims to be compensated.

The basic inquiry about automation safety should focus on whether automation reduces, or is expected to reduce, *overall* accidents, not whether it did in fact reduce accidents in a specific instance. If Tesla can prove its self-driving cars are more likely safer overall than human drivers, this should be sufficient to shift to negligence even in a case where a particular substitution of a human driver with a self-driving car results in more accidents. Better that there should be fewer accidents in total even if one normal self-driving car gets in more accidents than the class average.

This new standard might sometimes involve complex problems of proof. A manufacturer would have the initial burden to prove its computers are safer than people, which creates an incentive to misrepresent a computer's safety.[143] Even when manufacturers are acting in good faith, it may be difficult to determine whether a computer is safer than a person. Research conducted to the highest scientific standards sometimes fails to accurately predict real-world outcomes.[144] It may be that Tesla has reason to believe its self-driving cars are significantly safer than human drivers, but once its cars enter the market-

143 Ryan Abbott, *Big Data and Pharmacovigilance: Using Health Information Exchanges to Revolutionize Drug Safety*, 99 IOWA L. REV. 225, 232–37 (2013) (discussing differences between premarket and postmarket data for evaluating safety in the pharmaceutical context and the incentive for manufacturers to misrepresent safety profiles).

144 *Id.*

place, they fail to meet expectations. For instance, Tesla's research might fail to consider the reactions of drivers to self-driving vehicles in states other than California.[145] In practice, automation may turn out to be safer or more dangerous than initially predicted. Decisions often must be made based on incomplete information, and waiting for perfect knowledge risks sacrificing probable benefits at the altar of precaution.[146]

Adversarial legal proceedings are well suited for resolving such factual issues, and plaintiffs could use those proceedings to challenge manufacturer claims of safety.[147] Thus, if Tesla presents evidence that its vehicles were predicted to cause a fatality every 200 million miles, but plaintiffs show that Tesla's self-driving vehicles actually caused a fatality every 50 million miles, that should shift the standard back to strict liability. It is worth noting that postmarket data is not always superior to premarket data; sometimes premarket data may be more predictive of future outcomes, particularly where postmarket data is limited or skewed.[148]

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145 For example, although Google's self-driving vehicles have been involved in accidents, nearly all accidents involving these vehicles have been the fault of human drivers. Chris Ziegler, *A Google Self-Driving Car Caused a Crash for the First Time*, VERGE (Feb. 29, 2016, 1:50 PM), http://www.theverge.com/2016/2/29/11134344/google-self-driving-car-crash-report. Pre-2017 monthly reports of accidents involving Google's self-driving cars were originally available on Google's website. *See* Steve Kovach, *Google Quietly Stopped Publishing Monthly Accident Reports for Its Self Driving Cars*, BUS. INSIDER (Jan. 18, 2017, 6:32 PM), http://www.businessinsider.com/waymo-ends-publishing-self-driving-car-accident-reports-website-2017-1. However, in 2017 the Google Self-Driving Car Project rebranded as Waymo, and Waymo no longer publishes monthly accident reports. *See id.*

146 Ryan Abbott & Ian Ayres, *Evidence and Extrapolation: Mechanisms for Regulating Off-Label Uses of Drugs and Devices*, 64 DUKE. L.J. 377, 380 (2014).

147 *See* Abbott, *supra* note 143, at 266 (discussing benefits of adversarial dispute resolution). Alternately, manufacturers could have a duty to evaluate the safety of automation technologies before sale and an ongoing duty to monitor their postmarket performance. This could mean that instead of plaintiffs and defendants engaging in a "battle of the experts" focused on objective safety outcomes, a manufacturer's good faith belief that its computers were safe would be sufficient to give rise to a negligence standard. Plaintiffs could only rebut the presumption that a manufacturer acted in good faith. Thus, Tesla would remain liable in negligence if it could prove its vehicles were predicted to cause a fatality every 200 million miles, but plaintiffs could prove that Tesla's self-driving vehicles actually caused a fatality every 50 million miles. Unless plaintiffs could prove Tesla knew, or should have known, that its initial predictions were not accurate or prove that Tesla failed to monitor the performance of its cars, Tesla would not be liable. But this would create a greater risk that manufacturers would fail to aggressively monitor, or that manufacturers would fail to monitor appropriately despite their best efforts. Better to base the standard on objective evidence of safety than a manufacturer's subjective knowledge. Better also to empower plaintiffs' attorneys to hold manufacturers to account than to put foxes in charge of guarding henhouses.

148 *See generally* Ryan Abbott, *The Sentinel Initiative as a Cultural Commons*, *in* GOVERNING MEDICAL KNOWLEDGE COMMONS (Katherine J. Strandburg et al. eds., 2017), https://

It should not be necessary for a computer tortfeasor to physically replace a human operator for negligence to apply. It should be sufficient that a computer is performing a task which a person could reasonably do. For example, if a new taxi company goes into business using a fleet of only self-driving vehicles, computers would not have replaced human operators, but they would be doing work that human drivers could have done. By contrast, the portions of the taxis other than the self-driving software, e.g., the engine, could not be reasonably substituted. A person could drive a taxi instead of a computer, but a person could not reasonably replace the entire vehicle. So, the software operating the self-driving taxi could qualify as a computer tortfeasor, but the other parts of the vehicle would not.

