Driving into the Loop:

Mapping Automation Bias & Liability Issues for Advanced Driver Assistance Systems

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Introduction

Advanced Driver Assistance Systems (ADAS) are transforming the modern driving experience. Whether it's adaptive cruise control or lane keeping assist, high-tech automation systems augment today's drivers with promises to prevent blunders and achieve tricky tasks. Sirens sound to ward off driver errors, like drifting into an oncoming lane or rolling forward before a stoplight has turned green. With the help of ADAS, today's cars seem better equipped than ever before to improve safety by automating routine driving activities. The assumption appears straightforward: automation will improve road safety because automation replaces the human driver, thus reducing human driving errors. But is this a straightforward assumption? In this paper, we argue that this assumption has potentially dangerous limits, especially in the context of next-generation ADAS, and raises important liability issues for automotive manufacturers. We ask: how should we think about liability in cases where existing driver licensing regimes fail to ensure an adequate baseline for the appropriate operation of ADAS?

This paper builds upon previous scholarship on automated vehicle systems, asking specific questions about how regulatory regimes should respond to ADAS. Some engineering scholars have been investigating the cognitive challenges drivers face when they are relied upon as a last line of defence within partially automated driving systems. Our research builds on this ongoing effort, addressing the legal and policy gaps that exist in responding to the emerging complexity in this space. With automation bias as a framing mechanism, we harness empirical data we have already collected to problematize the assumption that automation directly leads to increased safety. The empirical research that we draw upon has been collected over the past five years (2016-2021) in a joint project by the Korean Transportation Institute (KOTI) and the Open Roboethics Institute (ORI). This includes a wealth of data from an online survey on drivers' attitudes, training, and familiarity with automated systems.[1] Currently, most drivers must make do with meagre instruction from their dealership or a quick flip through a manual for 'training' on ADAS. With these systems now enmeshed in modern vehicles, the evidence shows driver licensing and training regimes are in urgent need of modernization. By getting questions of human-automation interaction right from the outset, we will be able to offer concrete policy recommendations for the future of automated transportation.

In Part I, we explain the technical aspects of three common assistive driving technologies and show how they are best situated in the litany of automation concerns documented by the current SAE framework. In Part II, we offer a theoretical framing outlining the key concerns that arise when untrained people take control of dangerous automated machinery. This section prioritizes the concepts of trust and over-trust—and the well-studied and robustly observed driver complacency that is induced when humans shift into an operator mode when interacting with partially automated systems. In Part III, we provide an overview of Canadian driver licensing regimes, demonstrating the paucity of regulations designed to ensure the effective use of ADAS on public roads. We note challenges for regulators looking to allocate legal risk for ADAS, informed by approaches to technology in different legal spheres. Finally, in Part IV, we offer clear policy advice on how to better integrate assistive driving technologies with today's schemes for driver regulation. Here, the

[1] Sophie Le Page, Kelly Bronson, Katherine-Marie Robinson, AJung Moon, Shalaleh Rismani, Jason Millar, "Driver Awareness, Knowledge and Use of Advanced Driving Assistance Systems (ADAS) and Vehicle Automation" [publication forthcoming].

KOTI/ORI dataset proves especially useful, as we use empirical evidence to support our theoretical approach.

Part I. Technical Grounding: How ADAS Works

In the automated driving space, the SAE automated driving levels are used as a *de facto* standard for categorizing the degrees of automation enabled by ADAS tools. Compared to the crude dichotomy between human-driven cars and self-driving cars, the SAE taxonomy offers commentators specificity in describing and developing ADAS technologies across a spectrum of automation.[2] Six levels (0 to 6, where 0 indicates no automation) of automation are specified. Literature addressing automated driving from a safety perspective tends to discount the lower SAE levels, level 1 (driver assistance) and level 2 (partial automation), since the human driver remains responsible for the most critical driving tasks.[3] Instead, scholars have focused more on higher degrees of automation, usually beginning at level 3 (conditional automation), where drivers are relegated to a monitoring role to ensure the safe operation of automated systems.[4] Most analyses are aimed the two top tiers, level 4 (high automation) and level 5 (full automation), even though such vehicles are not yet commercially available.[5] Meanwhile, cars with ADAS at SAE levels 1-2 are increasingly the norm in today's automotive industry as major manufacturers focus on such technologies, incorporating them into all new vehicles. However, driver awareness of the availability of such features, as well as associated formal training on how to use them, remains low. In one recent study, only 50% of survey respondents were aware of their car's ADAS feature before test driving the car, casting doubt on the extent of consumer preference for ADAS. As manufacturers continue to frame the integration of ADAS in terms of driver convenience and safety, it is worth interrogating whether those framings are—in actuality—more about sales strategies than about achieving safety and convenience objectives.

