



# Insuring future automobility: A qualitative discussion of British and Dutch car insurer's responses to connected and automated vehicles

Johannes Kester

Transport Studies Unit, School of Geography and the Environment, University of Oxford, South Parks Road, OX1 3QY Oxford, United Kingdom

## ARTICLE INFO

### Keywords:

Car insurance  
Connected and automated vehicles  
Motor vehicle insurance  
Expectations  
Interviews

## ABSTRACT

Connected and Automated vehicles (CAVs) are transforming road-transport. Within this transformation, motor vehicle insurers are one of the key involved stakeholders. This paper explores car insurers' expectations, challenges and activities around the development of CAVs. It draws on a literature review and 31 semi-structured interviews with insurers and other experts in the United Kingdom and the Netherlands. The analysis confirms challenging, simultaneous local and international, discussions about 1) the shift in liability from drivers to automated driving systems, 2) a commercial conflict over in-vehicle data access and 3) the future of shared mobility. Interviewees anticipate that the outcome of these discussions will affect their underwriting, risks, claims processes, business models, product offerings and competitive strategies. Simultaneously, insurers respond to these challenges and affect them as they move forward, thereby helping shape the regulatory frameworks of future CAV mobility. They do so in various ways, which differ across countries and insurers, yet generally can be classified into three typical activities: (non) participation in pilot-projects, lobbying and learning. The paper concludes with a number of political and scholarly reflections.

## 1. Introduction

Connected and automated vehicles (CAVs) are vehicles that through automation and connectivity can take over part, or all, of the tasks of a human driver. Automation is differentiated in levels: level 0 (no driving automation), level 1 (driver assistance), level 2 (partial driving automation), level 3 (conditional driving automation), level 4 (high driving automation) and level 5 (full automation) (SAE, 2018). In turn, connectivity is expected to enable vehicles to communicate with each other and with their local infrastructure, which would, for instance, allow for cooperative collision mitigation and platooning (Shladover, 2018). CAVs are expected to reduce road fatalities, traffic congestion, road and parking space pressure, resource use and emission footprints (Fagnant & Kockelman, 2015; Maurer, Gerdes, Lenz, & Winner, 2016). Over the last decade, the number of CAV pilot projects with advanced driving systems (ADS) has been steadily increasing, as is the use and level of advanced driving assistance systems (ADAS) in commercially available vehicles. And while fully automated vehicles are still in development, their effects on transport and mobility are already visible: from innovations in machine learning, sensors, communication and vehicle technology (Sheehan, Murphy, Mullins, & Ryan, 2019; Stilgoe, 2018) to a renewed awareness around road safety (Bissell, 2018), new interactions with the

built environment (Fraedrich, Heinrichs, Bahamonde-Birke, & Cyganski, 2019), updated regulatory frameworks around safe innovation on public roads (Lee & Hess, 2020) or discussions about vehicle ownership and alternative travel modes, models and behaviour (Kim, Park, Oh, Lee, & Chung, 2019; Maurer et al., 2016).

A key understudied stakeholder in light duty CAV development is the motor vehicle insurance sector, which is both challenged by CAVs and affecting their development. Specifically, connectivity and automation from level 2 onwards challenge the driver-oriented focus of modern-day car insurance. They affect both 'risk exposure and insurance demand' (Gatzert & Osterrieder, 2020) to different degrees pending the level of automation. The current literature on the role of insurance around CAVs can be roughly characterized by four clusters. A first cluster includes grey literature and legal studies that primarily focus on the question of liability (e.g. Abraham & Rabin, 2019; Channon & Marson, 2021; Col-lingwood, 2017; Lohmann, 2016). A second cluster entails the grey literature that studies the impact of CAVs on the size of car insurance markets, premiums and new risks (e.g. Albright, Schneider, & Nyce, 2017; Cusano & Costonis, 2017; DAC Beachcroft, 2019; Hamilton, Strovink, & Young, 2019; Karp & Kim, 2017). A third cluster involves a smaller group of papers around insurance business models in a wider shared mobility ecosystem (e.g. Gatzert & Osterrieder, 2020; Pütz,

E-mail address: [johannes.kester@ouce.ox.ac.uk](mailto:johannes.kester@ouce.ox.ac.uk).

<https://doi.org/10.1016/j.rtbm.2022.100903>

Received 12 July 2021; Received in revised form 18 July 2022; Accepted 6 October 2022

Available online 18 October 2022

2210-5395/© 2022 The Author. Published by Elsevier Ltd. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

Murphy, Mullins, & O'Malley, 2019). While a last very limited number of papers looks at broader legal and governance questions and challenges around CAVs (Hansson, 2020; Lee & Hess, 2020). Together these studies depict a car insurance sector faced with: (1) a fundamental shift in legal liability from driver to ADAS and ADS that facilitate various levels of automation; (2) a legal and commercial conflict with car manufacturers about access to in-vehicle data; and (3) the growth of various new shared mobility models and their impact on private vehicle ownership.

The existing literature thus highlights challenges but contains little in-depth analyses on how individual insurers and the sector are actually responding to CAVs: how some ignore it while others adjust their internal processes, let alone the different responses to various levels of automation, the lobby at a sector level for legal clarity or the participation in pilot-projects. To extend the literature above, this paper utilizes a literature review and a set of 31 semi-structured interviews with car insurance and CAV stakeholders in the United Kingdom (UK) and the Netherlands (NL) to explore their expectations and activities around CAVs. Specifically, the paper examines to what extent CAV insurance differs from traditional car insurance, what kind of obstacles and challenges are identified, and how the insurers act upon these expectations. Contrasting these discussions in two leading European CAV countries further adds a level of contextuality that goes beyond local laws and regulations, highlighting the deeply political choices that insurers and the sector make regarding new technology, safety and investments.

## 2. Reviewing moter vehicle insurance

CAV insurance builds on and breaks away from existing car insurance frameworks and practices. Traditional car insurance is based on contracts wherein one party, the driver or owner of the vehicle, transfers their risk of a monetary loss to the insurer in exchange for a premium. From the consumer side such contracts present themselves as a range of insurance products around private and commercially owned road-approved vehicles (Dionne & Laberge-Nadeau, 2012). In many developed countries, car owners and/or drivers are legally obligated to take out liability insurance, which offers coverage for accidents caused by the driver to a third party. Liability coverage, however, is only one element of car insurance (Siddiqui, 2018). Other elements include collision coverage (for crashes not caused by the insured), comprehensive coverage (weather damage, theft, etc.), personal injury protection (medical expenses and missed income regardless of liability) and uninsured driver accident coverage (where the other party is liable but uninsured, especially valid in countries without an 'insurer of last resort'). Consumers further decide on the covered value, which can range from a car's new value, replacement value to its current sales value. While diverse in offerings, car insurance is highly standardized following strict regulation and decades of jurisprudence. Equally regulated are the premiums that include various obligatory costs, capital reserve requirements and financial taxes, resulting in a market that competes on a small share of said premiums.