Once a manufacturer establishes that a computer tortfeasor *is* safer than a person, the negligence test should focus on whether the computer's *act* was negligent, rather than whether the computer was negligently designed or marketed. Again, the computer is taking the place of a person in the traditional negligence paradigm, and this paradigm would treat the computer more like a person than a product. It makes no difference to an accident victim what a computer was "thinking"; only how the computer acted.[149] Accident victims have a right to demand careful conduct regardless of how well a computer tortfeasor may have been designed.[150]

Applying the above rules to the crane examples, Example 1 would result in human liability because the human operator acted carelessly and the crane did not interrupt a foreseeable chain of events. It would retain strict manufacturer liability for Example 2 because a person could not reasonably be substituted for a crane. It would permit negligent manufacturer liability for Example 3 (because the computer was automating a task which a person could have performed), but only if the computer tortfeasor is on average safer than a human operator.

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www.cambridge.org/core/books/governing-medical-knowledge-commons/sentinel-initiative-as-a-knowledge-commons/FE736CE30779C4FFE5BA740F2A0FBBFE/core-reader (discussing difficulties with using real-world data to predict safety outcomes in an example using the medication Dabigatran).

149 To appropriate criminal law terminology, we are interested in the actus reus rather than the mens rea. *See generally* DENNIS J. BAKER, TEXTBOOK OF CRIMINAL LAW 167 (3d ed. 2012) (explaining the concept of actus reus). There is no benefit to punishing computer tortfeasors for wrongful actions, even under civil law.

150 *See* Oliver Wendell Holmes, *Lecture III: Torts—Trespass and Negligence*, *in* 3 THE COLLECTED WORKS OF JUSTICE HOLMES 154, 157–58 (Sheldon M. Novick ed., 1995).

In the context of automated driving, human drivers would be liable for harms they cause due to their own driving decisions, while a manufacturer would be strictly liable for harms caused by defective machines that are not automating human functions (as would be the case for MacPherson's Buick[151]), but manufacturers would be liable in negligence rather than strict liability for errors made by autonomous driving software if the software were proven safer on average than a person.

F. Financial Liability

Autonomy exists on a continuum. In practice, the divide between an ordinary product and an autonomous computer may not be clear cut. In the self-driving car context, for example, under one widely adopted framework, vehicles are categorized on a zero to five scale based on who does what, when.[152] At level zero, the human driver does everything; at level five, the vehicle can perform all driving tasks under all conditions that a human driver could perform. In between, there are various degrees of assistance, control, and interaction between person and machine. When computers and people share decisionmaking, traditional principles of joint and several liability should apply.[153] For instance, where a human driver and a computer driver are both at fault, as may be the case where a Tesla system fails to detect a truck while a human driver is watching a movie, both drivers could be liable for either the entire injury or in proportion to their wrongdoing.[154]

Whether in strict liability or negligence, computers could not be financially liable for their harms. Computers do not have property rights, are owned as chattel, and would not be influenced by the specter of liability in the way a person might be influenced. For the purposes of financial liability, the computer's manufacturer and other members of the supply chain should still be responsible for satisfying judgments under standard principles of product liability law. Product liability law already has rules for allocating liability in complex cases where several parties contribute to the design and production of an ordinary product or where several parties are involved in the distribu-

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151 *See supra* notes 87–89 and accompanying text.

152 *See* SAE INT'L, AUTOMATED DRIVING (2014) (on file with the *Law Review*) (describing the SAE taxonomy).

153 *See generally* Richard W. Wright, *The Logic and Fairness of Joint and Several Liability*, 23 MEM. ST. U. L. REV. 45 (1992) (reviewing and analyzing the public policy debate over joint and several liability).

154 *Id.* at 46.

tion chain. For example, those rules could apply in a case in which Apple and Delphi jointly design self-driving car software, which General Motors licenses and incorporates in its vehicles, and the vehicles are then leased by an independent retailer to Lyft. Common law liability rules could be altered by firms in the supply chain. That would be particularly likely to occur where manufacturers and retailers are large, sophisticated entities. For example, General Motors might indemnify Apple, Delphi, and Lyft in return for more favorable licensing and leasing terms.

Alternately, the computer's owner could be liable for its harms. That would be somewhat akin to treating computer tortfeasors as employees and making owners liable under theories of vicarious liability.[155] It is particularly easy to imagine owners purchasing insurance for harms caused by autonomous computers in the self-driving car context, where insurance policies may soon come with a rider (or discount) for autonomous software. Owner liability might further incentivize the production of autonomous computers given that manufacturers would have less liability, but it might reduce adoption because owners would be taking on that liability. These two effects might offset each other if reduced manufacturer liability were to result in lower purchase prices. Ultimately, owner liability is not an ideal solution because owners may be the most likely victims of computer tortfeasors, and because manufacturers are in the best position to improve product safety and to weigh the risks and benefits of new technologies.

In practice, the economic impact of different liability standards for accidents by self-driving cars will be seen in the cost of insurance. Insurers base their premiums on risk, and once self-driving cars become significantly safer than human drivers, insurance rates will decrease for self-driving cars and perhaps increase for human drivers.[156] This should have a nudging effect on self-driving car adoption as financially sensitive individuals take auto premiums into account in deciding whether to drive. To the extent self-driving cars are judged under a more lenient negligence standard, we would expect lower premiums for self-driving cars, further incentivizing their adoption. If manufacturers and retailers rather than car owners are held responsible for accidents, the burden of insurance would shift from owners to manufacturers, although this cost may then be reflected in higher car purchase prices.

