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Autonomous self-driving vehicles - the advent of a new legal era?

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Autonomous Artificial Intelligence (AI) and its recent breakthroughs in machine–human interactions and machine-learning technology have had an ever-increasing impact on our lives. It is suspected that one of the next technological breakthrough might be the Internet of Things (IoT): a system that establishes network connections not only between computers but also with objects utilised daily, such as cars and other vehicles.[1] This web specifically dedicated to linking and operating vehicles is referred to as the Internet of Vehicles (IoV).[2] This system would not only be supported by massive amounts of data (Big Data), but this would be generated in the IoT, and would be analysed and processed by autonomous AI.[3] In fact, this digitisation process within cities is believed to economise transaction costs and foster economic efficiency, thereby boosting social wealth.[4] This digitalisation process also shifts some of its focus over to citizens and their health, as well as the notion of sustainability. Under this notion, implementing autonomous AI within such a process is encouraged, and said to bolster urbanisation, design and soon enough the governance of cities.[5]

Indeed, so-called Smart Cities provide real-time data about traffic and accidents to help individuals optimise their routes and introduce smart garages by optimising the use of current infrastructure via adaptive signal control technologies, thereby improving public

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[1] Swaroop Poudel, 'Internet of Things: Underlying Technologies, Interoperability, and Threats to Privacy and Security' (2016) 31 Berkeley Technology Law Journal 997.

[2] Min Chen, Yuanwen Tian, Giancarlo Fortino, Iztok Humar, 'Cognitive Internet of Vehicles' (2018) 120 Computer Communications 58.

[3] Autonomous cars generate a staggering amount of data. Intel estimated one car generates terabytes of data in 8 hours of operation. Multiple images, radar/lidar, time-of-flight, accelerometers, telemetry, and gyroscope sensors generate data streams that must be analysed in order to perform the calculations and adjustments required to safely navigate a car. Accordingly, an autonomous car runs machine-learning and deep-learning analytics engines powerful enough to recognise mission-critical data requiring immediate analysis and action on their own, without involving a human in the analysis. See Zaheer Allam, Zaynah A Dhunny, 'On Big Data, Artificial Intelligence and Smart Cities' (2019) 89 Cities 80.

[4] ibid.

[5] ibid.

safety overall. All of these benefit from the use of autonomous transportation and AI.[6] It is argued that transportation might be one of the first areas for which the general public will have to rely on AI.[7]

Yet, despite the unprecedented development of autonomous vehicles, IoV and AI, there is seemingly little to no progress in terms of enacting relevant legislation. This paper makes the contention that technological development is far ahead of the law in many areas, and that a new, more up-to-date regulatory framework is needed.[8] This is attributed to the fact that the law-making process is politically or bureaucratically constrained,[9] and often driven by specific interest groups [10] which are overwhelmingly reactive, as opposed to proactive.[11] For example, in Tempe, Arizona, a self-driving Uber test vehicle crashed in 2018, causing the death of a pedestrian. This is but one instance of the real risk posed by autonomous self-driving vehicles. In other words, the possibility of such fatal accidents being caused by AI is hardly trivial.

However, is worth noting that the need to regulate technology to manage its development and impact on society has been addressed by the academic community. A considerable amount of literature exists on this timely issue.[12] Stilgoe, for one, argues that 'autonomous vehicles will change the world in ways both anticipated and entirely unexpected' and that new rules are required.[13] Wynne, on the other hand, examines technologies as rule-following

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[6] ibid. See also Jon Walker, 'Smart city artificial intelligence applications and trends' (2019) Emerj Artificial Intelligence Research <https://emerj.com/ai-sector-overviews/smart-city-artificial-intelligence-applications-trends/>.

[7] Peter Stone, Rodney Brooks, Erik Brynjolfsson, Ryan Calo, Oren Etzioni, Greg Hager, Julia Hirschberg, Shivaram Kalyanakrishnan, EceKamar, Sarit Kraus, Kevin Leyton-Brown, David Parkes, William Press, AnnaLee Saxenian, Julie Shah, Milind Tambe, Astro Teller, 'Artificial Intelligence and Life in 2030. One Hundred Year Study on Artificial Intelligence: Report of the 2015-2016 Study Panel' (2016) 18 <https://ai100.stanford.edu/sites/default/files/ai100report10032016fnl_singles.pdf> accessed 10 March 2019

[8] Victor Li, 'The dangers of digital things: Self-driving cars steer proposed laws on robotics and automation' (2018) 104 American Bar Association Journal 23.

[9] This often occurs as a result of self-interest of bureaucrats in terms of maximising the budget and power of their departments, as well as their personal status and prestige; Roland Vaubel, 'The political economy of centralization and the European Community' (1994) 81 Public Choice 151; Niels Philipsen, 'Evolving Goals of EU State Aid Policy and Possible Lessons for China: a Law and Economics Approach', (2017) Regulatory Reform in China and the EU 139; Van den Bergh for example also argues that 'EU policy making has evolved in to a rent-seeking regulatory machine that has been created by an elite of technocrats and is being implemented by a budget maximizing technocracy' Roger Van den Bergh, 'Farewell utopia? Why the European Union should take the economics of federalism seriously' (2016) 23 Maastricht Journal of European and Comparative Law 937.

[10] 'Public choice theory': Dennis C Mueller, *Public Choice III* (Cambridge University Press 2003).

[11] Demetrius Klitou, 'Privacy by Design and Privacy-Invading Technologies: Safeguarding Privacy, Liberty and Security in the 21st Century' (2011) 5 Legisprudence 297.

[12] Michael Guihot, Anne F Matthew, Nicolas P Suzor, 'Nudging Robots: Innovative Solutions to Regulate Artificial Intelligence' (2017) 20 Vanderbilt Journal of Entertainment & Technology Law 388.

[13] Jack Stilgoe, 'We Need New Rules for Self-Driving Cars' (2018) 34 Issues in Science and Technology 52; Jack Stilgoe, 'Machine Learning, Social Learning and the Governance of Self-Driving Cars' (2017) 48 Social Studies of Science 25; Jack Stilgoe, 'Seeing Like a Tesla: How Can We Anticipate Self-Driving Worlds' (2017) Glocalism: Journal of Culture, Politics, and Innovation; Peter D Norton, *Fighting Traffic: The Dawn of the Motor Age in the American City* (MIT Press 2007).

behaviour, arguing it is emerging practices that define rules, rather than rules controlling practices.[14] Luetge contends that as the levels of automation progress, due to partly automated driving being standardised in new cars, the need for new ethical and legal standards is pressing.[15] To this end, the UK government recently issued the Autonomous and Electric Vehicles Act 2018.[16] Similarly, in 2017, the German Federal Ministry of Transport and Digital Infrastructure issued the field-specific 'Ethical rules for automated and connected vehicular traffic'.[17] Danks argues that autonomous vehicles cannot be regulated using traditional performance standards.[18] Instead, they believe these systems should instead be evaluated using a staged, iterative regulatory approach similar to that for pharmaceuticals and medical devices.

