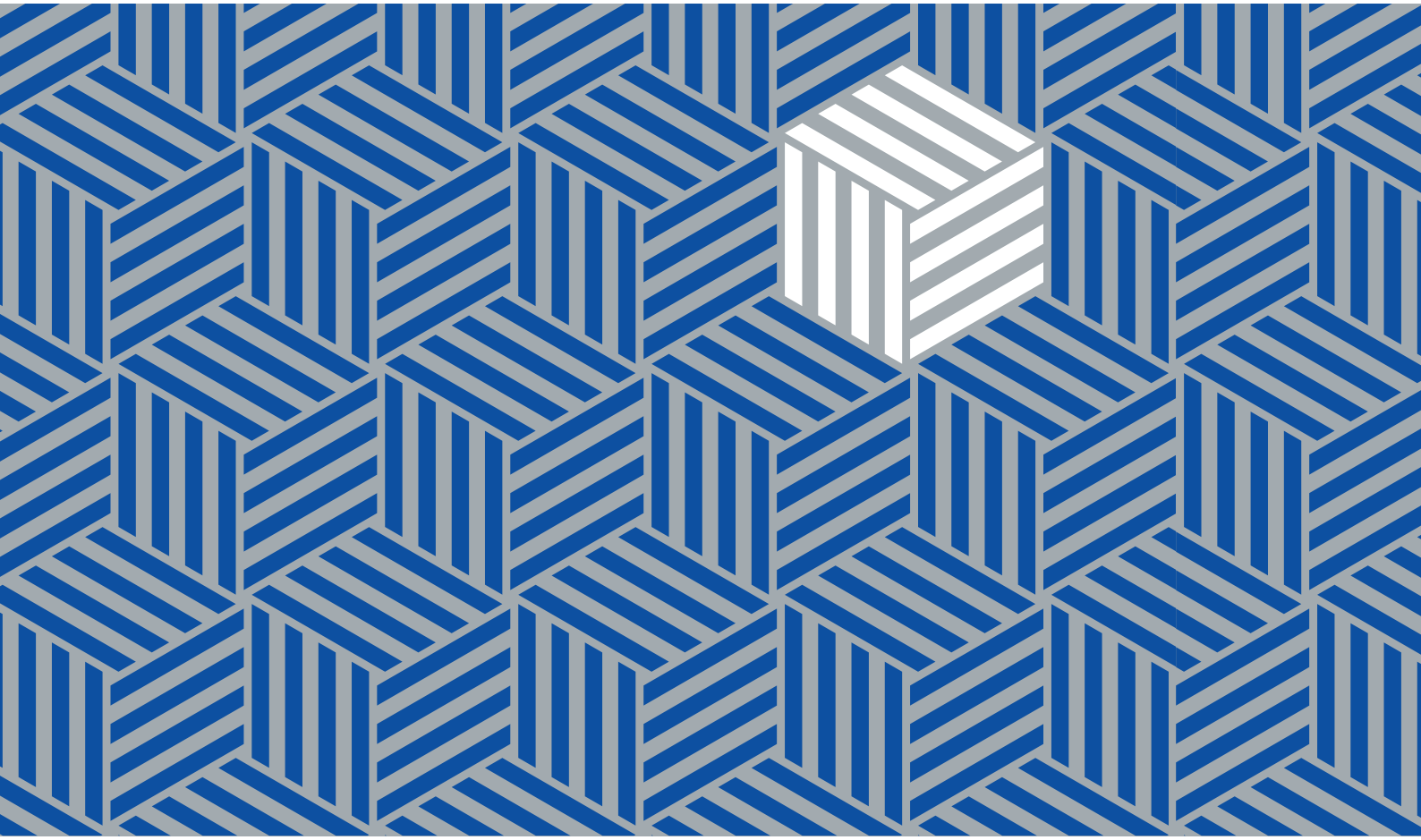
Singapore Academy of Law
Law Reform Committee

Report on the Attribution of Civil Liability for Accidents Involving Autonomous Cars

September 2020



SAL SINGAPORE ACADEMY OF LAW

Singapore Academy of Law
Law Reform Committee

Report on the Attribution of Civil Liability for Accidents Involving Autonomous Cars

September 2020

Part of the *Impact of Robotics and Artificial Intelligence on the Law* series

SAL SINGAPORE ACADEMY OF LAW

Members of the Robotics and Artificial Intelligence Subcommittee

1. The Honourable Justice Kannan Ramesh (co-chair)
2. Charles Lim Aeng Cheng (co-chair)
3. Chen Siyuan
4. Desmond Chew
5. Josh Lee Kok Thong
6. Gilbert Leong
7. Beverly Lim
8. Sampson Lim
9. Yvonne Tan Peck Hong
10. Ronald Wong Jian Jie
11. Yeong Zee Kin

The report was edited by Simon Constantine, Deputy Research Director, Singapore Academy of Law. An electronic copy may be accessed from the Singapore Academy of Law website *https://www.sal.org.sg/Resources-Tools/Law-Reform*.

National Library Board, Singapore Cataloguing in Publication Data

Name(s): Singapore Academy of Law. Law Reform Committee. | Constantine, Simon, editor.
Title: Report on the attribution of civil liability for accidents involving autonomous cars / Singapore Academy of Law, Law Reform Committee; edited by Simon Constantine.
Other title(s): Impact of robotics and artificial intelligence on the law
Description: Singapore: Law Reform Committee, Singapore Academy of Law, [2020]
Identifier(s): OCN 1193413274 | ISBN 978-981-14-7745-4 (paperback) | ISBN 978-981-14-7746-1 (ebook)
Subject(s): LCSH: Liability for traffic accidents–Singapore. | Automated vehicles–Law and legislation–Singapore. | Artificial intelligence–Law and legislation–Singapore.
Classification: DDC 346.59570322–dc23

ISBN 978-981-14-7745-4 (softcover)
978-981-14-7746-1 (e-book)

About the Law Reform Committee

The Law Reform Committee ("LRC") of the Singapore Academy of Law makes recommendations to the authorities on the need for legislation in any particular area or subject of the law. In addition, the Committee reviews any legislation before Parliament and makes recommendations for amendments to legislation (if any) and for carrying out law reform.

Comments and feedback on this report should be addressed to:

Law Reform Committee
Attn: Law Reform Director
Singapore Academy of Law
1 Coleman Street
#08-06 The Adelphi
Singapore 179803
Tel: +65 6332 4070
Fax: +65 6333 9747
Email: *lawreform@sal.org.sg*

IMPACT OF ROBOTICS AND ARTIFICIAL INTELLIGENCE ON THE LAW

SERIES PREFACE

It has been said that we are at an inflection point in the development and use of Artificial Intelligence (AI). The exponential growth in data in the past decade – from 2 trillion gigabytes in 2010 to around 33 trillion at the end of 2018, and an anticipated 175 trillion by 2025 – has enabled giant datasets to be compiled and used as the basis for developing ever-more sophisticated AI systems.

Those systems are in turn being used – in commercial, military, consumer and other contexts – to enhance humans' ability to carry out tasks, or to replace humans altogether. From self-driving cars and robotic carers, to autonomous weapons and automated financial trading systems, robotic and other data-driven AI systems are increasingly becoming the cornerstones of our economies and our daily lives. Increased automation promises significant societal benefits. Yet as ever more processes are carried out without the involvement of a 'human actor', the focus turns to how those robots and other autonomous systems operate, how they 'learn', and the data on which they base their decisions to act.

Even in Singapore, which ranked first in the 2019 International Development Research Centre's Government Artificial Intelligence Readiness Index, questions inevitably arise as to whether existing systems of law, regulation and wider public policy remain 'fit for purpose', given the pace and ceaselessness of change. That is, do they encourage and enable innovation, economic growth and public welfare, while at the same time offering protection against misuse and physical, financial or psychological harm to individuals?

To this end, the Singapore Academy of Law's Law Reform Committee ('LRC') established a Subcommittee on Robotics and Artificial Intelligence to consider, and make recommendations regarding, the application of the law to AI systems.

Having considered current Singapore law, as well as legal and policy developments in other parts of the world, the LRC is now publishing a series of reports addressing discrete legal issues arising in an AI context.

There is currently much work being undertaken at a national and international level in this field. Domestically, the Singapore Government has published the second edition of its Model AI Governance Framework and launched a National Artificial Intelligence Strategy to reap the benefits of systematic and extensive application of new technologies. The LRC hopes that its reports will complement and contribute to these efforts and help Singapore law – through legislation or 'soft law' – to develop in a way that fosters socially and economically beneficial development and use of robotic and AI-driven technologies.

The series does not purport to offer comprehensive solutions to the many issues raised. The LRC hopes, however, that it will stimulate systematic thought and debate on these issues by policy makers, legislators, industry, the legal profession and the public.

OTHER REPORTS IN THIS SERIES

- Applying Ethical Principles for Artificial Intelligence and Autonomous Systems in Regulatory Reform (published July 2020)
- Rethinking Database Rights and Data Ownership in an AI World (published July 2020)
- Report on the Application of Criminal Law to the Operation of Artificial Intelligence Systems and Technologies (*forthcoming*)

TABLE OF CONTENTS

REPORT ON THE ATTRIBUTION OF CIVIL LIABILITY FOR ACCIDENTS INVOLVING AUTONOMOUS CARS

EXECUTIVE SUMMARY

1 The revolution in autonomous cars (or "self-driving" cars, as they are more popularly known) has long been seen as promising significant benefits. And continuing advances in artificial intelligence (AI) and other technologies means that that revolution is fast becoming reality.

2 In Singapore, as elsewhere, significant emphasis has already been placed on developing and testing autonomous vehicle technologies, and the view taken that automation represents the desirable future for transport on public roads. Regulators around the world are actively examining and updating their laws to adjust to these emerging automated technologies, although – to date – concrete legal developments have been static and scattered.

3 Central among the myriad questions under consideration by regulators are questions regarding the attribution of civil liability when accidents or collisions involving such cars occur and cause injury or death. While it is hoped that autonomous vehicles will significantly reduce the number of accidents on public roads, accidents will still happen.

4 This report considers some of the challenges that automation raises for the laws, principles and practices that are currently applied following car accidents, and surveys how other jurisdictions are adapting laws and regulations to begin to meet those challenges. It does not seek to provide firm recommendations for how policy makers in Singapore should respond, but rather is intended to highlight the issues that we consider will need to be addressed in designing any future legal and regulatory frameworks for liability.

5 The issues (and thus regulatory questions) that arise when such accidents do occur are broadly analogous to those where non-autonomous vehicle accidents cause result in injury or harm. That is, (a) identifying the party that should be liable for the accident; (b) establishing that party's liability; and (c) assessing any relevant defences.

6 At present (i.e., for car accidents involving human drivers), Singapore law applies a fault-based negligence framework: the person most responsible for the accident is held liable (that liability then typically being covered by motor insurance). Under both negligence and product liability principles, a party may reduce or even eliminate its liability by relying on certain, defined defences – including, for example, by showing product misuse or contributory negligence on the part of the victim.

7 In accidents involving non-autonomous cars, identifying which party is liable under a negligence framework is often relatively straightforward. For self-driving cars, however, many (and ultimately, as technologies advance, all) events leading up to an accident may stem from decisions made by the car's autonomous features, with no human input or intervention whatsoever. As the car cannot be meaningfully held accountable and sued directly, a choice falls to be made (broadly stated) whether to attribute liability to either the car's manufacturer, the manufacturer of the components that did not function properly, or the car's owner or user.

8 Furthermore, questions also arise as to the standard of care to which any of those parties should be held, and whether, in any given case, that standard has been breached. Finally, and most fundamentally, the complexity of the AI systems governing the car's operation mean that there are also liable to be technological challenges in determining – as a *factual* matter – who was at fault, what malfunctioned and/or which factor or factors caused the accident (and to what extent).

9 Alongside these liability questions, various wider issues arise, including issues such as hacking, ethical questions, and potential barriers to accident investigations arising from, for example, privacy laws or international legal obligations. However – while (directly or indirectly) related to questions of liability – it is submitted that such issues remain either subordinate or logically subsequent to liability issues, and are not considered further in this report.

Approach in other jurisdictions

10 Authorities in various overseas jurisdictions have taken recent steps to review and reform aspects of their laws to accommodate the arrival on public roads of, in the first instance, *conditionally* autonomous cars (that is, those which can generally perform all driving tasks autonomously, but where a human driver is still required to be ready to take back control if necessary). These include:

- *European Union*. The European Commission has reviewed how its existing legislation on product liability and motor insurance is likely to operate in the context of autonomous vehicles. While the latter was found to remain fit for purpose, it was felt that self-driving technologies (particularly the potential difficulty of tracing damage back to a person, and the scope for "through-life" changes to be made to products) could render existing product liability laws less effective, increase costs for victims and make it difficult to found liability claims against anyone other than producers.

  Most recently, an expert group established by the European Commission has made various recommendations regarding liability for AI and other emerging digital technologies more

broadly, designed in particular to facilitate access to recourse for those who have suffered harm.

Changes have also been introduced at individual European state level, for example in Germany (which has issued a set of ethical rules for self-driving cars and legislation requiring manufacturers to install journey event data recording systems) and the UK (which has passed legislation (not yet in force) providing that insurers will generally be held liable in the first instance for accidents "caused" by self-driving cars, and are then left to seek to recover from those responsible in fact for the collision).

- *United States*. Thus far, no federal US legislation specifically pertaining to self-driving cars has been passed. However, (a) state legislation focused on permitting testing, and (b) non-binding policy guidance issued by the vehicle safety regulator, point to certain emergent trends in the US approach to the adoption of autonomous cars, which may inform consideration of equivalent regulations in other countries. These include efforts to establish a consistent nomenclature for self-driving vehicles, an emphasis on ensuring effective recording of journey data, and a focus on both cybersecurity and the vehicle's human-machine interface as priority matters that may require future regulation.
- *Japan*. Legislation has recently been passed in Japan to expedite the deployment of conditionally autonomous vehicles on public roads, including introducing mandatory safety standards and obligations to record and retain vehicle journey data. However, the new legislation does not impact the overall schema for liability, under which liability for personal injury resulting from accidents falls on the "person who puts an automobile into operational use". Insofar as it are not designed for cars with higher levels of automation, the new legislation is expected to be transitional in nature.

The Current Position in Singapore

11 While not inactive in this area, Singapore has, for its part, broadly adopted a 'wait and see' approach to wholesale legal and regulatory reform. As such, the changes made to date have been focused on introducing broad, light-touch 'sandbox' regulations that promote innovation in, and the safe construction and testing of, autonomous car technologies in Singapore, rather than seeking to legislate now for future mainstream use. To that end, recently introduced regulations prescribe, for example, certain roadworthiness, safety and upkeep requirements and duties to obtain relevant authorisations and insurance, but do not address directly issues of liability where accidents occur. Such liability issues therefore continue, in principle, to be governed by existing common law.

Challenges and Options for Future Regulation of Autonomous Cars

12 In considering whether and how such existing liability rules should be reformed to accommodate autonomous cars, it should be borne in mind, among other factors, that:

- A self-driving car, whether fully automated or otherwise, has many new characteristics not contemplated by the existing frameworks and standards applicable to manufacturers of non-autonomous vehicles. These include, for example, the need for a self-driving car's hardware and software to be constantly updated. These attributes may have critical implications for how liability should be determined and apportioned in the event of an accident.
- Given the pace of technological progress, although legislating incrementally may seem like a prudent approach, it may prove inefficient in the longer term. By contrast, although likely involving more fundamental reform, legal clarity around the apportionment of legal liabilities and risks for the 'end state' of accidents involving *fully* autonomous cars could help remove barriers both to manufacturers' development and deployment of such technologies, and to public adoption of the same.

13 However, in legislating for such an end state, numerous challenges will need to be overcome. These can, to some degree, be drawn out by attempting – as a conceptual experiment – to apply the different liability frameworks presently used (i.e., negligence, product liability and no-fault liability) to that fully autonomous paradigm.

Negligence

14 There may be challenges to the use of negligence as a framework for determining civil liability, regardless of whether the car is fully or only partly autonomous. Typically, negligence-based laws require the establishment of (a) a duty of care (foreseeability of harm); (b) a breach of that duty (standard of care); and (c) recoverable damage.

15 While establishing the requisite duty of care may not entail significant difficulty, identifying whether and how that duty has been breached is likely – given what we know about the complex, multi-faceted technology essential for powering self-driving cars – to require a more complex, nuanced approach. Although the forensic process of determining the source and nature of a *hardware* malfunction is unlikely to be radically more challenging than that presently undertaken for non-autonomous vehicle accidents, failures of *software* present a far greater challenge and render the question of breach much more complicated to resolve. Those challenges – which include questions around access to and interpretation of the relevant software code, and variances in how such software operates

depending on the data it was trained on or utilises when operational – are likely to increase at higher levels of automation.

Product liability

16 Product liability – broadly focused on dangerous product defects and manufacturers' failure to adopt reasonable product designs that mitigate foreseeable risks of harm – is less well developed than negligence in Singapore law. While well-established in jurisdictions such as the US, even such 'tried-and-tested' models are likely to face challenges when applied to self-driving cars.

17 As it is with negligence, the primary difficulty is likely to relate to proving a problem (defect) exists with a vehicle's *soft*ware. The process of investigating and gathering the required evidence of such flaws is liable to be so complex, long and costly (in particular where manufacturers are based overseas) as to render satisfactory dispute resolution illusory. Again, those evidential hurdles are likely only to increase as self-driving cars become more automated and technologically complex.

18 It is possible to frame product liability laws so as to impose, in effect, strict liability on manufacturers of the car and/or its components. This might be considered justified on the basis that (a) it would be extremely onerous for regulators (*ex ante*) or users/claimants (*ex post*) to be responsible for verifying the software of self-driving cars and ensuring they are safe for use; (b) there is inherent danger in the widespread use of such (relatively untested) technology (the analogy being with the strict liability framework imposed in the commercial aviation sector); and (c) greater certainty of recourse for injured users is likely to enhance consumer confidence in autonomous car technologies.