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

156 *See supra* text accompanying notes 112–19.

G. *Alternatives to Negligence*

Shifting from strict liability to negligence is not the only means of encouraging automation. The government could provide a variety of financial incentives to manufacturers and retailers to promote the creation and sale of safer technologies. In other contexts, government incentives have been effective at promoting innovation.[157] For example, incentives could take the form of grants for research and development,[158] loans to build production facilities,[159] enhanced intellectual property rights,[160] prizes,[161] preferential tax treatments,[162] or government guarantees.[163]

The government could even provide credits to consumers to purchase self-driving cars. This could be modeled after the Car Allowance Rebate System ("CARS"), better known as "cash for clunkers."[164] CARS provided consumers trading in old vehicles with

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157 *See generally* Nancy Gallini & Suzanne Scotchmer, *Intellectual Property: When Is It the Best Incentive System?*, *in* 2 INNOVATION POLICY AND THE ECONOMY 51 (Adam B. Jaffe et al. eds., 2002).

158 *See, e.g.*, Daniel J. Hemel & Lisa Larrimore Ouellette, *Beyond the Patents-Prizes Debate*, 92 TEX. L. REV. 303, 321 (2013) (discussing the role of government grants in innovation policy).

> Today, direct federal R&D spending (which includes the very small amount currently spent on prizes) is about $130–$140 billion per year—slightly more than half of which is defense-related. Many states also provide direct R&D support: in fiscal year 2009, states spent $3.6 billion on support for R&D at state universities and another $1.3 billion on other grants and facilities for in-state research.

Id. (footnote omitted).

159 *See, e.g.*, Joe Stephens & Carol D. Leonnig, *Solyndra: Politics Infused Obama Energy Programs*, WASH. POST (Dec. 25, 2011), https://www.washingtonpost.com/solyndra-politics-infused-obama-energy-programs/2011/12/14/gIQA4HllHP_story.html?utm_term=.Bb171adb15da (providing background information on the billions in unexpected costs to taxpayers from controversial loans defaulted on by green technology programs).

160 *See, e.g.*, Ryan Abbott, *Treating the Health Care Crisis: Complementary and Alternative Medicine for PPACA*, 14 DEPAUL J. HEALTH CARE L. 35, 62–98 (2011) (noting that pharmaceutical manufacturers can receive market exclusivity, extended patent terms, or even sui generis forms of intellectual property protection for preferred technologies).

161 *See, e.g.*, Richard A. Posner, *Intellectual Property: The Law and Economics Approach*, 19 J. ECON. PERSP. 57, 58–59 (2005).

162 *See, e.g.*, Nick Bloom et al., *Do R&D Tax Credits Work? Evidence from a Panel of Countries 1979–1997*, 85 J. PUB. ECON. 1, 2 (2002); Bronwyn Hall & John Van Reenen, *How Effective Are Fiscal Incentives for R&D? A Review of the Evidence*, 29 RES. POL'Y 449, 449 (2000).

163 *See, e.g.*, Gunhild Berg & Michael Fuchs, *Bank Financing of SMEs in Five Sub-Saharan African Countries: The Role of Competition, Innovation, and the Government* (World Bank, Policy Research Working Paper No. 6563, 2013).

164 TED GAYER & EMILY PARKER, CASH FOR CLUNKERS: AN EVALUATION OF THE CAR ALLOWANCE REBATE SYSTEM 1 (2013), https://www.brookings.edu/wp-content/uploads/2016/06/cash_for_clunkers_evaluation_paper_gayer.pdf.

vouchers of between $3500 and $4500 to purchase new cars.[165] It was a nearly $3 billion U.S. federal program designed as a short-term economic stimulus and to benefit U.S. auto manufacturers.[166] It was also intended to promote safer, cleaner, more fuel-efficient vehicles.[167] Ultimately, while critics dispute the effectiveness of the program at stimulating the economy and promoting domestically produced automobiles, it did succeed at improving fuel efficiency and safety, and it was popular with consumers.[168] In a similar manner, consumers trading in conventional vehicles could be provided with a voucher to purchase self-driving cars.

Even if incentives are limited to tort liability, there are still alternatives to shifting to negligence. For example, manufactures could have their liability limited through state or federal tort reform acts that place caps on damages, limit contingency fees, eliminate joint and several liability, mandate periodic payments, or reduce the statute of limitations.[169]

Finally, the government could promote safety by means of regulation. This could involve requirements for industries to achieve minimum safety targets or direct requirements to adopt certain technologies.[170] At the point where self-driving cars become ten or a

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165 *Id.*

166 *See id.* at 1–2; *$2 Billion More for Clunker Car Trade-Ins Passes Senate*, N.Y. TIMES: CAUCUS (Aug. 6, 2009, 9:05 PM), https://thecaucus.blogs.nytimes.com/2009/08/06/2-billion-more-for-clunker-car-trade-ins-passes-senate/.

167 *See* GAYER & PARKER, *supra* note 164, at 1–2.