While the risks posed by level 4 (high automation) and level 5 (full automation) vehicles are worth investigating, directing critical analyses to the hypothetical and farther-future technologies can risk conflating them with, or altogether overlooking, the current, existing problems of the lower-level automation systems in vehicles. The focus on higher level automation technologies employs what is sometimes known as the android fallacy—allowing science fiction conceptualizations of imagined futures to displace the reality of existing problems.[6] Robotics and human-automation interaction (HAI) scholarship—including those in human-computer interaction (HCI) and human-robot interaction (HRI)—takes a pragmatic look at existing technology and unpacks how humans interact with robotic systems. While the distinction between humans in-the-loop and on-the-loop

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[2] SAE, "Automated driving levels" SAE International Standard J3016, (2014) *SAE* online: <SAE.org>.

[3] Transport Canada, Safety Assessment for Automated Driving Systems in Canada (January 2019).

[4] For example, in Canada, the federal transport regulator has produced a voluntary Safety Assessment Tool directed at the automotive industry for vehicles equipped with SAE level 3-5 ADAS. *Ibid.*

[5] *Ibid.*

[6] Bill Smart and Neil Richards argue that when discussing AI, ML, and the implications of robots, we need to guard against commission of "The Android Fallacy", which they define as improperly conceptualizing of robots in a manner consistent with science fiction. They posit that an important element of discussing legal regulation for AI is sketching what robots can do, what they cannot do yet, and what they may never be able to do. Recognizing that "never" is a pretty long time, they suggest that "long after we are dead" is a workable standard. See Neil M. Richards & William D. Smart, "How Should The Law Think About Robots" in R. Calo, A.M. Froomkin, & I. Kerr (eds.), *Robot Law*, (Cheltenham: Edward Elgar Publishing, 2016) at 3.

has existed in HAI for decades,[7] current automated vehicle technologies blur that distinction by automating some tasks to place a driver in-the-loop while placing them on-the-loop for others, by varying system behaviours between different vehicle manufacturers, and by expecting the driver to serve as advanced systems monitor without ever receiving appropriate training.

To better illustrate the capabilities of these lower SAE level technologies we focus on the examples of: (a) adaptive cruise control ("**ACC**"); (b) lane keeping assist ("**LKA**"); and (c) parking assist. Each of these three technologies tend to be categorized as SAE level 1 or 2 automated systems.[8]

a. Adaptive Cruise Control

Most commercial ACC technologies use radar to ascertain the relative speed difference between the ego vehicle (*i.e.*, the vehicle in which the ACC is installed) and a target vehicle ahead of it on the roadway. The ACC system controls both throttle and brake to alter the speed of the ego vehicle, then the ACC system maintains a particular following distance between the ego vehicle and the target vehicle, or a maximum speed while no target vehicle is present. The following distance is based on a combination of driver input and sensor inputs, sometimes including weather conditions and road conditions. Some systems will respond to spontaneous changes to the situation with visual and acoustic alerts. For example, a BMW vehicle will alert the driver when the target vehicle brakes suddenly. Drivers are given the opportunity to respond to the alerts by braking, but if they do not, the vehicle will perform the braking function autonomously.

Recent studies have analyzed how ADAS systems are designed to communicate important driving information to drivers. Drivers were shown to be especially vulnerable to confusion when interacting with conventional cruise control systems.[9] Further, ACC was reportedly unpopular for use in urban and even casual highway driving, since drivers extrapolated from their previous experiences with conventional cruise control, which is typically used primarily for long-distance highway driving. While ACC is not universally capable of automatically braking to avoid crash scenarios, approximately one-third of drivers surveyed were unaware of this fact, raising flags for further evaluations of trust and reliance, and ultimately of the safety of such ADAS.[10]

b. Lane Keeping Assist

Lane Keeping Assist is an active ADAS that assists the driver when the vehicle begins to depart the traffic lane. Most systems use a forward-looking camera—usually mounted on top of the rear-view mirror—to detect the lanes on the road, warn the driver, and actively take control of the steering wheel if the car determines it is departing the lane. Some, but not all, systems also assist with keeping the vehicle centered within the lane. Most LKA systems provide support for the drivers in one of two ways: either by actively providing feedback to the steering wheel to steer the