19 Nonetheless, strict liability is likely to remain an extreme option, not least because of its likely adverse impact on, for example, the availability and cost of insurance, and the risk of stifling innovation. Further, for Singapore, moving to a novel strict liability regime from one based on negligence may involve significant transition costs, even if it were limited to self-driving car accidents.

No-fault liability

20 No-fault liability does not require it to be shown that the tortfeasor was somehow at fault (e.g. whether because they were negligent or their product was defective). Instead, provided it can be shown that harm was suffered due to the accident, compensation for the victim follows as a matter of course.

21 That represents a radical departure from the position in English common law, and *truly* no-fault regimes are comparatively rare in practice. For example, while the UK's proposed "insurer liability" regime for

automated vehicles may come close to no-fault liability, it in fact contains important derogations allowing for contributory negligence and limitations of liability.

22 The relative simplicity of a no-fault liability regime makes it initially attractive as a means to address the conceptual problems self-driving cars create. However, the requirements in the current law to prove certain legal and evidential issues exist for a reason, and so completely abandoning them would invariably raise further questions. Prime among these are questions as to who should contribute to any fund from which compensation payments are made, and how such a fund could be administered in a way that does not, for example, disincentivise manufacturers from entering the market or from adopting high safety standards. And as with strict liability, even if these issues can be resolved satisfactorily, the shift to such a system would still involve significant transition costs.

23 Given Singapore's long-established negligence-based liability regime and the potential transition costs entailed in adopting wholly new model, the more productive approach may therefore be to retain the existing system, but make targeted modifications to import the desirable features of product liability and no-fault liability. Although the UK's proposed system may provide an example of what might be practicable in that regard, that regime itself has challenges. Moreover, and critically, it was also designed for a legal and road traffic regime that differs in important respects from that existing in Singapore.

24 Given this, and the fact that no other jurisdiction has yet identified a comprehensive and convincing liability framework for motor accidents involving autonomous vehicles (regardless of their level of automation), a *sui generis* regime may be required for Singapore.

25 That may offer Singapore opportunities to be a first-mover in adopting a comprehensive, bespoke framework that facilitates the widespread use of autonomous vehicular technology on its roads. However, as the analysis in this report indicates, the optimal nature or basis for such a regulatory framework remains far from clear.

CHAPTER 1

INTRODUCTION

A BACKGROUND – THE EVOLUTION OF SELF-DRIVING TECHNOLOGIES

1.1 The experience of driving a car is already greatly aided and augmented by technology: from sensors and cameras that assist in parking and lane-keeping, to seatbelts that tighten when crashes or collisions might be imminent.[1] The adoption of such new technologies has been rapid. Self-parking cars, for example, became widely commercially available little more than a decade ago, and yet – relatively speaking – have already almost become anachronistic.[2]

1.2 Autonomous – or, more popularly, "self-driving" – cars[3] arguably represent the next step in that technological evolution. Most significantly, they offer the prospect of obviating entirely the need for a pair of hands to remain on the wheel when the car is in motion, something past technologies have never achieved.

1.3 This self-driving revolution promises significant benefits. It has been claimed that self-driving vehicles will lead to a drastic reduction in road-traffic accidents (and, in turn, to reduced workloads for lawyers, emergency responders, medical professionals and others, which would arguably have a positive nett social and economic effect) and greater efficiencies on the roads in terms of travelling and transportation times.[4]

1 See also "Car Safety Features List", *How Safe is Your Car.com.au* <*http://howsafeisyourcar.com.au/Safety-Features/Safety-Features-List/*> (accessed 9 September 2020).

2 Alison DeNisco Rayome, "Dossier: The Leaders in Self-driving Cars", *ZDNet* (1 February 2018): <*https://www.zdnet.com/article/dossier-the-leaders-in-self-driving-cars/*> (accessed 9 September 2020).

3 The specific definition of "autonomous cars" is discussed further below at paragraphs 1.15 and following.

4 See generally Jack Boeglin, "The Costs of Self-driving Cars" (2015) 17(1) Yale J Law & Tech 171, and James M. Anderson, Nidhi Kalra, Karlyn D. Stanley, Paul Sorensen, Constantine Samaras, and Oluwatobi A. Oluwatola, *Autonomous Vehicle Technologies – A Guide for Policymakers*, RAND Corporation (2016) <*https://www.rand.org/pubs/research_reports/RR443-2.html*> (accessed 9 September 2020). Other potential benefits include increased mobility for those unable or unwilling to drive, and (although less certain) reductions in congestion and emissions as a result of increased ride sharing.

1.4 Experiments involving autonomous vehicles ("**AVs**") have spanned almost a century.[5] But it is only within the last few years that the prospect of commercialising self-driving cars on a widescale basis has inched closer to feasibility, with companies such as Google (or more precisely, its sister company Waymo)[6] and Uber[7] test-driving autonomous cars on public roads (facilitated by liberalised testing laws in places like California and Florida)[8], and "traditional" car manufacturers such as General Motors and Daimler investing heavily in creating next-generation autonomous cars.

1.5 Locally, the Land Transport Authority ("**LTA**") has an ambitious Autonomous Vehicle Initiative in conjunction with the Agency for Science, Technology and Research, and in January 2019 Enterprise Singapore published provisional national standards to guide the industry in the development and deployment of fully autonomous vehicles.[9] Furthermore, one-north has been designated as the main site for both research and development and testing AV technology and applications,[10] and permitted test areas are being gradually extended to cover all roads in western

5 See generally Marc Weber, "Where to? A History of Autonomous Vehicles", *Computer History Museum* (8 May 2014) <*http://www.computerhistory.org/atchm/where-to-a-history-of-autonomous-vehicles/*> (accessed 9 September 2020).

6 Phil LeBeau, "Waymo's Self-driving Cars Log 1 Million Miles on Public Roads in a Month", *CNBC* (20 July 2018) <*https://www.cnbc.com/2018/07/20/waymos-autonomous-cars-log-1-million-miles-in-a-month.html*> (accessed 9 September 2020).

7 Leif Johnson and Michelle Fitzsimmons, "Uber Self-driving Cars: Everything You Need to Know", *TechRadar* (25 May 2018) <*https://www.techradar.com/news/uber-self-driving-cars*> (accessed 9 September 2020). Having scaled back its testing following a fatal accident involving one of its autonomous cars, Uber recently resumed testing on public roads in California. See Kirsten Korosec, "Uber self-driving cars are back testing on San Francisco streets", *TechCrunch* (10 March 2020) <*https://techcrunch.com/2020/03/10/uber-self-driving-cars-are-back-testing-on-san-francisco-streets/*> (accessed 9 September 2020).

8 See generally Andrew J Hawkins, "These Nine States will Serve as Testing Grounds for Self-driving Cars", *The Verge* (23 January 2017) <*https://www.theverge.com/2017/1/23/14357564/dot-self-driving-car-testing-sites-nine-states*> (accessed 9 September 2020).

9 TR 68 Technical Reference for autonomous vehicles (2019) <*https://www.singaporestandardseshop.sg/Product/SSPdtList?SearchString=TR+68*> (accessed 9 September 2020). See also "Joint Media Release by the Land Transport Authority (LTA), Enterprise Singapore, Standards Development Organisation & Singapore Standards Council – Singapore Develops Provisional National Standards to Guide Development of Fully Autonomous Vehicles" Land Transport Authority (Singapore) website (31 January 2019) <*https://www.lta.gov.sg/content/ltagov/en/newsroom/2019/1/2/joint-media-release-by-the-land-transport-authority-lta-enterprise-singapore-standards-development-organisation-singapo.html*> (accessed 9 September 2020). Under TR68, "fully autonomous" equates to SAE Level 4 and 5 vehicles (see below, paragraph 1.16).

10 "Joint Release by the Land Transport Authority, JTC & A*STAR – A SAVI Step Towards Autonomous Transport" (27 August 2014), Land Transport Authority (Singapore) website <*https://www.lta.gov.sg/content/ltagov/en/newsroom/2014/8/2/joint-release-by-the-land-transport-authority-jtc-astar---a-savi-step-towards-autonomous-transport.html*> (accessed 9 September 2020). This initiative is part of Smart Nation Singapore, a nation-wide project to integrate technology and the Internet of Things into various facets of day-to-day living.

Singapore.[11] Beyond cars, self-driving buses are expected to ply the Jurong Innovation District by 2022[12] and PSA Singapore is planning to implement both automated cranes and driverless cars to boost productivity substantially, in a bid to bolster Singapore's status as a maritime hub.[13]

1.6 More generally, however, regulators around the world are actively examining, updating, and even rewriting their laws to adjust to these emerging automated technologies. The myriad questions under consideration range from the highly technical (for instance, intellectual property protections or privacy rights over the information collected by self-driving cars when investigations and litigation occur,[14] or the implications of such collected data for insurance) to the morally nuanced (for instance, whether self-driving cars should have some degree of prioritisation written into the algorithms when faced with imminent deadly crashes).

1.7 That already-significant regulatory challenge is further heightened by the continued rapid development of technologies in this realm, which threaten to leave governments constantly playing catch-up in trying to understand fully how the science, engineering, electronics, and risk allocations operate and interrelate.

1.8 As a result, notwithstanding the need for some kind of governmental response, legal developments have been rather static or scattered. There are ongoing efforts at taking a multilateral approach to harmonising various regulatory standards, leading most recently, in June 2020, to the adoption by members of the United Nations World Forum for Harmonization of Vehicle Regulations of regulations prescribing certain standardised safety requirements for conditionally autonomous vehicles.[15] But in large part –

---

11 "Autonomous Vehicle Testbed to be Expanded to Western Singapore – Continued Emphasis on Public Safety" (24 October 2019) Land Transport Authority (Singapore) website <*https://www.lta.gov.sg/content/ltagov/en/newsroom/2019/10/1/Autonomous_vehicle_testbed_to_be_expanded.html*> (accessed 9 September 2020).

12 Kevin Kwang, "Singapore Relooking Road Rules to Allow for Self-driving Vehicles", *Channel NewsAsia* (6 June 2018) <*https://www.channelnewsasia.com/news/singapore/self-driving-cars-road-rules-singapore-mot-10397586*> (accessed 9 September 2020).

13 Isabelle Liew, "Automated Cranes on Trial at Pasir Panjang Terminal", *The Straits Times* (24 July 2018) <*https://www.straitstimes.com/singapore/automated-cranes-on-trial-at-pasir-panjang-terminal*> (accessed 9 September 2020).

14 This may occur in at least two senses: first, information surrounding the owner of the vehicle in terms of his or her travel (and consumption) patterns; and, secondly, the patents on automotive control systems and copyrights on software code.

15 These Regulations, which come into effect in January 2021, set out minimum regulatory standards for matters such as the human-driver interface (broadly, how and when the automated driving system takes over from the human driver and vice versa), journey data recording, cyber security and software updates. See UNECE, "UN Regulation on Automated Lane Keeping Systems is milestone for safe introduction of automated vehicles in traffic" (25 June 2020) <*http://www.unece.org/info/media/presscurrent-press-h/transport/2020/un-regulation-on-automated-lane-keeping-systems-is-milestone-for-safe-introduction-of-automated-vehicles-in-traffic/doc.html*> (accessed

(*cont'd on the next page*)

particularly in respect of matters such as liability for accidents – regulation of self-driving vehicles is primarily an issue for domestic consideration and resolution.[16] In that regard, there exists only a limited number of reference points for exemplary legislation, with a number of governments seemingly adopting a 'wait and see' approach (and, presumably, prioritising other domestic policy matters) while autonomous vehicles remain in their infancy.[17]

1.9 As seen in the many measures it already has underway, Singapore is among the first movers in this field. It recently ranked first in the 2020 KPMG Autonomous Vehicle Readiness Index (both overall and for "Policy & Legislation" specifically). Even here, however, developments have still been targeted primarily at facilitating testing and development of new technologies, rather than adaptations to fully enable widescale, 'mainstream' deployment on public roads.[18]

1.10 Given the groundwork it has set, a considerable opportunity (and indeed responsibility) therefore exists for Singapore to act as a model for others to follow, including in addressing directly the challenges automation raises for existing laws governing civil liability for vehicle accidents.

B TERMINOLOGY

1 The Nature of 'Autonomy'

1.11 In public discourse, the terminology surrounding autonomous vehicles and other AI technologies is often used loosely (particularly by the media, but also on occasion by governments and regulators). To that end, certain terminological issues central to this report warrant clarification at the outset.

1.12 References to "autonomous" entities with "artificial intelligence", for example, could cover a spectrum of possible interpretations – from sentient

---

9 September 2020); UNECE, "UN Regulations on Cybersecurity and Software Updates to pave the way for mass roll out of connected vehicles" (25 June 2020) <*http://www.unece.org/info/media/presscurrent-press-h/transport/2020/un-regulations-on-cybersecurity-and-software-updates-to-pave-the-way-for-mass-roll-out-of-connected-vehicles/doc.html*> (accessed 9 September 2020).

16 In certain regions, there may be a greater likelihood that self-driving vehicles traverse national borders, but the fact remains that implementation of domestic laws is the unavoidable first step.

17 See for instance, the manifold initiatives and varying states of readiness among countries listed in the KPMG Autonomous Vehicle Readiness Index (*Autonomous Vehicle Readiness Index 2020*, KPMG International <*https://assets.kpmg/content/dam/kpmg/xx/pdf/2020/07/2020-autonomous-vehicles-readiness-index.pdf*> (accessed 9 September 2020)).

18 *Ibid*. The current legal and regulatory position in Singapore is discussed further in Chapter 4.

entities with consciousness and able to make decisions outside their programmed remit at one extreme,[19] to an entity that simply follows and makes 'decisions' based on its coded algorithms at the other. Evidently, in the context of considering the 'decisions' an autonomous vehicle made immediately prior to an accident, such distinctions are of particular importance.

1.13 Similarly, consider terms such as "machine learning", "deep learning" and "neural networks", which are increasingly becoming part of everyday language. When a machine 'learns' by collecting and processing more and more data in its field runs, is it simply attempting to produce outcomes that are closer to its programmed function (for instance, self-driving cars correctly identifying human objects from other types of objects) or is it interpreting data in a way that shows some degree of (unprogrammed) transcendental decision-making abilities? "Deep learning algorithms" and "neural networks" are often compared to impenetrable "black boxes" whose workings are hidden or unexplainable. But something being (potentially extremely) tedious or technologically complex to decipher is not the same as indecipherable, because the machine can only interpret what has been taught (i.e. programmed). And if traceability of the source of a 'decision' is in principle possible, should technological complexity be allowed as a shield against liability?

1.14 The "autonomous" or "self-driving" technologies with which this report is concerned are those involving AI systems that (a) have been programmed to analyse data from their maps, cameras, and sensors; and (b) based thereon, make decisions regarding safe navigation and accident-avoidance.[20] We consider that various principles flow from that definition:

(a) The fact that such cars depend on more and more data (and sometimes updated algorithms) to make better decisions (the aforementioned "machine learning") does not – and should not – detract from the notion that their decision-making function is programmed. Nor does the fact that they may interpret data wrongly or may make "judgment calls" where there are gaps in that data;

(b) As such, any assumption that there is an impenetrable "black box" obscuring the computing mechanics of self-driving cars or the explainability of their decisions between stimulus and

19 See generally Gerhard Wagner, "Robot Liability", Social Sciences Research Network (19 June 2018) <*https://ssrn.com/abstract=3198764*> (accessed 9 September 2020).

20 Generally, a self-driving car has hardware and software that generate images of the car's surroundings as it moves and will thus be able to tell what sort of objects are in proximity, and the speed and direction of those objects. Over time, as the car travels the same route repeatedly, it should be able to better predict traffic conditions and even likely behaviour of the roads' users. A useful summary of how the technology works can be found in Jan de Bruyne and Cedric Vanleenhove, "The Rise of Self-driving Cars" (2018) 5(1) IALS Student L Rev 14.

response ought to be rejected – or, at least, not lightly accepted; and

(c) Even if an autonomous car appears to have made a calculation to avoid damage but in fact causes other damage in the process, this should be attributed to what it was programmed to do.

2 Levels of Vehicular Autonomy

1.15 The term "autonomous car" is evidently also capable of encompassing varying potential degrees of automation, in which the role of the human 'driver' diminishes as the level of autonomy increases.

1.16 In considering such issues, policymakers and others in search of a common language have increasingly adopted the "SAE levels", developed by the Society of Automotive Engineers International.[21] These describe the respective roles of human drivers and automated driving systems at six different levels of automation, as follows:

- Level 0. No Automation – zero autonomy: a human driver performs all aspects of all driving tasks, even though these could be enhanced by warning or intervention systems.
- Level 1. Driver Assistance – the vehicle is controlled by the driver, but some driving assistance features may be included in the vehicle design (for example either steering assistance or acceleration and deceleration).
- Level 2. Partial Automation – the vehicle has *combined* automated functions, like acceleration and steering, but the driver must remain engaged with the driving task and monitor the environment at all times.
- Level 3. Conditional Automation – the driving automation features are generally capable of performing all driving tasks, but the human driver, as a "fallback-ready user", is expected to respond appropriately to any requests to intervene. Thus,

21 Society of Automotive Engineers, *Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles J3016 JUN2018* (2018). The SAE Levels have been utilised or referred to by government and industry-specialist policymakers in (among other jurisdictions) Japan, the US, UK and EU, as well as by multinational organisations such as the United Nations and the OECD. Locally, while the SAE Levels are not specifically referenced in the Road Traffic (Amendment) Act 2017 (No. 10 of 2017) itself, during the parliamentary debates on the bill, the Minister clarified that "autonomous motor vehicles" covered by the Act equated to those at SAE levels 3, 4 and 5. (Second Reading of the Road Traffic (Amendment) Bill, Singapore Parliamentary Debates, Official Report (7 February 2017), vol 94, at 91 (Ng Chee Meng (Minister for Education (Schools) and Second Minister for Transport) <*https://sprs.parl.gov.sg/search/sprs3topic?reportid=bill-287*> (accessed 9 September 2020)). The SAE Levels also form the basis of the TR68 -1 standard (see above, n 9).

while the driver is not expected to monitor the driving environment, he must be receptive and responsive to a handover request or to an evident system failure.