168 The Department of Transportation reported the program succeeded at boosting economic growth and creating jobs. Press Release, Nat'l Highway Traffic Safety Admin., Secretary LaHood Touts Success of Cash for Clunkers; Responds to Reports by DOT Inspector General, GAO (Apr. 29, 2010), https://www.nhtsa.gov/press-releases/secretary-lahood-touts-success-cash-clunkers-responds-reports-dot-inspector-general. Others were less bullish. One study found that the total costs of the program outweighed the benefits by $1.4 billion. *See* Burton A. Abrams & George R. Parsons, *Is CARS a Clunker?*, ECONOMISTS' VOICE, Aug. 2009, at 4. Another study argued that the program increased short-term spending, but decreased overall spending on new cars. Mark Hoekstra et al., *Cash for Corollas: When Stimulus Reduces Spending* 23 (Nat'l Bureau of Econ. Research, NBER Working Paper Series No. 20349, 2014), http://www.nber.org/papers/w20349.pdf. With regard to fuel efficiency, one study found that the program improved the average fuel economy of all vehicles purchased by 0.6 mpg in July 2009, and by 0.7 mpg in August 2009. MICHAEL SIVAK & BRANDON SCHOETTLE, U. MICH. TRANSP. RESEARCH INST., THE EFFECT OF THE "CASH FOR CLUNKERS" PROGRAM ON THE OVERALL FUEL ECONOMY OF PURCHASED NEW VEHICLES 4 (2009), http://deepblue.lib.umich.edu/bitstream/2027.42/64025/1/102323.pdf.

169 These are some of the reforms created by the Medical Injury Compensation Reform Act of 1975 ("MICRA") enacted by the California legislature to lower medical malpractice liability insurance premiums. Cal. Civ. Code §§ 3333–3333.2 (West 2016).

170 *See generally* HEALTH & SAFETY EXEC., A GUIDE TO HEALTH AND SAFETY REGULATION IN GREAT BRITAIN 11 (2013), http://www.hse.gov.uk/pubns/hse49.pdf (outlining the occu-

hundred times safer than human drivers, nonautonomous driving could be prohibited.[171] Regulatory solutions may be most appropriate where the benefits of automation are overwhelming and where it is undisputed that automation would result in massive safety gains.

Yet there is reason to think that shifting to negligence may be a preferred mechanism. It is both a consumer- and business-friendly solution. While consumers would have more difficulty seeking to recover for accidents, they would also benefit from a reduced risk of accidents. Most consumers would probably prefer to avoid harm rather than to improve their odds of receiving compensation. For businesses, it would lower costs associated with liability (which may also result in lower consumer prices). Shifting to negligence would not require government funding, additional regulatory burdens on industry, or new administrative responsibilities. Additionally, it is an incremental solution that relies on existing mechanisms for distributing liability and builds upon the established common law. There may be less risk that shifting to negligence would produce unexpected outcomes than more radical solutions.[172] For all the above reasons, shifting to negligence should be a politically feasible solution.

Ultimately, to the extent that policymakers agree that automation should be promoted when it improves safety, there is no need to rely on a single mechanism. Negligence shifting could operate alongside government grants for research and development and consumer credits, combined with direct regulations in certain instances.

Shifting to negligence could be accomplished through legislation or judicial activism. Legislative implementation may be preferable because it would be faster than waiting on courts, and legislatures may be better suited for establishing public policy.[173] Indeed, automation

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pational health and safety system in Great Britain and the various types of safety standards imposed on businesses).

171 *See* Stuart Dredge, *Elon Musk: Self-Driving Cars Could Lead to Ban on Human Drivers*, GUARDIAN (Mar. 18, 2015, 3:22 AM), https://www.theguardian.com/technology/2015/mar/18/elon-musk-self-driving-cars-ban-human-drivers.

172 Indeed, some critics argued that CARS primarily subsidized Japanese auto manufacturers, while a similar Japanese stimulus program excluded American auto manufacturers. John Crawley, *Japanese, Koreans Gain Most from Cash for Clunkers*, REUTERS (Aug. 26, 2009, 5:34 PM), http://www.reuters.com/article/retire-us-usa-clunkers-sales-idUSTRE57P5C220090826; Douglas Stanglin, *U.S. Cars Excluded from Japan's Cash-for-Clunkers Program*, USA TODAY (Dec. 11, 2009, 2:09 PM), http://content.usatoday.com/communities/ondeadline/post/2009/12/us-cars-excluded-from-japans-cash-for-clunkers-program-/1#.WDwOQXfc-t8.

173 *See, e.g.*, Scherer, *supra* note 17, at 389–90 (discussing the reactionary nature of court proceedings); *see also* Bibb v. Navajo Freight Lines, Inc., 359 U.S. 520, 524 (1959) ("Policy decisions are for the . . . legislature . . . .").

to improve public safety is precisely the sort of activity that lawmakers should facilitate because it benefits the general welfare. If legislatures fail to act, courts could independently adopt these rules. Lawmakers would then have the option of modifying the common law.

III. The Reasonable Robot

> *If, for instance, a man is born hasty and awkward, is always having accidents and hurting himself or his neighbors, no doubt his congenital defects will be allowed for in the courts of Heaven, but his slips are no less troublesome to his neighbors than if they sprang from guilty neglect.*
>
> —Oliver Wendell Holmes, Jr.[174]

A. When Negligence Is Strict

Negligence may function almost like strict liability for people with below average abilities. Individuals with special challenges and disabilities may not be capable of always exercising ordinary prudence and may be unable to maintain "a certain average of conduct."[175] This issue was at the heart of *Vaughan v. Menlove*[176] in 1837, which concerned a defendant who lacked normal intelligence.[177] The defense argued that it would thus be unfair to hold him to the standard of an ordinary person and that he should instead be held to the standard of a person with below-average intelligence. The court disagreed, holding that ordinary prudence should apply in every case of negligence.[178] As Oliver Wendell Holmes, Jr., articulated in 1881, "The law considers . . . what would be blameworthy in the average man, the man of ordinary intelligence and prudence, and determines liability by that. If we fall below the level in those gifts, it is our misfortune."[179] That remains the case today; a modern defendant cannot generally escape

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174 O.W. Holmes, Jr., The Common Law 108 (1881).