This paper joins this debate by addressing the role of public policy, specifically traffic law and safety regulation in responding to the conundrum of autonomous self-driving vehicles; the potential harm caused by such driverless vehicles, public safety issues, related regulatory intervention, and innovation. It is argued that legal systems might need to become more sensitive in the ex-ante targeting of potential sources of unforeseeable harm caused by autonomous self-driving vehicles. This thesis asserts that the current hostile regulatory attitude might stifle innovation and that any intervention undertaken should not be excessive.

Moreover, this work contributes to the literature by considering the interrelationships between innovative activity of autonomous self-driving cars and specific regulatory regimes generated by different legal systems. In doing so, both positive and normative analysis is presented. The approach taken by this paper is interdisciplinary and builds on an economic analysis of law.[19] Yet, the scope of the argument must be clarified: this work discusses autonomous self-driving vehicles comparing English law, some EU laws and the laws of the United States of America, Germany and China. The argument advanced also pertains specifically to the narrow field of legislative activity regulating autonomous self-driving vehicles.

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[14] Brian Wynne, 'Unruly Technology: Practical Rules, Impractical Discourses and Public Understanding' (1988) 18 Social Studies of Science 147.

[15] Christoph Luetge, 'The German Ethics Code for Automated and Connected Driving' (2017) 30 Philosophy & Technology, 547.

[16] Automated and Electric Vehicles Act 2018.

[17] Ethics Commission on Automated and Connected Driving (German Federal Ministry of Transport and Digital Infrastructure 2017) <www.bmvi.de/SharedDocs/EN/publications/report-ethics-commission-automated-and-connected-driving.pdf?__blob=publicationFile>.

[18] David Danks, Alex John London, 'Regulating Autonomous Systems: Beyond Standards' (2017) 32 IEEE Intelligent Systems 88.

[19] For a synthesis of law and economics scholarship, see G De Geest, *Contract Law and Economics – Encyclopaedia of Law and Economics. Volume 6* (2nd edn, Edward Elgar Publishing 2011); R A Posner, *Economic Analysis of Law* (8th edn Wolters Kluwer Law Publishers 2011).

This argument is advanced through three stages. The first section addresses definitions relating to autonomous driving and discusses the development and deployment of AI generally in the stated jurisdictions. The second section of this paper describes the general regulatory outline currently applied to self-driving cars. The final section grounds the use of AI with an economic analysis of the function of tort law, explores the legal issues triggered by the appearance of autonomous self-driving vehicles and, finally, offers a set of suggestions for an improved regulatory response.

1. General background: definitions, concepts and the public domain

In both the USA and the Netherlands, car accident fatalities peaked in 1972.[20] By 2011, the figures had declined by up to 81 per cent in the Netherlands, but by only 41 per cent in the USA.[21] Furthermore, in the USA in 2015 and 2016 the number of car accidents resulting in casualties suddenly rose after decades of falling, and it is often claimed that smartphones have contributed to drivers being distracted.[22]Although phone use while driving is punishable by law, this remains an insufficient deterrence mechanism. This raises the question of whether the legal system is ready for the introduction of more advanced technology that could massively and irreversibly change human lives: autonomous vehicles. This section suggests that research supporting the move to rely on autonomous transport is compelling and would help eliminate certain major risks related to traffic dominated by human drivers.[23]

1.1 Definitions

Defining AI remains an arduous task. It is sometimes argued that AI is the name given to a technological process which is not understood.[24] For example, John McCarty, the very author of the term AI, stated there is not 'a solid definition of intelligence that doesn't depend on relating it to human intelligence'.[25] Moreover, the literature offers human-centric definitions,[26] rationalist ones [27] and even sceptical ones arguing that a universal definition of AI is almost impossible.[28] This paper is considered with employing a workable legal

[20] Leonard Evans, 'Traffic Fatality Reductions: United States Compared with 25 Other Countries' (2014) 104 American Journal of Public Health 1507.
[21] ibid.
[22] Stilgoe, 'We Need New Rules for Self-Driving Cars' (n 13) 53.
[23] Steven Seidenberg, 'Behind the Wheel: Who's to Blame When Self-Driving Cars Crash?' (2017) 103 American Bar Association Journal 26.
[24] P McCorduck, *Machines who think: a personal inquiry into the history and prospects of artificial intelligence* (2nd edn, A K Peters 2004).
[25] John McCarthy, 'What is artificial intelligence' (2019) <www-formal.stanford.edu/jmc/whatisai/node1.html> accessed 19 July 2019
[26] R Kurzweil, *The age of intelligent machines* (MIT Press 1992).
[27] S Russel and E Wefald, *Do the right thing: studies in limited rationality* (MIT Press 1991).
[28] R L Gregory, *The Oxford companion to the mind* (2nd edn, Oxford University Press 2004) 472.

definition, and thus, employs Nilsson's definition of AI as 'an activity devoted to making machines intelligent'. Here, intelligence is taken to be the quality that enables an entity to function appropriately and with foresight in its environment.[29]

1.2 The future: speculation meets reality

In China, experts from the National Development and Reform Commission have stated that, by 2020, cars with some automated functions may constitute up to 50 per cent of all cars sold in the country.[30] The CEO of Tesla, Elon Musk, predicted that by 2019, drivers and passengers will be able to sleep through a car trip.[31] In 2016, the transportation service company Lyft's co-founder John Zimmer shared his prediction that the 'driverless car revolution' will 'all but end' car ownership in American cities by 2025.[32] In reality, there are sound reasons to believe a full transition might take 20 years or more to accomplish. For one, a complete turnover of all the cars in America would take just under 12 years – assuming that all owners would be willing and able to purchase an autonomous car, and that producers would have sufficient capacity to meet demand.[33] Additionally, what one might envision as an autonomous vehicle probably does not even exist yet: no vehicle has thus far reached the highest level (or even full automation) as per the scale predicted by the Society of Automotive Engineers (SAE).[34]

The SAE provides a new visual chart for use, with its J3016™ 'Levels of Driving Automation' standard that defines the six levels of driving automation, from no automation through to full automation.[35] These levels apply to the *driving automation feature(s)* that are engaged in any instance of the on-road operation of an equipped *vehicle*. As such, although a vehicle may be equipped with a driving automation system capable of delivering multiple driving automation features that perform at different levels, the level of driving automation exhibited in any given instance is determined by the feature(s) that are engaged.