- Level 4. High Automation – the vehicle is capable of performing all driving tasks even if a human driver does not respond to a request to intervene. If the limits of the autonomous driving system are, for whatever reason, exceeded, the system will respond by putting the vehicle in a "minimal risk condition" (e.g., by coming to a gradual stop, or changing lanes to rest on the road shoulder). The driver may have the option to control the vehicle.
- Level 5. Full Automation – the vehicle is capable of performing all driving functions in all situations and conditions that a human driver could. The driver may have the option to control the vehicle.

1.17 Therefore, and in particular to aid comparison with other jurisdictions, we utilise the SAE Levels in this report where required to demarcate differing levels of automation.

1.18 Specifically, in this report the terms "autonomous cars" or "self-driving cars" (which are used interchangeably) equate to cars at SAE Level 3 and above.

1.19 We note further that, within that definition of autonomous cars (and as will be apparent from the above), a key distinction is between Levels 3 and 4, given both: (a) the current state of technology; and (b) the fact that it is at this threshold where the need (technologically) for a human to be ready to take control over the vehicle largely disappears.

1.20 However, it should be noted that the SAE Levels are not a legal classification, and do not themselves define legal consequences.

C SCOPE OF THIS REPORT

1.21 This report focuses on the regulation of autonomous cars (defined, as noted above, as those from SAE Levels 3 to 5) when used on public roads, by members of the public.[22]

22 That is, as opposed to commercial use in private spaces or governmental use in private and/or public spaces. For present purposes, it is irrelevant whether the vehicle is fleet-controlled (for example a fleet of driverless taxis for ride-hailing) or not. Such fleets would simply be akin to present-day fleets of non-autonomous taxis. In the non-autonomous context, the mode of liability for taxis does not differ fundamentally from privately owned cars, and, prima facie, the same would appear broadly to hold true even where both are autonomous.

1.22 Specifically – and acknowledging that there are consequently various potential regulatory issues and challenges that are beyond its scope – this report focuses on the attribution of civil liability when accidents or collisions involving such cars occur and cause injury or death.

1.23 The report does not address other forms of autonomous vehicle (including autonomous aircraft, drones, and so on). Given road cars' ubiquity, we consider that autonomous cars and their attendant applications are likely to see broader mainstream public adoption than other forms of autonomous vehicular technology, or be adopted sooner.[23] It is in respect of such cars, therefore, that consideration of the effectiveness of existing regulation appears most pressing.

1.24 Further, as alluded to above, this report addresses only *civil* liability. In our view, questions of criminal liability for accidents involving autonomous cars are to some degree parasitic on the attribution of civil liability. Issues regarding criminal liability in relation to AI systems and technologies more broadly will be considered in a forthcoming report in this series.[24]

D STRUCTURE OF THIS REPORT

1.25 The report is divided into four main parts:

(a) Chapter 2 sets out the main issues that arise in the regulation of autonomous cars, such as the determination of liability, defences, and alternative modes of liability.

(b) Chapter 3 examines the positions taken in three major jurisdictions that have considered issues relating to the development and deployment of autonomous cars: the European Union, the United States and Japan. It highlights in particular potential divergences, challenges, and emergent trends from which insights might be drawn.

(c) Chapter 4 considers the approach taken in Singapore to the regulation of autonomous cars, which has to date focused on

23 It is noted that certain forms of autonomous public transport (specifically, driverless trains) have been in widescale use in Singapore for almost two decades. However, such vehicles do not have to face the decision-making complexities that road-driving involves, such as detours, parking, overtaking, changing lanes, proximate pedestrians, and the like. See Christopher Tan, "Drivers Now Deployed on Singapore's Driverless MRT Trains to Improve Reliability", *The Straits Times* (4 March 2018) <*https://www.straitstimes.com/singapore/drivers-now-deployed-on-singapores-driverless-mrt-to-improve-reliability*> (accessed 9 September 2020). As noted above, to the extent that public transport is road-based (e.g. taxis) questions of liability for accidents are, in prime part, substantively equivalent to those for private cars.

24 Law Reform Committee, Singapore Academy of Law, *Application of Criminal Law to the Operation of Artificial Intelligence Systems and Technologies* (forthcoming) (Co-Chairs: Justice Kannan Ramesh and Charles Lim Aeng Cheng).

facilitating testing of such cars, rather than questions of liability where accidents on public roads occur.

(d) Chapter 5 considers possible approaches that might be taken in Singapore to such questions of liability based on existing negligence, strict liability and no-fault liability principles (and the difficulties therewith), taking into account Singapore's specific legal and socio-economic context.[25]

25 The Singapore Government's view is that self-driving vehicles are meant to create more efficient and convenient transport systems, thereby reducing the need for Singaporeans to own and/or drive their own cars: Singapore Parliament Debates. Official Report (7 February 2017, vol. 94) at 64 <*https://sprs.parl.gov.sg/search/fullreport?sittingdate=07-02-2017*> (accessed 9 September 2020) (Ng Chee Meng, Second Minister for Transport).

CHAPTER 2

ISSUES ARISING IN ACCIDENTS INVOLVING AUTONOMOUS CARS

2.1 It is hoped that autonomous vehicles will significantly reduce the number of accidents on public roads.[26] But accidents will still happen, particularly for as long as human-controlled cars – and even 'conditionally autonomous' (SAE Level 3) cars – share the road with fully autonomous ones.

2.2 The issues (and thus regulatory questions) that arise when those accidents happen are, broadly stated, analogous to those where non-autonomous vehicle accidents result in injury or harm. That is:

(a) Identifying the party that should be liable when an accident happens;

(b) Establishing liability; and

(c) Assessing defences to liability; plus

(d) Various related, wider issues (in the context of autonomous cars, these pertain principally to other complications that may arise in their operation, such as hacking and malfunctioning of equipment outside the vehicle).

2.3 Each of these is addressed in turn below.

A WHICH PARTY SHOULD BE LIABLE WHEN AN ACCIDENT HAPPENS?

2.4 Perhaps the first and most natural question when an accident occurs is *who* should be held responsible and, consequently, held *prima facie* liable?

2.5 In Singapore, in car accidents that involve human drivers, the party who is found to be the most responsible for the accident (by applying a fault-based framework in the form of negligence) is usually liable to compensate the other party, and this cost is in most cases covered by motor insurance,[27] the premiums of which may depend on the track record

26 It has been estimated that around 90% of road accidents are caused by human errors. See the European Commission's report, *Saving Lives: Boosting Car Safety in the EU* (COM(2016) 0787 final), European Commission (12 December 2016) <*https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52016DC0787*> (accessed 9 September 2020).

27 The drivers can, of course, also settle the matter privately without recourse to insurance. If there are injuries or fatalities, the Traffic Police will be involved in investigating the accident.

of the liable driver and other risk factors. If there is a dispute over fault, the determination of fault in normal car accidents is now aided by digital imaging of the aftermath and dashboard cameras that may have captured the incident, in addition to what can be forensically unveiled in repair workshops and the like. In many cases, identifying which party is liable is a relatively straightforward task, whether the dispute goes to court or not. If insurance is in place, compensation then follows as a matter of course.[28]

2.6 For self-driving cars, the fundamental complication is that there may (eventually) be no human driver to speak of – in the events leading up to the point of impact, the decisions may have all been made by the autonomous features of the car, with no human input or intervention whatsoever.[29] But, as it is not a legal person,[30] the self-driving car cannot be meaningfully held accountable and sued directly. As such – and assuming the car (driverless or otherwise), object, or person that was hit was not at fault, and the self-driving car had not been modified or tampered with – the remaining options for attributing liability are, broadly, to:

(a) the manufacturer of the car,

(b) the manufacturer of the relevant component(s) or technological device(s) of the car that did not function properly, or

(c) the owner or driver of the car.

2.7 It should be reiterated, however, that, at present, there are still liable to be technological challenges in determining who was at fault or what had malfunctioned, notwithstanding any principled commitment to explainability by manufacturers or developers of autonomous cars or the AI systems within them. Not least, the interconnectedness of the digital technologies underpinning autonomous cars and the myriad sources of data on which they may rely may make it extremely challenging to determine whether an accident was caused by any one factor, or by some combination of factors (and in such a case, the individual contribution of each such factor).[31]

28 To be clear, there are multiple possibilities. A claimant can claim against his own policy, claim against the defendant's insurance policy, or attempt private settlement.

29 In other words, even though it is presently still commonplace for safety drivers and command centres to be involved, all signs point towards fully autonomous vehicles being the norm in the not-too-distant-future. Legislating for the interim, only to modify the regulations shortly thereafter, would arguably therefore be counterproductive (see further paragraph 5.2 below).

30 The possibility of conferring legal personality on robotic and AI systems such as self-driving cars is discussed at paragraph 3.16 below.

31 This challenge is not unique to autonomous cars – accidents involving non-autonomous vehicles can equally have multiple contributing causes. However – due to the interconnectedness noted – the challenge is likely to be significantly greater in relation to such technologies.

B HOW SHOULD LIABILITY BE ESTABLISHED?

2.8 Inextricably linked to the above is the issue of what sort of liability framework should be adopted. Under existing tort rules, the key candidates are negligence and product liability. However, considering that proving negligence requires the proving of the breach of standard of care, this may not be so straightforward in the context of self-driving cars.

2.9 In an SAE Level 0 scenario, obviously the inquiry centres around the human driver, and maybe other road-users if there is an issue of contributory negligence. Beyond that and up until SAE Level 5, it would probably take some forensic skill to determine if it is the fault of the human driver (where that human retains some degree of control or oversight) or the vehicle's software and/or hardware (or some combination of the two). The whole point of a self-driving car is to take the human decision-making out of the equation, but the very technology that enables this – a voluminous amount of proprietary code and data – may well obscure the transparency of the vehicle's decision-making process. With this obscurity, the proving of negligence becomes much more difficult in terms of being able to gather evidence and evaluate it. It will be time-consuming and potentially prohibitively expensive.

2.10 The same can be said of product liability. Even though this area of law is not as well developed as negligence in common law jurisdictions, the main idea is that a manufacturer defect must be shown. Yet, for the reasons just stated, the means to proving this are likely to be very challenging in terms of time and money. Thus, whether it be negligence or product liability, the fact that motor insurance is compulsory in Singapore does not mean that compensation is guaranteed in the context of self-driving cars, as pay-outs can be contingent on ascertaining where the fault lies, and this is without mentioning that the quantum of the pay-out may be limited by the terms of the insurance policy (and concomitantly the bargaining power of the insured).

2.11 Then there is the possibility of moving away from a fault-based analysis, such that when an accident involving a self-driving car occurs, compensation is facilitated with ease – virtually automatically. This is done even without establishing who – whether the driver, the vehicle, another road-user, or even a third-party – might have caused the accident (although taking this approach does not necessarily foreclose the possibility of subsequent litigation to establish fault). The challenge with taking this approach is that of funding, since the compensation must be paid from somewhere. If the funding is from a community pool, this requires buy-in from a defined community. If the funding is from personal insurance, then compensation may vary greatly, depending on the terms and premiums set by the insurer.

2.12 These issues, and the wider challenges of applying existing models for attributing liability in the context of fully autonomous vehicles, are considered in further detail in Chapter 5 below.

C WHAT DEFENCES ARE AVAILABLE?

2.13 For each of the above bases for liability, a defendant may be able to rely on certain defences to reduce or even eliminate its liability.

2.14 In the context of self-driving cars, possible defences may include:

(a) from the manufacturer standpoint, product misuse by the driver (including failure to maintain or service the vehicle), undue driver or passenger interference (whether with the operation of the vehicle or with its software/hardware), third-party hacking, and the state of the art (i.e. that there are no safer alternative designs at the relevant point in time).

(b) for drivers (assuming the car is not fully self-driving[32]), apart from factors already present in general road-traffic accidents (such as environmental conditions and product malfunction), a finding that it was impossible to override the machine's erroneous decision.

In either case, if the victim was at fault, that may act as a (partial) defence for either the manufacturer or driver, based on the victim's contributory negligence.

D WIDER ISSUES

2.15 Investigating an accident involving an autonomous vehicle may raise numerous wider issues, include in relation to privacy and data concerns, ethical questions, evidence-gathering, and international legal obligations.

2.16 While all these issues have some (direct or indirect) relationship with the question of liability, we take the view that the issues are either subordinate to or – as in the case of compensation and remedies (in the form of insurance) for example – logically subsequent to, questions of liability.[33]

---

32 That is, the steering wheel, brake pedals and so forth are still present so that the human driver can intervene if necessary.

33 The Canadian Senate has this to say about insurance: "the advent of [autonomous vehicles] will likely result in fewer collisions, although the [repair] cost of these collisions will increase […] human error has been the predominant cause of collisions since motor vehicles were first introduced […] as automation increases, insurers and the legal system will also have to consider the role of software errors and equipment failure in collisions […] this raises questions about whether liability will shift entirely from drivers to manufacturers when fully automated vehicles become the predominant means of transport": *Driving Change: Technology and the Future of the Automated Vehicle*, Standing Senate Committee on Transport and Communications (Canada) (Ottawa, Ont: Senate Canada, 2018) at 65 <*https://sencanada.ca/content/sen/committee/421/TRCM/Reports/COM_RPT_TRCM_AutomatedVehicles_e.pdf*> (accessed 9 September 2020).

2.17 To some degree the above presupposes that market forces (the price of cars, insurance premiums, and so forth) would adjust to whatever starting point is imposed by regulators regarding liability, without undue compromises (i.e. without unduly deterring the provision of insurance or the development and sale of autonomous vehicles). Promoting the development, deployment, and adoption of autonomous vehicles appears to remain a central objective in Singapore for both regulators and manufacturers, and to the extent that is true, it seems reasonable to assume that the question of an appropriate liability/compensation framework will be the paramount, driving concern and the basis from which many other decisions will flow.

CHAPTER 3

STUDY OF KEY OVERSEAS JURISDICTIONS

3.1 As mentioned, the three main jurisdictions surveyed for the purposes of this report are the EU (including, where pertinent, individual European states), the US, and Japan.

A THE EUROPEAN UNION

1 EU-wide rules

3.2 The European Commission, which acts as the executive cabinet of the EU, conducted a review in 2018[34] of the existing framework for liability in the EU, which mainly comprises the Motor Insurance Directive[35] and the Product Liability Directive.[36]

- The Motor Insurance Directive was found to be appropriate to deal with self-driving cars without any amendments. Notably, the Motor Insurance Directive provides for the establishment of guarantee funds which pay for losses not covered by liability insurance.[37] In return for contributing to this fund, manufacturers, programmers, owners, and drivers could see their liability being limited to a certain amount.
- As for the Product Liability Directive, the European Commission recently published a report (and a related white paper), considering, among other issues, the safety and liability implications of autonomous and connected

34 *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee, the Committee of the Regions: On the Road to Automated Mobility: An EU Strategy for Mobility of the Future* (COM(2018) 283 final), European Commission (17 May 2018) <*https://ec.europa.eu/transport/sites/transport/files/3rd-mobility-pack/com20180283_en.pdf*> (accessed 9 September 2020).

35 Directive 2009/103/EC of the European Parliament and of the Council of 16 September 2009 Relating to Insurance against Civil Liability in respect of the Use of Motor Vehicles, and the Enforcement of the Obligation to Insure against such Liability ("**Motor Insurance Directive**").

36 Council Directive 85/374/EEC of 25 July 1985 on the Approximation of the Laws, Regulations and Administrative Provisions of the Member States concerning Liability for Defective Products ("**Product Liability Directive**").

37 *Civil Law Rules on Robotics: European Parliament Resolution of 16 February 2017 with Recommendations to the Commission on Civil Law Rules on Robotics* (2015/2103(INL)), European Parliament (16 February 2017) <*http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//NONSGML+TA+P8-TA-2017-0051+0+DOC+PDF+V0//EN*> (accessed 9 September 2020). See also Wagner, "Robot Liability", above, n 19.

technologies.[38] The report concluded that, despite the Directive's breadth and flexibility, characteristics of such technologies (particularly the potential difficulty of tracing damage back to a person, and the scope for "through-life" changes to be made to products) could render existing liability laws less effective, increase costs for victims and make it difficult to found liability claims against anyone other than producers. It therefore recommended that "all options" be considered to ensure those harmed by these technologies enjoy the same protection as those harmed by other technologies, while still allowing technological innovation to develop (including amendments to the Product Liability Directive or wholly new legislation specifically on AI). Specifically, views were sought on whether existing burdens of proof for proving damage needed to be amended to mitigate the challenges of AI applications' complexity.[39] Previously, certain lacunae in the application of the Product Liability Directive to self-driving cars had also been identified by the European Parliament.[40]

3.3 Until any further interpretive guidance or legislative amendments are made, however, the present position remains that the victim in an accident involving self-driving cars will be compensated, whether through insurance or the guarantee fund mentioned above. Compensation will be made through insurance where civil liability is established, as the Motor Insurance Directive mandates EU member states to take all appropriate measures to ensure that civil liability in respect of the use of vehicles is

38 *Report from the Commission to the European Parliament, the Council and the European Economic and Social Committee: Report on the safety and liability implications of Artificial Intelligence, the Internet of Things and robotics* (COM(2020) 64) European Commission (19 February 2020) <*https://ec.europa.eu/info/sites/info/files/report-safety-liability-artificial-intelligence-feb2020_en_1.pdf*> (accessed 9 September 2020). See also *White Paper on AI: a European approach to excellence and trust* (COM(2020) 65 final), European Commission (19 February 2020) <*https://ec.europa.eu/info/files/white-paper-artificial-intelligence-european-approach-excellence-and-trust_en*> (accessed 9 September 2020).

39 As regards product safety legislation, the report concluded that, although this could already be applied to risks arising from automated products, explicit provision for certain new risks of such technologies (e.g., risks arising from the possibility of autonomous changes or updates being made to a product during its lifetime that impact safety) may be warranted to provide clarity: *Report on the safety and liability implications of Artificial Intelligence, the Internet of Things and robotics*, above n.38.

