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**Adaptive and experimental governance in the implementation of
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Adaptive and experimental governance in the implementation of autonomous vehicles: The case of Singapore

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Abstract

While autonomous vehicle (AV) is dubbed as an innovative and disruptive transport solution that could potentially ease congestion and facilitate seamless mobility, there have been debates and discussions on the technological risks that AVs can pose, and the extent to which AVs are ready for large-scale deployment. Using a case study approach that combines both primary and secondary research, this paper examines the policy development and policy implementation experience of AVs in Singapore. We first charted the trajectory of AV adoption and regulatory progression of AVs in Singapore. We then analysed the five major technological risks and implications involved in AV deployment in Singapore, which include safety, privacy, cybersecurity, liability and effects on the incumbent industry. We also examined policy measures that have been taken so far to minimise the risks and implications. We further evaluated the various governing strategies adopted by the Singapore government in AV deployment. Our findings reveal that provisions within the current legislations continue to govern privacy, cybersecurity and liability issues, while a five-year regulatory sandbox has been implemented to govern the safety of AVs. Singapore dominantly exhibits an adaptive strategy that is both pre-emptive and responsive in governing many of the uncertain and intricate issues that could arise in AV deployment. The quest to be nimble in governing novel technologies such as AVs in Singapore exhibits two seemingly opposing policy styles – prescriptive and experimental – harmonising within the regulatory environment to facilitate rapid adoption of AVs in the near future. The regulatory lessons derived from the governance of AVs in Singapore could provide both policy guidance and facilitate and inform advanced policy discussions among the regulators and developers of AVs as well as other autonomous systems as the world gears up to face the impending technological disruptions due to the large scale adoption of autonomous systems.

Keywords: Autonomous vehicles, Driverless cars, Adaptive, Experimental, Governance, Singapore, Safety, Privacy, Cybersecurity, Liability, Incumbent Industry, Case study

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Introduction

The rise in the adoption of autonomous vehicles (AVs) across many countries in the world is expected to disrupt our conventional ways of travelling, working and enjoying our leisure in time to come (West 2016). While AVs hold many promises in improving our overall quality of life, there have also been discussions on the adverse implications of AVs (Crayton and Meier 2017; Thomopoulos and Givoni 2015; Pettigrew 2016; Taeihagh and Lim 2019). This poses governing constraints to the authorities when policy and law are not well in place to address the technological risks of AVs that could occur. This paper will address the current knowledge gap by discussing the regulatory risks and governance strategies of AV adoption by illustrating and analysing the implementation experiences in Singapore using a case study approach. As one of the top seven economies that achieve the highest performance in terms of ICT investment and innovative technology adoption worldwide (Baller, Dutta, and Lanvin 2016), Singapore is witnessing tremendous technical progress and significant regulatory changes in the development of AVs in recent years. This rapidly changing policy landscape in AV adoption makes Singapore well-positioned to be an illuminating case that could offer important policy lessons to other countries which are still contemplating on the deployment of AVs as a potential transport solution to alleviate heightened transport demand.

This study aims to examine the risk implications and governance strategies adopted in the implementation of AVs in Singapore. The paper is organised as follows: the next section provides an overview of AVs and is followed by the presentation of an analytical framework that comprises various types of technological risks and governance strategies of autonomous systems in the third section. The fourth section describes the case study of AV adoption in Singapore and the fifth section discusses the different types of technological risks of AVs and analyses the governance strategies adopted by the Singapore government. The discussion section addresses some of the remaining challenges of the large-scale roll-out of AVs, as well

as appraises the policy capacity and policy responses of the Singapore government in AV adoption. The last section concludes with policy implications.

Analytical Framework: Technological Risks and Governance Strategies for Emerging Technologies

Technological risks

AVs, like many other emerging technologies, possess both uncertain and embedded technological risks such as safety, privacy, cybersecurity, liability, and effects on the incumbent industry (Taeihagh and Lim 2019). The exponential pace in the development of disruptive technology which is now pervasive in almost every aspect of the human sphere stimulates heightened academic interests and warrants an upsurge of policy attention on the governance of their technological risks prior to their massive roll-outs. Indeed, there has been burgeoning scholarly work in recent years focusing on the debates, imperatives and frameworks of risk governance in emerging technologies.

Table One: Technological risks of AVs

Types of risks	Definitions
Safety	Ensuring that human lives are protected from fatal or injurious car accidents through road safety regulations.
Privacy	Compelling the party that controls sensors, high definition maps and other systems in AV that contain personal information to preserve the anonymity of that information and ensuring the ethical use of data.
Cybersecurity	The ability to prevent software hacking and misuse of vehicles at all levels of automation by shielding the wireless network from the hackers' control.
Liability	The apportionment of the responsibility of errors among the first party (human driver) or third-parties (manufacturers and/or developers involved in the design of the safety system) in the event of vehicle accidents.
Effects on the incumbent industry	Employment implications and labour market effects of widespread AV adoption to the existing actors in the incumbent industries (i.e. transport industry such as taxi drivers, bus drivers, truck drivers and private car owners).