There are common misconceptions as to what constitutes a self-driving car as well. Many vehicles are now equipped with driver assistance such as emergency braking and lane-

[29] N J Nilsson, *The Quest for Artificial Intelligence: A History of Ideas and Achievements* (Cambridge University Press 2010).
[30] Fusheng Li, 'Country Issues National Standards For Autonomous Vehicle Testing' (Chinadaily.com.cn, 2018) <www.chinadaily.com.cn/a/201808/13/WS5b70f60aa310add14f385697.html> accessed 6 March 2019.
[31] Li (n 8).
[32] David Milder, 'Let's Get Real About Self-Driving Cars: The Transition Will Take a Significant Amount of Time' (2018) 11 Journal of Urban Regeneration and Renewal 223.
[33] ibid 225.
[34] Andreas Wolkenstein, 'What Has the Trolley Dilemma Ever Done for Us (and What Will It Do in the Future)? On Some Recent Debates about the Ethics of Self-Driving Cars' (2018) 20 Ethics and Information Technology 163.
[35] SAE International Releases Updated Visual Chart for Its 'Levels of Driving Automation' Standard for Self-Driving Vehicles' (SAE International, 11 December 2018) <www.sae.org/news/press-room/2018/12/sae-international-releases-updated-visual-chart-for-its-%E2%80%9Clevels-of-driving-automation%E2%80%9D-standard-for-self-driving-vehicles> accessed 19 July 2019.

detection systems,[36] and what is sometimes referred to as an 'automated car' may in fact be a vehicle classified on level 0 (no automation) or 1 (semi automation, where the driver must constantly supervise the support features and must steer, brake or accelerate as needed to maintain safety).[37]

Unsurprisingly, the topic of AI technology has not been free of speculation either. After DeepMind was bought by Google's parent company, Alphabet Inc, and employed in tests in a data centre, there were reports of as much as a 40 per cent[38] drop in energy consumption due to the use of AI.[39] By using a system of neural networks trained with different operating scenarios and parameters within their data centres, they created a more efficient framework to understand data-centre dynamics and optimise efficiency.[40] Historical data collected by thousands of sensors within the data centre was used to train an ensemble of deep neural networks, such as those of temperatures, power, pump speeds, setpoints.[41] The objective here was to improve the data centre's energy efficiency and neural networks on the average future PUE (Power Usage Effectiveness, defined as the ratio of total building energy use to IT energy use).[42] This training sparked a discussion around AI-technology applications that could increase energetic efficiency, or even help in efforts addressing global warming.[43] According to research, the implementation of AI could change the way new cities are designed and built thanks to its data-processing and examining capacities within the Internet of Things concept.[44] Such AI-designed cities with automated vehicles would then ensure smooth transport, and address issues faced today, such as traffic jams and consequently cutting transport costs; this would also ensure greater energy efficiency.

1.3 Behavioural patterns: public attitudes and concerns in the USA, the EU and China

In the USA, some scholars[45] argue that the human factor must be completely eliminated if one is to fully exploit the benefits of self-driving cars.[46] Some studies estimate crashes could be reduced by as much as a third if all vehicles were to be equipped with adaptive headlights, forward-collision warnings, lane-departure warnings, and blind-spot

[36] Sarah J Simkin, 'Top 8 Implications of Self-Driving Vehicle Technology' (2018) 25 Business Torts Journal 14.
[37] Brian Browne, 'Self-Driving Cars: On the Road to a New Regulatory Era' (2017) 8 Journal of Law, Technology & the Internet 1-2.
[38] Guihot et al (n 12) 387-388.
[39] ibid.
[40] Richard Evans and Jim Gao, 'DeepMind AI Reduces Google Data Centre Cooling Bill by 40%' (DeepMind, 2016) <https://deepmind.com/blog/deepmind-ai-reduces-google-data-centre-cooling-bill-40/> accessed 19 July 2019.
[41] ibid.
[42] ibid.
[43] Guihot et al (n 12) 388.
[44] Allam and Dhunny (n 3) 82.
[45] Saed A Bagloee, Madjid Tawana, Mohsen Asadi, Tracey Oliver, 'Autonomous vehicles: challenges, opportunities, and future implications for transportation policies' (2016) 24 Journal of Modern Transportation 284.
[46] ibid.

assistance.[47] Moreover, human error is responsible for more than 90 percent of crashes.[48] Therefore, AVs should be able to prevent an appreciable number of these crashes, in turn eliminating the vast majority of all traffic delays.[49] Still, a recent study shows that only 30 per cent of the American population would support a legal ban on human drivers, even if the completely automated vehicles were demonstrated to be safer, while 54 per cent would continue to oppose it.[50]

The potential positive impact of autonomous vehicles is vast and self-driving cars will make traffic safer. A study conducted in 2013 estimated that, by changing 10 per cent of all cars on American roads to highly automated vehicles, 1,100 lives would be saved every year. If 90 per cent of all cars were highly automated, the number of people saved would rise to 21,700.[51] Some states in the US have already introduced autonomous vehicles in daily traffic. For example, in Michigan, a plan that allows driverless trucks to form closely synchronised convoys ('platoons') on highways has been approved and is currently being tested. It is predicted to ensure a positive effect on travel time and fuel consumption. This is because autonomous vehicles would adjust the speed in an automatic manner, hence reducing congestion and the required spacing between the trucks.[52]

On the other hand, the EU has established a specialised agency responsible for the strategic, development, implemental, economic and regulatory aspects of autonomous vehicles. In the European Union (including the UK), autonomous self-driving vehicle regulation is governed by the European Road Transport Research Advisory Council (ERTRAC), which forms part of the European Technology Platform (ETP) for Road Transport. The ERTRAC is tasked to, inter alia, 'stimulate investment in road transport research and innovation' and 'promote the European commitment to research and technological development'.[53] Amongst the documents published on the ERTRAC website are 'Roadmaps' (action plans), some of which are specifically dedicated to innovation in the autonomous vehicle sector. ERTRAC has been publishing the 'Automated Driving Roadmap' since 2015 with the aim to encourage research and innovation within the EU.[54] The Roadmap published in June 2017 provides a range of

[47] ibid.
[48] John Maddox, 'Improving driving safety through automation, congressional robotics caucus' (2012) National Highway Traffic Safety Administration; and Mark AGeistfeld, 'A Roadmap for Autonomous Vehicles: State Tort Liability, Automobile Insurance, and Federal Safety Regulation' (2017) 105 California Law Review 1611.
[49] ibid.
[50] Milder (n 32) 226.
[51] Seidenberg (n 23) 26.
[52] Li (n 8) 23.
[53]'ERTRAC - About ERTRAC' (Ertrac.org 2019) <www.ertrac.org/index.php?page=what-is-ertrac> accessed 10 January 2019.
[54] 'ERTRAC - ERTRAC Roadmaps' (Ertrac.org 2019) <www.ertrac.org/index.php?page=ertrac-roadmap> accessed 10 January 2019.