Within this setting, car insurers aim to minimize their risks by specifying the coverage through detailed risk analyses on their customers based on key variables such as claims history, driving record, residential area and driver age. These profiles are bundled together in risk pools, which help set premiums and spread potential individual losses across all participants. Insurance companies profit from any surplus premiums received and from the investment returns made on prepaid premiums. The companies compete in various ways, including via cost-savings through optimization and automatization of claims and repair processes. They also fine-tune their risk profiles and risk analyses to reduce the uncertainty of their portfolios, among others by gaining more customer information or by specializing in sectors or geographies. This increase in certainty allows insurers to better target, e.g. lower, their premiums and compete for market share. Companies further compete on the re-insurance of their portfolios to global reinsurance companies which redistribute the risk of portfolios across seasons and

geographies. This is especially relevant for potentially high-cost but low-likelihood claims, like highway multi-car accidents with fatalities, which are too big for any insurer to carry alone. It is however up to the insurance company to decide what level of potential claims is unacceptable and in need of reinsurance or how much they are willing to pay for that.

Besides an optimization of internal processes and a fine-tuning of risk analyses, insurers compete by engaging in activities that reduce the claim level of their driver pools. In other words, they actively inform and induce customers to reduce their risk profile, e.g. to drive more safely. To do so, insurers draw on increasingly richer and personalized databases. The increasing use of more personalized data has seen public and regulatory pushback. For example, some countries no longer allow price discrimination on ethnicity or gender but allow it for age and driving experience, while others forbid the use of all such categories (Abraham, 2013, p. 691). The search for ever finer data continues however, shifting from personal characteristics to actual (real-time) trip frequency and driving behaviour data through voluntary telematics (aftermarket sensors and apps) and accompanying user-based-insurance products like *Pay as You Drive* and *Pay How you Drive* (Tselentis, Yannis, & Vlahogianni, 2017). In doing so, insurers shift from passive to active management of desired driving behaviour. In other words, they shift from investments in road safety campaigns and driver training curricula to direct consumer contact and (dynamic) premium differentiation.

This focus on training and/or incentivizing of drivers originates from a number of challenges that car insurers face. The car insurance literature has extensively discussed moral hazard, adverse selection and fraud as three key operational risks (Abraham, 2013; Siddiqui, 2018). Moral hazard is the tendency of an insured party (the driver) to exercise less care trying to avoid the insured event and its loss (a crash), compared to the care that people without insurance exercise. Adverse selection highlights that "responsible" consumers with less risk of a claim are less likely to procure insurance, while those who know they likely will incur such a loss seek to mitigate it through insurance. Lastly, fraud is a core concern and cost that insurers ultimately pass on to their customers, leading to various detection and surveillance programs (Button & Brooks, 2016; Viaene, Ayuso, Guillen, Van Gheel, & Dedene, 2007). Other pressing operational concerns include regulatory compliance and solvency requirements as well as the impact of automation and big data that are moving underwriting away from specialized human expertise to general portfolio risk management algorithms by large (re) insurers (Jarzabkowski, Bednarek, & Spee, 2015). And then there are more fundamental debates and developments that challenge the business models of car insurance. These include discussions about the insurance of ride-sharing and peer-to-peer sharing economies (Davis, 2015; Longhi & Nanni, 2020; Sachs, 2015), as well as revived discussions about *fault* insurance models versus *no-fault* insurance models where an insurance company pays and only then establishes liability with the other party's insurer (Cole, Eastman, Maroney, McCullough, & Macpherson, 2012).

Given the above, current and future levels of automation and connectivity constitute a fundamental development for car insurers as they displace the driver-orientation that permeates their risk and premium assessments, products and business models. With each level of automation, the driver becomes more of a passenger and hence less relevant in risk and premium assessments. Simultaneously, the automated driving systems, connectivity systems and the interaction between driver and automated systems all bring new risks that affect insurer's risk and premium assessments. For a proper understanding of the extent to which CAVs affect insurers, and insurers affect CAV development, the following sections will study the emerging responses to CAVs from car insurers in the Netherlands and the UK.

## 3. Method

This explorative paper into the response of the car insurance sector to the development of CAVs builds on two methods. First, it is based on a

non-systematic but extensive exploration and review of the academic and grey literature on car insurance and CAVs. This includes the use of broad search terms like insurance, liability and various synonyms for CAVs across Google Scholar and Scopus, with snowballing through references. Second, the study is based on 31 transcribed semi-interviews with experts on car insurance, CAV regulation and CAV development in the United Kingdom and the Netherlands. These countries were chosen as both are recognized and/or self-proclaimed frontrunners in the development of automated vehicles and house strong insurance sectors. Pragmatically, language skills, lockdown regulations and a pre-COVID19 desire to minimize travel emissions played a role as well.

Briefly, the UK is home to the fourth largest insurance market in the world and the largest in Europe. Third-party motor vehicle insurance is a legal requirement in the UK. According to the Association of British Insurers (ABI, 2019), the UK motor insurance market was listed at £10.1 billion annually with around 20 million households owning motor insurance at an average premium of £468 pounds in 2018. That year, for the fourth time since 1994, the sector witnessed an underwriting profit of £515 m pounds a year (up from £258 m 2017). Simultaneously, the sector accepted 98,4% of claims to a value of £29 m pounds per day, the highest claims level in years. It also witnessed an increase in the value of theft claims, a higher number of vehicle fires, and motor fraud estimates at over 54,000 cases to a value of £628 m. In the Netherlands, third party liability car insurance is similarly obligatory. However, given its size and population, it reflects a somewhat smaller market compared to the UK with a total yearly premium value of €5.6 billion in 2019 (Dutch Association of Insurers, 2019). Similarly however, the Dutch car insurance market is witness to strong competition and increasing claim levels due to new technology that drives up repair costs, increasing car fires (12% up from 2018 to a total of 4941), theft and fraud.

For the interviews, experts were identified through a mapping of the main insurance companies and organizations dealing with CAVs in both countries and then tracing the core in-house experts. Other experts followed from snowballing questions during the interviews. Together these approaches and subsequent practical availability resulted in the list in Table 1. The interviews were based on semi-structured questions (see attachment 1) and conducted via phone and video conferencing from June to August 2020. The 45–60 min average interviews were conducted with a guarantee of full anonymity, hence the respondents codes (R01). Recordings were transcribed verbatim in English and Dutch. Transcripts were subsequently coded thematically in NVIVO with English codes applied to the Dutch transcripts.

## 4. Results

The interviews reproduced most of the well-known challenges and expectations on CAV development listed in the introduction, but situated and nuanced them with a range of positions taken by various individual parties. This section describes interviewee's expectations and concerns, starting with a brief overview of the car insurers' wider context, then their sectoral market expectations, their operational challenges, and three arch-typical responses to CAV developments.

### 4.1. Situating, defining and timing CAVs

Interviewees situated their CAV response against a wide range of challenges and developments. Tracked developments include climate change and progressively severe weather patterns, COVID-19, demographic developments (aging population), Artificial Intelligence (AI) and the increasing integration of telecom, energy, food, water and transport systems such that a disruption in one cascades onto others. Other key overarching challenges for the sector include issues around compliance, new regulations on solvency, consumer privacy and cyber risk. Interviewees further reinforced that the car insurance market is a highly competitive market with 'virtually non-existent margins (R21)', where smaller companies specialize and general insurers keep it around