40 Tatjana Evas, *A Common EU Approach to Liability Rules and Insurance for Connected and Autonomous Vehicles: European Value Added Assessment: Accompanying the European Parliament's Legislative Own-initiative Report (Rapporteur: Mady Delvaux)* (PE 615.635) (Brussels: European Added Value Unit, European Parliamentary Research Service, European Parliament, 2018) <*http://www.europarl.europa.eu/RegData/etudes/STUD/2018/615635/EPRS_STU(2018)615635_EN.pdf*> (accessed 9 September 2020).

covered by insurance.[41] The relevant regime pursuant to which civil liability may be established differs among member states. For example, the Netherlands has a semi-strict liability system, whereas France has a no-fault liability system.[42] The insurer can, in turn, take action against the relevant manufacturer under the Product Liability Directive[43] where there is a defect in the self-driving car.[44] For those purposes, a self-driving car will be considered "defective" where it does not provide the safety which a person is entitled to expect, taking into account the presentation of the vehicle, the use to which it could reasonably be expected to be put, and the time when the vehicle was put into circulation.[45]

3.4 Liability under the Product Liability Directive is essentially strict, though this is subject to certain exceptions – some of which are likely to be relevant to self-driving cars.

(a) First, where it is "probable that the defect which caused the damage did not exist at the time when the product was put into circulation by him or that this defect came into being afterwards".[46]

- In the context of self-driving cars, this may apply where there is a "black box" situation, where the self-driving car responds or develops in a manner that is opaque (although, as stated at paragraph 1.14 above, we take the view that claims of unexplainability, whether related to proprietary concerns due to compelled disclosure or otherwise, should not lightly be accepted).
- This exception would also potentially cover situations where the software of the self-driving car is tampered with, causing a defect.

(b) Second, where "the defect is due to compliance of the product with mandatory regulations issued by the public authorities".[47]

- Presumably, this exception would apply, for example, where the authorities mandate the inclusion of certain software or firmware, or updates, causing a defect.

41 Motor Insurance Directive, above, n 35, art 3.

42 Evas, *A Common EU Approach to Liability Rules and Insurance for Connected and Autonomous Vehicles*, above, n 40 at 12.

43 The Directive imposes liability on "producers", defined as "the manufacturer of a finished product, the producer of any raw material or the manufacturer of a component part and any person who, by putting his name, trade mark or other distinguishing feature on the product presents himself as its producer." Product Liability Directive, above, n 36, art 3.

44 *An EU Strategy for Mobility of the Future*, above, n 34 at 10.

45 Product Liability Directive, above, n 36, art 6.

46 *Id*, art 7(b).

47 *Id*, art 7(d).

(c) Thirdly, where "the state of scientific and technical knowledge at the time when he put the product into circulation was not such as to enable the existence of the defect to be discovered".[48]

- Considering the rapidity at which the technology of self-driving cars is developing, this exception is likely to be of particular relevance (although it should not, presumably, act as a 'back door' through which manufacturers can seek to use the opacity around how precisely a 'black box' AI system reached its decision to escape liability).

(d) Fourth, "in the case of a manufacturer of a component, that the defect is attributable to the design of the product in which the component has been fitted or to the instructions given by the manufacturer of the product".[49]

- This exception will provide protection to manufacturers of components for self-driving cars.

3.5 Significantly, the Product Liability Directive further provides for the defence of contributory negligence: where "the damage is caused both by a defect in the product and by the fault of the injured person or any person for whom the injured person is responsible", the liability of the producer may be reduced or disallowed. Even outside of the context of the existing Product Liability Directive (which as noted earlier only applies where there is a "defect") it is likely that the defence of contributory negligence will be available in accidents involving self-driving cars. The European Parliament in a 2017 resolution has suggested that "once the parties bearing the ultimate responsibility have been identified, their liability should be proportional to the actual level of instructions given to the robot and of its degree of autonomy".[50]

3.6 Commentators have raised a possible issue in relation to the applicability of the Product Liability Directive to self-driving cars. Specifically, the current limitation period for claims under the Product Liability Directive is ten years from the date the product is put on the market.[51] This could pose a difficulty in the context of self-driving cars, which require regular software and firmware updates. The question is thus

48 *Id*, art 7(e).

49 *Id*, art 7(f).

50 *Civil Law Rules on Robotics*, above, n 37 at [56]; see also Wagner, "Robot Liability", above, n 19.

51 Jan De Bruyne and Jarich Werbrouck, "Merging Self-driving Cars with the Law" (2018) 34(5) Computer L & Security Rev 1150 at 3 <*https://doi.org/10.1016/j.clsr.2018.02.008*> (accessed 9 September 2020. See also, *White Paper on Artificial Intelligence – A European approach to excellence and trust* and *Report on the safety and liability implications of Artificial Intelligence, the Internet of Things and robotics*, above, n 38.

whether a claim in respect of a self-driving car, which has been placed on the market more than ten years ago, but has, after a period of ten years, undergone a software or firmware update, will be barred. A further question that arises is, if the claim is not barred, will the producer be liable for every aspect of the self-driving car, or just the software or firmware update?

3.7 Most recently, issues of liability for Artificial Intelligence and other emerging digital technologies have been considered by an expert group established by the European Commission.[52] The group makes a series of recommendations (intended to be broadly applicable across various AI technologies, and not just autonomous vehicles) on how liability regimes should be designed or adapted for new technologies, many of which are pertinent to the current analysis. Key recommendations include:[53]

(a) A person operating[54] a technology carrying an increased risk of harm to others (of which autonomous cars would be one) should be subject to strict liability for damage resulting from its operation.

(b) A person using a (partly or fully) autonomous technology should be no less accountable for any harm than if a "human auxiliary" of that person had caused the harm (i.e. vicarious liability principles may apply, as they do for employers in relation to acts of their employees).

(c) Manufacturers of AI-enabled products should be liable for damage caused by defects in those products, even if the defect resulted from changes (under the producer's control) made after the product was put on the market.

(d) Where there is a heightened risk of third parties being harmed, compulsory liability insurance could provide the more effective means of ensuring victims have access to compensation and potential tortfeasors are not exposed to unduly onerous liability.

(e) Where the nature of a particular technology increases the difficulty of proving some element of liability "beyond what

52 See *Liability for Artificial Intelligence and Other Emerging Digital Technologies*, Expert Group on Liability and New Technologies – New Technologies Formation (November 2019) <*https://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupMeetingDoc&docid=36608*> (accessed 9 September 2020).

53 *Id.* at 3-4.

54 The 'operator' being the "person who is in control of the risk connected with the operation of emerging digital technologies and who benefits from such operation" (*Id.* at 41). The report acknowledges that, on occasion, a service provider ensuring the necessary technical framework may have more control than the owner/user of an AI-equipped product, and that this should be taken into account in determining who the primary 'operator' is.

can be reasonably expected", victims should be entitled to facilitation of proof.

(f) Emerging technologies must have data recording capabilities, and the burden of proof should be reversed if such data is not recorded or made reasonably accessible.

(g) There is no need to create a new legal personality for devices or autonomous systems: the harm they cause "can and should be attributable to existing persons or bodies".

2 Developments in key European jurisdictions

3.8 Aside from the Motor Insurance Directive (which, as noted, harmonises laws across the EU only for liability insurance cover, not civil liability itself) and the Product Liability Directive, the EU member states have their own national laws governing liability for vehicles.[55] More than that, some EU member states have begun to specifically address liability for self-driving cars.

3.9 For instance, Germany's Federal Ministry of Transport and Digital Infrastructure has issued a set of ethical rules for self-driving cars.[56] These rules provide hints for how liability for self-driving cars will be implemented. The rules confirm that liability for damage caused by self-driving cars will be attributed according to the Product Liability Directive, but with an additional obligation on manufacturers and operators to continuously optimise their systems and to observe systems which have already been placed on the market. Drivers of self-driving cars are not required to monitor the vehicle constantly, but must pay sufficient attention so as to take control of the vehicle if prompted to by the vehicle, or if circumstances are such that immediate manual control is required (for example, where the autonomous vehicle is unable to react to a policeman's signals). Failure to observe these rules may result in a driver being held liable for any ensuing accident.

3.10 As for proving liability, the German Transport Minister has introduced legislation requiring manufacturers to install event data

55 Evas, *A Common EU Approach to Liability Rules and Insurance for Connected and Autonomous Vehicles*, above, n 40 at 12. Typically, such national laws impose liability on the owner/keeper of a vehicle and/or on the driver, although some member state laws provide for direct claims against the insurer, regardless of any other person's liability (See *Liability for Artificial Intelligence and Other Emerging Digital Technologies*, above, n 52 at 16).

56 *Ethics Commission: Automated and Connected Driving*, Federal Ministry of Transport and Digital Infrastructure (June 2017) <*https://www.bmvi.de/SharedDocs/EN/publications/report-ethics-commission.pdf?__blob=publicationFile*> (accessed 9 September 2020).

recording systems[57] into self-driving cars.[58] Victims of accidents involving self-driving cars would have the right to access such records, so as to assist them in proving fault on the part of the driver or the self-driving car itself.[59, 60] It has also been reported that the German transportation ministry has begun work on new legislation that would allow for the operation (within defined environments) of SAE Level 4 cars on public roads.[61]

3.11 The United Kingdom[62] has also passed legislation catering specifically to self-driving cars, the Automated and Electric Vehicles Act 2018 ("**AEVA**").[63] Under the AEVA, insurers will be generally held liable for accidents "caused" by self-driving cars[64] (subject to any contributory negligence on the part of the injured person).[65] Where the vehicle is not insured, such as where it is a public vehicle, the owner of the vehicle will be liable.[66] However, the insurer or owner of the vehicle would be entitled to

57 Showing, for example, when a human driver was or was not in charge, and alerts or requests by the AI system for the driver to take over. Such devices (which have been installed in aircraft for many years) are popularly called 'black boxes' – however, we use the term 'event data recorder' here to avoid confusion with the use of "black box" to also describe a device whose internal workings are opaque.

58 §63A, Straßenverkehrsgesetz (StVG) (Germany). See also Markus Wacket and Caroline Copley, "Germany to Require 'Black Box' in Autonomous Cars", *Reuters* (18 July 2016) <*https://www.reuters.com/article/us-germany-autos-idUSKCN0ZY1LT*> (accessed 9 September 2020).

59 §63A, Straßenverkehrsgesetz (StVG) (Germany). See also, Wagner, "Robot Liability", above, n 19 at 14.

60 In addition, the EU's General Data Protection Regulation confers upon citizens what has been termed as a "right to explanation" – a right to obtain an explanation of decisions reached through automated means – although it remains unclear how that right may apply in the context of decisions made by a self-driving car. Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the Protection of Natural Persons with regard to the Processing of Personal Data and on the Free Movement of such Data, and Repealing Directive 95/46/EC. See, in particular, recital 71.

61 Matthew Beedham, "Germany developing legislation to be first to commercialize Level 4 autonomous vehicles" *TNW Shift* (20 July 2020) <*https://thenextweb.com/shift/2020/07/20/germany-developing-legislation-to-be-first-to-commercialize-level-4-autonomous-vehicles/*> (accessed 9 September 2020); Christoph Hammerschmidt, "German law aims to be first for driverless cars", *eeNews Europe* (27 July 2020) <*https://www.eenewseurope.com/news/german-law-aims-be-first-driverless-cars*> (accessed 9 September 2020).

62 Although the UK is formally no longer a member of the European Union, it continues for the time being to be bound by EU rules for a 'transitional period'.

63 2018 c 18 (UK). The bill received Royal Assent on 19 July 2018 but the Act has not yet been brought fully into force. It appears that the Act was passed in advance so as to give the market a head start in developing suitable insurance products by the time self-driving cars start to become publicly available, see *Impact Assessment: Pathway to Driverless Cars: Insurance for Automated Vehicles*, Centre for Connected and Autonomous Vehicles (7 October 2016) at 5 <*https://publications.parliament.uk/pa/bills/cbill/2017-2019/0112/Automated-and-Electric-Vehicles-IA2.pdf*> (accessed 9 September 2020).

64 AEVA, *Id*, s 2(1).

65 *Id*. s 3.

66 *Id*, s 2(2).

claim against the "person responsible for [the] accident",[67] such as the manufacturer or supplier of the self-driving car.[68] Unfortunately, at present, no further guidance appears to have been given as to how the "person responsible for [the] accident" will be determined.[69]

3.12 Liability under the AEVA is fashioned in a manner to ensure that victims are compensated without undue delay – by giving them a right to claim from the insurer, provided the victim is able to show that the accident was "caused" by the self-driving car in question and the defences elaborated on below do not apply. The insurer can then claim against the relevant parties.[70] Notably, it seems that insurers in the UK are supportive of the approach taken in the AEVA,[71] possibly because it is envisaged that insurers will, over time, be able to quickly and easily subrogate claims and recover their costs from manufacturers.[72] It has been noted that it would not be in manufacturers' commercial interest to be uncooperative when it comes to subrogated claims. As insurers will not be compelled to provide insurance for self-driving cars, if they are consistently prevented from recovering their costs, they could potentially simply cease offering insurance products for such vehicles at all.[73]

3.13 As the Law Commission and Scottish Law Commission have noted, there is some debate about whether causation under the AEVA involves an element of fault. For example, if a self-driving car swerves to avoid an erratic cyclist and hits a parked car, would the insurer of the self-driving car be liable for the accident even though the fault lay entirely with the cyclist? The Law Commissions' preliminary view seems to be that the test for causation should be left to the courts to resolve on a case by case basis, applying civil liability principles.[74]

---

67 *Id*, s 5(1).

68 *Automated Vehicles: Summary of the Preliminary Consultation Paper*, Law Commission and Scottish Law Commission, (2019) at [6.11] <*https://s3-eu-west-2.amazonaws.com/lawcom-prod-storage-11jsxou24uy7q/uploads/2018/11/6.5066_LC_AV_Final-summary_061118_WEB.pdf*> (accessed 9 September 2020).

69 The UK government is also presently consulting on the future use on public roads of 'Automated Lane Keeping Systems' (i.e., automated driving systems that control the car's direction and speed without driver command), including issues such as the residual expectations on the driver of a (SAE level 3) car when it is in self-driving mode. *Safe Use of Automated Lane Keeping System (ALKS) Call for Evidence*, Centre for Connected & Autonomous Vehicles (August 2020) <*https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/911016/safe-use-of-automated-lane-keeping-system-alks-call-for-evidence.pdf*> (accessed 9 September 2020).

70 *Id* at [6.11].

71 *Library Briefing: Automated and Electric Vehicles Bill*, House of Lords (8 February 2018) at 5–6 <*https://lordslibrary.parliament.uk/research-briefings/lln-2018-0022/*> (accessed 9 September 2020).

72 *Impact Assessment: Pathway to Driverless Cars: Insurance for Automated Vehicles*, above, n. 63 at 9.

73 *Ibid*.

74 *Automated Vehicles: Summary of the Preliminary Consultation Paper*, above, n 68 at [6.5] – [6.6]. Responses to the Law Commissions' consultation on this point were

(*cont'd on the next page*)

3.14 The AEVA provides for several defences. To begin with, as alluded to above, the law on contributory negligence applies equally to accidents involving self-driving cars.[75] It thus follows that the insurer or owner of the self-driving car will not be liable to the person in charge of the vehicle where the accident was wholly due to that person's negligence in, for example, allowing the autonomous vehicle to begin driving itself when it was not appropriate to do so.[76]

3.15 Next, insurers are allowed to exclude or limit liability for accidents which are a direct result of prohibited software alterations made by the insured person or with the insured person's knowledge,[77] or a failure to install safety-critical software updates that the insured person knows or ought reasonably to know are safety-critical.[78] An update is safety-critical where it would be unsafe to use the vehicle without the update being installed.[79]

3.16 Finally, and looking to the future, it bears mentioning that the European Parliament, as part of a series of recommendations on robotics, has suggested that the European Commission "consider the implications of … creating a specific legal status for robots in the long run, so that at least the most sophisticated autonomous robots could be established as having the status of electronic persons responsible for making good any damage they may cause."[80] This legal status would enable such robots to be held responsible directly. However, whether it is truly necessary (or, indeed, productive) to adopt this mechanism to facilitate dispute resolution is, in our view, open to question, and the notion has since been rebutted by the European Commission Expert Group on Liability and New Technologies.[81]

---

mixed, with (broadly speaking) insurers and their representatives calling for further guidance (although not necessarily agreeing on what guidance) and legal groups asserting that the issue could be left to the courts. Law Commission and Scottish Law Commission, *Automated Vehicles: Analysis of Responses to the Preliminary Consultation Paper* (19 June 2019) at [6.22]–[6.41] <*https://s3-eu-west-2.amazonaws.com/lawcom-prod-storage-11jsxou24uy7q/uploads/2019/06/Automated-Vehicles-Analysis-of-Responses.pdf*> (accessed 9 September 2020).

75 AEVA, above, n 63, s 3(1).

76 *Id*, s 3(2).

77 *Id*, s 4(1)(a).

78 *Id*, s 4(1)(b).

79 *Id*, s 4(6)(b).

80 *Civil Law Rules on Robotics*, above, n 37 at [59(f)]; see also Wagner, "Robot Liability", above, n 19 at 2.

81 *Liability for Artificial Intelligence and Other Emerging Digital Technologies*, above, n 52 at 37-38: "Harm caused by even fully autonomous technologies is generally reducible to risks attributable to natural persons or existing categories of legal persons, and where this is not the case, new laws directed at individuals are a better response than creating a new category of legal person." It is possible that such notions *may* come under strain once AI systems are able to reach human-level intelligence and to think and process the implications of their actions (i.e. to approach the 'sentience' described at paragraph 1.12 above). However, the vague consensus among AI experts appears to be that such technologies are at least two decades away (if not more). As

(*cont'd on the next page*)

Moreover, to our knowledge, no other jurisdiction has shown any concrete indication in legislating for this. As noted below, there may be more direct means to hold those responsible for the AI system to account for the harms it causes.