[7] See, *e.g.*, Mathew DeDonato et al, "Human-in-the-loop Control of a Humanoid Robot for Disaster Response: A Report from the DARPA Robotics Challenge Trials (2015) 32 Journal of Field Robotics 275.
[8] BMW, online: <https://www.bmw.ca/en/topics/experience/connected-drive/bmw-connecteddrive-driver-assistance.html#>
[9] Ashley McDonald, Cher Carney, & Daniel V. McGehee, "Vehicle Owners' Experiences with and Reactions to Advanced Driver Assistance Systems" (September 2018), AAA Foundation for Traffic Safety.
[10] McDonald *et al* at 3 (collating a number of reports on ACC systems that indicate drivers are unaware of important technological limitations).

car toward the middle of the lane or by giving feedback only if the driver steers the vehicle towards the edges of the detected lanes.

LKA relies on clearly visible standard lane markings and good road and visibility conditions to function properly and requires that the driver always pay attention to the road and ADAS. Absent clear conditions, the LKA system sensing capabilities tend to be degraded. Most LKA systems also require a certain minimum speed limit to operate. The driver is always able to override the system simply by steering; the system will also often be temporarily deactivated while the driver depresses the brake pedals or activates a turn signal. Many LKA systems will not operate in situations when the turning signal is activated and the vehicle is being steered in the direction of the turn signal.[11] However, the literature suggests many drivers remain unaware of this limitation, pointing to issues with identifying the environments and conditions under which the system works best.[12]

c. Parking Assist

Automated parking assist features are rapidly being implemented by major car manufacturers. In some implementations, parking is still controlled manually by the driver, but the driver receives information and control prompts based on numerous ultrasonic sensors, radar, and video cameras.[13] Other systems offer a fully automated approach, with the system taking control of the steering system to perform the parking maneuver based on the real-time sensor data.[14] Both types of approaches are being deployed and both varieties are implicated when drivers refer to parking assist systems. Recent trends demonstrate a shift to fully automated parking systems. For example, Lexus's LS sedan series (equipped with Intelligent Parking Assist) offers an automated parking system where the driver need only set the reverse gear and the parking assist uses ultrasonic sensors and cameras to park.[15] Similarly, Volkswagen offers the Park Assist Vision, the first demonstration of a fully automatic parking system,[16] while Audi has also begun developing an automated system that connects to a driver's cellphone.[17]

A useful exemplar of fully automated parking is the Autopark feature in the Tesla Model X, where a combination of sensors and cameras allow the system to control the steering wheel.[18] This allows the car to back autonomously into a parking spot.[19] Autopark use may, however, be associated

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[11] McDonald *et al*.
[12] Bekiaris, Evangelos, Evangelia Gaitanidou & Marion Wiethoff, *Infrastructure and Safety in a Collaborative World: Road Traffic Safety,* 1st ed (Berlin, Heidelberg: Springer-Verlag, 2011) at 193; "Lane Keeping Assist Systems", online: *Verband derAutomobilindustrie* <https://www.vda.de/en/topics/safety-and-standards/lkas/lane-keeping-assist-systems.html>.
[13] W. Wang, Y. Song, J. Zhang, & H. Deng, "Automatic Parking of Vehicles: A Review of Literatures" (2014) 15 International Journal of Automotive Technology 967.
[14] *Ibid*.
[15] *Ibid*.
[16] *Ibid*.
[17] *Ibid*.
[18] United States Patent Application Publication. Bonnet et al. METHOD FOR AUTONOMOUR PARKING OF A MOTOR VEHICLE, DRIVER ASSISTANCE DEVICE FOR PERFORMING THE METHOD AND MOTOR VEHICLE WITH THE DRIVER ASSISTANCE DEVICE. Pub. No. US 2015/0088360 A1.
[19] Nathan L. Tenhundfeld, Ewart J. de Visser, Anthony J. Ries, Victor S. Finomore, Chad C. Tossell, "Trust and Distrust of Automated Parking in a Tesla Model X" (2020) 62 Human Factors and Advanced Vehicle Automation 194 at 195.