'paths', each of which is applicable to a vehicle on a different automatisation level.[55] In the first chapter of the ERTRAC Roadmap published in 2017, the authors listed reasons why the development of automated driving should continue. For one, users would have better access to city centres, facilitating the mobility of all members of society, including the elderly and handicapped, and increasing the efficiency of public transport systems.[56] The roadmap went on to emphasise that automated vehicles will play a crucial role in the future of EU transportation, not only for private persons but for organisations (eg in freight transport).[57] According to the information contained in the Roadmap, the research on automated driving has been funded by the EU for more than a decade through many programmes, the most recent being Horizon 2020.[58]

By contrast, public opinion in China is surprisingly very enthusiastic according to the 2018 Ford Trends Report. Over 80 per cent of the Chinese population is 'hopeful' about further advances in autonomous vehicle innovation.[59] In other words, the Chinese public do not exhibit the same fear of AI and autonomous vehicles that is expressed in America, England and the EU. Instead, they appear to recognise and rationalise the potential benefits: the general expectation is of a lowered number of car crashes and improved road safety.[60]

A compelling behavioural phenomenon that further distinguishes the Chinese public's attitude from their counterparts in Europe and the USA is their reaction to accidents involving autonomous vehicles. Namely, the Autonomous Vehicles Readiness index[61] of 2019 demonstrates that in Western countries, the press tend to focus more on reporting accidents caused by autonomous occurs than on daily accidents involving regular cars.[62] In China, on the other hand, if an autonomous vehicle is involved in a crash, it usually does not make the headlines and is regarded as an unavoidable side-effect of scientific and social progress. [63]

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[55] ERTRAC Working Group 'Connectivity and Automated Driving', Automated Driving Roadmap (Ertrac.org 2017) 12-15 <www.ertrac.org/uploads/documentsearch/id48/ERTRAC_Automated_Driving_2017.pdf> accessed 10 January 2019.
[56] ibid 4.
[57] ibid 6-8.
[58] ibid 16.
[59] 'Looking Further with Ford 2018 Trends' (Social.ford.com 2018) <https://social.ford.com/content/dam/fordsocial/en_US/articles/fords-2018-trend-report-what-to-know-about-the-year-ahead/2018%20Looking_Further_with_Ford_Trend%20Report_.pdf?logActivity=true> accessed 10 January 2019.
[60] Steve Dickinson, 'Self Driving Cars in China: The Absence of Non-Technical Barriers' (China Law Blog 2018) <www.chinalawblog.com/2018/07/self-driving-cars-in-china-the-absence-of-non-technical-barriers.html> accessed 10 January 2019.
[61] KPMG International, 'Autonomous vehicles readiness index: Assessing countries' preparedness for autonomous vehicles' (KPMG International, 2019) <https://assets.kpmg/content/dam/kpmg/xx/pdf/2019/02/2019-autonomous-vehicles-readiness-index.pdf> accessed 19 July 2019.
[62] ibid.
[63] Dickinson (n 60).

Despite this, according to the Autonomous Vehicles Readiness index, the Netherlands and the UK are the leading countries in adopting IA technology for freight. This is due to a plan to launch platoons of more than 100 driverless trucks on major routes from Amsterdam to Antwerp and Rotterdam to the Ruhr Valley and large public trials in England.[64] The Dutch and UK governments have also taken an active role in IA safety and legal issues with for instance, the Dutch infrastructure minister announcing in March 2019 in a speech a 'driving licence' for self-driving cars.[65] Baidu Incorporated has been able to attract foreign cooperation for its self-driving project, including Ford Motor Co and Daimler AG, the company behind Mercedes-Benz.[66] The Chinese car market is the largest in the world by sales and an attractive prospect for many overseas manufacturers.[67] New guidelines implemented in April 2018, which provide nationally universal rules for autonomous vehicle testing, are claimed to encourage innovation and development in the country.[68] China is expected to see substantial development of the technology and aims to attain global leadership of the automated vehicle sector by 2035.[69]

2. Current regulatory framework in the USA, England, Germany, the EU and China

Regulating an industry that has only recently emerged and is developing is a lengthy and onerous process. Some lawmakers seek to defer the law-making process, allowing for technological progress to influence the shape of the new legislation on liability. This is supported by the claim that in some states, it might take two years to review the regulation and feedback from testing, which is said to be ineffective for new technology.[70] According to these commentators, the way to ensure order when self-driving cars become a fact is to create a uniform and congruent code upon which all autonomous vehicles can be judged.[71] Such legislation should encourage manufacturers to programme their cars to always act in the best interest of the user,[72] while also limiting the liability of both the developers and consumers.[73]

Regulating AI remains a complex issue due to the multiplicity of meanings and frequent misuse of the term.[74] One solution suggested for this problem is to divide AI into classes

[64] ibid.
[65] ibid.
[66] Li (n 30)
[67] ibid.
[68] Fan Feifei, 'Guidelines to Ensure Safe Self-Driving Vehicle Tests' (English.gov.cn 2018) <http://english.gov.cn/state_council/ministries/2018/04/13/content_281476110368454.htm> accessed 23 March 2019.
[69] Li (n 30).
[70] Li (n 8) 23.
[71] Nick Belay, 'Robot Ethics and Self-Driving Cars: How Ethical Determinations in Software Will Require a New Legal Framework' (2015) 40 Journal of the Legal Profession 119, 130.
[72] ibid 129.
[73] ibid 129-30.
[74] Guihot et al (n 12) 396.

based on risk levels and to formulate laws addressing each class separately.[75] It is believed that as AI, the IoT and other technologies continue to be developed and improved, the likelihood of their users' private information being targeted increases substantially.[76] Therefore, it is suggested that data security ought to be a priority in the policymaking process.[77]

2.1 The United States

The federal government has excused thousands of vehicles from the obligation of abiding by some regulations for the purpose of testing automated systems.[78] By law, the testing cars must feature pedals and steering wheels in case the driver decides to take control of the vehicle.[79] Yet, at present, Michigan remains the only American state where it is possible for the testing of self-driving cars to be conducted on public roads without a human operator at the wheel.[80]

2.2 The European Union and Germany

In general, legislation could have a detrimental effect on innovation.[81] Specifically, product liability should ideally promote efficient levels of product safety, but misdirected liability efforts and various litigation mechanisms may suppress beneficial innovations. Viscusi and Moore examined the competing effects of liability costs on product R&D intensity and new product introductions by manufacturing firms.[82] They convincingly show that at low to moderate levels of expected liability costs there is a positive effect of liability costs on product innovation,[83] whereas at very high levels of liability costs, the effect is negative.[84] As anecdotal evidence, one can look at Volkswagen's recent decision to launch its self-driving concept car, the battery-powered *Sedric*, in the USA and not in Germany where its R&D