**Table 1**  
Overview of interviewees

Nr.	Country	Title	Sector
R01	UK	Managing Director (Underwriting)	Insurance company
R02	NL	Special advisor	Semi-public authority
R03	NL	Innovation manager	Insurance company
R04	UK	Partner	Law company
R05	UK	Director	Consumer and research organization
R06	UK	Manager (Repair strategy)	Insurance company
R07	UK	Project manager	Regulation
R08	UK	Director of Research	Insurance company
R09	UK	Head of Strategy	Branch organization (CAV industry)
R10	NL	Policy Advisor	Branch organization (vehicle industry)
R11	UK	Market Services Executive	Branch organization (insurance)
R12	NL	Director (x1) & Head of Innovation (x1)	Insurance company
R13	NL	Director	CAV operator
R14	NL	Assistant Professor (Law)	Research
R15	UK	Manager (Claims)	Insurance company
R16	NL	Council member (x1) & project managers (x2)	Safety organization
R17	NL	Director of Public Affairs	Consumer organization
R18	UK	CEO	Insurance company
R19	UK	Lecturer (Law)	Research
R20	NL	Senior product manager	Insurance company
R21	UK	Program Manager	Branch organization (insurance)
R22	UK	Independent Senior Consultant	Consultancy
R23	UK	Program Manager	Public authority
R24	NL	Manager (x1) & Consultant (x1)	Consultancy
R25	UK	Project Lead	Branch organization (vehicle industry)
R26	NL	Senior Policy Advisor	Branch organization (insurance)
R27	UK	Solicitor	Insurance company
R28	NL	Manager	Insurance company
R29	Europe	Policy Officer	Public authority
R30	NL	Client Director	Insurance company
R31	Europe	Policy Advisor	Branch organization (insurance)

for its predictable yearly revenue and cashflow, which pays for infrastructure and staff. Inherent to the debate, and thus mentioned in almost every interview and the literature, are the broader mobility changes beyond CAVs that challenge the car insurance market even further: the beginning trend to more shared and alternative forms of vehicle ownership and usage, micro-mobility, mobility-as-a-service and further electrification. These mobility developments affect insurers as they all require attention and thus take up capacity to identify new risks and alternative business models and products (Pütz et al., 2019).

Within this context, the shift from drivers to ADS challenges established liability definitions and practices. One of the first questions for insurers is therefore about definitions and language. The interviews highlighted a variety of CAV conceptualizations. While some interviewees kept to clear cut distinctions (cf SAE, 2018; Stayton & Stilgoe, 2020), others used terms like assisted driving, autonomous vehicles, self-driving, 'part-time self-driving (R14)' interchangeably. Generally, assisted driving referred to vehicles with ADAS technologies that are on the market, such as blind spot monitoring, adaptive cruise control, break assist or self-parking features (SAE levels 1 and 2). The use of concepts like self-driving or driverless was generally frowned upon as imprecise and depicted by some as a marketing trick of private vehicle manufacturers. In contrast, the use of automated and autonomous vehicles was more fluent, although the former is gaining credit for its processual character in the literature and the interviews. For insurers, however, the key distinction is not between automated and autonomous, but between (assisted) human control and ADS control: 'Either something

is automated or it's not ... by which we mean, is it capable of driving itself in that particular scenario, for example on a motorway, without the need for any human oversight to ensure safety, in which case the liability rests on that particular system (R21).' This differentiation between level 2 and 3 is not clear cut (different parties and governments see it differently), but once accepted leads to two phases: one where driver and ADS operate the vehicle in turns (level 3–4), and one where drivers have become passengers (level 5) and insurance shifts purely to product liability. Lastly, some interviewees deemed connectivity another concept in need of clarification; pointing to the many levels of connectivity, data sharing and integration available as well as the multitude of new technological options that they enable. As one Dutch respondent summarized their position: *'I at times call the first generation automated vehicles autistic; they are only looking and working for themselves (R17).'*

Language use is of key importance as these concepts carry various temporal expectations. In line with earlier discussions, experts, explicitly or implicitly, touched on what could be seen as two development pathways (cf Law Commission & CCAV, 2018). The first, automation, with a focus on the evolution of ADAS to initial ADS (SAE levels 2 & 3), reflects the increasing automation of vehicles already or soon available in the private vehicle market. In this vision the focus is on the present and near term future and a constant roll-out of new functionality towards the promise of full autonomy. The second pathway (SAE level 4 and up) instead describes upgraded vehicles that drive fully autonomous in particular situations (and with safety drivers). Here automation and autonomy denote a future promise, as *'being something further down the line (R15)'*, which some see happening in the near to mid-range future and others discuss on a long-term future bases. Such temporal expectations matter as they can be (mis) used to gain public support or market new vehicles (Borup, Brown, Konrad, & Van Lente, 2006). They also contain assumptions about operational design domain (e.g. areas where vehicles are operating, whether particular road-types, speed limits, weather conditions, etc.) and the type and rate of adoption (which affect mixed-traffic conditions where non-automated traffic mixes with various levels of automation). This too is of interest to insurers, as the speed of transition and/or adoption determines their capacity and ability to identify risk and calculate prices (Cusano & Costonis, 2017).

#### 4.2. The future of car insurance

In addition to the development pathways, insurance participants voiced their expectations around the impact of CAVs on the overall car insurance market. With a ~ 63% estimated reduction in claims costs by 2050 and a shift from insurance products aimed at private vehicle customers to a mix of commercial fleet insurance and product liability products (valued up to a cumulative \$81 billion for first movers by 2025 - Karp & Kim, 2017), KPMG expected the global vehicle insurance market to shrink in size by around 70% (Albright et al., 2017). In terms of business products, these reports highlight new opportunities like cyber security, product liability for sensors, algorithms and infrastructure problems (Karp & Kim, 2017) as well as commercial opportunities around in-vehicle data collection for Original Equipment Manufacturers (OEMs) with insurers to either license said data, form partnerships, act as a third-party administrator or compete with OEMs and fleet operators (Albright et al., 2017).

The interviews confirm most of these sentiments. Experts shared the vision that automation and ultimately autonomy will lead to safer vehicles and road-transport. The insurer stakeholders among them acknowledged that this would have consequences: lower premiums for customers following a reduction in damages and claims, and lower revenues for the sector (given less premiums and less vehicles) leading to a loss of capacity. Adding the other mobility developments, like vehicle data gathering and the shift from private ownership to leasing, renting and services, could *'radically transform our business model (R03).'* Such a shift will force insurers to focus (even) more on growing business-to-business (B2B) and business-to-business-to-consumer (B2B2C)

markets: e.g. more vertical integration of insurance products at the point of sale of the vehicle, insurance products sold to fleet managers and operators, etc. This likely leads to new competition dynamics among insurers, but also between insurers and vehicle manufacturers and/or fleet operators. For example, vehicle manufacturers and fleet operators of level 5 vehicles could potentially pay for product liability cover and put up the capital to cover minor negligence incidents while directly reinsuring for bigger incidents. In the interim, they might actively compete with insurers by offering in-house insurance to the safest drivers of their vehicles based on their vehicle data (Zarifis, 2020) or work with preferred insurance suppliers at point of sale. CAVs will also affect insurance companies internally, as it shifts investments from consumer insurance to their business-to-business departments. Another potential consequence of automation is that insurers could lose a regular yearly consumer contact point, thereby losing consumer updates, brand recognition and the ability to draw attention to other insurance products.