175 *Id.* Holmes did distinguish between a lack of "intelligence and prudence" and "distinct defect[s]" which he believed did not generally lead to strict liability. *Id.* at 108–10.

176 (1837) 132 Eng. Rep. 490, 492; 3 Bing. (N.C.) 468, 471.

177 *Id.* at 492.

178 *Id.* at 490, 492.

> Instead, therefore, of saying that the liability for negligence should be co-extensive with the judgment of each individual, which would be as variable as the length of the foot of each individual, we ought rather to adhere to the rule which requires in all cases a regard to caution such as a man of ordinary prudence would observe. That was in substance the criterion presented to the jury in this case, and therefore the present rule must be discharged.

Id. at 493.

179 Holmes, *supra* note 174, at 108.

liability for causing a motor vehicle accident because she has slow reflexes, poor vision, or anxiety while driving.[180]

There are benefits to such a rule. Logistically, as Justice Tindal noted in *Vaughan*, it is difficult to take individual peculiarities into account and to determine a defendant's actual mental state.[181] Better for administrative purposes to work with an external, objective standard than to prove individual capacities and state of mind. Substantively, the rule reinforces social norms, creates greater deterrent pressure, and strengthens each person's right to demand normal conduct of others.[182] As Holmes articulated, damages caused by individuals with reduced capabilities are no less burdensome than those caused by ordinary people. This rule thus benefits the general welfare, but at the cost of telling some individuals that their best is not good enough. Those with diminished capabilities drive at their own peril, or else perhaps "should refrain from operating an automobile" at all.[183]

B. The New Hasty and Awkward

Collectively, people are not the best drivers, even when they refrain from drinking behind the wheel,[184] falling asleep on the highway,[185] or colliding into police cars while playing Pokémon Go.[186] But compared to computers? It will not be long until computers are safer than the average person and then safer than any human driver. Principles of harm avoidance suggest that once it becomes practical to automate, and once doing so is safer, a computer should become the new "reasonable person" or standard of care.

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180 *See, e.g.*, Roberts v. Ring, 173 N.W. 437, 437–38 (Minn. 1919).

181 *Vaughan*, 132 Eng. Rep. at 493.

182 *See* Holmes, *supra* note 150, at 154–55.

183 *Roberts*, 173 N.W. at 438. In this case, a seventy-seven-year-old defendant with defective sight and hearing was held liable for running over a seven-year-old boy when it was established that a reasonable driver could have stopped the car. *Id.*

184 *See* J. Michael Kennedy, *Allowed in 26 States: Drinking and Driving: A Legal Mix*, L.A. TIMES (Jan. 26, 1985), http://articles.latimes.com/1985-01-26/news/mn-13688_1_container-law (noting that until recently, it was even legal in many states to "sip[] on a Scotch and soda while cruising down the interstate").

185 *See* David Boroff, *Two Women Dead as Greyhound Bus Driver Falls Asleep at Wheel During California Crash; Driver was 'Fatigued,' Police Say*, N.Y. DAILY NEWS (Jan. 19, 2016, 9:01 PM), http://www.nydailynews.com/news/national/greyhound-bus-crash-kills-2-injures-18-article-1.2501658.

186 *See* Sarah Begley, *Driver Hits Cop Car While Playing* Pokémon Go*. The Whole Thing Was Caught on Video*, TIME (July 20, 2016), http://time.com/4414998/pokemon-go-hits-cop-body-cam/ (discussing a driver playing Pokémon Go who collided with a police car and had the incident captured on video, and quoting the driver as saying, "That's what I get for playing this dumb – game").

In practice, this would mean that instead of judging a defendant's action against what a reasonable person would have done, the defendant would be judged against what a computer would have done. For instance, today a defendant might not be liable for striking a child running in front of their car if a reasonable driver would not have been able to stop immediately. But that person would soon be liable under the exact same circumstances if an automated car would have prevented the injury. In fact, it may be that the automated vehicle is only able to prevent such an accident because it has superhuman abilities. It may have software capable of ultrafast decisionmaking, monitors that surpass human senses, and external cameras that expand peripheral view beyond that of a person.[187]

With the reasonable person test, jurors are asked to put themselves in the shoes of a reasonable person and decide what that person would have done.[188] It may be a challenge for a juror to follow that reasoning in the case of a reasonable computer (or reasonable robot or machine). The reasonable computer, however, is a far less nebulous and fictional concept than the reasonable person. The term "reasonable" in the context of a computer is an anthropomorphism to assist people conceptually. In fact, computers largely function according to fixed rules which—when all goes well—result in foreseeable behavior.[189] Even those computers which can generate unpredictable behavior are still likely to be more predictable than people, particularly where such machines have been found to improve safety.[190] It should be more or less possible to determine what a computer would have done in a particular situation.

To take a simple case, imagine an individual driving on dry pavement at forty miles per hour colliding with a child running into the road 150 feet ahead of the driver's vehicle.[191] To determine whether the driver is liable under the reasonable computer standard, a plaintiff could present a jury with evidence that when a child runs in front of the same make and model of car being operated by automated software under the same conditions, the vehicle stops in about 100 feet. Because the reasonable computer would not have collided with

187 *See supra* notes 116–19 and accompanying text.