with risking damage to the car or bodily harm, especially in situations of "miscalibrated trust" in the automation.[20] Autopark is not functional in all circumstances: the feature is limited to certain types of parking spaces and conditions where the corresponding sensors can obtain sufficient information from its surroundings. Tight parking situations in private car parks do not play well with Autopark.[21] Nonetheless, automated parking assist features do offer potential advantages to drivers. Due to the complexity of the parking task, drivers tend to require heightened parking skills in situations with increased numbers of cars and fewer parking spaces.[22] Appropriately designed and deployed automated parking systems can increase driver safety, comfort levels, and reduce fatigue, often touted as making the overall driving experience more enjoyable. [23]

Even at low SAE automation levels, ADAS technologies transform the nature of driving, shifting drivers away from directly performing critical driving tasks and instead asking them to monitor one or more automated systems now performing those safety-critical tasks. Literature exploring whether drivers understand new ADAS technologies has confirmed key issues with their deployment: misperceptions, lack of awareness, uncertainty and confusion all plague the smooth adoption of ADAS, in addition to raising safety concerns.[24] In particular, drivers have struggled to make sense of how some systems work in combination with one another, and how various ADAS systems differ from one another. As drivers are increasingly thrust into the role of systems monitor, their tasks behind the wheel expand to ensuring that the system behaviour adheres to their expectations for safe driving. Drivers now share responsibility with automated systems for critical driving tasks, yet the automated driving paradigm does not yet seem to have incorporated important wisdom from human-automation interaction research, specifically in related fields such as human factors engineering and ergonomics. With this technical grounding in mind, we move on to consider automation bias as a critical aspect that frames our debate.

Part II. Automation Bias as a Theoretical Framework for Driver-ADAS Systems

Human factors engineering and ergonomics literatures have documented the dominant phenomena that occur when new technologies transform existing realities. In the driving context, automation transforms how drivers allocate their attention resources; it also creates new cognitive tasks and replaces some or all of the functions (cognitive and physical) related to driving.[25] Because automated systems reduce an operator's degree of control over a system, operators become more

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[20] *Ibid* at 195; they focus their research on Tesla Model X.
[21] United States Patent Application Publication. Bonnet et al. METHOD FOR AUTONOMOUR PARKING OF A MOTOR VEHICLE, DRIVER ASSISTANCE DEVICE FOR PERFORMING THE METHOD AND MOTOR VEHICLE WITH THE DRIVER ASSISTANCE DEVICE. Pub. No. US 2015/0088360 A1.
[22] W Wang, Y Songg, J Zhang and H Deng, "Automatic Parking of Vehicles: A Review of Literatures" (2014) 15 International Journal of Automotive Technology at 967.
[23] *Ibid*.
[24] McDonald *et al*.
[25] Yusuke Yamani & William J Horrey, "A theoretical model of human-automation interaction grounded in resource allocation policy during automated driving" (2018) 5 Int. J. Human Factors and Ergonomics 225.

likely to "misuse"[26] that system.[27] Over time, operators engage with many tasks and have less control over the execution of each individual task. This can lead to over-trust and over-reliance on automated systems. As ADAS increasingly demands that operators engage with multiple tasks at once, operators are forced to strategize about how to best allocate their cognitive resources (*i.e.*, attention) and how to best process new streams of information. Over-trust and over-reliance on automated systems can occur at both the attention allocation and information processing levels, inducing errors in the driver-ADAS system.[28] Automation complacency and automation bias thereby offer helpful lenses through which to analyze the emergent issues ADAS presents.[29]

1. Automation Complacency

Complacency becomes a possible problem when system operators perform multiple tasks simultaneously.[30] Drivers asked to monitor ADAS are handed an increased cognitive task load, which forces drivers to monitor automation while also performing other manual tasks associated with driving.[31] This new monitoring task can be particularly unfamiliar to experienced drivers. Simultaneously, reliable systems can increase over-trust, as drivers become unthinkingly reliant on their continued operation. Coupled with multi-task loads, this can create increased complacency.[32] Increased complacency then reduces visual attention paid to the primary information sources feeding automation—which must be monitored to detect failures.[33] While training in attention strategies was found to decrease complacency, extended practice had no effect on reducing complacency.[34]

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[26] We use the term "misuse" reluctantly since it is not clear that a system that demands too much of a human operator, for example by robustly inducing the psychological state of over-trust or cognitive overload, is actually being misused in the sense that is most often intended by the term "misuse". A driver-ADAS system that exhibits driving errors because of human over-trust does not suggest the driver misused any part of the system; such a failure simply suggests a malfunctioning driver-ADAS system.