[75] ibid 396-397.
[76] Allam and Dhunny (n 3) 83.
[77] ibid.
[78] Stilgoe, 'We Need New Rules for Self-Driving Cars' (n 12) 56.
[79] Marco della Cava, 'Google Car Hits Bus, First Time at Fault' (Eu.usatoday.com 2016) <https://eu.usatoday.com/story/tech/news/2016/02/29/google-car-hits-bus-first-time-fault/81115258/> accessed 10 January 2019.
[80] Li (n 8).
[81] For a treatise on comparative tort law of England, Germany, the EU and France: C Van Dam, *European tort law* (Oxford University Press, 2007).
[82] W Kip Viscusi, Michael J Moore, 'Product liability, research and development, and innovation' (1993) 101 Journal of Political Economy 161; See also Paul A Herbig and James E Golden, 'Differences in Forecasting Behaviour between Industrial Product Firms and Consumer Product Firms' (1994) 9 Journal of Business & Industrial Marketing 60.
[83] ibid.
[84] ibid.

department is located.[85] The laws on traffic and vehicle testing in Europe are much stricter.[86] For example, the Vienna Convention on Road Traffic restricts autonomous vehicles from becoming commercially operational, only allowing for a limited number of testing situations. The United Nations Economic Commission for Europe has not allowed self-driving cars to be used on European roads. Both are limiting not only the road-testing possibilities but also the implementation of relevant technology within the countries of Europe.[87]

To tackle this problem, EU lawmakers have launched initiatives supposed to bring substantial legislative change. For one, the Horizon 2020 programme funded by the EU is worth noting. Furthermore, CARTRE recently concluded that its goal has become: to support the development of more transparent and consistent policies for the EU Member States, in cooperation with industry players and innovators, and to guarantee that automated road transport systems and services are compatible at the European level and are released in an orderly manner.[88]

Another notable response is that of the German government in 2017. Specifically, the German Federal Ministry of Transport and Digital Infrastructure released the 'ethical rules for automated and connected vehicular traffic', which introduced manufacturers' strict liability.[89]Article 7.1 provides that, in the case of automated and connected driving systems, accountability previously of the sole preserve of the individual shifts from the motorist to the manufacturers and operators of the technological systems and/ or bodies responsible for taking infrastructure, policy and legal decisions.[90] Moreover, the Ethics Commission places the reduction of harm and increase in safety at the core of the 'ethical rules', and states that due regard for 'human dignity, personal freedom of choice and data autonomy' is key when considering the implications.[91] Its report suggests that using the technology's potential for damage limitation will encourage social engagement and acceptance.[92]

Furthermore, these rules set out in Germany acknowledge that whilst these automated systems are likely to significantly reduce the probability of accidents, it is impossible at this stage to entirely prevent them and therefore sets out guidelines for what developers should

[85] Christiaan Hetzner, 'Europe Fears It's Losing Autonomous Race' (Automotive News 2018) <https://www.autonews.com/article/20180827/OEM06/180829832/europe-fears-it-s-losing-autonomous-race> accessed 8 March 2019.
[86] Stefan Nicola, Elisabeth Behrmann, Marie Mawad, 'It's A Good Thing Europe's Autonomous Car Testing is Slow' (Bloomberg.com 2018) <https://www.bloomberg.com/news/articles/2018-03-20/it-s-a-good-thing-europe-s-autonomous-car-testing-is-slow> accessed 10 January 2019.
[87] Hetzner (n 85).
[88] ERTRAC Working Group 'Connectivity and Automated Driving' (n 55).
[89] Whilst these ethical rules currently have no legally binding effect, the German government welcomed the findings of the report and intends to assist with the evolution of the technology, setting out in its action plan how it plans to implement the findings.
[90] Ethics Commission on Automated and Connected Driving (n 17).
[91] ibid.
[92] ibid.

ensure is captured in the technology.[93] The 'ethical rules' also offer an example of where the technology must prevent accidents wherever practically possible to do so and how it should be conducted in practice. Where it is not possible, the vehicle's computer must 'decide' to do the least amount of harm, for instance systems should be programmed to accept damage to animals or property over risking human life. If it is unavoidable that a human will be harmed, the computer should not discriminate based on any personal features (such as age, gender, physical or mental constitution). Under such terms, human life is to be considered equal and victims cannot simply be numerically offset against one another in dilemmatic situations.

2.3 China

China has implemented several policies to develop autonomous vehicles. These policies can be divided into three categories: finance policy, infrastructure promotion, and R&D investment.

In 2018, the Chinese government issued a nationwide set of guidelines regulating the testing of self-driving cars.[94] The guidelines were jointly issued by the Ministry of Industry and Information Technology, the Ministry of Public Security and the Ministry of Transport.[95] This came after approximately a dozen regional standards had been issued, the first one in Beijing as early as 2017, which were said to hinder the developmental process of innovating automated cars.[96] The guidelines allow local authorities to evaluate the local conditions and arrange road tests for autonomous vehicles. The guidelines state the test vehicles should be passenger or commercial automobiles, not low-speed vehicles or motorcycles.[97] The nationwide standards list 34 scenarios for testing these vehicles. Although they do not include extreme weather conditions[98], the safety of future users is clarified as paramount over all other benefits of the technology. This was further emphasised by the statements of China's Vice-minister for Industry and Technology, Xin Guobin.[99] Unlike in the West, it is believed that neither Chinese legislation nor the general population require

[93] ibid.
[94] For a synthesis of Chinese law, see L Golota, J Hu, K van der Borght and S Wang (eds), *Perspectives on Chinese Business and Law* (Intersentia 2018).
[95] M Schaub, A Zhao, *Regulating self-driving cars in China* (King & Wood 2019).
[96] Li (n 30).
[97] ArazTaeihagh and Hazel Si Min Lim, 'Governing autonomous vehicles: emerging responses for safety, liability, privacy, cybersecurity, and industry risks'(2019) 39 Transport Reviews 103; Jiuyu Du and DanhuaQuyang, 'Progress of Chinese electric vehicles industrialization: a review' (2017) 188 Applied Energy 529; Darell M West, 'Moving forward: Self-driving vehicles in China, Europe, Japan, Korea, and the United States' (Center for Technology Innovation at Brookings 2016).
[98] Li (n 30).
[99] Fan (n 68).

self-driving cars to be completely faultless, instead, they are accepted as a necessity to decrease the accident incidence and danger significantly.[100]