In the short to medium term however, with driver assisted vehicles, insurers expect premiums to go up. There are multiple reasons for this. One reason is rising repair costs, following the increasing use of sensors and cameras in vehicles. What used to be a matter of removing a dent from a bumper or windshield is increasingly turning into a full replacement of the part and its sensors. The sensors also need recalibration with the vehicle's internal systems adding further costs. Furthermore, ADAS and ADS *'won't tell us what damage has been prevented, but your vehicle's sensors also don't prevent other vehicles or shopping carts crashing into yours' (R12)'* – meaning claims will continue and risk assessments are somewhat uncertain if not biased (on that see Section 4.3). Nevertheless, experts expect that over time the share of these costs in the premiums will decrease as ADAS and ADS *'reduce the frequency of events, [even if they] increase the costs (R21)'*. In fact, given that insurers currently cannot as of yet measure near-misses – *'you will see an upwards momentum [of premiums due to the higher repair costs] as we can objectively measure those (R12).'*

In terms of their work, interviewees noted that CAVs do not radically affect the actuarial insurance practices of underwriting and risk assessment. The risks themselves change as the liability shift leads to the inclusion of new variables and revised safety statistics (subsequently affecting insurance products and premiums), however it hardly affects the way insurers work. What is expected to affect the practices of insurance are big data and machine learning. These developments allow insurers, besides automating some of the underwriting (Section 2), to move away from asking their customers for information, to building up profiles based on both customer information and third party data sources; thus increasing customer convenience while gaining *'significantly better information (R12)'*.

The amount of in-vehicle data gathered by OEMs from vehicles with ADAS and ADS, will only further these dynamics and, if shared with them, will allow insurers to increasingly break with the relative static yearly product offering in traditional car insurance. Insurers generally expect a switch to more user-based-insurance products (Pay as You Drive or Pay How You Drive schemes), adaptive micro-insurance products in relation to temporary rentals and Mobility-as-a-Service, and even pilot insurance-in-the-loop products whereby the insurance company is directly linked to a CAV and directs it to 'acceptable' risk levels of driving (Newman, 2019). Interestingly, a key challenge resulting from this big data dynamic is that insurers will need to work harder to explain and justify the obfuscated results from machine-learning analyses which could end up offering people with similar vehicles and backgrounds different premiums.

#### 4.3. Operating expectations and challenges

None of the above is to say that CAVs do not challenge car insurance. In fact, the interviewees discussed a range of challenges having to do with questions around liability, new risks and (in-vehicle) data.



#### 4.3.1. Liability

As insurance is a contract based product between insurer and insured, the legal definition of who is liable when driving needs clarification given the shift from drivers to the product liability of ADS and connected infrastructure systems. Looking across the interviews, there was a stronger focus on updating the various legal frameworks in the UK compared to the Netherlands (and other EU countries, see [DAC Beachcroft, 2019](#)). This follows partly from the UK's historic focus on *named driver* versus the Dutch focus on the *registered owner* in legal texts across these countries, implying that ADS legally cannot operate on public roads in the UK but is not directly excluded in the Netherlands. The UK focus on legal clarity further follows from government support and attention to these development and the attention and lobby from the insurance sector itself.

Consequently, the English liability concern around the *named driver* has been settled with the Automated and Electric Vehicle Act 2018 ([HM Government, 2018](#)). This Act reaffirmed a need for the existing Road Traffic Act compliant motor policies regarding the role of drivers and complemented the UK Code of Practice, which enables safe trailing of CAVs on public roads. Specifically, the Act (8(1)(a)) defines CAVs as a self-driving vehicle 'operating in a mode in which it is not being controlled, and does not need to be monitored, by an individual' but listed (and thus interpreted) by the Secretary of State for Transport. The Act further details that insurers compensate victims immediately without proof of fault and settle whether it is product liability or driver fault at a later stage. In the UK, civil liability and product liability are considered adequate for now, although the Law Commission in early consultations suggests that criminal liability (speeding, dangerous driving, driving without insurance) requires further clarity on the role of users, especially in the early stage of automated driving when users are not driving but still responsible to take over at a moment's notice. In the Netherlands, the legal side came up less as a topic of discussion primarily because insurance, road and product liability laws are centred on the owner of the car instead of the driver and thus are able to handle a "driverless" car. They are also heavily structured by EU directives, which are considered relatively adequate for the current state of technology. Nevertheless, for safety reasons autonomous vehicle testing takes place as pilot-projects under the 'Experiment for self-driving vehicles law' ([Experimenteerwet zelfrijdende auto's, 2018](#)).

In other words, both the UK and Dutch have a system in place that principally hold drivers responsible except when vehicles with ADS are admitted on the road by the highest political levels. Most interviewees agreed that these latter lists and experiments are a stop-gap solution in need of future development. Interviewees listed a host of highly political yet very detailed practical questions that insurers and other stakeholders would like to see answered, among others:

- Who has responsibility for software updates in terms of road-safety and type-approval, especially when people delay updates to a later moment in time?
- Who is responsible to take out insurance in various dynamic scenarios, for example when buying or renting software enabled upgrade packages?
- How is liability distributed during the handover moment between ADS and driver especially when the driver is unresponsive for an x amount of time (what is x)?
- How is liability distributed in case of emergencies, e.g. what counts as minimum risk manoeuvre? Is it enough for a CAV to stop in lane or does it need to find safe harbour?
- How is liability distributed when CAVs are increasingly connected to their environment?
- Who is responsible for informal road-rules, e.g. when adhering to the letter of the law generates unsafe conditions, or for limits of operational domains and geofencing?

Interviewees wanted questions like these to be answered before

insurers can fully insure CAVs, and even then they expect that the courts will play a large role in settling of these and future questions.

Furthermore, these are just the more general practical concerns. Whether these questions are resolved or not, car insurers will also have their own internal commercial decision-making matrix when it comes to investigating liability for accidents:

*'I think for our industry what's going to be challenging is establishing at what point you really investigate an accident to understand whether the vehicle was at fault or the driver was at fault, and how you manage that process because proving causation with some of these accidents is going to be really difficult. [...] I don't think some of these things will get tested in court until there is a big accident where the compensation is potentially very large [...] if it's a minor accident we probably won't spend a huge amount of time trying to investigate or pin liability back to the manufacturer (R06).'*

In other words, given the costs of court cases to set detailed legal precedence, some interviewees expect that insurers will take on some lower value and/or lower frequency claims, rather than settle liability through long and complicated court cases.

#### 4.3.2. New risks

Besides agreeing on liability, insurers are imagining and identifying new risks around CAVs and they work through how these affect liability, risk assessments, premiums and claims in existing and future contracts. Experts mentioned a range of risks from well discussed elements like cyber security ([Sheehan et al., 2019](#)) and driver inattention during hand-over or misuse of ADS ([Kyriakidis et al., 2019](#)) to broader risks related to telecom and the increasing fleet and infrastructure integration (like signal dropping). Cyber security was mentioned frequently, but not discussed to the extent that [Channon and Marson \(2021\)](#) do, when they show how large scale hacking of level 4 or 5 vehicles by a third-party likely will not be covered under normal vehicle insurance products and as such will need to fall back on the government or a pool from the insurer of last resort, similar to terrorism (Pool Re) or flooding (Flood Re). Another risk mentioned in the interviews is the safety testing of CAV software that is increasingly being digitalized. These models are highly dependent on properly prepared input data leading insurers and other safety experts fearing for biased data and improperly trained safety testing software. Similarly, the increasing dynamic nature of CAVs through software updates constitutes another new risk as this not only offers desirable road and vehicle safety improvements but also the ability for customers to buy or rent a package that adds functionality to the car; not dissimilar from chipping the engine management system of combustion engines. From the perspective of the insurer this makes the vehicles dynamic, which is a risk that will need to be priced in and/or regulated and communicated to customers. And even though CAVs are moving beyond drivers, experts agreed that as long as CAVs have drivers or operators they need proper communication, information and training to prevent improper use, which from an insurance perspective is a potential risk not just for new private car buyers, but also for second-hand vehicle buyers (who do not benefit from dealer information and leaflets) or shared vehicle drivers (especially without standardized user interfaces, ADS driving behaviour and human-machine interaction).