[27] J Elin Bahner, Anke-Dorothea Huper, & Dietrich Manzey, "Misuse of automated decision aids: Complacency, automation bias and the impact of training experience.*"* (2008) 66 Int J Human-Computer Studies 688.

[28] *Ibid*.

[29] Raja Parasuraman & Dietrich Manzey, "Complacency and Bias in Human Use of Automaton: An Attentional Integration" (2010) 52 Human Factors 381 at 405.

[30] *Ibid.*

[31] Earlier studies examining the cause and effects of misuse in the context of complacency and automation bias measure complacency according to an operator's responsiveness towards the system, independent from performance consequences. The studies found that higher levels of operator complacency increased the likelihood that an operator's performance would decrease (see Bahner at 690). It is important to note that where automated decision aids are correct, complacency can be beneficial to the operator. However, if the decision aid provides incorrect information—a commission error—complacency is likely to increase. More recent literature looks more closely at the relationship between complacency and automation bias. For example, Wickens et al. define complacency more narrowly as "the state of monitoring prior to an automation decision aid failure that expresses itself as a delayed or "guessing" response when the decision aid fails to function at all." They then define automation bias as the "expression of such poor monitoring, when the decision aid provides incorrect advice, by following that advice."

[32] Yamani & Horrey.

[33] Yamani & Horrey.

[34] Studies found that participants exposed to failures of the diagnostic function of the aid had lower levels of complacency. The correlation did not hold for those exposed to failures of the alarm function. This meant that higher levels of complacency were associated with increased commission errors. See Parasuraman & Manzey at 405.

2. Automation Bias

Automation bias occurs when a driver relies on an imperfect automated decision-making aid. Literature distinguishes between two types of aids: alerts and recommendations.[35] Relying on these aids can lead to two key types of errors: omission and commission errors.[36] Where there is an error of omission, the system fails to alert the operator to some important information. Where there is an error of commission, the system incorrectly alerts the operator of an issue that is not in fact important.[37] Table 1 below summarizes the distinction between these two types of errors.

Table 1: Omission Error versus Commission Error[38]

Omission Error (no alert)	Commission Error (false/incorrect alert)
Triggers Overreliance	Triggers Overcompliance
Associated with alerting systems	Associated with alerting systems
Induces complacency	Induces automation bias
Less serious	More serious

Automation bias yields particularly problematic results when the alerting system provides false alerts or incorrect recommendations.[39] By relying on automated decision aids, users' own decision-making capabilities are negated, amplifying any technological errors. This phenomenon is reported across sectors, such as in aviation.[40] Similarly, in shooter targeting simulations, military operators' decision-making accuracy declined as the level of automation increased.[41] Higher levels of automation reliability correspond with lower decision-making accuracy. In the context of ADAS, automation bias is especially likely when drivers use automatic parking assist systems, due to the reliance on alerting systems required.[42] Drivers often fail to visually inspect the relevant parking space before selecting to park automatically.[43]

3. Human Automation Interaction Risks & Hazards

Recent literature examining perceived trust and complacency in automated vehicle technology examines partially automated vehicles—SAE level 2 (partial automation)—which place the driver

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[35] Yamani & Horrey.
[36] Christopher D Wickens, Benjamin A Clegg, Alex Z Vieane, & Angelia L Sebok. "Complacency and Automation Bias in the Use of Imperfect Automation." (2015) 57 Human Factors 728 at 729.
[37] *Ibid* at 728.
[38] Wickens.
[39] Juergen Sauer, Alain Chavaillaz, & David Wastell, "Experience of automation failures in training: effects on trust, automation bias, complacency and performance" (2016) 59 Ergonomics 767.
[40] Mosier *et al*. 1998.
[41] E Rovira, K McGarry, & R Parasuraman (2007) "Effects of imperfect automation on decision making in a simulated command and control task" 29 Human Factors at 76.
[42] Yamani & Horrey at 228.
[43] *Ibid*.