Adopted from Taeihagh and Lim (2019)

Governance strategies for emerging technologies

In this study, we applied a framework depicting five different types of governance strategies which have been applied in previous studies on the governance of disruptive technologies in the transport sector (Li, Taeihagh, and de Jong 2018; Taeihagh and Lim 2019). We strengthened the original framework by synthesising it with the various approaches adopted in risk regulation and governance highlighted above. Our analytical framework for the analysis of risks in AV implementation comprises five governance strategies as follows:

Table Two: Explanations of Five Governance Strategies in Novel Technology Adoption

Governance Strategies	Explanations
No-response	This strategy is commonplace, especially in the early stage of new technology adoption fraught with information asymmetries (Li, Taeihagh, and de Jong 2018). A no-response strategy is also likely to be taken when there remain tremendous ambiguities in the adoption of new instruments and policies.
Prevention-oriented	This strategy is most notably observed when there are vested interests between government and various interest groups to preserve the status-quo (Li, Taeihagh, and de Jong 2018).
Control-oriented	This strategy resembles the conventional regulatory state approach observed in many traditional risk assessments (Moran 2003). It is commonly adopted when governments decide to allow novel policies to be rolled out but at the same time try to deploy measures that maintain government authority (Moran 2003).
Toleration-oriented	This strategy focuses on risk tolerance rather than risk mitigation, and is strongly anticipatory in nature. (O’Grady 2015).
Adaptation-oriented	This strategy focuses on building robust structures within the government that could withstand volatility and policy uncertainty. It is imbued with policy learning and lesson-drawing at its core and ongoing stakeholder participation, policy experiments, and the ability to engage in long-term thinking and planning are some of the hallmarks of this strategy (Boin and van Eeten 2013; Li, Taeihagh, and de Jong 2018; Janssen and van der Voort 2016; Duit 2015).

Methods

We employed a single case study approach to analyse the development, risks and governance strategies of AVs in Singapore from 2013 to 2018. The case study is an all-encompassing approach that allows an inquiry to be approached using flexible research design, various data collection methods and distinctive approaches to data analysis (Yin, 2018).

Our data sources are built from both primary and secondary research.² Combination of both primary and secondary data sources not only allowed a more enriching case description to be constructed but also enabled sufficient triangulation to build a compelling and verifiable narrative, besides achieving higher conceptual validity (Creswell and Miller 2000).

Case Description

Phase One: Agenda-setting (June 2013 – May 2014)

The idea of AV implementation in Singapore first surfaced in the public domain in June 2013 after a speech given by the former Minister of National Development, Mr Khaw Boon Wan, in World Cities Summit Mayors Forum in Spain. The idea of driverless electric cars actively replacing private cars was envisioned to be a likely event in Singapore in a decade. This will be facilitated by the extension of the invitation to private industries to tap into Singapore's business-friendly environment to implement mobility innovations (The Straits Times, 2013). The following year, the Land Transport Authority (LTA) was actively studying the viability of AV as a deployable and scalable mode of transport in Singapore (Tan 2014).

Phase Two: Formation of Policy Advisory Group and AV Research Initiatives (June 2014 – December 2014)

The policy agenda of AV adoption in Singapore took off with the formation of a 17-member Committee on Autonomous Road Transport for Singapore (CARTS), led by Permanent Secretary from the Ministry of Transport. CARTS comprised international experts, academics, and industry leaders to lead the policy visions and lay out the technological possibilities of AV

² Our primary research involved key informant interviews. We interviewed multiple stakeholders who are involved primarily in the formulation and implementation of AV in Singapore to gauge their perspectives and experiences on the design, policy intention and implications of the policies governing AV in Singapore. These interviews were supplemented by secondary research, which involved collecting news articles, grey literature, policy documents, law, and statutes of Singapore, which were related to AV.

in Singapore (Ministry of Transport 2014). CARTS was the very first policy advisory group on AVs in Singapore that attempted to lead the direction of mobility concepts in self-driving vehicles. Since its formation, CARTS has been working towards developing four major AV portfolios: (i) fixed and scheduled services (efficient mass transport on intra- and inter-town services), (ii) point-to-point, mobility-on-demand services (shared services with dynamic routing that cover point-to-point, first- and last- mile type journeys), (iii) freight (long distance delivery of goods), and (iv) utility (street cleaners) (LTA 2015).

Around the same time, some major research initiatives were launched. For instance, Singapore Autonomous Vehicle Initiative (SAVI) was set up to support CARTS in charting the directions of AV development in Singapore. Complementing CARTS, SAVI was initiated to be a technology platform to drive research and development and test-bedding for AV in Singapore. A memorandum of understanding was signed between LTA and A*STAR for this initiative, with LTA assuming an active regulatory role in implementing AV in the next five years. Three significant research portfolios – AV, autonomous mobility system and automated road system - were announced to be the focus in improving Singapore's land transport system by driving AV adoption and implementation in Singapore (LTA 2014).

Phase Three: Active Implementation via Intensive roll-out of new AV trials (January 2015 – January 2017)

Phase three that spanned about two years was an intense AV trial period in Singapore that witnessed the burgeoning roll-out of new AV trials across the entire city-state. In January 2015, the first AV research hub and test bed - a collaboration between LTA and JTC Corporation in One-North Business Park - was officially announced by LTA. Both parties would cooperate to test out a 6 km long test route in phases during the trial. The optimism for AV in Singapore was ramped up in June 2015, when a request for information (RFI) was rolled out by LTA to

seek proposals for point-to-point mobility-on-demand – a real-time and demand-driven autonomous bus trial in the One-North business park was launched (Tan 2015). In October the same year, another AV trial kickstarted in Gardens by the Bay (The Straits Times 2015).