188 *See supra* notes 65, 71 and accompanying text.

189 THOMAS A. PETERS, COMPUTERIZED MONITORING AND ONLINE PRIVACY 97 (1999). Malfunctioning computers would not be "reasonable" computers.

190 *See id.*

191 *See Why Your Reaction Time Matters at Speed*, NAT'L HIGHWAY TRAFFIC SAFETY ADMIN. (Aug. 2015), www.nhtsa.gov/nhtsa/Safety1nNum3ers/august2015/S1N_Aug15_Speeding_1.html.

the child, the human driver would be liable. Juries would not need to take distraction into account, the reaction time of self-driving software would be known, and the breaking distance could be standardized if the driver's vehicle could not directly be compared because it was not a vehicle type operated by self-driving software. Even in more complex cases, it should be easier to predict how a computer would have behaved than a person because computers are more predictable. Thus, it is possible to have a more objective test for the reasonable computer than for the reasonable person.

A defendant might argue that it is unfair for his best efforts to result in liability. A computer standard of care essentially makes people strictly liable for their accidental harms. That is the case now for below-average drivers, and the underlying rationale for the rule will not change when an above-average human driver becomes a below-average driver due to computers. It may appear unfair to impose liability on human drivers for doing their best, but it would be more unfair to prevent accident victims from recovering for harms that would have been avoided had a robot been driving. It does not matter to an accident victim whether he was run over by a person or a computer.

Tort liability would not prohibit people from driving even at the point where computers become substantially safer than people. If that were a desired outcome it could be accomplished through command-and-control legislation.[192] Instead, a computer standard of care would mean that people drive at their own risk. If a driver causes an accident, he or she will be liable for the resultant damages. A tort-based incentive may be superior to an inflexible statutory mandate because there may be benefits to human driving unrelated to accidents, for instance, promoting freedom and autonomy.[193] Individuals who particularly value their freedom may still choose to drive and accept the consequences of their accidents.

While not outright prohibiting activities, a computer standard of care is likely to have a significant impact on behavior. Making individuals and businesses essentially strictly liable for their harms will strongly discourage certain undertakings. In the self-driving car context, it would likely result in far fewer human drivers as insurance

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192 *See* Orly Lobel, *The Renew Deal: The Fall of Regulation and the Rise of Governance in Contemporary Legal Thought*, 89 MINN. L. REV. 342, 371–404 (2004) (discussing the trend from regulations to incentive-based regimes).

193 *See generally* Ryan & Deci, *supra* note 20, at 6–7 (arguing that people have three basic psychological needs: (1) connectedness, (2) autonomy, and (3) feeling competent).

rates for traditional vehicles become prohibitively expensive relative to rates for self-driving cars.

A rule requiring automation at the time it first becomes available would be too harsh. Automatons may be prohibitively expensive or only available in limited quantities. That is particularly likely early in a technology's lifecycle. It would be unfair to penalize people for not automating when doing so would be impossible or impractical. Therefore, to introduce a computer standard of care, a plaintiff should have to show by a preponderance of the evidence that a person was performing a task that could be performed by a computer and that it would have been practicable for the defendant to automate. This means that a defendant would not be judged against the standard of a computer operator where 1) no such operator existed at the time of the accident, 2) no computer operator was available to the defendant, 3) a computer operator was prohibitively expensive, or 4) there were other overriding interests for not automating (e.g., regulatory requirements for a human operator). If Tesla could manufacturer a completely safe autonomous vehicle but at a cost of $1 million dollars, it would not be reasonable to require consumers to automate.

C. Reasonable People Use Autonomous Computers

As an alternative to the reasonable computer standard, the reasonable person could be a person using an autonomous computer. For example, once self-driving cars become safer than traditional vehicles, a jury might find that it is unreasonable to drive yourself rather than to use a self-driving car. Applying the "reasonable person using an autonomous computer" standard to the earlier hypothetical involving a child running into the street, the human driver's negligence would not be based on failing to stop in 100 feet as a self-driving car would have; rather, liability would be based on her driving in the first place. A reasonable person would not have driven.

Under either the reasonable person or reasonable computer standard, a human driver would be compared with a self-driving car, but in different ways. With the reasonable computer standard, courts would evaluate the human driver's proximally harmful act, whereas with the reasonable person standard, courts would evaluate the human driver's a priori decision to automate (a bad decision would then be considered the harmful act). Maintaining the reasonable person standard would be more in line with the existing negligence regime, and it would be a less radical way to accomplish the goal of incentivizing automation to improve safety.

While keeping the reasonable person standard would be conceptually easier, in practice it would be less desirable. The goal is to compare the harmful act of the person and computer, not to target the initial decision to automate. It is problematic to base liability on the decision to automate because it either must focus on the question of whether automation is generally or situationally beneficial. A general focus fails to consider instances in which a person will outperform a machine. A situational focus must still compare the harmful act of a person versus a computer.

It is likely that as autonomous computers are introduced they will be safer at automating certain activities than others. For instance, automated computers working to diagnose disease may be superior to physicians at detecting certain conditions, but not others. Self-driving cars may be safer than human drivers on average, but not safer than professional or above-average drivers. Autonomous vehicles may also be safer under most conditions, but might be relatively poor at, for example, driving off road. So, while automation may generally improve safety, optimal accident reduction may require a mix of computer and human activity.