B THE UNITED STATES

3.17 Even though it will be one of the biggest markets for self-driving cars, the US has thus far not enacted any federal legislation specifically pertaining to such vehicles. In the interim, common law tort rules and principles continue to constitute the predominant mode of regulating liability for accidents or collisions leading to injury or death.

3.18 Efforts at federal legislation have been made. In 2017, the House of Representatives passed the Safely Ensuring Lives Future Deployment and Research In Vehicle Evolution ("**SELF DRIVE**") Act, [82] However, a complementary bill – the American Vision for Safer Transportation Through Advancement of Revolutionary Technologies ("**AV START**") Act[83] failed to pass the Senate. At the time of writing, bipartisan efforts to pass that Act had been renewed, but it remains unclear if agreement will be reached.[84]

3.19 However, this does not mean that there is an absence of legislative activity in the sphere of self-driving cars. More than 30 states have already enacted legislation that is meant to facilitate the testing of self-driving cars.[85] While these legislative measures are concerned primarily with testing (rather than mainstream use on public roads) and/or have yet to be

---

such, creation of such legal personality for robots or other AI systems would appear – *at best* – premature. See, Simon Chesterman, "Artificial Intelligence and the Limits of Legal Personality" (2020) NUS Law Working Paper No 2020/025 forthcoming in International & Comparative Law Quarterly) <*https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3682372*> (accessed 9 September 2020); Katja Grace, John Salvatier, Allan Dafoe, Baobao Zhang, "When Will AI Exceed Human Performance?" (2018) 62 JAIR 729 at 731; Seth D Baum, Ben Goertzel, Ted G. Goertzel, "How Long Until Human-Level AI? Results from an Expert Assessment" (2011) 78(1) Technological Forecasting and Social Change 185.

82 Safely Ensuring Lives Future Deployment and Research in Vehicle Evolution Act, HR 3388, 115th Cong (2017).

83 American Vision for Safer Transportation Through Advancement of Revolutionary Technologies Act, S 1885, 115th Cong (2017).

84 See Zac George, "Congress nears agreement on comprehensive framework for autonomous vehicles", *NaCO* (18 February 2020) <*https://www.naco.org/blog/congress-nears-agreement-comprehensive-framework-autonomous-vehicles*> (accessed 9 September 2020), and Sam Sabin, "Self-Driving Bill's Path to Passage Hits a Familiar Obstacle: Forced Arbitration" *Morning Consult* (10 March 2020) <*https://morningconsult.com/2020/03/10/self-driving-bills-path-to-passage-hits-a-familiar-obstacle-forced-arbitration*> (accessed 9 September 2020).

85 An up-to-date list can be found at "Autonomous Vehicles State Bill Tracking Database", National Conference of State Legislatures (20 March 2020) <*https://www.ncsl.org/research/transportation/autonomous-vehicles-legislative-database.aspx*> (accessed 9 September 2020).

passed, they provide important hints as to the future regulation of self-driving cars in the US.

3.20 In the sphere of executive action, the National Highway Traffic Safety Administration ("**NHTSA**"), the US Department of Transportation agency charged with the writing and enforcing of vehicle safety standards, has issued a series of policy guidance papers that provide non-binding guidance to relevant stakeholders as well as an insight into future regulatory measures it may take.[86]

3.21 To give a broader flavour of the developments in the US, the following paragraphs will first examine tort liability under US laws, and its interaction with self-driving cars. They will then consider, based on the existing or proposed state and federal legislation in relation to self-driving cars and NHTSA policy guidance described above, possible emerging legislative and regulatory trends in respect of self-driving cars in the US.[87]

1 Tort liability

3.22 While there have been a handful of known fatalities involving self-driving cars in the US, none of these incidents have, to our knowledge, yet resulted in court decisions clarifying the scope of tortious liability in relation to self-driving cars. These incidents have either been settled out of court, or are still pending investigation and in the pre-trial phase of their actions. However, scholarly discussion in this area of US law is relatively vibrant and provides valuable direction in relation to the different modes of liability for self-driving cars.

3.23 The prevailing academic consensus in the US appears to be that "the proliferation of driverless vehicles will eventually lead to an 'upward' shift in the locus of civil liability for everyday accidents away from drivers and

86 See, for example *Federal Automated Vehicles Policy: Accelerating the Next Revolution in Roadway Safety* (Washington, DC: National Highway Traffic Safety Administration, US Department of Transportation, 2016) ("**FAVP**") <*https://www.transportation.gov/sites/dot.gov/files/docs/AV%20policy%20guidance%20PDF.pdf*> (accessed 9 September 2020); *Automated Driving Systems 2.0: A Vision for Safety* (Washington, DC: National Highway Traffic Safety Administration, US Department of Transportation, 2017) ("**ADS 2.0**") <*https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/13069a-ads2.0_090617_v9a_tag.pdf*> (accessed 9 September 2020).

87 In common with many other policymakers internationally (see n 21 above) the NHTSA has adopted the SAE Levels to classify differing levels of automation. See *Federal Automated Vehicles Policy*, *id* at 9–10; "US DoT chooses SAE J3016 for Vehicle-autonomy Policy Guidance", SAE International (20 September 2016) <*http://articles.sae.org/15021/*> (accessed 9 September 2020). See also Ella Pyman, "The Liability Blind Spot: Civil Liability's Blurred Vision of Conditionally Automated Vehicles" (2018) 92 Aust LJ 293.

towards the manufacturers of these devices".[88] In other words, the elimination of human drivers as a cause of harm in traffic incidents will shift the focus of tort litigation in this area from human negligence to civil liability falling on the manufacturer (whether under product liability and/or negligence laws).[89]

3.24 In terms of product liability claims, US law generally categorises such claims into three broad categories: design defect, warning defect, and manufacturing defect claims.[90] It is anticipated that in the area of self-driving cars, design and warning defect claims will be more common. This is because manufacturing defect claims will not change drastically with the introduction of self-driving vehicles, and are mostly limited to quality control problems, which manufacturers are familiar with.[91]

3.25 The scope for an element of human fault as an exculpatory factor for the product liability of manufacturers will broadly depend on the level of automation of the vehicle. For example, vehicles identified as SAE Level 3 require that the human driver be ready to take control of the vehicle with notice. In such a scenario, there is arguably a case to be made that a human driver may be – at a minimum – contributorily negligent in the event of a crash if he or she fails to take over the vehicle when notice is given.

3.26 In such circumstances, there may be a concern that too much responsibility might fall on the human user to minimise risks by taking control – particularly insofar as (a) the vehicle will likely have been marketed on the basis of its ability to reduce the need for the human user to undertake the driving task; and (b) the human can therefore reasonably be expected to be less attentive and more reliant on the automated driving system. US tort law appears to moderate such a concern, however, through the use of the concept of "fault-tolerant product designs". If "a safer design can be reasonably implemented and risks can be reasonably designed out of a product", a manufacturer that does not adopt a reasonably safe, fault tolerant design is subject to tortious liability, and in such a scenario, no liability would fall on the human driver.[92]

3.27 Human fault as an exculpatory factor diminishes in significance as the SAE level of automation of the relevant vehicle increases. At SAE Level 4, there is no necessity for the human driver to take over the vehicle

88 Dorothy Glancy, Robert Peterson & Kyle Graham, "A Look at the Legal Environment for Driverless Vehicles" (Washington, DC: The National Academies Press, 2016) at 35 <*https://doi.org/10.17226/23453*> (accessed 9 September 2020).

89 Mark A Geistfeld, "A Roadmap for Autonomous Vehicles: State Tort Liability, Automobile Insurance, and Federal Safety Regulation" (2018) 105 California Law Review 1611 at 1619. See also Pyman, "The Liability Blind Spot", above, n 87 at 294.

90 Geistfeld, "A Roadmap for Autonomous Vehicles", *id* at 1632.

91 *Id* at 1633.

92 *Id* at 1627–1629, citing *Restatement (Third) of torts: products liability* § 2 cmt. l (Am. Law Inst. 1998).

at any point, and hence the issues highlighted in the preceding paragraph regarding the human driver's likely attentiveness (and the consequent balancing of responsibility between the human and the manufacturer) should not arise.

3.28 Beyond the broad trends identified above, there is no academic consensus as to the possible direction tort liability in the US will take in relation to self-driving cars. This is further complicated by the fact that state tort laws are not necessarily uniform, and the current legal framework in the US leaves individual states to deal with tort liability matters as they see fit.[93]

3.29 The tentative nature of tort law in this specific area is implicitly acknowledged in ADS 2.0 which states: "States could begin to consider rules and laws allocating tort responsibility."[94] This indicates that there has yet to be any comprehensive legislative attempt, on a federal or even state level, to grapple with tort law reform to respond to the challenge of self-driving cars and presumably, the courts will apply established tort principles to deal with the novel situations created by self-driving cars.

2 Emerging trends derived from legislation and policy papers

3.30 Four trends in the US approach to the adoption of autonomous cars warrant specific mention.

3.31 First, there has been a concerted effort to establish consistency in nomenclature relating to self-driving cars. In addition to adoption of the SAE Levels by the NHTSA (and indeed in the AV START Act),[95] both FAVP and ADS 2.0 emphasise the importance of car manufacturers defining the 'Operational Design Domain' of the automated vehicles they wish to test or put on the market. The Operational Design Domain is a description of the specific conditions in which the car is designed to operate.[96] This allows for easier classification into the various SAE Levels, which is important for regulatory purposes, since different regulations may apply to the vehicles depending on the SAE Level of the vehicle. If federal legislation is ultimately adopted, it appears likely that different regulations may apply to SAE Level 3 as compared to SAE Level 4 and 5 vehicles: the previous version of the AV START Act, for example, drew a distinction between "highly automated

93 With regard to self-driving cars, there are also differing practices. To illustrate, some states such as California require companies testing self-driving cars to provide comprehensive reports whenever accidents occur, but this obviously has great implications on competitiveness.

94 *Automated Driving Systems 2.0*, above, n 86 at 24.

95 AV START Act, above, n 83, s 8.

96 *Federal Automated Vehicles Policy*, above, n 86 at 27; *Automated Driving Systems 2.0*, above, n 86 at 6.

vehicles" (covering SAE Level 3, 4 or 5 vehicles), and "dedicated highly automated vehicles" (covering only SAE Level 4 and 5 vehicles).[97]

3.32 Second, there has been an emphasis on the necessity of data recording features on all self-driving cars. ADS 2.0 dedicates a section to describing the standards of data recording expected of manufacturers. However, this is still a work in progress, as evidenced by the statement: "Meanwhile, for consistency and to build public trust and acceptance, NHTSA will continue working with SAE International to begin the work necessary to establish uniform data elements for ADS [Automated Driving Systems] crash reconstruction."[98] In other words, it appears that no uniform standard of what data needs to be collected and what format it ought to be in has yet been established in the US.

3.33 The first and second points mentioned above are important in the context of civil liability for self-driving car accidents. Achieving consistency in classification and data recording is an important precursor to allowing both regulators and the courts to understand exactly what each self-driving car was designed to do and precisely how the self-driving car has failed in the event of an accident. Understanding incidents relating to self-driving cars in this sense is the first step in the imposition of any framework of ascribing any liability.

3.34 Third, there is a recognition that another aspect that may require future regulation is the Human-Machine Interface in the car. This refers to the interaction between any humans and the vehicle. ADS 2.0 discusses the possibility of incorporating driving engagement monitoring software, especially for SAE Level 3 vehicles and below, which may require human intervention at certain points. ADS 2.0 and FAVP have also highlighted that at minimum, any self-driving car must indicate whether it is: (a) functioning properly; (b) currently engaged in automated driving mode; (c) currently "unavailable" for automated driving; (d) experiencing a malfunction with the automated driving system; and (e) requesting a control transition (from the self-driving car to the human operator).[99]

3.35 The importance of ensuring that the Human-Machine Interface is of an acceptable standard was highlighted by the fatal accident in 2016 involving a (SAE Level 2) Tesla vehicle and a tractor-trailer. The official

97 AV START Act, above, n 83, s 2(b)(5).

98 *Automated Driving Systems 2.0*, above, n 86 at 14. The Driver Privacy Act of 2015 established that, for existing data recorders fitted in conventional cars (which capture a limited amount of information about a vehicle and its occupants immediately prior to a crash, such as the car's speed and whether seatbelts were in use), the data collected is the property of the vehicle owner. However, that Act does not extend to the other types of data that autonomous vehicles will collect. See Bill Canis, *Issues in Autonomous Vehicle Testing and Deployment*, Congressional Research Service (February 2020) at 5 <*https://fas.org/sgp/crs/misc/R45985.pdf*> (accessed 9 September).

99 *Id* at 10.

report into the crash found that, in addition to other factors (including the truck driver's failure to yield and the Tesla driver's inattention due to overreliance on the car's automation), a contributory factor in the accident was the car's operation design, which "permitted prolonged disengagement from the driving task and use of the automation in ways inconsistent with Tesla's guidance and warnings." (Since the crash, Tesla has updated its "autopilot" feature so that drivers who ignore safety warnings will have their autopilot disabled until the next time they start the car.)[100]

3.36 Finally, there is recognition that vehicle cybersecurity has to keep pace with developments in automation, although there has been no consistent standard developed as yet. Both ADS 2.0 and FAVP have made tentative suggestions for vehicle cybersecurity and have stressed its importance.[101] Additionally, the AV START Act previously considered by Congress required that manufacturers "develop, maintain, and execute a written plan for identifying and reducing cybersecurity risks".[102]

3.37 The four issues discussed above (operational design domains, electronic data recorders, human-machine interfaces and cybersecurity) are not US-specific – they are issues that all nations will need to grapple with. Indeed, each is listed as one of the "key issues and principles to be considered … as a priority" in the United Nations World Forum for Harmonization of Vehicle Regulations' 2019 *Revised Framework Document on Automated/Autonomous Vehicles*[103] and were the focus of regulations adopted by the Forum's member countries in June 2020.[104]

---

100 *Collision Between a Car Operating With Automated Vehicle Control Systems and a Tractor-Semitrailer Truck Near Williston, Florida May 7, 2016* (*HAR1702*), National Transportation Safety Board (12 September 2017) <*https://www.ntsb.gov/investigations/AccidentReports/Pages/HAR1702.aspx*> (accessed 9 September 2020). Similarly, the NTSB report into a more recent accident, between a Tesla and a truck-tractor in March 2019, again found the operational design of Tesla's partial automation system, insofar as it permitted disengagement, to have been a contributory factor in the crash (alongside various other factors) (*Highway Accident Brief: Collision Between Car Operating with Partial Driving Automation and Truck-Tractor Semitrailer (HAB 2001)*, National Transportation Safety Board (1 March 2020) <*https://www.ntsb.gov/investigations/AccidentReports/Pages/HAB2001.aspx*> (accessed 9 September 2020).

101 *Federal Automated Vehicles Policy*, above, n 86 at 21–22; *Automated Driving Systems 2.0*, above, n 86 at 11.

102 AV START Act, above, n 83, s 14.

103 *Revised Framework document on automated/autonomous vehicles*, United Nations Economic and Social Council Europe World Forum for Harmonization of Vehicle Regulations (June 2019) <*https://www.unece.org/fileadmin/DAM/trans/doc/2019/wp29/ECE-TRANS-WP29-2019-34-rev.1e.pdf*> (accessed 9 September 2020). The stated objective of this framework is to "capture the shared interests and concerns of regulatory authorities, provide the general parameters for work, and to provide common definitions and guidance" (*Id* at [8]).

104 See above, paragraph 1.8 and n 15.

C JAPAN

3.38 Developments in self-driving vehicles in Japan have been motivated by the Japanese government's target of having an automated vehicle service on Tokyo's public roads in time for the (now postponed) 2020 Tokyo Olympic Games.[105] This has led to a series of ongoing regulatory developments. To understand these developments, it is important to first set out Japan's road traffic regime. Five statutes are of particular relevance:

(a) The Road Traffic Act (Act No 105 of 25 June 1960) ("**JRTA**").[106]

(b) The Road Transport Vehicles Act (Act No 185 of 1951) ("**JRTVA**").[107]

(c) The Japanese Civil Code (Act No 89 of 27 April 1896) ("**JCC**"), in particular, Part III, Chapter 5, which is titled "Torts".[108]

(d) The Product Liability Act (Act No 85 of 1 July 1994) ("**JPLA**").[109]

(e) The Act on Securing Compensation for Automobile Accidents (Act No 97 of 29 July 1955) (also referred to as the Automobile Liability Security Act) ("**JASLA**").[110]

3.39 The JRTA deals with various road traffic rules and regulations, while the JRTVA deals with road vehicle safety standards. The latter three statutes form the legal basis for three types of claims that are relevant for our purposes.

3.40 First, the JPLA establishes strict product liability. Article 3 states that "the manufacturer" shall be liable for any "damages arising from the infringement of life, body or property of others which is caused by the defect in the delivered product". Article 2(3) JPLA defines "the manufacturer" as any person who "manufactured, processed or imported

105 *The Prime Minister in Action: Council on Investments for the Future*, Cabinet Public Relations Office (30 March 2018) <*https://japan.kantei.go.jp/98_abe/actions/201803/30Article4.html*> (accessed 9 September 2020).

106 A non-official government supplied translation is available online as *Road Traffic Act: Law Number: Act No 105 of 1960*, Japanese Law Translation (23 August 2016) <*http://www.japaneselawtranslation.go.jp/law/detail/?id=2962&vm=04&re=02*> (accessed 9 September 2020).

107 There does not appear to be an English translation for this statute available online.

108 A non-official government supplied translation is available online as *Civil Code (Act No 89 of April 27, 1896)*, Japan Ministry of Justice <*http://www.moj.go.jp/content/000056024.pdf*> (accessed 9 September 2020).

109 A non-official government supplied translation is available online as *Product Liability Act: Law Number: Act No 85 of 1994*, Japanese Law Translation (1 April 2009) <*http://www.japaneselawtranslation.go.jp/law/detail/?id=86&vm=04&re=02*> (accessed 9 September 2020).