In January 2016, an AV trial for a shuttle was launched in Sentosa Island (LTA) (Duca 2015). Three months later, AV initiative was seen expanded to mobility pods with a partnership forged between SMRT and 2getthere (a Dutch-based company) to bring in 24-passenger driverless pods to Singapore as a form of group rapid transit vehicle that will operate in “semi-controlled” designated areas where drivers’ behaviours and speed can be better managed. Already proven to be working in major cities such as Abu Dhabi and Rotterdam, driverless pods are touted to be safer and more energy efficient. Not only they were driverless, but they could also operate on-demand, effectively providing first- and last-mile services in the future (Lim 2016a; Lim 2016c). In August 2016, a second major research initiative on AV – Centre of Excellence for Testing and Research of Autonomous Vehicle (CETRAN) – was launched in Nanyang Technological University (NTU) (Abdullah 2016b). The launching of CETRAN is a further signal of aspiration that Singapore inclines to be the world leader in AV systems not only in virtual programming and technical operations but also in setting regulatory and licensing standards that govern safety and cybersecurity (Abdullah 2016b). At the same time, LTA also announced its partnership with NuTonomy - a US-based driverless vehicle start-up to launch the world’s first driverless taxi trial (Abdullah 2016c). This partnership quickly bears fruit when NuTonomy launched the first on-demand driverless taxi trial in the world, ahead of Uber's driverless taxi trial in Pittsburgh, by the end of August (Abdullah 2016d).

Throughout the intensive implementations of one trial after another since January 2015, the technological risks of AV had not been widely discussed in the public domain. Preliminary discussion in the media, however, had started to increase incrementally by the end of 2015. For instance, preventive measures that accounted for the design of each physical component in the

AV comprehensively to minimise security breaches - including to consider whether the vehicle needs to be connected to the internet all the time - was urged to be put in place. Besides, deciding the extent of control given to the third party in taking charge of some of the critical systems in AV to prevent hackers from wreaking havoc of the information systems before it is too late also started surfacing in the public domain (Duca 2015).

In October 2016, the first AV accident that involved a collision between a driverless car and a lorry occurred, bringing public attention to the safety and security of AV roll-out in Singapore (Channel News Asia 2016). NuTonomy, the industry player that was involved in this incident, called for a temporary halt in its AV trial (Lee 2016). There was no significant discussion on liability issues at that point. This incident, nevertheless, did not seem to result in significant backlash and deter the authorities from taking a step back from AV trial implementations. In the immediate aftermath of the first AV accident, Singapore ramped up the installation of infrastructure for AV test-beds and expanded the test routes for AVs (Siong 2016). In addition, many new partnerships on AV were formed in the same month. First, the National Environment Agency (NEA) and MoT released a joint RFI on the design and development of AVs for street-cleaning (Abdullah 2016a). Besides, the first driverless bus trial – a collaboration between LTA and NTU - was launched in Jurong West around the same time (Lim 2016c). Within a month, NuTonomy announced that it had resumed its AV trial, citing the collision that happened a month ago as a technical fault arising from a software anomaly. It, however, announced that it had worked to improve its software system (Lim 2016b).

In January 2017, MoT announced the testing of the first autonomous truck platooning system to transport containers on driverless trucks within the port terminal in Singapore. An agreement was also signed with two automobile companies (Toyota Tusho and Scania) to develop and test this AV system that is intending to bring about more efficient freight movement (Channel News Asia 2017c).

Phase Four: Crystallisation of regulatory framework and expansion of AV capacity (February 2017 – December 2018)

The year 2017 witnessed the crystallisation of a preliminary regulatory framework for AV as well as the expansion of capacity in AV trials and vision in Singapore. In February 2017, the regulation of AV in Singapore was in place with the amendment of the Road Traffic Act (Channel News Asia 2017b). The revision of legislation effectively endows MoT with the power to set new rules that can place time and space limits on the AV trials. The new ruling also prescribes construction and determines standards for the design and use of AV equipment. These standards include requiring the vehicle to be equipped with devices to capture and store sensor data and video footage and have a failure alert system that allows safety human drivers to take immediate manual control of the vehicle in the event of technical failure. The need to place liability insurance or security deposits before the inception of any approved AV trials was also enacted in the amended Road Traffic Act. The amended act further impose requirements for data sharing from all ongoing AV trials (The Law Revision Commission, 2018). By August 2017, road traffic rules specifically for AVs, which are more comprehensive compared to the amended Road Traffic Act announced earlier in the year, was in place. These rules specify the criteria for application to undertake the trial or the actual use of AV, the conditions for authorisation of AV, and the obligation to place liability insurance or paying a security deposit of no less than \$1.5 million in the event of inability to obtain liability insurance. The exact penalties in the form of fines were also stipulated and enforced should the manufacturers fail to place liability insurance or fail to ensure proper maintenance of AV. The road traffic rules for AV also requires every AV to be installed with a data recorder for data collection and ensuring that data and records are kept for an additional three years beyond the expiry date of authorisation.