#### 4.3.3. Data

All of these risk were stated to be influenced by what insurers perceived as a lack of data, which includes both availability of data, access to data and data standards. As mentioned, the car insurance market might not be the most profitable, but it is large and predictable. The introduction of the first CAVs, whatever their level of automation, challenges this predictability. Normally the evolutionary dynamics of technological development and adoption allow initial insurance claims to be absorbed by the overall risk pool. Still, some insurers expressed concern that CAVs are a radical new technology for which insurers have no precedent and only a slowly growing number of observations and therefore that they had no statistical data to support underwriting (as of yet). The earlier discussed uncertainty around claims and repair costs

exemplifies part of the insurers' risks exposure towards these new technologies and their applications: the increased complexity of vehicles, new (cyber security) risks, the lack of consumer knowledge and their (mis or non) use of automated systems, and the effects of these systems in increasingly diversified mixed traffic all are uncertain. While part of this uncertainty is ontological, as CAVs are a new and untested technology, insurers approach it mostly as epistemic uncertainty; as a lack of knowledge that can be countered with the proper tools and data. As one interviewee stated:

*'The challenge is that we are moving away from having these three types [human factors, vehicle factors, environmental factors] where we have decades worth of data that we can analyze and therefore price risk accurately, or as accurately as possible, and now we're seeing that shift which effectively moves away from the human and into the latter two, i.e. the vehicle as such is becoming much more important because it takes on the functions of the human driver and also because the vehicle as such, its software is proprietary information, it's the intellectual property of whoever developed it. We don't know how it might function in certain ways [or] in certain situations. [...] But you are suddenly moving away from an industry [...] that for the past three hundred years or so has worked on a retrospective assessment of risk and projecting it into the future. Now suddenly it is: OK here's a black box of data. The software will do something. Assess that risk and price it (R21).'*

Specifically, insurers are interested in pre-accident and post-accident data. On the one hand, insurers aim to gather commercial information on CAV driving profiles, information on the vehicle and its systems, the actual use of ADS by drivers and operators, the vehicle's driver and passengers, and the infrastructure and environment. Part of this interest derives from a safety interest to initiate preventative measures through either vehicle, driver/operator or system level interventions based on data around near-misses and in-depth vehicle component analysis, like which producer has designed the automatic breaking system with the lowest real world accident scores in various situations – and thus serves a public function. However, insurers also have a strong commercial interest in this data to improve their own portfolios relative to competing insurance companies by gaining information that helps optimize their risk assessment and premiums. In both cases however, the desire to gain access to in-vehicle data conflicts with the interests of OEMs and other third parties, like dealers, repair shops, breakdown services (Pütz et al., 2019). And as mentioned in section 4.2, the in-vehicle data gathering by OEMs has the potential to disrupt the sector with new competition dynamics.

Post-accident data is different however, as insurers have a legal obligation to acquire data necessary to determine causation and liability. Interestingly, in the case of CAVs this too has an added commercial component as in-vehicle data allows for faster claim processing (e.g. cost savings and faster processes with happier customers) and can be used for fraud and safety analyses. However, interviewees noted that current international standardization discussions at the United Nations Economic Commission for Europe (UNECE) on event data recorders, specifically the Data Storage System for Automated Driving, entail only a limited dataset to determine liability, not the wider in-vehicle data that the cars collect and which could offer context to the accident (see section 4.4.2). Furthermore, there are national and international debates over how this data-sharing should take place: including discussions on access protocols, event triggers (does the recorder work in all scenarios), whether it will be the operator, a third party or a public body that will store the data, how long the data needs to be stored, how this is paid for, and how consumer privacy is guaranteed.

#### 4.4. Acting on CAVs: Participation, lobbying and learning

These CAV expectations and challenges lead insurers to a range of activities broadly centred around participation in pilot projects, lobbying, and learning.

##### 4.4.1. (Non) participation

Those insurer representatives who recognized the potential of CAVs and who were successful to classify it as a potential business risk within the company, subsequently recognized their lack of knowledge about these systems and their risks. One way that this group mitigates their knowledge gap is by getting involved in pilot projects through (1) a willingness to write coverage and (2) a willingness to invest and offer this coverage for free or at a reduced premium, thus taking the risk of having to absorb any potential adverse claims in their overall portfolios. They would do so for the network and learning effect, as it allows them to sit at the table with the foremost CAV experts while discussions about technology, costs, data, commercialization and safety are conducted. Besides a general understanding of the technological developments and risks, insurers gain insight about the datapoints they need and the results of these initial datapoints in terms of risks and claims handling. The hope is that by comparing these datapoints to their current car insurance data, they get 'an advantage, an insight, an opportunity (R01)' and an overall better understanding of their future portfolios.

Not all insurance companies participated in pilot projects, or had good experience with them. Some insurers explained that they did not participate because of a lack of internal capacity (e.g. no clear spokesperson or occupied with other priorities); others because they decided that these vehicles did not fall within their risk appetite or because they had various pragmatic reasons, including competition from other insurers bidding into the projects or internal judgments about the potential success of the pilot projects. Another respondent shared that they had participated but found the project to be insufficiently rewarding in terms of access to data and insights gained. This second group of insurers instead aims to buy future commercially available data, look for data within their own organization from colleagues working in other countries with OEMs or pilot projects, draw on representative insurance associations (cf. section 3), or join new cross-sectoral groups like the ADAS Alliantie in the Netherlands, Zenzic in the UK, or AFCAR in Europe.

##### 4.4.2. Lobbying

Insurers are actively involved in lobby activities and legal discussions about liability and definitions of users, albeit more so in the UK than the Netherlands.

UK insurers especially have been instrumental in the definition of users and the liability discussion. Non-insurers described the UK insurers as quite involved and open, with strong leadership via ABI and technically competency through Thatcham Research. Multiple respondents acknowledged that it was insurers' input that led to the proactive AEV Act 2018, the first law ever to be signed before a technology actually exists (Channon, 2019). This discussion is far from over however. Late 2020 the UNECE approved a standard on Automated Lane Keeping Systems (ALKS) that offer speed and steering control on highways under 35 miles/h. In the UK, this has led to a push by particular OEMs to have vehicles with ALKS registered on the list of the Secretary of State as the first automated vehicles, which would allow them to market the vehicle as such. The insurance sector challenges this, together with other mobility and consumer associations, as they categorizes lane keeping under these conditions still as assisted driving given the key role that the driver plays in utilizing the system correctly. A particular concern with these advanced level 2 technologies is that the driver need to remain vigilant and able to resume control at a moment's notice. However, staying alert in 'the most ergonomically designed chair that you own in a vehicle that's been designed to waft you in great comfort with probably the best sound system you own (R05)' is challenging for all. One interviewee further remarked that the AEV Act 2018 was originally written for SAE level 4 automated driving and up precisely because of driver alertness (cf. Venturer Project, 2018), but is now reinterpreted by OEMs based on the increasing use of driver monitoring systems.