110 A non-official government supplied translation is available online as *Act on Securing Compensation for Automobile Accidents: Law Number: Act No 97 of 1955*, Japanese Law Translation (28 March 2016) <*http://www.japaneselawtranslation.go.jp/law/detail_main?re=&vm=02&id=3135*> (accessed 9 September 2020).

the product in the course of trade", as well as any person who "in light of the manner concerning the manufacturing, processing, importation or sales of the product, and other circumstances, holds himself/herself out as its substantial manufacturer". The definition of "manufacturer" is framed widely, and can include car manufacturers, software developers and even fleet operators.

3.41 Second, article 709 JCC states that "A person who has […] negligently infringed any right of others, or legally protected interest of others, shall be liable to compensate any damages resulting in consequence". This is a rough analogue to the tort of negligence in Singapore and English law.

3.42 Third, the JASLA sets out the basis for liability in circumstances where death or bodily injury arises out of the operation of automobiles. Article 3 JASLA states that "a person that puts an automobile into operational use for that person's own benefit is liable to compensate for damage arising from the operation of the automobile if this results in death or bodily injury of another person". This is unless "the person and the driver" prove that they had exercised due care, the victim acted intentionally or negligently, and there was no "defect in automotive structure or function". It has been noted that these three cumulative exemption requirements are practically difficult for perpetrators of road traffic accidents to substantiate and as such, article 3 effectively imposes no-fault liability on the perpetrator.[111]

3.43 Article 4 JASLA clarifies that other than the circumstances set out in article 3, liability to compensate for automobile accidents will be governed by the JCC. Article 5 JASLA establishes a compulsory insurance scheme for motor vehicles, primarily to insure the liability founded on the JASLA.[112] The JASLA does not pin liability solely on the driver, rather it is the "person who puts an automobile into operational use" for his own benefit who is liable. Article 2(2) JASLA defines "operation" to include using an automobile "in keeping with the way that such a machine is used". This definition is wide enough to cover fleet operators who put self-driving cars into automated operation.

111 Seiichi Ochiai, "Civil Liability for Automated Driving Systems in Japan", in *Japan's Insurance Market 2018* (Tokyo: The Toa Reinsurance Company, Limited, 2018) at 2 <*https://www.toare.co.jp/english/img/knowledge/pdf/2018_insurance.pdf*> (accessed 9 September 2020).

112 Seiichi Nishioka, "Japanese Legal System Related to Automated Driving – The Current Liability will be Maintained in the 'Transition Period'", in *Laws and Insurance in Our Coming Automated-driving Society: How Insurance can Contribute to Enhancing Social Receptivity* (Tokyo: Sompo Japan Nipponkoa Insurance Inc, 2018) at 3–4 <*http://www.sjnk.co.jp/~/media/SJNK/files/english/news/sjnk/2018/e_nikkei.pdf*> (accessed 9 September 2020).

3.44 As earlier highlighted, Japan has embarked on a concerted effort to have self-driving vehicles on the road in the near future. It is significant to note, however, that the Japanese government's aim was not to have *fully automated* self-driving vehicles operationalised this year, but rather SAE Level 3 vehicles.[113] As such, the immediate legislative and regulatory changes to facilitate the operationalisation of SAE Level 3 vehicles in Japan are likely to be transitional in nature and more significant legislative developments will take place in response to greater levels of automation.[114]

3.45 We now turn to examine the legislative and regulatory changes to facilitate the Japanese government's immediate goal of having SAE Level 3 vehicles on the road this year.

3.46 The Japanese government has made amendments to the JRTA to legalise the use of SAE Level 3 autonomous vehicles on roads, which came into effect earlier this year.[115] However, manufacturers of such vehicles will first have to demonstrate that the vehicles satisfy a series of criteria intended to show that the vehicles can operate safely in varying conditions and on different types of roads.[116] In addition, such vehicles would need to be fitted with travel data recorders and data from the use of the vehicles will be saved.

3.47 Parallel amendments to the JRTVA have also been made. These amendments pertain to introducing new regulatory standards for the cameras, sensors and regulatory equipment used in self-driving cars. Additionally, the amendments provide for rules for testing and servicing of self-driving systems.[117]

3.48 In terms of civil liability for accidents caused by self-driving cars, the Japanese Ministry of Land, Infrastructure, Transport and Tourism published a report in March 2018 focusing on whether the JASLA should be amended during the transition period where SAE Level 0 to SAE Level 4 vehicles would share the road. The report's findings were adopted by the Japanese government in April 2018. In gist, the report recommended that

113 "Cabinet paves way for self-driving vehicles on Japan's roads next year with new rules", *The Japan Times* (20 September 2019) <*https://www.japantimes.co.jp/news/2019/09/20/national/japans-cabinet-autonomous-driving/*> (accessed 9 September 2020).

114 Ochiai, above, n 111 at 5.

115 "Cabinet paves way for self-driving vehicles on Japan's roads next year with new rules", above, n 113; James Nepaulsingh, Naoki Matsushita & Jochen Ellrott, "Autonomous driving in Japan – part 1: road traffic law" *Freshfields Bruckhaus Deringer* (28 August 2020) <*https://digital.freshfields.com/post/102ge6o/autonomous-driving-in-japan-part-1-road-traffic-law*> (accessed 9 September 2020).

116 "Cabinet paves way for self-driving vehicles on Japan's roads next year with new rules", *Ibid*.

117 *Ibid*. and Kazuhiro Ogawa, "Japan Revamps Laws to Put Self-driving Cars on Roads: Drivers will be Allowed to Look at Smartphones while Operating Level 3 Vehicles", *Nikkei Asian Review* (9 March 2019) <*https://asia.nikkei.com/Politics/Japan-revamps-laws-to-put-self-driving-cars-on-roads*> (accessed 9 September 2020).

the existing liability regime under the JASLA should be retained[118], and liability for personal injury in accidents involving self-driving cars would remain on the "person who puts an automobile into operational use". Such operators would be required to have insurance, and manufacturers will be liable only where there is an evident fault in the car's autonomous driving system.[119]

3.49 According to a subsequent paper written by the chair of the research group behind the March 2018 report, the group considered three options:[120]

(a) Leaving the existing liability regime under the JASLA in place.

(b) Complementing the existing regime with "a new mechanism that calls on automobile manufacturers and other related parties to pay a certain amount in advance as premiums for automobile liability insurance".

(c) Complementing the existing regime with "a newly established legal concept of a 'liability of the system provider' mechanism that assigns no-fault liability to automobile manufacturers and other related parties".

3.50 The research group eventually decided to retain the status quo for four reasons. First, they felt that the "legal interpretation of 'liability of the automobile operator' posed no problems even during the transition period". Second, they did not think it prudent to drastically overhaul the existing system during such a transitional phase, so maintaining the JASLA liability regime, which had functioned smoothly, was appropriate. Third, the other two proposals "required the resolution of numerous issues to function smoothly". Fourth, key countries overseas were not moving towards drastic revisions of their legal systems in relation to assigning liability to automobile manufacturers and other related parties.[121]

3.51 As for the JCC and JPLA, there has been no indication as yet that the Japanese government will be putting forward amendments to those two statutes in anticipation of the introduction of self-driving vehicles on the roads. Thus, it appears that in the realm of civil liability for accidents involving self-driving, the Japanese government has not yet decided to drastically change the applicable statutory framework, until a later date.

118 Ochiai, above, n 111 at 3.

119 Nikkei Staff, "Japan to place accident liability on self-driving car owners" *Nikkei Asian Review* (31 March 2018) <*https://asia.nikkei.com/Economy/Japan-to-place-accident-liability-on-self-driving-car-owners*> (accessed 9 September 2020).

120 *Id* at 5.

121 *Ibid*.

CHAPTER 4

THE CURRENT POSITION IN SINGAPORE

4.1 Before considering the sort of liability framework that might be adopted locally, it is necessary for us to first consider the current state of the law in Singapore.

4.2 Broadly speaking (and in particular as regards questions of liability) the Singapore government has essentially adopted a 'wait-and-see' approach to the regulation of self-driving cars.

4.3 This does not mean that it has been inactive, however. In addition to the various policy initiatives highlighted at paragraph 1.5 above, certain broad regulations are already in place (following parliamentary debates on the issue in 2016), and – as previously noted – the testing of self-driving cars has been ongoing for several years, with medium-scale commercialisation anticipated not far from now.

4.4 Rather than let the free market run its course uninhibited, the default starting point has been to grant local authorities extremely wide-ranging control in prescribing and modifying rules and limits regarding any testing, use, and construction of any forms of autonomous car technology in Singapore.[122]

4.5 As early as 2016, the LTA took the position that all self-driving vehicles to be used for trials must demonstrate roadworthiness and pass a safety assessment before any steps can be taken.[123] Some other specific requirements that have since passed into law and need to be complied with include:[124]

(a) A person cannot use or undertake any trial of automated vehicle technology on any road unless properly authorised and with liability insurance in place.[125]

---

122 Road Traffic Act (Cap 276, 2004 Rev Ed) ('**RTA**'), s 6C. The principal limitation to their powers is that in making the rules they have to "take reasonable steps to prevent information that is commercially sensitive in nature […] from being published or otherwise made public": *Id*, s 6C.

123 See Khaw Boon Wan (Coordinating Minister for Infrastructure and Minister for Transport), "Written Answers to Questions for Oral Answer not Answered by End of Question Time: Becoming an Autonomous Vehicle-Ready Nation", *Singapore Parliamentary Reports, Official Report* (9 November 2016), vol 94.

124 For completeness, the Misuse of Drugs (Amendment) Act 2019 (No 1 of 2019) has also introduced certain changes pertaining to police powers over autonomous vehicles, but these are not explored in this report.

125 RTA, above, n 122, ss 6C(1)(a) and (b); Road Traffic (Autonomous Motor Vehicles) Rules 2017 (S 464/2017) ('**RTAVR**'), rr 4, 7 and 14. Security may be deposited in lieu of insurance: *id*, r 15.

(b) Any such authorised person must ensure that the vehicle is at all times functioning properly and maintained in a state of good condition.[126]

(c) Any such authorised person must ensure that the vehicle is installed with a data recorder capable of storing information when the vehicle is being used; this data must be in digital format and include information such as date, time, location, speed, front- and rear-facing imaging, and must be kept for at least three years.[127]

(d) Any such authorised person also has a duty to keep records of, and to notify, any incidents and accidents.[128]

(e) The vehicle must have a failure alert system that allows the driver to take immediate manual control of the vehicle when a failure of the autonomous system or other emergency is detected.[129]

(f) Nobody is allowed to hinder or obstruct the carrying out of the use of autonomous motor vehicles; interference with the equipment of such vehicles is also prohibited.[130]

As previously noted, several US states (and indeed jurisdictions such as China) have passed similar "testing phase" regulations to these.

4.6 For present purposes, there is benefit in reviewing what was said in Parliament[131] when the Road Traffic Act[132] was amended to accommodate trials with autonomous vehicle technology – keeping in mind that these amendments were to establish a regulatory sandbox for autonomous vehicle trials, which would probably be reviewed again in a few years:

(a) The government wants to adopt a balanced, light-touch regulatory stance that protects the safety of passengers and road users but gives space for innovation to occur and ensures that autonomous technologies can flourish.

(b) Because autonomous technologies challenge the very notion of human responsibility which lies at the core of Singapore's current road and criminal laws, developers of these technologies must provide enough measures to ensure their safe operation on the roads.

126 RTAVR, *id*, r 16.
127 RTA, above, n 122, s 6C(1)(g)(i); RTAVR, *id*, r 17.
128 RTA, *id*, s 6C(1)(i); RTAVR, rr 18 and 19.
129 RTA, *id*, s 6C(1)(g)(ii).
130 *Id*, s 6E. See also the Computer Misuse and Cybersecurity Act (Cap 50A, 2007 Rev Ed).
131 Ng Chee Meng (Minister for Education (Schools) and Second Minister for Transport), speech during the Second Reading of the Road Traffic (Amendment) Bill, *Singapore Parliamentary Debates, Official Report* (7 February 2017), vol 94, at 63–67 and 86–93.
132 Above, n 122.

(c) The traditional basis of claims for negligence may not work so well where there is no driver in control of a vehicle, but the courts may draw references from auto-pilot systems for airplanes, auto-navigational systems for maritime vessels, and product liability law.

(d) However, it is likely that the issues of liability for automated vehicles will be resolved through proof of fault and existing common law. Because of this, all test autonomous vehicles must log travel data to facilitate accident investigation and liability claims.

(e) Any autonomous vehicles are expected to be able to operate on existing roads with minimal supporting structure.

(f) Questions regarding insurance, data-sharing and intellectual property are still being studied by the authorities.

4.7 Notably, while the above points give a sense as to the Government's broad priorities and views on the balance between facilitating technological advancement and ensuring road safety,[133] they do not provide direct answers to the liability-related issues we have identified. However, it is important to reiterate that the existing regulations concern the authorised use and testing of autonomous vehicle technology, rather than mainstream use. They are crafted with the assumption that such technology is still in its infancy and not ready for large-scale commercialisation, and therefore will probably change over time – if not completely fall away – as the technology becomes mainstream and stabilises in terms of predictability and reliability, and as greater pressure is put on the government to facilitate the state to be a front-runner in this field.

4.8 At the same time, as mentioned earlier, much is already underway behind the scenes in terms of the authorities allowing various manufacturers and companies to experiment with autonomous vehicles, even on Singapore's public roads. The precise regulatory framework (beyond the requirements mentioned above) applicable to any complications that arise during testing, including for example issues how attribution of liability or compensation are regulated, does not appear to be

133 Taeihagh and Lim describe the Singapore government's present approach as an example of the "control-oriented" approach. Control-oriented policy makers, per their taxonomy, "allow for the existence of risks, but take steps to control them by implementing formal policies and regulations" and adopt "[t]raditional methods of risk assessment … to predict and regulate risks" (at 107). Other countries classified by Taeihagh and Lim as taking an equivalent 'control-oriented' approach to Singapore – at least in respect of liability – include Japan, Australia and Germany. Araz Taeihagh & Hazel Si Min Lim, "Governing autonomous vehicles: emerging responses for safety, liability, privacy, cybersecurity, and industry risks" (2019) 39(1) Transport Reviews 103.

publicly known – as noted above, it appears these issues may simply be left to be resolved under existing common law principles.[134]

4.9 In any event, to the extent such testing indicates that the prospect of fully autonomous vehicles on Singapore's roads will become a reality sooner rather than later, such issues will soon need to be addressed directly.

134 In comparison, to use the California example again, apart from having testing regulations that are similar to Singapore's, there is a requirement of US$5 million of insurance.

CHAPTER 5

POSSIBLE FRAMEWORKS FOR DETERMINING LIABILTY

5.1 Preliminarily, one must recognise that any given existing regulatory framework for car manufacturers (of human-driven, non-autonomous cars) to ensure safety – covering features such as airbags, brakes, engines, tyres and so forth – has severe limitations or leaves material gaps if transposed directly to the driverless car context. A self-driving car, whether fully automated or otherwise, has many new characteristics not contemplated by existing frameworks, chief of which is the need for its hardware and software to be constantly updated with patches and new data.[135] As will be seen, this has critical implications on how liability should be determined and apportioned in the event of an accident.

5.2 Furthermore, it should also be recognised that, while legislating based on the various levels of automation may seem sensible in theory, it may not be the most effective or productive approach in the longer term. From a technology perspective, fully autonomous, SAE Level 5 vehicles able to function without human involvement no longer belong in the realm of science fiction. As such, it could be argued that the main impediment to mass deployment of such technology is that almost every country has avoided the question of comprehensively reforming their laws or creating new laws to cope with this new technology: without firm laws in place, manufacturers cannot move from controlled testing to mass deployment. There is also the very visceral fear that any fatal accidents involving an SAE Level 5 vehicle would unduly set back public confidence in the technology, further delaying its introduction to the mainstream.

5.3 On a general level, the jurisdictions surveyed in this report have taken divergent positions with no obvious irreducible common core on how liability should be determined and who should assume the greatest burdens. Broadly however, all liability regimes proposed internationally to date can be said to fall under three distinct streams: (a) negligence; (b) product liability; and (c) no-fault liability. Thus, it is worth considering – as a conceptual experiment and to highlight some of the questions and challenges regulators may face – how those different liability frameworks might apply in a high-autonomy scenario.

5.4 Beginning first with **negligence** – does it provide a suitable framework for determining liability? As briefly mentioned earlier, this would not be an easy route. This is so regardless of the automation level of the self-driving car.

135 Other characteristics not found in regular cars include the vulnerability to cyberattacks and the greater need for fail-safe redundancies.

5.5 Though the laws of negligence may differ depending on the jurisdiction in question, the foundational requirements, in most common law countries at least, are that of duty of care (foreseeability of harm), breach (standard of care), and recoverable damage.[136]

5.6 With reference to Singapore negligence law (using the 2007 Court of Appeal decision in *Spandeck Engineering (S) Pte Ltd v Defence Science & Technology Agency* as a reference),[137] a leading commentator has opined that the first requirement of duty of care might not pose much of an issue in the context of self-driving cars:[138]

> For the manufacturers of AVs … it is factually foreseeable that, should manufacturers be at fault in their design or manufacture of the AV, the owner or user or other road users will suffer loss and very likely personal injury as well. The first stage of the legal proximity test will also be satisfied as there is a physical and causal closeness between the manufacturer and the AV user, owner and other road users … there would appear to be no policy reasons that would serve to negate the liability of the AV manufacturer …[139]

5.7 Indeed, insofar as it is (factually) foreseeable that any negligent act or omission by a self-driving car manufacturer would result in personal injury or loss to the user of the car, and indeed other road users, it would not be difficult to find physical, causal, and circumstantial proximity between the manufacturer and the user (as well as other road users). Further, the policy considerations (the absence of which would negate the imposition of a duty of care under the *Spandeck* test) to promote road safety and public welfare would likely be in favour of an imposition of a duty of care.