Furthermore, the rules oblige AV developers to report incidents that arise as a result of a malfunction and any accidents that involve deaths and injuries (Pang 2017). The amendment of the Road Traffic Act and the enactment of Road Traffic Rules for Autonomous Motor Vehicles are intended to be a regulatory sandbox that will be effective for five years. After which, either an enactment of permanent legislation or an extension of the current regulatory sandbox will ensue to govern AVs in Singapore (Channel News Asia 2017b).

Since February 2017, capacity for AV trials was further increased by expanding the test areas of existing trials, increasing new trials and announcing the masterplans for future trials. In April 2017, LTA announced that driverless buses would be rolled out in Singapore by 2020 after the signing of a partnership agreement with ST Kinetics. Cybersecurity of AV was one of the key agenda covered in the announcement, with the new partnership promised to tap on cybersecurity academic experts to perform vulnerability analysis and penetration tests to ensure the fidelity of the AV system and safety of the passengers (Loke 2017). Two months later, the Minister of Transport announced that test routes for AV trials in One-North Business Park were extended by 55km covering the entire campus of NUS and two nearby residential estates – Dover and Bouna Vista. The residents of these estates would also be actively involved in the trial in time to come (Channel News Asia 2017a).

In October 2017, the first driverless truck was launched and piloted by a Belgian logistics company Katoen Natie on a US oil and gas multinational Exxon Mobil's integrated manufacturing hub in Jurong Island. The driverless truck will be used to transport goods and products between the company's packaging stations and storage facilities. This partnership initiative also announced various safety measures that were in place such as demarcated speed zones with inbuilt speed controls in the vehicles and installation of key signs on the road including a safety bumper that would trigger emergency stop of the vehicle in the event of its physical contact with another object (Tanoto 2017). In November 2017, LTA announced that

three new towns - Punggol, Tengah and Jurong Innovation District – would be the first three areas in Singapore with driverless buses and shuttles operating on the public roads at off-peak hours from 2022 onwards. This announcement was also followed by a six-month RFI to seek extensive feedback from industry players and academic institutions on information and facilitators required for successful implementation of AV buses and shuttles (Kwang 2017).

In March 2018, a new skills framework under the Industry Transformation Map (ITM) was unveiled by LTA as a proactive strategy to gear up the nation's transport workforce to be ready for the ongoing trials and deployments of disruptive technologies that will change the transport industry job demand in the near future. This framework plans to up-skill or re-skill existing transport workers to assume job roles that require higher skill sets. Besides, LTA plans to create 8,000 high value-added new public transport jobs that cross-fertilise expertise from both transport and IT industries at all job levels, including professionals, managers, executive and technicians, to keep up with the pace of transport development in Singapore by 2030 (Farhan 2018). The announcement of the new AV trials went on after the introduction of new skills framework by LTA. In April 2018, NTU announced the plan to deploy driverless minibuses, a group rapid transit AVs on its campus by 2019 (Teo 2018). In June 2018, LTA announced that a public trial for a driverless shuttle in Sentosa Island would begin in 2019 (Channel News Asia 2018b).

Case Analysis

Technological risks in AV implementation

Safety: The safety of AVs remains a hot-button issue to date. Globally, this issue generated a surge of public attention with the occurrence of a fatal accident involving a self-driving car by Uber hitting a woman in Arizona that resulted in her death in March 2018 (Channel News Asia

2018a). Other safety concerns with regard to the conditions of issuance of AV licence for AV pilots, whether or not there is a need for human driver to be on board, and the extent of intervention from human drivers that are needed as well as whether they have adequate time to react, are salient questions that would need to be addressed (Holder et al. 2016; Borenstein, Herkert, and Miller 2017). In Singapore, the first AV accident involving a piloted AV and a lorry controlled by a human driver raised safety concerns (Channel News Asia 2016). At the immediate aftermath of this incident, an investigation by LTA and the traffic police was launched. After verifying that there were no major flaws in the AV system, the AV pilot was allowed to resume its trial (Respondent 1). Amidst the multiple AV trials that have taken place in Singapore, private AV developers opined that the clarity of safety regulations for AV can be further enhanced.

Privacy: Privacy breach is prevalent in the era of big data when information in digital devices could easily be exposed to an algorithmic risk that is often exploited for commercial gains (Hannah-Moffat 2018). In Singapore, The Personal Data Protection Act (PDPA) is a standard, harmonised and content-neutral regulation enacted in the parliament in October 2012 and in effect since the middle of 2014 governs privacy issues across all private sector entities (Chik 2013). In the context of privacy for AVs, PDPA is currently the *prima facie* guide for the implementation of AVs in Singapore. A few respondents opined that PDPA needs to be enhanced for better safeguarding against the misuse of personal information (Respondents 10, 15).

Cybersecurity: Cybersecurity threat is most commonly associated with the malicious attack by hackers into the information systems of AV to extract either personal information of the drivers/passengers or the vehicles (Holder et al. 2016). In Singapore, some respondents opined that the new cybersecurity law which was enacted in early 2018 is overall generically targeted and to address the upstream manufacturing issues for small AV companies that depend heavily

on other companies to provide key components of AVs for the process of assembling the AVs there need to be additional targeted legislation (Respondents 15, 19, 20). As the sector lead, LTA is currently working with the various government agencies and think-tanks to launch a technical reference to set clear standards for AV implementation in Singapore. This technical reference, which will inform the testing and certification regime in Singapore, entails a highway-code for the AVs, functional safety requirements of the technology, cybersecurity assessment and data exchange format (Respondent 1, 4 and 19).