In the Netherlands, insurers were seen by other interviewees to take a mostly reactive position. This follows partly from the overall smaller car insurance market and the resulting lower capacity at individual insurers

and the industry association to get involved. Another reason, as stated, is that the Netherlands has felt less need to change its car insurance laws compared to the UK, going for regulated exemptions while awaiting EU standards and regulation around vehicle-type approval (Min I&W., 2020). Interestingly, a small number of interviewees hinted that behind-the-scenes more far reaching discussions were being reignited about a complete overhaul of car insurance towards direct insurance models. Furthermore, the political will to support new pilot projects decreased after a cabinet change. Additionally, the interviews made clear that the debate in the Netherlands is less centred on autonomy but instead focuses on ADAS and connectivity. ADAS dominated the interviews because of an impactful report by the Dutch Safety Board (OVV, 2019) that identified a range of safety concerns around existing ADAS, thus pulling attention to the present fleet and market options. In turn, connectivity, or smart mobility more generally, is a key strategic topic of mobility organizations and the Ministry of Infrastructure and Water Management as a way to smooth future traffic flows (Partnership Talking Traffic, 2021).

One legal and practical debate that insurers, in both the UK and NL, are actively monitoring and involved in is around in-vehicle data access. As mentioned, insurers have both statutory and commercial interests to access this data. An interest, which especially in the latter case, is shared by third-party aftermarket but questioned by OEMs. Complicating both the in-vehicle and automated driving system approval decisions is that the detailed technical discussions and standards that are locking-in ethical and political choices are conducted at an international level. This includes European level groups, like the Vienna Convention and especially UNECE working groups 1 and 29 consisting of member state representatives with observer seats taken up primarily by OEM representatives while insurers have a single observer position via their European lobby group *Insurance Europe* (equally underrepresented as consumer and aftermarket groups). One consequence of these interconnected relationships is the above described tension to have vehicles with ALKS listed as automated vehicles, given that the UNECE documents do talk in terms of automation, opening up discursive space for proponents 'to sell the dream' and have it added to the UK's Secretary of State's list (R01, R08).

#### 4.4.3. Learning

As automation and connectivity are not stand-alone developments, a direct prompt from the interviewer led experts to share that they were learning about liability, new business models, risks and so on from other countries, sectors and technological developments.

Interviewees looked across a range of countries to see how liability was organized differently, including the United States, Germany, Singapore, Sweden and South Korea. They further liaised with colleagues and customers within their organizations, especially those within larger internationally operating insurers, not just on CAVs but topics like the development and regulation of AI, the internet of things and virtual reality as well as automation in other sectors like rail, aviation, drones, marine and mining operations. Among these latter examples, interviewees particularly focused on automation and hand-over moments, whole systems approaches, connected infrastructure and controllers at a distance; all the while highlighting how much more complex, open and dynamic road-transport is compared to these other sectors. For example, AI came up regularly, with more than one interviewee mentioning that the safety and liability discussions around CAVs do not stand on their own, but are a subset of parallel AI discussions in other sectors, like the use of AI in the medical sciences. Two interesting outliers were mentioned. The first included one interviewee touching on planning around land use and urban design as an example of structured and open decision-making around controversial topics that could be used for live tested technologies like CAVs. The other outlier involved an insurer looking at Fintech, especially in relation to the validation and verification protocols of whole systems. In reflection, a lot of these focus areas have less to do with learning about how to do insurance, as they

are about gaining technical, regulatory and procedural insight in domains directly related to CAVs or related with automation, connectivity, liability, cyber security and whole system dynamics.

## 5. Conclusion

The above in-depth analysis of the key expectations, challenges and practices around CAVs by car insurers in the UK and the Netherlands, confirms that '*If automation was easy we'd have automated trains by now* (R05).' The literature has discussions on the shift in liability from driver to ADS, the conflict about in-vehicle data, and the consequences of CAVs and shared mobility on traditional car insurance business models and markets. The findings here confirm and deepen the salience of these specialized debates by uncovering *what* some car insurers expect, *how* some actually approach CAVs, and what reasons are brought up to justify particular (in)actions around lobbying, learning, networking, piloting, underwriting, claims handling and competitive portfolio management. Importantly, while the interviews highlight a range of the challenges, responses and strategies, these are not exhaustive. They miss, for example, the likely growing importance of the insurer of last resort for system-wide CAV incidents (Channon & Marson, 2021) or the insurance effects of local authorities' unclear responsibilities in "smart" road construction and maintenance<sup>1</sup> – even as they confirmed that underwriting, risks, claims and competitive strategies are all affected by CAVs. Instead of summarizing, the conclusion offers a number of political and scholarly reflections on the broader debate and positions.

First, the CAV debate shows that insurers are a key stakeholder in this and other road-based transitions. Insurance has this role based on its statutory interest, but also because their data driven and legalistic approach makes them well placed to steer discussions around new technologies forward. That is, if they want, need and have the capacity to get involved. With strong individual promoters among insurers in both countries, the Dutch case showed a rather different CAV debate from the active lobbying in the UK, notable for the reduced presence of the insurance sector. Another key insight from the insurance debate around CAVs is the increasingly politicized nature of highly detailed technical standardization decisions at international levels. Fair representation and access to these decisions at project, national and international levels is something worthy of further study.

Second, there is a disconnect between the traditional car insurance literature and the CAV insurance literature that is worth further study. Just as insurers are struggling with the newness of CAVs, so too are the traditional judicial, actuarial, and econometric studies, which normally built on years of case work and insurance data. Hardly discussed in the interviews or the current CAV insurance literature, however, are notions of moral hazard, adverse selection and fraud (Button & Brooks, 2016; Robinson, Sloan, & Eldred, 2018; Viaene et al., 2007). In reflection there are interesting parallels and some elements of these notions that remain in place with further connectivity and automation. For instance, moral hazard has an interesting dynamic with driver's overconfidence in automation and the future public acceptance of accidents by automated systems (Bennett, Challinor, Modesto, & Prabhakaran, 2020). In turn, adverse selection could be stated to be the purpose of CAV development: to reduce the number of crashes, thus reducing claims, reducing the need for insurance and thereby reducing the market size. And when it comes to fraud, CAVs make that (and theft) a lot harder, if only because of the surveillance in and around the vehicle by the various exterior and interior sensors and cameras (Musk, 2019).

Third, the discussion nuances various critical transport discussions around CAVs. For example, Kassens-Noor et al. (2020) argue that CAV discussions remain highly car focused and thus reinforce a system of automobility. Similarly, transport climate research indicates that just "autonowashing" (Dixon, 2020) the car fleets will not be enough. The

<sup>1</sup> My thanks to an anonymous reviewer for pointing this out.



above discussion highlights however how insurers are certainly car focused, but well aware of these debates and open to support developments in the wider mobility scene. Elsewhere, Sparrow and Howard (2020) warn against the increasing individualization and commoditization of mobility through business models that allow for differential pricing in shared connected automated mobility. Translated to insurance this relates to the adverse selection that CAVs enable, as most of the safety benefits accrue to those who can afford automated mobility, while the cost for insurance will be increasingly personalized and higher for those still driving traditional vehicles (as the risk pool shrinks). While concerning and worthy of further study, private benefit does of course not automatically exclude the social benefit of safety. It is further noteworthy that some of the insurers behind this paper are aware of the ethical and practical challenges around machine learning (Stilgoe, 2018), partly following wider societal AI discussions but also influenced by their own history of discriminatory risk analyses (e.g. when still utilizing variables like gender or race).