2.4 England

In 2017, the UK government concluded a consultation on driverless vehicle development[101] and issued the 'Autonomous and Electric Vehicles Act 2018'. According to commentators,[102] this Act addresses the issue of driverless vehicles from the perspective of gaps in current insurance coverage caused by fully autonomous driving.[103] The Act, in principle, provides that if one is hit by an insured party's autonomous vehicle, the insurer at fault pays damages. If the vehicle at fault is not covered by insurance, then the Motor Insurers Bureau will pay out in the usual way and seek to recover its losses from the owner of the uninsured vehicle.[104]

In addition, the Law Commission of England and Wales in a joint project with the Law Commission for Scotland, was asked to conduct a wide-ranging review of the laws relating to the regulation and review of autonomous vehicles in recognition of the inadequacies in the law.[105] In light of this, one may argue that the UK government's forward-thinking approach of deploying automated vehicles places it in second place on the policy and legislation pillar, and first on the new data-sharing sub-pillar.[106] The 2018 Automated and Electric Vehicles Act also seeks to adapts the existing motor insurance framework by extending compulsory insurance to AVs as well as the driver.[107] In November 2018, the UK government took another step forward by announcing its support for three public trials in 2021, including AV buses across the Forth Bridge in Scotland and self-driving taxis in

[100] Dickinson (n 60).
[101] Centre for Connected & Autonomous Vehicles, 'Pathway to driverless cars: Consultation on proposals to support Advanced Driver Assistance Systems and Automated Vehicles. Government Response' (Department for Transport 2017) <https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/581577/pathway-to-driverless-cars-consultation-response.pdf>.
[102] John Buyers, *Artificial intelligence: the practical legal issues* (Law Brief Publishing 2018).
[103] Section 2 of the Autonomous and Electric Vehicles Act 2018 provides: 'where […] an accident is caused by an automated vehicle when driving itself […] the vehicle is insured at the time of the accident, and […] an insured person or any other person suffers damage as a result of the accident, the insurer is liable for that damage'.
[104] Buyers (n 102) 33.
[105] Addressing concerns related to safety assurance mechanisms, accountability in terms of crime and accidents, and assessing how to decide whether such vehicles are safe for road use; see project 'Automated vehicles' (Law Commission) <http://www.lawcom.gov.uk/project/automated-vehicles/>.
[106] KPMG International (n 61) 20.
[107] AEVA 2018 (n 16).

London.[108] Indeed, in December 2018, Parliament also published an extensive report outlining its proactive approach to pursuing the benefits of MaaS.[109]

3. Economic functions and triggering legal issues: towards an improved regulatory response

Nevertheless, one should take note of the discontent that has been voiced over the relative indolence of legislative progress compared to the advances made by technology. It is argued that not enough emphasis is being put on the cybersecurity of the users, as well as the quality standard of the software systems that are to direct the vehicles.[110] Therefore, one may say the biggest challenges for policymakers with regard to self-driving cars will be the aggregation of data and the safety of consumers on the roads.

3.1 Is the harm caused by autonomous vehicles trivial?

Joshua Brown was the first known victim of an accident involving a self-driving car. In May 2016, his Tesla crashed into a truck on a highway in Florida while in autopilot mode.[111] Tesla initially refused to take responsibility for the accident, stating the driver was liable as the car had repeatedly advised him to take control of the steering wheel. However, according to Seidenberg, the car did not register the truck, brake or warn Brown.[112] Yet, the driver could have seen the truck and had approximately seven seconds to react and steer out of danger, had he paid attention.[113]After an evaluation by the National Transportation Safety Board which ruled the accident was the result of both human error and deficient system safeguards, a company spokesperson assured that the NTSB's finding be taken into account in future development.[114]

Data released by Google show that out of more than 15 accidents involving automated cars from 2009 to 2016, only one was caused by the autonomous car.[115] According to Google, the vast majority of the other accidents were caused by human drivers, who anticipated the

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[108] UK Department for Business, Energy and Industrial Strategy, Greg Clark, 'From science fiction to reality: People in London and Edinburgh set to be the first to trial self-driving vehicle services' (Gov.uk, 22 November 2018) <www.gov.uk/government/news/from-science-fiction-to-reality-people-in-london-and-edinburgh-set-to-be-the-first-to-trial-self-driving-vehicle-services>.
[109] UK Parliament, 'Mobility as a Service' (UK Parliament, 19 December 2018) <https://publications.parliament.uk/pa/cm201719/cmselect/cmtrans/590/report-overview.html>.
[110] Li (n 8).
[111] Seidenberg (n 23).
[112] ibid. In addition, the CEO of the automobile manufacturer Tesla, Elon Musk, set out that the company would not assume responsibility for any accidents involving its driverless cars: Li (n 7).
[113] Currently, according to the law in the USA, it is the human being's responsibility to avoid causing an accident, even in a self-driving car in autopilot mode.
[114] Li (n 8).
[115] Browne (n 37) 5.

Google car to move forward at intersections and as a result crashed into the rear of the car in front at low speeds.[116]

3.2 Triggering legal and moral issues

It is known that technological advancement requires support and at times direction from the law, AI and autonomous vehicles will be subject to that as well, for example to ensure that the human aspect is not neglected.[117]Among the countless aspects of the legal system in need of innovation is the issue of data-sharing. It is believed that, ideally, the manufacturers of self-driving cars will share information with each other leading to improved safety results. Nonetheless, without proper legislation, manufacturing companies are unlikely to disclose data.[118] Conversely, automated vehicles would record and store the data of their users, which could hold serious ramifications if the information is not handled properly or stolen.[119]

Another problem might be the ethical and moral dilemmas human drivers encounter on a daily basis, but for which computers and machines cannot solve by themselves without an algorithm or system.[120] Consequently, this will see new legal issues rise to the surface, bringing the need for specific and appropriate provisions in the law.[121] An example illustrating how complex these provisions may be is the famous 'trolley problem' in ethics, a thought experiment where the participant is asked whether they would push the lever before the train comes so that it kills one rail worker, or leave it as it is, so that it kills five.[122] The developers of autonomous vehicles will inevitably face such considerations and it is vital for them to ascertain their product will ultimately make 'the right ethical decision'. That is also due to the fact that UK tort law encompasses a scale of accountability which assists in better determining whether or not a human fulfilled their duty towards other humans. An autonomous vehicle will not go through the same thought process a human would; instead, it will act based on how it is predetermined to act by its developer.[123]

It is believed that if the responsibility for any accidents caused by autonomous vehicles is placed exclusively on the manufacturer (ie strict manufacturer liability), it would likely discourage further progress with the innovation. Such consideration is not trivial since literature shows that, for example, product liability costs in the USA have prompted some manufacturers to abandon valuable new technologies, life-saving drugs, and innovative product designs.[124] Moreover, it is speculated that it would cause consumers to be subject to