Liability: Liability issue is another aspect of technological risk that warrants explicit legislatures and governing frameworks. At the heart of the current debates concerning liability is which party should bear the responsibility in the event of vehicle collisions, under what circumstances are insurance claims justified, how should insurance premiums be recalibrated under different scenarios (Thomopoulos and Givoni 2015; Nikitas et al. 2017). One expert opined that the current legislation would be untenable to resolve the liability issues as AV technology becomes more complex and sophisticated over time. For instance, it was suggested that there needs to be a protocol and systematic approach to establish the reasons of AV accidents, and ascertain whether they are due to technical failure or a result of a security breach (Respondent 20).

Effects on the incumbent industry: Massive adoption of AV will have profound labour market impacts on the existing actors hired by the incumbent industries. These impacts do not only confine within the conventional transport industries (Beede, Powers, and Ingram 2017; Alonso Raposo et al. 2018), but also has rippling effects to many other service industries (West 2015; Beede, Powers, and Ingram 2017; Clements and Kockelman 2017). In Singapore, AV deployment will inevitably affect workers in the incumbent transport industry in the medium to long-term. These impacts are likely to be felt more directly among taxi drivers and bus operators as compared to other types of transport occupations (i.e. truck), as more AV public

shuttles ply the street and shared AVs replace human driver centric ride-sharing services at the moment (respondent 1, 2, 4, 5, 10, 11). Respondent 11 expressed optimism that the public transport ITM launched in March 2018 will be able to transit local transport workers to roles whereby higher technical skills are required through job redesigns and training programmes aiming to re-skill the workers.

Governance strategies in AV deployment in Singapore

No-response strategy: Before 2013, AVs were an emotionally-distant mobility concept to most Singaporeans as there were no significant public-private partnerships observed in the AV scene, and the public debates that were going on were not significant. Until 2013, the government had been adopting a no-response strategy for AV implementation.

Prevention-oriented strategy: This strategy has not been adopted by the Singapore government in AV implementation so far. There has been no direct sanction of AV start-ups in Singapore since AV was brought to the policy agenda in 2013. Besides, neither penalties nor forfeitures have been reported to date.

Control-oriented strategy: The launch of a five-year regulatory sandbox after the amendment of Road Traffic Act and enactment of Road Traffic Rules for Autonomous Motor Vehicles in 2017 that would pave the way for permanent regulations governing the AV systems in Singapore signals a more active and authoritative role taken by the government in AV implementation (The Law Revision Commission 2018; Pang 2017). With MoT given the full authority to set the rules for AV and determines its product design (The Law Revision Commission 2018), the government formally assumes full control of setting the rules and standards of AV implementation in Singapore.

Toleration-oriented strategy: While the guidelines and strategies adopted by the Singapore government in AV governance are mostly prescriptive especially in governing safety (Respondent 1 and 8), there are also elements of a toleration-oriented strategy observed. The best example to illustrate this is the entrepreneurship promoting spirit adopted by the Singapore government towards the policy community of the AV industry, especially the developers and scientific communities. When the collision involving an AV piloted by NuTonomy and a lorry occurred in October 2016 and resulted in the temporary halting of the AV trial, an investigation into the incident was immediately launched.

Adaptation-oriented strategy: Adaptation-oriented strategy is the most dominant strategy taken by the Singapore government in strengthening the city-state's readiness in AV deployment in several pilot towns in the near future. One could argue that this strategy is inherent in the political DNA for a small and young country like Singapore that has always inculcated in its political leaders the need to be visionary, adaptive and flexible in various public policies. The launch of the first driverless taxi trial between LTA and NuTonomy in August 2016 is an example to illustrate the adaptive experimental spirit of Singapore in embracing novel technologies. Besides, the set-up of CARTS - the policy advisory group and the launch of major research initiatives also illustrated adaptive policy response in the governance of AVs in Singapore. The constant alignment of AV safety and cybersecurity practices in Singapore with international standards is another policy move to be agile and keep abreast with the latest safety and cybersecurity norms worldwide (Respondent 19). In light of the labour market disruptions that could occur as a result of AV adoption in the future, the launch of the new skills framework under the ITM in March 2018 further showcases the government's responsiveness in adapting to the changing demands of the future transport labour markets.

Discussion

In the midst of gearing up towards widening the geographical coverage for AV deployment, Singapore has ample room to devise safety guidelines and road traffic regulations for AV that are timely and in line with the dynamic evolution of AV technology. The foremost challenge is to enable AVs to move seamlessly in various road traffic conditions that comprise vehicles with mixed operating modes during the trials. In the early stage of AV deployment, there will be a combination of fully-autonomous, semi-autonomous and non-autonomous vehicles on the road, and how would the situational awareness and interpretive logic of AVs be raised in their interactions with human drivers would be a key challenge (Prakken 2017). At this point, Singapore, alongside many western countries that have piloted AVs, is employing a non-binding regulatory framework in governing the risk of AVs in order to avoid stifling the development and adoption of AVs (Taeihagh and Lim 2019; Vellinga 2017). As the regulatory sandbox governing AVs are now recommended for five years, the road traffic regulations in Singapore are bound to evolve as more learnings occur from various pilot trials.