5.8 But as regards the second requirement concerning breach of the duty of care, a more nuanced approach is necessitated, given what we know about the multi-faceted technology essential for powering self-driving cars:[140]

> [F]or an AV manufacturer to meet the standard of taking reasonable care in developing a usable and safe AV, the AV must be able to drive and

136 Hannah YeeFen Lim, *Autonomous Vehicles and the Law: Technology, Algorithms and Ethics* (Edward Elgar, 2018), chapter 3.

137 [2007] 4 SLR(R) 100.

138 Hannah Lim, *Autonomous Vehicles and the Law: Technology, Algorithms and Ethics*, above, n 136, chapter 3. One could, of course, argue that negligence only makes sense if there is a driver, as the traditional "reasonable person" analysis in the context of traffic accidents has been centred on the driver's skill rather than the manufacturer's quality.

139 Such principles of 'proximity' may equally be relevant in considering other forms of potential regulatory or legal liability for harms caused by the operation of AI systems. See generally, Law Reform Committee, *Report on the Application of Criminal Law to the Operation of Artificial Intelligence Systems and Technologies*, above, n 24.

140 Hannah Lim, *Autonomous Vehicles and the Law: Technology, Algorithms and Ethics*, above, n 136, chapter 3.

> adequately detect and avoid all kinds of obstacles … the AV must have on-board multiple redundant overlapping detection systems [such as] GPS systems, HD maps, lidars, radars, cameras and infrared systems … and they must be appropriately positioned on the AV … sonar systems and ultrasonic sensors … are to be encouraged as they do complement the work of lidars and radars …
>
> … AVs should, as a matter of back-up safety, include some basic driver controls in the AV, such as a steering wheel[141] and brake pedals, even if they are Level 5 … In the event of any malfunction, hacking or cybersecurity breach, a human being must be able to steer or brake or take other appropriate actions …

5.9 The above, however, mainly pertains to hardware – or otherwise a verifiable standard of care. As previously discussed, the forensic process to determine the source and type of such a malfunction is unlikely to be radically more challenging than what is already done in traffic accidents involving non-autonomous vehicles. But software presents a different level of challenge altogether and renders the question of breach much more complicated to resolve, a problem that will probably be exacerbated as we move up the scale of automation and data processing:[142]

> Hard-coding software is tedious and time-consuming but it must be done with due care and properly. A machine learning algorithm, although itself mathematically sound, is to a large extent heavily dependent on the data it has been trained on, which in turn raises issues concerning the quantity and quality of the datasets, the duration of the training and the parameters and input variables the computer programmers have designed … it is simply not feasible for regulators to work through possibly millions of lines of programming code for each AV to verify that it has been properly programmed to be safe and fit to have on public roads … It is inconceivable that any regulator would be able to hire enough highly specialised personnel skilled … to evaluate all of the algorithms used in an AV … All of the foregoing difficulties would be even more acute for a plaintiff owing to their having lower levels of resources than a regulator and greater difficulties in gaining access to proprietary software source code, input datasets and so on.

141 See also Hannah Lim, *Autonomous Vehicles and the Law: Technology, Algorithms and Ethics*, above, n 136, chapter 3: "eye-tracking or head position tracking technologies would be more appropriate and effective than [a] system of requiring the driver to momentarily touch the steering wheel, and these … would meet the standard of care required for a Level 2 vehicle manufacturer."

142 *Ibid*, chapters 4 and 5. Because of this, the same author went on to state (in chapter 5): "Strict liability is the only way to ensure public safety. It will curb any misleading or deceptive conduct by AV manufacturers and will also engender a responsible culture in the development of AV, and not one driven by profits and kudos … manufacturers and developers are the only ones who know intimately how their AV have been constructed, hence they are in the best position to bear the financial and other risks. Strict liability will also ensure trust in AV as the general public will have recourse to compensation when things go amiss." Product and strict liability are considered further below.

5.10 In other words, bearing in mind that in the general negligence context the standard of care is pegged to industry standards (or the general objective standard of a reasonable manufacturer exercising ordinary care and skill, pursuant to the 2014 decision of *Jurong Primewide Pte Ltd v Moh Seng Cranes Pte Ltd*),[143] proving software defects would be far more challenging than proving hardware defects (i.e. defects in lidars, radars, sensors, and so forth).[144]

5.11 A key challenge is that the relevant evidence for the former, such as programming codes, are usually accessible only by the manufacturer; these are also likely to be proprietary material that would not be amenable to easy discovery or disclosure at any point of the proceedings. Further, one manufacturer's self-driving car may react differently from that of other manufacturers in a particular situation, because the respective computer systems are presented with different datasets, different quantities in these datasets, and use different algorithms in their decision-making. This will again result in greater costs just to secure viable evidence of a possible negligent breach.

5.12 At first blush, one possible way to overcome these evidential hurdles would be to apply *res ipsa loquitur*. This doctrine allows the courts to infer negligence from the circumstances in which such an accident occurred insofar as the occurrence of the accident can be said to "speak for itself".[145] But while *res ipsa loquitur* has been applied in motor vehicle situations by courts around the world[146] and also in Singapore,[147] its successful invocation has been the exception rather than the norm. There is also some doubt as to whether the doctrine changes the legal burden of proof or merely alters the evidential burden of proof,[148] creating another layer of uncertainty that would not bode well if adopted as the primary means for users to establish breach in the self-driving car context.

5.13 In any event, it appears unlikely that the self-driving car scenario would fulfil the elements required for the doctrine to operate. Based on the 2018 Singapore Court of Appeal decision in *Grace Electrical Engineering Pte*

143 [2014] 2 SLR 360.

144 It is also unclear, going forward, what the extent of LTA's involvement is in certifying the viability of every manufacturer's self-driving car, bearing in mind that unlike hardware, software standards are harder to evaluate, and further, the nature of self-driving cars is such that its software and firmware need to be constantly finetuned and updated. The last point assumes greatest relevance when it comes to proving things such as defects and standards of care – would the fact that LTA (or some other body) has "cleared" the self-driving car have any bearing, for instance?

145 See, for instance, *Tan Siok Yee v Chong Voon Kee Ivan* [2005] SGHC 157 at [49].

146 See, for instance, *In re Toyota Motor Corp. Unintended Acceleration Marketing, Sales Practices, and Products Liability Litigation* [2013] WL 5763178.

147 *Ooi Han Sun v Bee Hua Meng* [1991] 1 SLR(R) 922.

148 See generally, Chen Siyuan and Lionel Leo, *The Law of Evidence in Singapore* (Sweet & Maxwell: 2018), chapter 3.

Ltd v Te Deum Engineering Pte Ltd,[149] three elements are conjunctively required: (a) the defendant must have been in control of the situation or thing which resulted in the accident; (b) the accident would not have happened, in the ordinary course of things, if proper care had been taken; and (c) the cause of the accident must be unknown. For self-driving cars, one imagines that the first two elements are likely to be difficult to establish.

5.14 Without being able to prove breach (whether concerning hardware or software issues), the question of recoverability does not even arise, and the claim will necessarily fail once we are talking about self-driving cars that are of SAE Level 3 automation and beyond. Nor is it satisfactory to say, for example, that because human drivers owe a duty of care to other road users, liability should be maintained on the human driver for self-driving cars that are below SAE Level 4. This is because it should still remain open for the victim (or indeed, anyone) to ascertain if the self-driving car was at fault. While regulators could in principle take a radical approach and decide to presumptively locate the burden on the human driver to prove that the self-driving car did not malfunction, this would border on the absurd and make bad policy (presumably, the duty of care is also not located on the regulator, albeit for different reasons).[150] It is of course theoretically true that for non-fully automated vehicles, there may be situations in which the human driver ought to have "overridden" the decisions made by the self-driving car. But for reasons mentioned, it is anticipated that the forensic process to even determine whether this was the real or even partial cause of the accident is where the true difficulty lies.

5.15 Negligence is thus afflicted with a fundamental problem, and on this basis another mode of liability has to be considered.[151]

---

149 [2018] 1 SLR 76.

150 It could be asserted that for self-driving cars that still require a "standby" human driver, there should still be a duty on the driver not to be flagrantly negligent and do things such as speeding or failing to keep a proper lookout. However, it seems purposeless to have a human driver assume exactly the same responsibilities as though the automated systems did not exist. There was a rationale for requiring this when manufacturers were conducting test-drives and the technology was still in development, but by the time self-driving cars are allowed to be marketed en masse, it is unclear why this should still be the case.

151 It is emphasised that this conclusion relates specifically to civil claims. As will be seen in the remainder of this report, because it is so difficult for a party to prove breach – which then affects where the blame should be located – it may not be fanciful to suggest that a scheme that facilitates compensation, with few or no questions asked, may well be preferred (noting that such a scheme would itself raise questions as to, for example, how such a scheme would be funded and the possibility of subsequent litigation (see further paragraphs 2.11 above and 5.23 – 5.29 below)). Whether one wants to take such a 'blunt' approach is ultimately a policy, cost-benefit decision for the regulators. In our view, this approach is more amenable in the context of civil claims, perhaps most so in the context of AVs, where there may still be some doubt over the safety of the technology and no jurisdiction has taken the

(*cont'd on the next page*)

5.16 That being so, might **product liability** provide a suitable basis? As mentioned, while the concept of product liability has never quite taken off in Singapore, it is more well-established in some other jurisdictions, such as the US.[152] However, applying the US conception of product liability to self-driving cars also creates material difficulties. As Hannah YeeFen Lim notes:[153]

> Courts in the US have generally used two tests to determine whether a product has a design defect … a product is defective if it is "dangerous to an extent beyond that which would be contemplated by the ordinary consumer who purchases it" … [or] the foreseeable risks of harm posed by the product could have been reduced or avoided by the adoption of a reasonable alternative design by the seller or other distributor, or a predecessor in the commercial chain of distribution, and the omission of the alternative design renders the product not reasonably safe …
>
> If an AV can navigate one roundabout without problems but crashes at the next roundabout, and the plaintiff cannot access, or cannot comprehend the machine learning algorithms on the entire AV, how does one determine the question of "extent"?
>
> … At the best of times, it will be extremely difficult to discern the design of any given algorithm as it will be, for example, impossible to check through all of the training datasets fed to the algorithms, let alone suggest an alternative design.

5.17 Thus, just as for negligence, the challenge arises less from seeking to show that there was a hardware issue, and more from demonstrating a problem (defect) with the software. This quagmire is seen too in the European conception of product liability. Reference has already been made above to the EU Product Liability Directive; in the context of self-driving cars, the challenge of applying that directive has been stated in the following terms:[154]

---

bold step of rolling out AV technology *en masse*. In contrast, greater precision in determining culpability may be more important in determining, for example, any criminal liability. In that context, therefore, notwithstanding the evidential difficulties described above, it may make sense to adopt a more nuanced approach (for instance, differentiating between levels of automation, defining specific elements of, and defences to the crime in question, and so forth).

152 There are, of course, consumer protection laws but generally the threshold for the consumer to successfully prove unfair practices is quite high.

153 Hannah Lim, *Autonomous Vehicles and the Law: Technology, Algorithms and Ethics*, above, n 136, chapter 5. See also Kim Sunghyo, "Crashed Software: Assessing Product Liability for Software Defects in Automated Vehicles" (2018) 16 Duke Law & Technology Review 300.

154 Hannah Lim, *Ibid*. See also Pyman, "The Liability Blind Spot: Civil Liability's Blurred Vision of Conditionally Automated Vehicles", above, n 87, at 300: "software flaws are neither reasonably preventable nor detectable in individual circumstances […] semantic and syntactic errors can be mitigated by new programming techniques and compilers, often the only method to guarantee there are absolutely no errors is to test its performance in real-life scenarios".

> … what a person would be entitled to expect with respect to safety is a fairly general test and would appear to set the bar quite high for manufacturers of AVs to ensure that their vehicles are safe, do not contain programming bugs or security flaws and so on. This would be the safety level a person is entitled to expect from an AV and a competent driver in the driving task, and since many competent drivers never encounter accidents, the AV should also not encounter accidents …
>
> [However] if a producer can show that the state of scientific and technical knowledge at the time when the product was put into circulation was not able to detect the defect, then it can escape liability …
>
> [This would] swing the pendulum too far in favour of the manufacturer of AVs … It opens the door for manufacturers of AVs to simply assert that they were not able to check through the millions of training datasets they had fed their algorithms … To be able to circumvent strict liability by a qualification that feeds on the incomplete knowledge of an immature technology defeats the purpose of protecting the general public from untested technology.

5.18 In other words, while it might seemingly be less problematic for someone to make a claim under product liability rather than negligence, the process of investigating and gathering evidence – not to mention hiring lawyers with the right skill sets and overcoming challenges relating to manufacturers being out of jurisdiction – is still an unduly long and costly one liable to render satisfactory dispute resolution illusory. Moreover, the evidential hurdles for the claimants, not least in terms of the voluminous data to be sifted through, would only increase as self-driving cars become more and more automated and technologically complex. This challenge persists even if one broadens the definition of a developer or manufacturer (whether in the context of negligence or product liability) to include related parties such as engineers and the makers of parts.

5.19 Moreover, just as it is not necessarily helpful to distinguish between the various levels of automation for negligence, it equally seems unproductive to make that distinction for product liability. One cannot lightly assume that so long as self-driving cars remain conditionally automated, a human driver's failure to actively monitor and respond to the car's automated systems is indistinguishable from a failure to avoid accidents as though those systems were absent – that is, to assume that the quality of the human-machine interface makes it clear when it is reasonable to expect the human to take control promptly and effectively. The real issue, at bottom, is whether it should be for anyone other than the manufacturer to show whether or not the fault lay with the vehicle rather than a human. But being able to do this would likely be expensive and time-consuming, regardless of the level of automation of the self-driving car.

5.20 It is of course possible to consider product liability not in terms of fault but strict liability (broadly conceived) on the manufacturer, including manufacturers of parts. Given in particular how challenging it is (as discussed above), to prove breach of the relevant standard of care, a system of strict liability would arguably be justified on the following bases.

- First, given the nature of programming codes and machine learning, it would be extremely onerous for regulators and claimants to verify the software of self-driving cars and ensure that they are safe for use.
- Second, a system of strict liability would enhance consumer confidence in autonomous vehicle technology, and consumers knowing that they would have smoother recourse to compensation in the event of an accident would presumably be more encouraged to use self-driving cars (whether privately owned or as a ride-hailer).
- Third, the untested nature of autonomous vehicle technology means that there is greater inherent danger in its widespread use, numerous claims of greater reliability and safety notwithstanding. Commentators have analogised the self-driving car situation to the strict liability framework imposed on the aviation industry, even after safety records had improved and commercial aviation became prevalent.[155] In this connection, any argument that strict product liability may stifle innovation and make Singapore a less desirable ground for autonomous vehicle technology should duly countenance the fact that autonomous vehicle manufacturers are in the prime position to alleviate any possible risks and take necessary mitigating measures when developing their technology; it would also not be fanciful to suggest that they have the most incentive to avoid costs by ensuring that their hardware and software are performing properly.[156]

5.21 But these arguments for strict liability aside, there is no question that such liability remains by default an extreme option – maybe even the most extreme option – not least because of its impact on costs and insurance, and (notwithstanding the caveats above) the potential stifling of innovation. At best, it could be conceived as a stopgap measure until the technology reaches a very steady state, a scenario complicated by the sliding scale of autonomy for self-driving cars in the foreseeable future. And as mentioned, if concrete legislative steps are to be taken to regulate the mass deployment of self-driving car technology, then seeking to do so incrementally and differentiate between levels of automation may ultimately outweigh any benefit.

5.22 In any event, in Singapore's case, moving to a strict liability regime from our existing negligence regime could involve significant transition

155 See for instance Kyle Graham, "Of Frightened Horses and Autonomous Vehicles: Tort Law and Its Assimilation of Innovations" (2012) 52 Santa Clara Law Review 1241.

156 See also John Zipp, "The Road Will Never Be the Same: A Reexamination of Tort Liability for Autonomous Vehicles" (2016) Transportation Law Journal 32(2) 137.

costs, even if the new regime were tailored specifically to apply only to self-driving car accidents (which entails its own difficulties).

5.23 How about a **no-fault liability** regime? To disambiguate, no-fault liability regimes (i.e., akin to the one that has been adopted in the UK's AEVA)[157] must be carefully distinguished from strict liability regimes. Although liability in the latter is strict, this merely means that taking reasonable care does not defeat liability (unlike in a negligence framework). The victim still needs to show some sort of fault on the tortfeasor-manufacturer's part by proving the product defective. As explained above, this may seem slightly easier than under a negligence rule – but the victim must still show that the defect caused the accident. A no-fault liability regime, on the other hand, is better understood as a "no questions asked" regime where the victim gets compensation, so long as any harm is suffered. The victim's primary burden is showing that the accident in fact occurred, and that the accident, rather than any negligence or product defect, caused the harm suffered.

5.24 As no-fault liability regimes represent a radical departure from the position in English common law (which has historically been premised on the principle of "no liability without fault"), an *entirely* no-fault tort regime is rare in practice. Japan's "operator liability" rules are in form negligence-based, albeit that the high burden it imposes on the operator to prove three stringent exemption requirements brings it close to no-fault liability in substance. Likewise, the UK has described the AEVA's "insurer liability" regime as coming close to a no-fault liability system, but it is not fully so because of important derogations to allow for contributory negligence and limitations of liability (in this vein, one cannot simply assume that the current compulsory motor insurance regime in Singapore would function exactly the same for autonomous vehicles as well – and if insurance was to work in a universal, no-questions-asked way, there would need to be a lengthy consultation process for that).