[116] della Cava (n 79).
[117] Allam and Dhunny (n 3) 88.
[118] Stilgoe 'We Need New Rules for Self-Driving Cars' (n 12) 56.
[119] Simkin (n 36).
[120] Belay (n 71) 120-21.
[121] ibid.
[122] Wolkenstein (n 34) 164.
[123] Belay (n 71) 121.
[124] Paul A Herbig and James E Golden, 'Differences in Forecasting Behavior between Industrial Product Firms and Consumer Product Firms'(1994) 9 Journal of Business & Industrial Marketing 60; Richard W Malott, 'Rule-

the developer's ethics and morals, which may be an undesirable side-effect.[125] Yet, the option to make the owners of autonomous vehicles liable for any damages would also impact the industry negatively: the law would not induce companies to make their cars 'smart' or 'ethical', while users would be responsible for machines they cannot control.[126]One of the solutions suggested for this problem is that there should perhaps always be a driver at the steering wheel, prepared to take control of the vehicle in an emergency. However, this would eliminate certain selling points of self-driving cars and thus, this could only be a temporary solution until the technology is sufficiently developed to employ a different approach.[127]

3.3 Legislative initiatives and reflections on legal and economic aspects

English and US tort law define the conditions under which a person is entitled to damage compensation if their claim is not based on a contractual obligation and encompasses all legal norms that concern the claim made by an injured party against a tortfeasor.[128] Economically speaking, any reduction of an individual's utility level caused by a tortious act may be regarded as damage.[129] Tort law rules aim to draw a just and fair line between those noxious events that should lead to damage compensation and others for which the damage should lie where it falls. It should be emphasised that tort law and economics literature traditionally address three broad aspects of tortious liability.[130] The first is the assessment of its effects on incentives (both whether to engage in activities and how much care to exercise to reduce the risk when so doing), the second concerns risk-bearing capacity and insurance, while the third is its administrative expense comprising the costs of legal services, the value of litigants' time and the court's operating costs.[131]

Yet, it is worth emphasising that alternative institutions like no-fault insurance schemes or ex-ante safety regulation might be better suited for reducing the overall costs of accidents than tort liability. Shavell, for instance, addressed the effects of liability rules and direct

governed behavior and behavioral anthropology' (1988) 11 Behavioral analysis 181; Jean B McGuire, 'A Dialectical Analysis of Inter-organizational Networks' (1988)14 Journal of Management 109.

[125] Belay (n 71).

[126] ibid.

[127] ibid.

[128] For an excellent treatise see eg Jenny Steele, *Tort Law: Text, Cases, and Materials* (4th edn, Oxford University Press 2017); Jenny Steele, *Proof of Causation in Tort Law* (Cambridge Studies in International and Comparative Law, Oxford University Press 2017); Mark Lunney, Donal Nolan, Ken Oliphant, *Tort Law: Text and Materials* (Oxford University Press 2017); John C P Goldberg, *The Oxford Introductions to U.S. Law: Torts* (Oxford University Press 2010).

[129] Hans-Bernd Schaefer, *Tort Law* (De Geest Gerrit); Boudewijn Bouckaert and Gerrit De Geest (eds.), *Encyclopaedia of law and economics. Volume II. Civil Law and Economics* (Edward Elgar 2000).

[130] H Bernd Schaefer and C Ott, *The economic analysis of civil law* (Edward Elgar 2004) 107-261; S Shavell, *Foundations of Economic analysis of law* (Harvard University Press 2004) 175-289.

[131] S Shavell, 'Liability for Accidents' (2006) Harvard Law School National Bureau of Economic Research, Working Paper No w11781<https://ssrn.com/abstract=851690> accessed 18 March 2019; A Mitchell Polinsky and S Shavell (eds), *Handbook of law and economics, Volume 1* (North-Holland 2007) 139-183.

regulation upon the rational self-interested party's decision-making process.[132] Namely, liability in tort and the safety regulation represent two different approaches to controlling activities that create risks of harm and which induce the optimal amount of precaution.[133] Exclusively-applied regulation has often proved inadequate and tort liability might also provide sub-optimal deterrence incentives due to causation problems.[134] The question then becomes how to overcome the shortcomings of tort law and prevent stifling innovation. This paper suggests that regulation and tort law should be applied simultaneously as complementary legal instruments. That is, regulation removes problems affecting liability, while liability limits the cost of regulation.

Economic analysis of the UK's 'Autonomous and Electric Vehicles Act 2018' reveals several deficiencies and potential sources of inefficiencies that call for improvement. The UK's Act is indeed an immediate and pragmatic response to a problem caused by the use of self-driving vehicles, but merely pushes causation issues directly[135] into the laps of insurers who will encounter considerable difficulties pursuing claims against third parties (eg manufacturers). This causal link also implies that the entire risk is now shifted to insurers which will hence result in sub-optimal deterrence, inefficient risk-bearing, users' and manufacturers' under-precaution and thus fail to provide the optimal harm-deterrence incentives for manufacturers and users (eg potential moral hazard and opportunism on the side of manufacturers and insured persons).

In addition, it must be emphasised that the principles of economic efficiency actually support the 'least amount of harm' principle encapsulated in the previously discussed German code of ethics as enhancing efficiency and suggest that they indeed should be the governing principle for the entire EU. Namely, this 'least amount of harm' principle fits neatly into the classical 'Learned Hand's' (Judge Learned Hand) negligence formula, denoting P as the probability of loss, L as the magnitude of loss and B as the cost of precaution. Judge Hand wrote that a potential injurer is negligent if, but only if, the costs of precaution are lower than the expected magnitude of loss ($B < PL$).[136] Although the Hand

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[132] S Shavell, 'Liability for Harm versus Regulation of Safety' (1984) 13 Journal of Legal Studies 357.

[133] Tort liability is private in nature and works not by social command but rather indirectly, through the deterrent effect of damaging actions that may be brought once harm occurs, whereas standards and ex-ante regulations are public in character and modify behaviour in an immediate way through requirements that are imposed before the actual occurrence of harm; ibid 357.

[134] When harm is so diffused that individuals have little incentives to sue and cannot cheaply organise as a group, this rational apathy of victims leads to systematic under-compensation and consequently to underdeterrence. Shavell also notes that conversely certain regulations might be too restrictive, unduly constraining or imposing excessive costs on industry; See Epstein A Richard, 'The principles of environmental protection; the case of superfund'(1982) 2 Cato Journal 9.

[135] This might be hugely problematic for insurers if the relevant fault or defect cannot easily be traced; Buyers (n 102) 105.