Overall, the Singapore government possesses high policy capacity in the policy implementation of AVs. In particular, there exists high institutional capacity in strategically monitoring and steering the adoption of AVs as a predominant mode of transport in the next decade, high political capacity in controlling the public agenda of AVs to be in line with its strategic interest, high regulatory capacity in applying a non-binding instrument for its road traffic regulations with flexibility of amendment in the near future, and high financial capacity to generate and invest a significant amount of its financial resources to a novel technology that holds uncertain promise in the eyes of many other countries (Saguin, Tan, and Goyal, forthcoming). The non-binding five-year regulatory sandbox launched to govern the risks of AVs at this point exhibits the adaptive experimentation spirit of the government which is a key characteristic in the

regulatory life cycle that has emerged from gestation period and slowly progresses towards its maturity (Howlett and Newman 2013; Newman and Howlett 2014).

Conclusion

Singapore is joining the ranks of other leading innovation hubs across the world to actively develop standards and regulate technological risks that are associated with AV deployment. The dominant adaptive governing strategy and prescriptive policy style adopted in the governance of AVs are testimonies of its determination to leverage on autonomous systems in its quest to implement a smart nation initiative. It also possesses the ability to strike a delicate balance between promoting innovation and placing the necessary regulations. The Singapore case of governing AVs exemplifies that strong political will coupled with high policy capacity could drive the rapid implementation of a novel technology, conditioned upon the presence of public policies that foster experimentalist and dynamic partnerships, an open business environment that favours innovation, as well as inter-agency collaboration that implement utility-maximising policy decisions that are consistently subjected to careful deliberations.

References

- Abdullah, Zaki. 2016a. Driverless Cleaning Vehicles in the Works for Singapore Streets. *The Straits Times*, 17/10/2016. <https://www.straitstimes.com/singapore/driverless-cleaning-vehicles-in-the-works-for-singapore-streets>.
- 2016b. New Centre for Testing and Research on Driverless Vehicles. *The Straits Times*, 02/08/2016. <https://www.straitstimes.com/singapore/new-centre-for-testing-and-research-on-driverless-vehicles>.

[research-on-driverless-vehicles.](#)

——— 2016c. Two Firms to Test Driverless Cars for Last-Mile Trips; Service Set to Start by 2018. *The Straits Times*, 02/082016.

[https://www.straitstimes.com/singapore/transport/two-firms-to-test-driverless-cars-for-last-mile-trips-service-set-to-start-by.](https://www.straitstimes.com/singapore/transport/two-firms-to-test-driverless-cars-for-last-mile-trips-service-set-to-start-by)

——— 2016d. World's First Driverless Taxi Trial Kicks off in Singapore. *The Straits Times*, 26/08/2016. [https://www.straitstimes.com/singapore/transport/worlds-first-driverless-taxi-trial-kicks-off-in-singapore.](https://www.straitstimes.com/singapore/transport/worlds-first-driverless-taxi-trial-kicks-off-in-singapore)

Alonso Raposo et al. 2018. An Analysis of Possible Socio-Economic Effects of a Cooperative, Connected and Automated Mobility in Europe. Ispra, Italy.

[http://publications.jrc.ec.europa.eu/repository/bitstream/JRC111477/kjna29226enn.pdf.](http://publications.jrc.ec.europa.eu/repository/bitstream/JRC111477/kjna29226enn.pdf)

Baller, Silja, Soumitra Dutta, and Bruno Lanvin. 2016. The Global Information Technology Report 2016: Geneva.

[http://www3.weforum.org/docs/GITR2016/WEF_GITR_Full_Report.pdf.](http://www3.weforum.org/docs/GITR2016/WEF_GITR_Full_Report.pdf)

Beede, David, Regina Powers, and Cassandra Ingram. 2017. The Employment Impact of Autonomous Vehicles. Washington, D.C.

[http://www.esa.doc.gov/sites/default/files/Employment_Impact_Autonomous_Vehicles_0.pdf.](http://www.esa.doc.gov/sites/default/files/Employment_Impact_Autonomous_Vehicles_0.pdf)

Boin, Arjen, and Michel J. G. van Eeten. 2013. The Resilient Organization. *Public Management Review* 15(3):429–45.

CNA 2016. Driverless Car Collides with Lorry in One-North. *Channel News Asia*, 18/10/2016. [https://www.channelnewsasia.com/news/singapore/driverless-car-collides-with-lorry-in-one-north-7748244.](https://www.channelnewsasia.com/news/singapore/driverless-car-collides-with-lorry-in-one-north-7748244)