5.25 The relative simplicity of a no-fault liability regime seems particularly attractive for addressing the aforesaid conceptual problems that self-driving cars create. But insofar as there exists cogent reasons for why the law has required those legal and evidential issues to be proven in the first

157 While it has not been applied to self-driving cars just yet, New Zealand's existing motor accident compensation regime provides a useful comparison. There, the Accident Compensation Corporation or ACC is a government body that handles all claims for personal injuries, including injuries not caused by motor accidents. Anyone, regardless of the circumstances leading to their personal injury, has coverage (but this also means they essentially relinquish their right to sue at-fault parties). Funds for motor accident injury pay-outs come from the ACC's Motor Vehicle Account. This account is funded by petrol levies and motor vehicle licensing fees. Seeking compensation is not meant to be a cumbersome process, and the longstanding status of the ACC implies that there is public buy-in to this method of fund creation.

place, completely abandoning them would invariably raise further questions. In the case of a manufacturer-funded no-fault liability scheme, for example, it may be asked why manufacturers should be made to pay for accidents even if they had taken all reasonable care (as opposed to absolutely all efforts) to produce a non-defective autonomous vehicle. Further, without a system for screening out irresponsible manufacturers from responsible manufacturers, a free-rider problem could emerge if we applied an economics analysis: if all manufacturers contribute to the fund regardless of how safe their technology is, there would be inefficiently low incentives for manufacturers to ensure the safety of their products. The burden would then fall on the government (or whoever else is administering the no-fault regime) to investigate each case to police out irresponsible manufacturers. Although the government or regulator may be better placed to do this than the victim, given the complex state of autonomous vehicle technology, intractable difficulties are likely to remain.

5.26 In the final analysis, the most important questions with regard to a no-fault liability regime concern which party(ies) should bear the formal incidence of contributions to the fund and whether this fund can be administered in a way that does not overly disincentivise precaution and safety. Various other policy considerations will also likely arise, such as how any compulsory manufacturer contributions would be received by and enforced against manufacturers (most of whom are not based in Singapore).[158] Nor is imposing a broad-based levy a perfect alternative: why, for example, should all road users (including those who do not use or own self-driving cars) bear formal incidence for such a fund (assuming the fund only extends to self-driving car accidents). And finally, as is the case for product liability, for Singapore to move to a no-fault liability regime, even just for autonomous vehicles, would involve significant transition costs.

5.27 Given the foregoing, and Singapore's current use of a negligence-based regime (for non-autonomous vehicles), perhaps the question to be asked is whether certain modifications can be made to that existing regime to import the desirable features of product liability and no-fault liability, while preserving the advantages of a negligence rule. In this light, the UK's experience of seeking to introduce 'no-fault' elements through the AEVA acts as a useful reference. While it was bold in putting forth that legislation (and appears to have been a frontrunner internationally in expounding on safety driver standards and responsibilities), there are issues with the legislation that serve as a lesson for policy makers here:

158 However, if a manufacturer's contributions are tied to a measure of the safety of that manufacturer's vehicles (e.g. the number of accidents its vehicles have been involved in or performance on certain safety tests), then this compulsory contribution could become in itself a screening device to identify safe manufacturers, since unsafe manufacturers would be less willing to contribute and self-select themselves out by exiting Singapore.

(a) First, the statute does not address the underlying legal issues with autonomous vehicle accidents. The statute's primary mechanism lies in deeming the vehicle's insurer primarily liable for accidents. The intention is for the insurer to then claim against whoever is "responsible" for the collision. The question of establishing who is "responsible", as well as questions of causation (see the terms "cause", "direct result of", "resulting from", "arising out of", which under conventional statutory interpretation do not mean the same things), are presumably left to the courts to decide on a case-by-case basis (or less charitably, for subsequent law review).

(b) Second, the UK explicitly declined to follow the SAE International's definitions, preferring instead to establish a register of automated vehicles. While this allows flexibility in the class of vehicles to be regulated, it may also introduce additional uncertainty to an AV industry already familiar with the SAE definitions. Notably, in the US, the NHTSA's definitions are more aligned with the SAE's.

(c) Third, there may be legal conceptual problems raised by the AEVA's approach. Implicit in the statute is the recognition that AVs may drive themselves,[159] "cause" accidents,[160] and have "fault" for certain "behaviour".[161] It remains to be seen how a doctrine like causation, which requires both causation in fact and law, may be applied to automated vehicles. One might argue that the statute confers a limited form of legal personality to the vehicle such that it is capable of the above legal acts. Yet this does not seem intentional, particularly insofar as past proposals to confer electronic personality to autonomous systems have been vehemently opposed by industry experts and promptly shelved.

5.28 Moreover, even though the UK's legal regime as established in their Road Traffic Act is superficially similar to Singapore's,[162] there exists a subtle, but material difference in how vehicles are insured in both countries. Effectively, the UK insures the driver while Singapore insures the vehicle. To illustrate, suppose X is the registered owner of the vehicle and its primary driver. In both countries, X would be required to purchase insurance for the vehicle. In the UK, this insurance policy would only cover

159 This is implied by the definition of an automated vehicle as a vehicle capable of driving itself.

160 Section 2 is titled "Liability of Insurers etc where accident caused by automated vehicle".

161 Section 6(3) establishes that contributory negligence should take effect "as if the behaviour of the automated vehicle were the fault of the person made liable for the damage by section 2 of this Act".

162 Compare sections 143 and 145 of the UK Road Traffic Act 1988 with sections 3 and 4 of Singapore's Motor Vehicles (Third Party Risks and Compensation) Act.

situations where X is negligent. If X permits Y to drive the vehicle and Y negligently gets into an accident, it is Y's insurer that will be liable.[163] In Singapore, X's insurance policy would cover situations where X is negligent and also situations where other permitted drivers like Y are negligent. So while it is true that adopting a model akin to the AEVA here could alleviate the problem that victims have in proving negligence, if it were, it may need to be tailored to ensure that it matched local insurance practices.

5.29 In conclusion, there are probably cogent reasons why no jurisdiction has come up with a comprehensive and convincing liability framework for motor accidents involving autonomous vehicles (wherever they may lie in the SAE spectrum). While Singapore may desire to be a first-mover in using autonomous vehicular technology on our roads, the best regulatory framework to put in place is far from clear.[164]

163 The AEVA amends the UK Road Traffic Act 1988 to require that the policy under which the driver is insured also covers situations where the accident was caused by an automated vehicle (AEVA, Schedule, para. 19).

164 As mentioned earlier, another development worth observing would be that of operators of fleets – be it cars or buses, or run by private or public entities. Indeed, such AVs may well be deployed en masse before privately owned AVs. Whether a different liability framework should apply for such operators may depend partly on whether there is a "command centre" of sorts. For instance, in one model of autonomous fleets that some jurisdictions are considering, the command centre can "take over" when a vehicle of its fleet has run into problems. Of course, this requires a reliable way for the vehicle and the command centre to communicate, and there will be related questions of when the command centre is supposed to assume and relinquish control, and whether that could affect the issue of liability. Our tentative view is that the existence of a command centre should not necessarily have any effect on liability. A command centre may be better thought of as a regulatory requirement, so that when an AV – especially a fully autonomous, Level 5 vehicle – has run into problems, passengers will not be left stranded in the middle of nowhere. Moreover, because of the additional resources fleet operators have, an even stronger case may be made that (for civil cases at least) there should be default compensation across the board.

GLOSSARY[165]

AI System — a machine-based system able, for a given set of human-defined objectives, to make predictions, recommendations, or decisions that influence real or virtual environments. Such systems are able to operate with some level of **autonomy**, and can be incorporated into hardware devices or entirely software-based.

Algorithm — a set of rules or instructions (i.e. mathematical formulas and/or programming commands) given to a computer for it to complete a given task.

Artificial Intelligence (AI) — a set of technologies that seek to simulate human traits such as knowledge, reasoning, problem solving, perception, learning and planning, and, depending on the AI model, produce an output or decision (such as a prediction, recommendation, and/or classification).[166]

Auditability — the readiness of an **AI system** to undergo an assessment, by internal or external auditors, of its **algorithms**, **data** and design processes.

Autonomy/autonomous — the ability of an **AI system** to function (i.e. to take decisions and act) independently without human intervention.

Bias — the distortion or skewing of an **AI system**'s outputs, either due to the design of the algorithm or due to the input **datasets** utilised by the AI system being unrepresentative or discriminatory. Two common forms of bias in **data** include:

- selection bias (when the **data** on which an **AI system** bases its outputs are not representative of the actual **data** or environment in which the **AI system** operates); and
- measurement bias (when the process or means by which **data** is collected results in that gathered **data** being skewed or distorted).

165 The definitions in this glossary have been adapted from various sources for the specific purposes of the present series of reports. They are intended as an aid to the reader and should not be treated as exhaustive or authoritative.

166 We note that there is no widely-accepted or authoritative definition of artificial intelligence. The definition used here is a non-exhaustive, adapted definition used in the Personal Data Protection Commission Singapore's Model Artificial Intelligence Governance Framework, Second Edition (2020) <*https://www.pdpc.gov.sg/-/media/Files/PDPC/PDF-Files/Resource-for-Organisation/AI/SGModelAIGovFramework2.pdf*> (accessed 9 September 2020).

Big Data — datasets characterised by their:

(a) size ("Volume");

(b) complexity ("Variety") (i.e. typically including structured, semi-structured and unstructured **data** derived from diverse sources); and/or,

(c) rate of growth ("Velocity"),

from which detailed insights can be derived using advanced analytical methods and technologies (e.g. **neural networks** and **deep learning**).

Black box (1) — an **AI system** whose decision-making operations are not **explainable** – that is, the means by which it reached a particular decision or action are neither disclosed nor able to be ascertained by human **users** or other interested parties (for example regulators, testers or auditors).

Black box (2) — see **Event Data Recorder**.

Bot — a software program (typically operating on the internet) designed to run automated tasks.

Chatbot — an **AI system**, commonly used in customer-facing commercial settings, designed to engage in dialogue with a human **user** via voice or written methods, and thus to simulate a human-to-human conversation. As the Chatbot engages in more conversations, it learns to better respond to future questions and more closely imitate real conversations. Examples include the "Ask Jamie" chatbot on the Singapore Ministry of Health's website, or the 'Live Chat' help functions on e-commerce platforms such as Lazada or Shopee.

Cyberattacks — a malicious attack launched from one or more computers against other computers, networks or devices.

Data — information defined as and stored in code to be processed or analysed. Individual records of data (for example a person's name or the temperature recorded by a smart home device at a particular date and time) can be combined together to form **datasets**. A distinction is commonly drawn between personal data (those which individually or in combination with other data, identify an individual) and non-personal data (those that do not).

Data portability — the legal obligation to comply with a data subject's request for their **data** to be moved from one organisation to another in a commonly used machine-readable format.

Dataset — a collection of **data** (often stored in the form of one or more databases).

Deep learning — a specific form of **machine learning** that utilises **neural networks** to model and draw insights from complex structures and relationships between **data** and **datasets**. The term derives from the 'layers' of the **neural network** down through which the **data** passes.

Deployer — the person or legal entity responsible for putting an **AI system** on the market or otherwise making it available to users. The deployer may also have on ongoing role in operating or managing the **AI system** after deployment.

Derived data — any **data** element that is created and/or derived by an organisation through the processing of other **data** in the possession and/or control of the organisation.

Designer / **Developer** — a person or legal entity who takes decisions that determine and control the course or manner of the development of **AI systems** and related technologies. 'Development' for these purposes means (a) designing and constructing **algorithms**, (b) writing and designing software, and/or (c) collecting, storing and managing **data** for use in creating or training **AI systems**.

Event Data Recorder — a machine that continuously records the inputs received by an **AI system** (e.g. what its sensors 'see'), its relevant internal status data, and its outputs. Sometimes colloquially known as a 'black box recorder'. The intention of such event data recorders, equivalent to those installed in aircraft, is to allow post-hoc analysis of the **AI system**'s operation (e.g. in the lead up to an accident or system failure).

Explainability — the ability for a human, by analysing an **AI system**, to understand how and why the system reached a particular decision or output.

Explainable AI — broadly, either (a) **AI systems** which are designed to be inherently **explainable**, such that a human can understand how and why the system reached a particular decision or output; or (b) tools designed to help extract explanation from pre-existing **black box** and other complex **AI systems**.

Human-Machine Interface — a screen, dashboard or other interface which enables a human **user** to engage with an **AI system** or other machine.

Internet of Things, the (IoT) — a system comprised of interconnected devices (commonly known as smart devices) that transfer **data** and communicate with one another via the internet.

Machine Learning — a technique whereby a set of **algorithms** utilise input **data** to make decisions or predictions, and thus to 'learn' how to complete a task without having been specifically programmed to do so.

(Artificial) Neural Networks — a series of 'layered' **algorithms** used to analyse, classify, learn from and interpret input **data**. The values from one layer are fed into the next layer to derive increasingly refined insights. Artificial Neural Networks are so named because they broadly mimic the biological neural networks in the human brain.

Operational Design Domain (ODD) — the domain within which an **AI system** is designed to operate, and which may be limited by geography, in time, or by some other parameter.

Operator — see **User**.

Over-the-air updates — updates or changes automatically made to an **AI system** by an entity (for example the **deployer**) after the system has been deployed and is operational.

Robotics — technologies that enable machines to perform tasks traditionally performed by humans, including by way of **AI** or other related technologies. This series of reports focuses on robots that act fully or partially autonomously, without human intervention.

Robustness — the ability of an **AI system** to deal with errors that arise during execution or erroneous input, and to continue to function as intended or without insensible, unexpected or potentially harmful results.

SAE Levels — a classification system developed by the Society of Automotive Engineers International, which classifies **autonomous** vehicle technologies according to six levels of increasing automation (and declining human involvement).

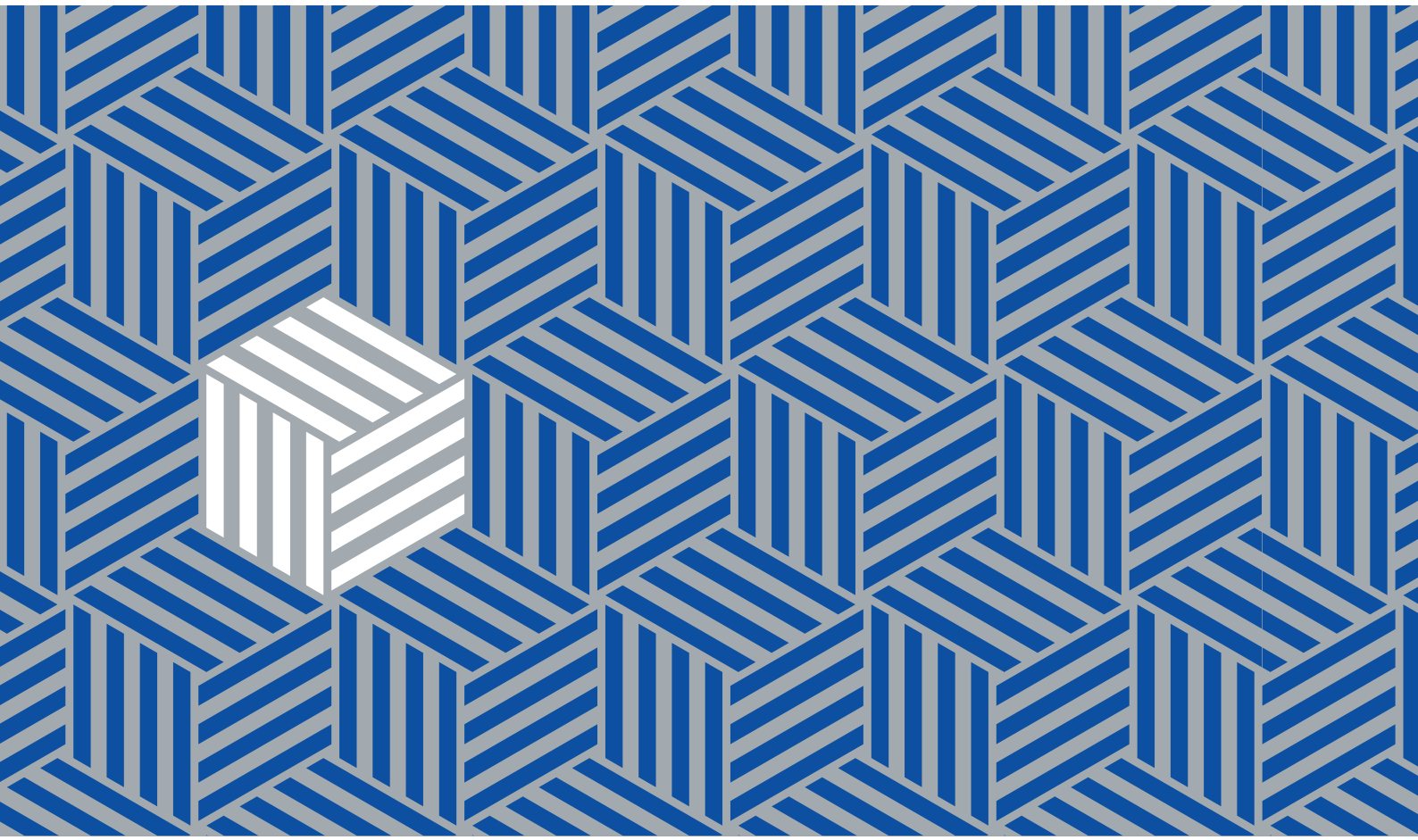
Traceability — the documentation, in an easily understandable way, of (a) an **AI system**'s decisions, and (b) the **datasets** and processes that yield those decisions (including those of data gathering, data labelling and the **algorithms** used). This provides a means to verify the history, and contexts in which decisions are made.

Transparency — various mechanisms or requirements intended to provide additional information to users, regulators and other stakeholders regarding the algorithmic decision-making processes undertaken by **AI systems**, and the input **data** relied on by such systems. Such transparency may be achieved through, for example, disclosure of source code, **explainability** and/or **traceability**. Transparency also implies that **AI systems** should (in practice, and by design) carry out their functions in the way communicated to others (including **users**).

User — any natural or legal person who uses an **AI system** for purposes other than development or deployment.

Verifiability — the process of ensuring that the outputs of an **AI system** correspond with its intended function or purpose (for example by testing

the system using a range of different inputs, or ensuring that a particular input consistently and repeatedly leads to a desired output).



ISBN 978-981-14-7745-4 (softcover)
978-981-14-7746-1 (e-book)