Fourth, underneath the discussions about risks, liability, data and definitions, it is possible to observe how a fundamentally data-driven sector acts in the face of the absence of pre-existing data, which offers an interesting case for the sociological literature on risk and insurance (Ericson, Doyle, & Barry, 2003; Ewald, 1991; Jarzabkowski et al., 2015). The interviews highlight that CAVs break open, yet do not change, existing statistical practices given the ontological and epistemological uncertainty around automation. For the first number of vehicles at least, this forces CAV insurers to draw back on more human expertise based underwriting instead of solely data driven actuarial models, by attributing at least part of the premium to reasoning by analogy (i.e., insuring an autonomous pod as a full passenger bus) or some investment or marketing logic (i.e., investing to learn). Pending the speed of adoption and introduction of further automation and connectivity, insurers will be able to gain data and optimize their premiums with a higher or lower uncertainty factor.

Lastly, with CAVs insurers will benefit more from a further specialization and analysis of the software and hardware components in the vehicles in both the mixed traffic and the ultimate autonomous scenario. In other words, they would benefit from access to in-vehicle data, specifically geared to vehicle and environmental data (Gatzert & Osterrieder, 2020; Pütz et al., 2019). Above we distinguished between pre-accident commercial data and statutory accident data. Missing from the interviews and policy discussions however is a debate about insurers' safety data: accident data across vehicle brands in particular geographies and environments. Whereas OEMs have full knowledge about any safety risks or corrections in their own fleet, they are not in a position to compare and contrast real-life incident behaviour of automated break systems from different brands at different speeds and in different locations. Nor are they in a position to suggest to local road-authorities that particular crossings or (future connected) infrastructure are witness to a significant higher number of incidents. As consumer acceptance is seen as a key challenge to the uptake of CAVs, having a debate on who helps collect and analyze such vehicle and traffic safety data is a discussion well worth to be had, especially in the near-term mixed traffic conditions.

## Funding

The author would like to thank the John Fell Fund, Oxford, UK [JQD00030] for financial support.

## Declaration of Competing Interest

None.

## Acknowledgements

The author is grateful to the interviewees for sharing their time and

expertise and to the reviewers and editor for their helpful and insightful comments on earlier drafts. Any opinions, findings, and conclusions or recommendations expressed in this material are the responsibility of the author.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.rtbm.2022.100903>.

## References

- ABI. (2019). *Key Facts*. Association of British Insurers. [https://www.abi.org.uk/globalassets/files/publications/public/key-facts/key\\_facts\\_2019\\_spread.pdf](https://www.abi.org.uk/globalassets/files/publications/public/key-facts/key_facts_2019_spread.pdf).
- Abraham, K. S. (2013). *Four conceptions of insurance*. 161 p. 46). University of Pennsylvania Law Review.
- Abraham, K. S., & Rabin, R. L. (2019). *Automated vehicles and manufacturer responsibility for accidents: A new legal regime for a new era*. 105 p. 171). Virginia Law Review Association. <https://doi.org/10.2139/ssrn.3159525>
- Albright, J., Schneider, J., & Nyce, C. (2017). The chaotic middle. In *The autonomous vehicle and disruption in automobile insurance* (p. 64) [white paper]. KPMG.
- Bennett, J. M., Challinor, K. L., Modesto, O., & Prabhakaran, P. (2020). Attribution of blame of crash causation across varying levels of vehicle automation. *Safety Science*, 132, Article 104968. <https://doi.org/10.1016/j.ssci.2020.104968>
- Bissell, D. (2018). Automation interrupted: How autonomous vehicle accidents transform the material politics of automation. *Political Geography*, 65, 57–66. <https://doi.org/10.1016/j.polgeo.2018.05.003>
- Borup, M., Brown, N., Konrad, K., & Van Lente, H. (2006). The sociology of expectations in science and technology. *Technology Analysis & Strategic Management*, 18(3–4), 285–298.
- Button, M., & Brooks, G. (2016). From 'shallow' to 'deep' policing: 'Crash-for-cash' insurance fraud investigation in England and Wales and the need for greater regulation. *Policing and Society*, 26(2), 210–229. <https://doi.org/10.1080/10439463.2014.942847>
- Channon, M. (2019). Automated and electric vehicles act 2018: An evaluation in light of proactive law and regulatory disconnect. *European Journal of Law and Technology*, 10 (2). <http://ejlt.org/article/view/702>.
- Channon, M., & Marson, J. (2021). The liability for cybersecurity breaches of connected and autonomous vehicles. *Computer Law and Security Review*, 43, Article 105628. <https://doi.org/10.1016/j.clsr.2021.105628>
- Cole, C., Eastman, K., Maroney, P., McCullough, K., & Macpherson, D. (2012). The impact of no-fault legislation on automobile insurance. *North American Actuarial Journal*, 16(3), 306–322. <https://doi.org/10.1080/10920277.2012.10590644>
- Collingwood, L. (2017). Privacy implications and liability issues of autonomous vehicles. *Information & Communications Technology Law*, 26(1), 32–45. <https://doi.org/10.1080/13600834.2017.1269871>
- Cusano, J., & Costonis, M. (2017, December 5). Driverless cars will change auto insurance. Here's how insurers can adapt. *Harvard Business Review*, n.a.. <https://hbr.org/2017/12/driverless-cars-will-change-auto-insurance-heres-how-insurers-can-adapt>.
- DAC Beachcroft. (2019). *Informed insurance: Thought leadership 2019/20*. DAC Beachcroft: The Drive for Automation. <https://insurance.dacbeachcroft.com/media/uzfeneq4/the-drive-for-automation.pdf>.
- Davis, J. (2015). Drive at your own risk: Uber violates unfair competition Laws by misleading Uberx drivers about their insurance Covergae. *Boston College Law Review*, 56(3), 1097–1142.
- Dionne, G., & Laberge-Nadeau, C. (2012). *Automobile insurance: Road safety, new drivers, risks, insurance fraud and regulation*. Springer Science & Business Media.
- Dixon, L. (2020). Autowashing: The greenwashing of vehicle automation. *Transportation Research Interdisciplinary Perspectives*, 5, Article 100113. <https://doi.org/10.1016/j.trip.2020.100113>
- Dutch Association of Insurers. (2019). *Financieel jaarverslag verzekeringsbranche*. 36. Verbond van Verzekeraars.
- Ericson, R. V., Doyle, A., & Barry, D. (2003). *Insurance as governance*. University of Toronto Press.
- Ewald, F. (1991). Insurance and risk. In G. Burchell, C. Gordon, & P. Miller (Eds.), *The Foucault effect: Studies in governmentality* (pp. 197–210). Harvester Wheatsheaf.
- Expirimenteerwet zelfrijdende auto's. (2018). *Wet van 26 september 2018 tot wijziging van de Wegenverkeerswet 1994 in verband met mogelijk maken van experimenten met geautomatiseerde systemen in motorrijtuigen*. Staatsblad 347(4).
- Fagnant, D. J., & Kockelman, K. (2015). Preparing a nation for autonomous vehicles: Opportunities, barriers and policy recommendations. *Transportation Research Part A: Policy and Practice*, 77, 167–181. <https://doi.org/10.1016/j.tra.2015.04.003>
- Fraedrich, E., Heinrichs, D., Bahamonde-Birke, F. J., & Cyganski, R. (2019). Autonomous driving, the built environment and policy implications. *Transportation Research Part A: Policy and Practice*, 122, 162–172. <https://doi.org/10.1016/j.tra.2018.02.018>
- Gatzert, N., & Osterrieder, K. (2020). The future of mobility and its impact on the automobile insurance industry. *Risk Management and Insurance Review*. <https://doi.org/10.1111/rmir.12140>
- Hamilton, D., Strovink, K., & Young, K. (2019). Can auto insurance-and insurers-keep up with the changing nature of mobility? *The McKinsey Quarterly*, 1, 9–10.