- 2017a. Autonomous Vehicle Trials to Be Expanded beyond One-North: Khaw Boon Wan. *Channel News Asia*, 23/06/2017.
<https://www.channelnewsasia.com/news/singapore/autonomous-vehicle-trials-to-be-expanded-beyond-one-north-khaw-8972562>.
- 2017b. Regulations in Place to Ramp up Driverless Vehicle Trials in Singapore. *Channel News Asia*, 07/02/2017.
<https://www.channelnewsasia.com/news/singapore/regulations-in-place-to-ramp-up-driverless-vehicle-trials-in-sin-7622038>.
- 2017c. Singapore to Start Trials of Driverless Trucks for Port Transport. *Channel News Asia*, 09/01/2017. <https://www.channelnewsasia.com/news/singapore/singapore-to-start-trials-of-driverless-trucks-for-port-transport-7558490>.
- 2018a. Self-Driving Uber Car Kills Arizona Woman Crossing Street. *Channel News Asia*, 20/03/2018. <https://www.channelnewsasia.com/news/world/uber-self-driving-car-kills-woman-pedestrian-arizona-10057942>.
- 2018b. Sentosa Testing Autonomous Shuttle; Public Trial to Begin in 2019. *Channel New Asia*, 05/06/2018.
<https://www.channelnewsasia.com/news/singapore/sentosa-testing-autonomous-shuttle-public-trial-to-begin-in-2019-10382496>.
- Chik, Warren B. 2013. The Singapore Personal Data Protection Act and an Assessment of Future Trends in Data Privacy Reform. *Computer Law & Security Review* 29(5):554–75.
- Clements, Lewis M, and Kara M Kockelman. 2017. Economic Effects of Automated Vehicles. *Transportation Research Record*, 2606(1):106–114.
- Crayton, Travis J, and Benjamin Mason Meier. 2017. Autonomous Vehicles: Developing a

- Public Health Research Agenda to Frame the Future of Transportation Policy. *Journal of Transport & Health* 6:245–52.
- Creswell, John W, and Dana L Miller. 2000. Determining Validity in Qualitative Inquiry. *Theory Into Practice* 39(3):124–30.
- Duca, Sean. 2015. Security Must Drive Design of Driverless Cars. *The Straits Times*, 19/12/2015. <https://www.straitstimes.com/opinion/security-must-drive-design-of-driverless-cars>.
- Duit, Andreas. 2015. Resilience Thinking: Lessons for Public Administration. *Public Administration* 94(2):364–80.
- Farhan, Noor. 2018. Up to 8,000 Public Transport Jobs to Be Created by 2030 under Industry Transformation Map. *Channel News Asia*, 12/02/2018. <https://www.channelnewsasia.com/news/singapore/jobs-public-transport-industry-transformation-map-lta-9950796>.
- Hannah-Moffat, Kelly. 2018. Algorithmic Risk Governance: Big Data Analytics, Race and Information Activism in Criminal Justice Debates. *Theoretical Criminology* 1-18.
- Holder, Chris, Vikram Khurana, Faye Harrison, and Louisa Jacobs. 2016. Robotics and Law: Key Legal and Regulatory Implications of the Robotics Age (Part I). *Computer Law & Security Review* 32(3):383–402.
- Howlett, Michael, and Joshua Newman. 2013. After ‘the Regulatory Moment’ in Comparative Regulatory Studies: Modeling the Early Stages of Regulatory Life Cycles. *Journal of Comparative Policy Analysis: Research and Practice* 15 (2):107–21.
- Janssen, Marijn, and Haiko van der Voort. 2016. Adaptive Governance: Towards a Stable, Accountable and Responsive Government. *Government Information Quarterly* 33(1):1–

5.

Kwang, Kevin. 2017. Self-Driving Buses, Shuttles to Be Tested in 3 Towns from 2022.

Channel News Asia, 22/11/2017. <https://www.channelnewsasia.com/news/singapore/self-driving-buses-shuttles-test-punggol-jurong-tengah-9427850>.

Li, Yanwei, Araz Taeihagh, and Martin de Jong. 2018. The Governance of Risks in Ridesharing: A Revelatory Case from Singapore. *Energies* 11(5):1277.

LTA 2014. Joint Release by the Land Transport Authority, JTC & A*STAR - A SAVI Step towards Autonomous Transport.

<https://www.lta.gov.sg/apps/news/page.aspx?c=2&id=29525082-5265-4139-bc3b-0241a4639d46>.

——— 2015. Joint Release by the Land Transport Authority & MOT - Self-Driving Vehicles Will Transform Singapore's Transport Landscape.

<https://www.lta.gov.sg/apps/news/page.aspx?c=2&id=e6dc5dff-8892-4f7f-9a3e-c89d29c0642c>.

Lee, Yi Ying. 2016. nuTonomy Halts Vehicle Trials after Accident at One-North. *Channel News Asia*, 19/10/2016. <https://www.channelnewsasia.com/news/singapore/nuatomy-halts-vehicle-trials-after-accident-at-one-north-7738274>.

Lim, Adrian. 2016a. Driverless 'Pods' May Run Here Soon. *The Straits Times*, 21/04/2016.

<https://www.straitstimes.com/singapore/transport/driverless-pods-may-run-here-soon>.

——— 2016b. nuTonomy Resumes Driverless Car Trials in One-North, Says Software Glitch to Blame for Accident. *The Straits Times*, 24/11/2016.

<https://www.straitstimes.com/singapore/nuatomy-resumes-driverless-car-trials-in-one-north-after-accident>.