in a passive monitoring role.[44] Wilson *et al*. measured (1) engagement, (2) workload, and (3) perceived safety before and after drivers tested a partially automated vehicle on a public highway, finding high levels of trust, and perceived ease of use, usefulness, and safety. Although satisfaction in the technology was high, engagement was low, and many drivers reported feeling as though they were "switching off."[45] These results are consistent with prior findings that over-trust in automated vehicle technology leads to lower driver engagement and increased distracted and inattentive behaviour.[46] They highlight other safety concerns that arise after driver disengagement including mode confusion where a driver failed to realize whether they were operating in automated or manual driving mode.[47]

In the HAI literature, several models are used to offer frameworks for how humans respond to automation. Notably, the Technology Acceptance Model (TAM) is used to conceptualize perceived usefulness, ease, safety, and trust of technology.[48] Similarly, the Unified Theory of Acceptance and Use of Technology (UTAUT) combines TAM and with the Theory of Planned Behaviour model. The UTAUT model assumes that technology acceptance is influenced by hedonic motivation (the degree to which the technology is perceived to be enjoyable), performance expectancy, ease of use, social influence, price, and habit.[49] TAM has been applied to the SAE level 2 automation HAI to evaluate the effects of low levels and high levels of trust (over-trust) in technology. Choi and Ji found corresponding higher levels of complacency with higher levels of trust.[50] Over-trust is more likely to cause drivers to engage in non-driving related tasks, ignore automation system failures and inhibit driver control over the vehicle.[51] In addition, studies by Kundinger *et al*. highlight other related safety concerns associated with SAE level 2 automated driving technology. They compared driver fatigue between manual and automated driving technology and found that the SAE level 2 automated drivers demonstrated significantly higher levels of driver drowsiness than manual drivers.[52]

Meanwhile, other studies have looked critically at the likelihood of successfully making SAE level 3 automation a commercial reality. The handoff problem—the process of handing control authority over to a driver when an automated system encounters a problem and must disengage, and when the driver has not been actively involved or trained in dynamic automated driving tasks—raises several alarm bells for safety.[53] Testing on optimal designs for the requests-to-intervene (RTI)

[44] *Ibid.*
[45] *Ibid.*
[46] *Ibid.*
[47] *Ibid.*
[48] Fred D Davis, "Perceived usefulness, perceived ease of use, and user acceptance of information technology." (1989) 13 MIS Quart 319; J.K Choi, & Y.G Ji, "Investigating the importance of trust on adopting an autonomous vehicle" 31 Int J Human-Computer Interaction 692.
[49] Sina Nordhoff, Tyron Louw, Satu Innamaa, Esko Lehtonen, Anja Beuster, Guilhermina Torra, Afsaneh Bjorvatn, Tanja Kessel, Fanny Malin, Riender Happee, & Natasha Merat. "Using the UTAUT2 model to explain public acceptance of conditional automated (L3) cars: A questionnaire study among 9,118 car drivers from eight European countries"
[50] Choi & Ji.
[51] Kyle M. Wilson, Shiyan Yang, Trey Roady, Jonny Juo, & Michael G Lenné. "Driver trust & mode confusion in an on-road study of level-2 automated vehicle technology" (2020) Safety Science 130.
[52] Thomas Kundinger, Andreas Riener, Nikoletta Sofra & Klemens Weigl, "Driver drowsiness in automated and manual driving: insights from a test track study" (2020) IUI'20: Proceedings of the 25th International Conference on Intelligent User Interfaces.
[53] Ingaki-Sheridan.

processes (*i.e.*, the handoff) has revealed conceptual flaws, since the process of trading authority from computer to person is fraught with challenges, even in the cases of professional, highly trained operators such as pilots.[54] Automation handoffs focused on an RTI expect that the driver will necessarily notice the alert and accept the trading of authority for vehicle control from the automation to the driver. If the driver is more dependable than the automation in emergency situations, the coupling of an RTI and automatic safety control is beneficial. However, if the driver is less dependable than the automation in emergency situations, automatic safety control can make a situation worse because it may cause the driver to perform poor fallback in emergencies. Corresponding risks for enhanced automation systems—crucial considerations like driver distraction, complacency, fatigue, safety, and requests to intervene—prompt thorough considerations for driver training and awareness in emerging ADAS-enhanced vehicles.