[136] Judge Learned Hand suggests that 'the owner's duty to provide against resulting injuries is a function of three variables: a) the probability that she will break away; b) the gravity of the resulting injury, if she does; and c) the burden of adequate precautions.' See *United States v Carroll Towing Co.*, 159 F.2d 169, 173 (2d Cir 1947)

Formula is relatively recent, the method[137] has been used to determine negligence ever since negligence was first adopted as the standard to govern accident cases.[138] Analytically speaking, the optimal level of care that such a rule would produce with respect to autonomous self-driving vehicles is given by B=PL, and hence there is a particular amount of precaution that is economically reasonable and is dependent on the probability or the risk of damage.[139] Thus, such 'least amount of harm' principle codified in the German code of ethics is in accord with legal and economic reasoning.

Furthermore, Article 7.1 of the German ethical rules of 2017 also states that in the case of automated and connected driving systems the accountability which previously was the sole preserve of the individual shifts from the motorist to the manufacturers and operators of the technological systems and to the bodies responsible for taking infrastructure, policy and legal decisions.[140] In economic terms, this provision introduces manufacturer's strict liability and vicarious liability for other stakeholders. In English tort law one the other hand, vicarious liability imposes strict liability on employers (principals) for the wrongdoings of their agents (employees). Generally, a principal will be held liable for any tort committed while an agent (employee) is performing their duties. In accordance with the principle of vicarious liability, the principal (owner) should be held vicariously liable for the losses caused by the agent (AI). If a principal can observe the agent's level of care, then the imposition of vicarious liability will induce the principal to compel the agent to exercise optimal care. Yet, if the principal is unable to observe and control the agent's level of care, he will generally be unable to induce the agent. If the principal can control the AI's level of activity (while having no capacity for observation) such liability allows the principal to reduce the AI's participation in potentially risky situations.

This paper also argues the EU's current regulatory attitude might suppress innovation and that such a regulatory intervention should not be excessive and should follow the principles encapsulated in Germany's ethical rules. Governments should intervene in markets if such intervention is needed to solve market failures like information asymmetries, negative externalities caused by low-quality autonomous self-driving vehicles (and not covered by

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[137] See P Z Grossman, R W Cearley, D H Cole, 'Uncertainty, insurance and the Learned Hand formula' (2006) 5 Law, Probability and Risk 1; Richard A Posner, *Economic analysis of law* (Aspen Law & Business 2011) 168;Barbara Ann White, 'Risk-utility analysis and the Learned Hand formula: a hand that helps or a hand that hides?' (1989) 32 Arizona Law Review 77.

[138]R A Posner, 'A Theory of Negligence' (1972) 1 Journal of Legal Studies 29; H T Terry, 'Negligence'(1915) 29 Harvard Law Review 40.

[139] See for example, R Cooter, T Ulen, *Law and Economics* (6th edn, Pearson 2013) 287; M Faure, *Tort Law and Economics* (Encyclopaedia of Law and Economics, 2dn edn Edward Elgar 2009); H B Schaefer, C Ott, *The Economic analysis of Civil law* (Edward Elgar 2004) 135.

[140] German Ethics Commission on Automated and Connected Driving (n 17).

existing tort law and safety regulations) and abuse of market power.[141] However, Ogus suggests that should one of these market failures occur, regulatory intervention may be able to generate social welfare increases provided that the benefits of regulation exceed the costs and if there are no other, existing legal instruments that are better suited to dealing with the market failure.[142] In line with Ogus' thesis, this paper contends that the existing tort liability of firms will not have a significant negative effect on firm-level innovation. Such product liability and related litigation might be perceived as a filter that screens hazardous innovation in the autonomous self-driving vehicle industry. But it will provide an incentive for efficient, productive and safe innovations. Still, introducing regulation that would exceed the existing domain and application scope of tort and safety law might be an excessive, wealth-decimating and counterproductive exercise.

Conclusion

The general trend for the future of transportation is to free humans of the responsibility of driving; this is also said to be potentially able to reduce danger on the roads. This paper argues that human lives will continue to be influenced by two specific technologies. Thus, it has suggested likely avenues of regulatory action as a response to the hazardous tendency of legislation not being updated in a manner that keeps up with the pace of technological advancements. The paper also discussed perceptions of the issue of self-driving cars held by the public in four different legal regimes: the USA, Germany, England, the EU and China. In doing so, this article has portrayed the distinct approach taken by each legal system to policy-making on self-driving cars. As far as automated driving is concerned, the most liberal legal regime is the Chinese system, with driverless car tests being permitted on the streets of large cities, including Beijing and Guangzhou, and the country's population being supportive of this trend. In terms of legal limitations, lawmakers in the USA have assumed a similar approach, but with some restrictions. By contrast, the EU's approach remains conservative, with the stated priority being the protection of citizens rather than pursuing technological advancement. Specifically, there is room for improvement in the English and German models. One option might be the introduction of a specific regulatory intervention which encompasses: a) standards regarding the principal's minimum equity capital and assets

[141] G J Stigler, 'The Theory of Economic Regulation' (1971) 2 Bell Journal of Economics and Management Science 3; Roger Van den Bergh, 'Economic Criteria for Applying Subsidiarity Principle in the European Community: The Case of Competition Policy' (1996) 16 International Review of Law and Economics 363.

[142] Ogus also argues that, in practice, government regulation is often one part of instruments aimed at solving market failures. Such instruments might include taxation, liability rules, self-regulation, private standard setting or certification systems. A Ogus, *Regulation: Legal form and economic theory* (Hart Publishing 2004); E V Towfigh, N Philipsen, *Economic methods for lawyers* (Edward Elgar 2015); J V Erp, M Faure, A Nollkaemper, N Philipsen (eds), *Smart Mixes in Relation to Transboundary Environmental Harm* (Oxford University Press 2018).

required to engage in an activity, b) the compulsory purchase of liability insurance coverage, and c) the direct ex-ante regulation of AI's risk-creating behaviour.

Nevertheless, it must be acknowledged that formulating a legal solution to the advent of autonomous vehicles and AI remains onerous. Despite progress being made in certain aspects of legislation, the pace and nature of legislative process differs from country to country. Yet, what unites the legal systems of English, American, German, Chinese and EU legal systems is two overarching positive assumptions: that autonomous vehicles supported by AI systems are the future of transportation, and that the overall safety of their users is of great importance. However, what is also clear, is that the legal systems listed must become equally if not more sensitive in the ex-ante targeting of potential sources of unforeseeable harm caused by autonomous self-driving vehicles. Moreover, as this paper has shown, today's hostile regulatory attitude might stifle innovation, for such field-specific regulatory intervention should not be excessive.