- Hansson, L. (2020). Regulatory governance in emerging technologies: The case of autonomous vehicles in Sweden and Norway. *Research in Transportation Economics*, 83, Article 100967. <https://doi.org/10.1016/j.retrec.2020.100967>
- HM Government. (2018). *Automated and electric vehicles act 2018* (p. 19).
- Jarabkowski, P., Bednarek, R., & Spee, P. (2015). *Making a market for acts of god: The practice of risk-trading in the global reinsurance industry*. Oxford University Press.
- Karp, L., & Kim, R. (2017). *Insuring autonomous vehicles: An \$81 billion opportunity between now and 2025*. Accenture & Stevens Institute of Technology. <https://www.accenture.com/acnmedia/pdf-60/accenture-insurance-autonomous-vehicles-pov.pdf>.
- Kassens-Noor, E., Dake, D., Decaminada, T., Kotval-K, Z., Qu, T., Wilson, M., & Pentland, B. (2020). Sociomobility of the 21st century: Autonomous vehicles, planning, and the future city. *Transport Policy*, 99, 329–335. <https://doi.org/10.1016/j.tranpol.2020.08.022>
- Kim, M.-K., Park, J.-H., Oh, J., Lee, W.-S., & Chung, D. (2019). Identifying and prioritizing the benefits and concerns of connected and autonomous vehicles: A comparison of individual and expert perceptions. *Research in Transportation Business & Management*, 32, Article 100438. <https://doi.org/10.1016/j.rtbm.2020.100438>
- Kyriakidis, M., Winter, J. C. F.d., Stanton, N., Bellet, T., Arem, B.v., Brookhuis, K., ... Happee, R. (2019). A human factors perspective on automated driving. *Theoretical Issues in Ergonomics Science*, 20(3), 223–249. <https://doi.org/10.1080/1463922X.2017.1293187>
- Law Commission, & CCAV. (2018). *Automated vehicles: A joint preliminary consultation paper* (p. 234). Centre for Connected and Automated Vehicles.
- Lee, D., & Hess, D. J. (2020). Regulations for on-road testing of connected and automated vehicles: Assessing the potential for global safety harmonization. *Transportation Research Part A: Policy and Practice*, 136, 85–98. <https://doi.org/10.1016/j.tra.2020.03.026>
- Lohmann, M. F. (2016). Liability issues concerning self-driving vehicles. *European Journal of Risk Regulation*, 7(2), 335–340. <https://doi.org/10.1017/S1867299X00005754>
- Longhi, L., & Nanni, M. (2020). Car telematics big data analytics for insurance and innovative mobility services. *Journal of Ambient Intelligence and Humanized Computing*, 11(10), 3989–3999. <https://doi.org/10.1007/s12652-019-01632-4>
- Maurer, M., Gerdes, J. C., Lenz, B., & Winner, H. (Eds.). (2016). *Autonomous driving*. Berlin Heidelberg: Springer. <https://doi.org/10.1007/978-3-662-48847-8>.
- Min I&W.. (2020). *Smart Mobility, Dutch Reality: Resultaten beleid, projecten en onderzoek op het gebied van smart mobility in het wegverkeer 2018-2020*. Ministerie van Infrastructuur en Waterstaat.
- Musk, E. (2019, February 7). Sentry mode (and dog mode) roll out next week [tweet]. @elonmusk. <https://twitter.com/elonmusk/status/1093425726139772929>.
- Newman, P.( D.). (2019). CogX 2018 - Bits to Move Atoms: The Wide View of the Future of Mobility. <https://www.youtube.com/watch?v=msUEh6HzOo&feature=youtu.be&t=948>.
- OVV. (2019). *Wie stuurt? Verkeersveiligheid en automatisering in het wegverkeer* (p. 156). Onderzoeksraad voor Veiligheid [Dutch Safety Board].
- Partnership Talking Traffic. (2021). What if traffic regulates traffic?. <https://www.talking-traffic.com/nl/>.
- Pütz, F., Murphy, F., Mullins, M., & O'Malley, L. (2019). Connected automated vehicles and insurance: Analysing future market-structure from a business ecosystem perspective. *Technology in Society*, 59, Article 101182. <https://doi.org/10.1016/j.techsoc.2019.101182>
- Robinson, P. A., Sloan, F. A., & Eldred, L. M. (2018). Advantageous selection, moral Hazard, and insurer sorting on risk in the U.S. Automobile insurance market. *The Journal of Risk and Insurance*, 85(2), 545–575. <https://doi.org/10.1111/jori.12170>
- Sachs, R. (2015). The common carrier barrier: An analysis of standard of care requirements, insurance policies, and liability regulations for ride-sharing companies comments. *DePaul Law Review*, 65(2), 873–906.
- SAE. (2018). *Taxonomy and definitions for terms related to driving automation Systems for on-Road Motor Vehicles (J3016.201806)*. Society of Automotive Engineers.
- Sheehan, B., Murphy, F., Mullins, M., & Ryan, C. (2019). Connected and autonomous vehicles: A cyber-risk classification framework. *Transportation Research Part A: Policy and Practice*, 124, 523–536. <https://doi.org/10.1016/j.tra.2018.06.033>
- Shladover, S. E. (2018). Connected and automated vehicle systems: Introduction and overview. *Journal of Intelligent Transportation Systems*, 22(3), 190–200. <https://doi.org/10.1080/15472450.2017.1336053>
- Siddiqui, H. (2018). Gone in sixty seconds: Fading automobile insurance costs in a driverless future notes. *University of Illinois Journal of Law, Technology & Policy*, 1, i–248.
- Sparrow, R., & Howard, M. (2020). Make way for the wealthy? Autonomous vehicles, markets in mobility, and social justice. *Mobilities*, 15(4), 514–526. <https://doi.org/10.1080/17450101.2020.1739832>
- Stayton, E., & Stilgoe, J. (2020). It's time to rethink levels of automation for self-driving vehicles. *SSRN Electronic Journal*. <https://doi.org/10.2139/ssrn.3579386>
- Stilgoe, J. (2018). Machine learning, social learning and the governance of self-driving cars. *Social Studies of Science*, 48(1), 25–56. <https://doi.org/10.1177/0306312717741687>
- Tselentis, D. I., Yannis, G., & Vlahogianni, E. I. (2017). Innovative motor insurance schemes: A review of current practices and emerging challenges. *Accident Analysis & Prevention*, 98, 139–148. <https://doi.org/10.1016/j.aap.2016.10.006>
- Venturer Project. (2018). Driverless cars: Liability frameworks and safety by design—Insurance and legal report 2018. In AXA and Burges Salmon. <https://www.venturer-cars.com/wp-content/uploads/2018/06/Year-3-Legal-and-Insurance-Report.pdf>.
- Viaene, S., Ayuso, M., Guillen, M., Van Gheel, D., & Dedene, G. (2007). Strategies for detecting fraudulent claims in the automobile insurance industry. *European Journal of Operational Research*, 176(1), 565–583. <https://doi.org/10.1016/j.ejor.2005.08.005>
- Zarifis, A. (2020, January). Why is tesla selling insurance and what does it mean for drivers? The conversation. <http://theconversation.com/why-is-tesla-selling-insurance-and-what-does-it-mean-for-drivers-130910>.