Part III. Driver Licencing Regimes & Liability Frameworks

With so many transformational technologies integrated into the driving experience, one might expect that driver licencing regimes have been updated to account for ADAS' emergence. Instead, *our current regulatory reality demands that drivers be able to effectively monitor and operate ADAS without obtaining any formal training or licensing to do so*. This is premised on the outdated notion, given the evidence we have so far presented, that the driving task has been relatively unchanged by ADAS. That is, the current regulatory regime problematically assumes that drivers are still in full control of critical driving tasks and that ADAS has not changed the driving task in any significant or fundamental ways. As we argue, the emergence of ever more sophisticated ADAS has ushered in a transformation of the driving experience, asking drivers to both drive the vehicle and simultaneously monitor these complex systems.

While initial consultations have identified the problem, this significant shift in the driving experience is not yet reflected in driving licencing regimes or transportation liability regulations. This paper focuses on the Canadian regulatory environment for driver licensing. In Canada, driver licensing is a provincial responsibility, although the federal regulator, Transport Canada, does offer some over-arching guidelines for the administration of the overall system. Under the *Guidelines for Testing of ADS Vehicles* in Canada, the government provides some recommendations on SAE International definitions for jurisdictions and manufacturers to follow.[55] The Canadian Council of Motor Transport Administrators (CCMTA) acknowledges the paucity of ADAS information on provincial driver manuals and has stated the need to develop a training method for drivers and licensing examiners to keep pace with the technological evolution.[56] Although this provides future guidelines for SAE level 3-5 vehicles, the processes and methods pertaining to the current driver licensing regimes remain outdated. Approximately 15% or 3.7 million vehicles in Canada use ADAS technology bordering definitions of SAE level 2-3 guidelines.[57] The disconnect between current drivers and their lack of awareness in ADAS technology must be addressed. Broad interpretations of SAE levels and ambiguous driver licensing rules require immediate attention

[54] *Ibid.*
[55] Canadian Jurisdictional Guidelines for the Safe Testing and Deployment of Highly Automated Vehicles CCMTA (page 35).
[56] *Ibid* at 48.
[57] Belron Canada, "The Hidden Link Between Windshields and Road Safety: The role of advanced driver assistance systems (ADAS) in Canada's quest for the world's safest roads" (2019) at 3.

and amendments. This section demonstrates the scarcity of ADAS information in the context of driver licensing regimes.

1. Paucity of ADAS Regulation in Driver Licensing Regimes

Safety critical technologies such as backup cameras, lane departure warnings, blind spot warnings, and automatic emergency braking are sometimes permissible during driver testing. While the CCMTA recommends that safety technologies be engaged during the testing process, those few provinces that have explicitly incorporated the CCMTA's recommendations caution that drivers must still demonstrate traditional safety behaviours like blind spot checking and mirror usage. While driving candidates might be encouraged to use some assistive technologies, the emphasis on acting as though the technology is absent privileges traditional driving behaviours, ignoring the environment in which most drivers will operate most of the time. It underscores the problematic assumptions that engaging an ADAS leaves the driving task unchanged, or simply increases driver safety, neither of which seems straightforward or accurate. Admittedly, variability in manufacturing across vehicles presents challenges for potential standardization in the formal testing environment. But failing to directly examine use of ADAS in the testing environment undermines the importance of drivers actually knowing how their ADAS technologies work and how effectively to operate them. Drivers are asked to suspend modern driving aids—and their own disbelief—to operate a vehicle as if it does not possess these transformative features. The current testing measures are therefore not conducive to teaching new drivers how best to effectively operate ADAS technologies.

Table 2 offers a list of provinces that currently portray an interpretation of the CCMTA guidelines. Under current driver licensing regimes, due to the lack of consistent regulations and definitions, the use of ADAS is contingent on the specific examiner or testing centre.

Table 2: Driver Licensing Parameters for Canada's Ten Provinces

Provinces	Additional Training Required?	Jurisdictional ADAS Rules for Passenger Vehicles
Alberta	X	Convenience and safety critical technologies allowed – will be deducted points for not using the mirrors or manually blind spot checking when changing lanes.[58]
British Columbia	X	Tracking and recording devices are restricted. Digital devices such as GPS must be disconnected before the test. Safety critical technologies are allowed but should not be relied on during the test.[59]
Manitoba	X	The Manitoba Public Insurance Driver's Handbook does not have any written rules on the use of ADAS technology.[60]
New Brunswick	X	No written rules on the provincial Driver's Handbook.[61]
Newfoundland and Labrador	X	No written rules on the provincial Driver's Handbook.[62]
Nova Scotia	✓	No written rules on the provincial Driver's Handbook.[63]