- 2016c. Self-Driving Buses to Be Tested in Jurong West under LTA and NTU Tie-Up. *The Straits Times*, 19/10/2016. <https://www.straitstimes.com/singapore/transport/self-driving-buses-to-be-tested-in-jurong-west-under-lta-and-ntu-tie-up>.
- 2016d. SMRT Ties up with Dutch Company in Plans to Bring Driverless ‘Pod’ Travel into Singapore. *The Straits Times*, 20/04/2016. <https://www.straitstimes.com/singapore/transport/smrt-ties-up-with-dutch-company-in-plans-to-bring-driverless-pod-travel-into>.
- Lim, Hazel Si Min, and Araz Taeihagh. 2018. Autonomous Vehicles for Smart and Sustainable Cities: An in-Depth Exploration of Privacy and Cybersecurity Implications. *Energies* 11(5):1062.
- Loke, K.F. 2017. Driverless Buses to Be Rolled out on Singapore’s Roads by 2020. *Channel News Asia*, 10/04/2017. <https://www.channelnewsasia.com/news/singapore/driverless-buses-to-be-rolled-out-on-singapore-s-roads-by-2020-8698180>.
- MOT 2014. Committee on Autonomous Road Transport for Singapore. Ministry of Transport. <https://www.mot.gov.sg/news-centre/news/Detail/Committee-on-Autonomous-Road-Transport-for-Singapore>.
- Moran, M. 2003. *The British Regulatory State*. Oxford: Oxford University Press.
- Newman, Joshua, and Michael Howlett. 2014. Regulation and Time: Temporal Patterns in Regulatory Development. *International Review of Administrative Sciences* 80 (3):493–511.
- Nikitas, Alexandros, Ioannis Kougiyas, Elena Alyavina, and Eric Njyoya Tchouamou. 2017. How Can Autonomous and Connected Vehicles, Electromobility, BRT, Hyperloop, Shared Use Mobility and Mobility-As-A-Service Shape Transport Futures for the Context

- of Smart Cities? *Urban Science* 1(4):365–85.
- O’Grady, Nathaniel. 2015. Data, Interface, Security: Assembling Technologies That Govern the Future. *Geoforum* 64:130–37.
- Pang, Kin Keong. 2017. *Road Traffic Act (Chapt.276): Road Traffic (Autonomous Motor Vehicles) Rules 2017*. Singapore.
- Pettigrew, Simone. 2016. Why Public Health Should Embrace the Autonomous Car. *Australian and New Zealand Journal of Public Health* 41(1):5–7.
- Prakken, Henry. 2017. On the Problem of Making Autonomous Vehicles Conform to Traffic Law. *Artificial Intelligence and Law* 25(3):341–63.
- Saguin, Kidjie, Si Ying Tan, and Nihit Goyal. 2018. Mapping Scientific Research on Policy Capacity: A Bibliometric Analysis and Qualitative Framework Synthesis. International Workshop on Public Policy I. Pittsburgh.
- Siong, Olivia. 2016. Test Beds for Driverless Vehicles Ramped up at One-North. *Channel News Asia*, 18 October 2016. <https://www.channelnewsasia.com/news/singapore/test-bed-for-driverless-vehicles-ramped-up-at-one-north-7748346>.
- Taeihagh, Araz, and Hazel Si Min Lim. 2019. Governing Autonomous Vehicles: Emerging Responses for Safety, Liability, Privacy, Cybersecurity, and Industry Risks. *Transport Reviews* 39(1):103-28.
- Tan, Christopher. 2015. The Drive to Be Driverless. *The Straits Times*, 25/07/2015. <https://www.straitstimes.com/lifestyle/motoring/the-drive-to-be-driverless>.
- Tan, Dawn Wei. 2014. LTA to Study Use of Driverless Vehicles as Viable Mode of Transport. *The Straits Times*, 03/06/2014. <https://www.straitstimes.com/singapore/transport/lta-to-study-use-of-driverless-vehicles->

[as-viable-mode-of-transport.](#)

Tanoto, Brandon. 2017. Singapore's First Driverless Truck Makes Debut at Jurong Island.

Channel News Asia, 24/10/2017.

<https://www.channelnewsasia.com/news/singapore/singapore-s-first-driverless-truck-makes-debut-at-jurong-island-9338308>.

Teo, Gwyneth. 2018. Driverless Minibuses to Be Rolled out at NTU by 2019. *Channel News*

Asia, 16/04/2018. <https://www.channelnewsasia.com/news/business/autonomous-vehicle-ntu-smart-campus-10142506>.

The Law Revision Commission. 2018. *The Statutes of the Republic of Singapore: Road*

Traffic Act (Chapt.276) (2004 Ed., Informal Consolidation May 2018). Singapore.

The Straits Times. 2013. Driverless Cars May Be Reality within 10 Years: Singapore's

Khaw. *The Straits Times*, 15/06/2013. <https://www.straitstimes.com/world/driverless-cars-may-be-reality-within-10-years-singapores-khaw>.

The Straits Times. 2015. Singapore's First Self-Driving Vehicle Trials Takeoff. *The Straits*

Times, 11/12/2015. <https://www.straitstimes.com/singapore/transport/singapores-first-self-driving-vehicle-trials-take-off>. [

Thomopoulos, Nikolas, and Moshe Givoni. 2015. The Autonomous Car—a Blessing or a

Curse for the Future of Low Carbon Mobility? *European Journal of Futures Research* 3:14.

Vellinga, Nynke E. 2017. From the Testing to the Deployment of Self-Driving Cars,

Computer Law & Security Review 33(6):847–63.

West, Darrell M. 2016. *Moving Forward: Self-Driving Vehicles in China, Europe, Japan,*

Korea, and the United States. Washington DC.

<https://www.brookings.edu/research/moving-forward-self-driving-vehicles-in-china-europe-japan-korea-and-the-united-states/>

Yin, Robert K. 2018. *Case Study Research and Applications*, 6th edition. Thousand Oaks, Calif.: SAGE.