Suppose a self-driving car is ten times safer than a human driver generally, but only half as safe as a human driver in icy conditions. Now suppose a human driver encounters a patch of black ice and causes an accident under circumstances in which she would not be negligent by comparison to a reasonable human driver. If courts were to hold her to the standard of a reasonable computer, she would escape liability if the computer would have been unable to avoid the accident (which is likely if the computer is half as safe in icy conditions). If the reasonable person using an autonomous computer test focuses on whether an autonomous computer is generally safer, however, she would be liable. That test would conclude that it would have been unreasonable *not* to use a self-driving car because self-driving cars are generally safer. This would penalize human action even when it would be preferred.

Alternately, the reasonable person using an autonomous computer evaluation could be situational. For instance, it could be reasonable not to use an autonomous computer, but only in icy conditions. However, this is just a more convoluted version of the reasonable computer test because it requires evaluating whether a computer would be safer than a person in a particular instance. That essentially asks how the computer would have acted in a situation—which is the

reasonable computer standard.[194] It would then require asking, based on that knowledge, which might be impractical for a person to have, whether an earlier decision to automate was reasonable. On top of that, it presupposes the ability to activate and deactivate automation as needed. In the black ice hypothetical, it could require the driver to know in advance of activating self-driving software whether there were icy conditions and how the computer would perform in icy conditions. It might require the driver to activate or deactivate automation only during icy conditions or to understand whether the risk of using the computer in icy conditions outweighed the benefits of using the computer for other parts of the trip.

D. The Reasonable Computer Standard for Computer Tortfeasors

This Article proposes holding computer tortfeasors to a negligence standard and comparing their acts to the acts of a reasonable person after technology has advanced to the point that computers have been proven safer than people.[195] It also proposes replacing the reasonable person standard with the reasonable computer standard, again, once this point has been reached.[196] This means that computer tortfeasors would be held to the reasonable computer standard.

There will be instances in which it still makes sense to apply the reasonable person standard to computer tortfeasors. As described above, there will be cases in which a human defendant would not be judged against the standard of a computer, for instance, where automation is prohibitively expensive or where computer operators are not widely available. We would not want to hold a computer tortfeasor to a higher standard than a human defendant. In some industries, it may take *decades* after the introduction of autonomous technologies for the use of such technologies to become customary or to meet the criteria proposed earlier for adopting the reasonable computer standard.

Eventually, once a reasonable computer becomes the standard of care, it would also be the standard for computer tortfeasors. For instance, if a self-driving Audi collided with a child running in front of the vehicle, the negligence test could take into account the stopping times of self-driving Volvo cars. There are a variety of ways to determine the reasonable computer standard, for example, considering the industry customary, average, or safest technology. Under any stan-

194 *See supra* text accompanying notes 184–93.

195 *See supra* text accompanying notes 184–93.

196 *See supra* text accompanying notes 184–93.

dard, this is a different test than the current strict liability standard, in which the inquiry focuses on whether a product was defectively designed or its properties falsely represented.

As computers improve, the reasonable computer standard would grow stricter. That is alright, because once the reasonable computer is exponentially safer than a person, it is likely that computer tortfeasors will rarely cause accidents. At that point, the economic impact of tort liability on automation adoption may be slight, and the primary effect of the reasonable computer standard would be to internalize the cost of accidents on human tortfeasors. For certain types of automation, it may take a lifetime until computers are exponentially safer than people.

E. The Automation Problem

The impact of automation goes far beyond accident reduction. Just focusing on autonomous vehicles, the widespread adoption of this technology could have revolutionary benefits. It will allow people to be more productive and mobile, and it will reduce emissions and congestion.[197] One autonomous vehicle could replace up to twelve normal cars.[198] Given that the average automobile spends about ninety-five percent of its time sitting in place, self-driving cars may also eliminate the need for most parking.[199] Getting rid of parking just in the United States would free up space the size of Connecticut and could allow redesigned, pedestrian-friendly urban areas.[200] Automation will increase freedom for the disabled, blind, and unlicensed. It might eliminate traffic lights and the need for private car ownership.[201] The net result of self-driving cars could be substantial environmental, economic, and social benefits.[202]

Driverless technologies may also result in the displacement of human workers, increased unemployment, greater wealth disparities, and a reduction of the tax base. Automation threatens the jobs of truck, bus, and taxi drivers who collectively make up about three percent of the working population.[203] In other industries, automation has

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197 DEP'T FOR TRANSPORT, THE PATHWAY TO DRIVERLESS CARS: SUMMARY REPORT AND ACTION PLAN 6 (2015).

198 Clive Thompson, *No Parking Here*, MOTHER JONES (Jan.–Feb. 2016), http://www.motherjones.com/environment/2016/01/future-parking-self-driving-cars.

199 *Id.*

200 *Id.*

201 DEP'T FOR TRANSPORT, *supra* note 197, at 6.

202 *Id.*

203 RICHARD HENDERSON, INDUSTRY EMPLOYMENT AND OUTPUT PROJECTIONS TO 2024,

resulted in reduced workforces.[204] For instance, employment at computer and electronic companies decreased forty-five percent from 2001 to 2016.[205] Employment at semiconductor makers decreased by half during the same period.[206]

These are all important issues to consider in formulating automation policies, but tort law may not be the best mechanism to address these broader concerns.[207] Ultimately, tort liability alone will not determine whether automation occurs. Consumer demand and the economics of automation will bring about increasing automation in the absence of laws prohibiting it.[208] Tesla, for example, is planning to make all its cars self-driving, and Tesla is far from alone in automating vehicles.[209] Billions of dollars have been invested in self-driving technologies by at least forty-four corporations including Apple, Google, and General Motors.[210]

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at 2 (2015); *see* AUSTL. BUREAU OF STATISTICS, 2011 CENSUS COMMUNITY PROFILES, http://www.censusdata.abs.gov.au/census_services/getproduct/census/2011/communityprofile/0?opendocument&navpos=220 (last updated Jan. 12, 2017) (select "Working Population Profile").

204 For example, WhatsApp had fifty-five employees when Facebook acquired it for $21.8 billion in 2014. Jon Swartz, *Tech's Gilded Glory Didn't Mean Much to Trump's Supporters*, USA TODAY (Nov. 14, 2016), http://www.usatoday.com/story/tech/2016/11/14/techs-gilded-glory-didnt-mean-much-trumps-supporters/93598484/. Amazon, Tesla, and other companies have developed production lines that minimize the use of people. *Id.*

205 *Id.*

206 *Id.*

207 *See, e.g.*, Priest, *supra* note 11, at 5–6.

208 *See* Brad Templeton, *Robotaxi Economics*, BRAD IDEAS (Sept. 8, 2016, 2:07 PM), http://ideas.4brad.com/robotaxi-economics [https://perma.cc/T4JU-D866]; *see also Who's Self-Driving Your Car?*, ECONOMIST (Sept. 22, 2016), http://www.economist.com/news/business/21707600-battle-driverless-cars-revs-up-whos-self-driving-your-car (noting a tight race between major technology companies competing to make autonomous driving software due to financial expectations).

209 *Tesla to Make All Its New Cars Self-Driving*, BBC NEWS (Oct. 20, 2016), http://www.bbc.co.uk/news/technology-37711489. Not all autonomous vehicles are created equal. A variety of technologies are in development to automate cars to a greater or lesser degree—ranging from driverless cars to self-parking vehicles. *See generally* SCIENCEWISE EXPERT RES. CTR., AUTOMATED VEHICLES: WHAT THE PUBLIC THINKS (2014), http://www.sciencewise-erc.org.uk/cms/assets/Uploads/Automated-Vehicles-Update-Jan-2015.pdf.

210 *44 Corporations Working on Autonomous Vehicles*, CB INSIGHTS (May 18, 2017), https://www.cbinsights.com/blog/autonomous-driverless-vehicles-corporations-list/ [https://perma.cc/JM38-TR7D]; *see Investment into Auto Tech on Pace to Break Annual Records*, CB INSIGHTS (July 14, 2016), https://www.cbinsights.com/blog/auto-tech-funding-h1-2016/ [https://perma.cc/ZTE9-MH7E].

CONCLUSION

In the coming decades, as people and machines compete in an expanding array of activities, it is vital that appropriate legal and policy frameworks be put in place to guide the development of technology and to ensure its widespread benefits.[211] It is particularly important that tort liability be structured to optimize accident deterrence.

Technological advances present new challenges to existing frameworks. At some point in the future, there are likely to be few or no activities for which computers cannot outperform people.[212] Self-driving cars may eventually be a thousand times safer than the best human driver.[213] At some point, computers will cause so little harm that the economics of negligence versus strict liability will be irrelevant. Autonomous computers will have become so ubiquitous that the constantly improving reasonable computer should be the benchmark for most or all areas of accident law. In fact, autonomous computers are likely to become so safe that regulatory mandates for automation will be desirable.

In the meantime, creating incentives for developing and adopting safer technologies could prevent countless accidents. It has become acceptable for more than a million people a year to die in traffic accidents worldwide, but only because there has not been a reasonable alternative until now.[214] We could soon be living in a world where no one dies from unintended injury, or from medical error for that matter. Once the third and fourth leading causes of death are eliminated, that would just leave us to deal with the leading two causes of death:

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211 *See, e.g.*, Press Release, European Parliament, Robots: Legal Affairs Committee Calls for EU-Wide Rules (Jan. 12, 2017), http://www.europarl.europa.eu/sides/getDoc.do?type=IM-PRESS&reference=20170110IPR57613&language=EN&format=XML ("EU rules for the fast-evolving field of robotics, to settle issues such as compliance with ethical standards and liability for accidents involving driverless cars, should be put forward by the EU Commission, urged the Legal Affairs Committee . . . .").

212 *See generally* RAY KURZWEIL, THE SINGULARITY IS NEAR 7 (2005) (predicting that machines will be able to automate all human work in "a future period during which the pace of technological change will be so rapid, its impact so deep, that human life will be irreversibly transformed").

213 *See* Dredge, *supra* note 171.

214 *See* Press Release, United Nations Secretary-General, Traffic Accidents Kill 1.3 Million People Each Year, but with Commitment Roads Can Be Made Safer for All, Secretary General Says in Video Message (May 6, 2013), https://www.un.org/press/en/2013/sgsm15005.doc.htm [https://perma.cc/B2QQ-UN59].

cardiovascular disease and cancer. Automation may eliminate those as well.[215]

215 *See* Abbott, *supra* note 19, at 1118 (hypothesizing about how artificial intelligence could cure cancer in an article about creative computers that are already independently generating patentable subject matter).