[58] https://www.transportation.alberta.ca/content/docType45/Production/Preparingforyourroadtest.pdf
[59] https://www.icbc.com/about-icbc/newsroom/Pages/2019-may15-interview-with-a-driver-examiner.aspx
[60] https://apps.mpi.mb.ca/comms/drivershandbook/index.html
[61] https://www2.gnb.ca/content/gnb/en/departments/public-safety/community_safety/content/drivers_vehicles/content/new_brunswick_drivers_handbook.html
[62] https://tests.ca/newfoundland-and-labrador/drivers-guide/
[63] https://novascotia.ca/sns/rmv/safe/handbook.asp

Ontario	X	No written rules on the provincial Driver's Handbook. [64] Safety critical technologies are allowed, but not advised to be used during the test. [65] Ontario driving centres advise you to ask the Examiner before the test starts on the rules of using ADAS tech.
Prince Edward Island	X	No written rules on the provincial Driver's Handbook.[66] Drivers should not rely on the safety critical technologies. Drivers still need to manually shoulder check and use mirrors appropriately.[67]
Quebec	X	No written rules on the provincial Driver's Handbook.[68]
Saskatchewan	✓	Safety critical technologies can be used as a back-up tool.[69]

2. Lack of ADAS Awareness and Inadequate Driver Training

Under the Motor Vehicle Safety Regulations (CMVSS 111 Rear Visibility Systems), all passenger cars manufactured after May 2018 are required to accommodate rear-view cameras – a necessary component for parking assist.[70] However, only two provinces (Nova Scotia and Saskatchewan) require additional road training on their use. Although the content of the training varies, educators are not specifically required to teach about ADAS technology. As a result, the public is not provided with clear government instructions on the limitations of ADAS technology or the safe driving behaviours when using ADAS features. A recent survey by Belron Canada showed that 51% of Canadian drivers have little or no familiarity with ADAS as many were never offered any information or training by their vehicle dealers.[71] In light of this, policy considerations for amending the current driver licensing regimes are required to either educate future drivers in the use of this evolving technology or impose regulations on manufacturers to provide training and transparent information about the use and operational limitations of ADAS. The CCMTA further recommended that ADAS information be included in future jurisdiction driver manuals and applied in licensing knowledge tests.[72]

3. Allocating Legal Risk

In the absence of robust driver licensing regulations, we observe a vacuum for allocating legal risk associated with use of ADAS technologies. Such conversations are exacerbated by predominant dialogues on high-level automated vehicles (SAE levels 4 and 5), which remain fixated on "trolly problem"-styled inquiries. By unduly focusing on ethical quandaries like assigning moral value to decision processes, questions on how to best conceptualize legal risk when drivers interact with ADAS are ignored. Understanding liability in new technological environments can require teasing out various legal responsibilities for the different players involved, including appropriate government regulation, manufacturer/product liability, and individual operator liability. Where specific liability frameworks remain underdeveloped, general areas of law like tort or contract may expand to encapsulate legal risk in the new space.

[64] https://www.ontario.ca/document/official-mto-drivers-handbook
[65] https://www.sonnet.ca/blog/auto/how-your-teen-can-ace-their-driving-test
[66] http://www.gov.pe.ca/photos/original/tpw_dh_full03.pdf
[67] https://www.cbc.ca/news/canada/prince-edward-island/pei-driving-instructor-road-test-technology-1.3535863
[68] https://saaq.gouv.qc.ca/en/saaq/documents/publications/publications-quebec/
[69] https://www.sgi.sk.ca/handbook/-/knowledge_base/drivers/parking
[70] https://laws-lois.justice.gc.ca/eng/regulations/C.R.C.,_c._1038/
[71] Belron Canada at 70.
[72] CCMTA at 52.

Both Canada and the United States have favoured a "light-touch" regulatory approach that responds to fears that early regulation in a developing industry could stymie innovation.[73] Conversely, the European Union (EU) has signalled an interventionist, demand-pull approach, focused on generating public comfort with automated systems. The EU have already started the transition through the General Data Protection Regulation (GDPR) to help protect the digital rights of citizens.[74] The UK parliament have passed the Automated and Electric Vehicles Bill and is currently developing a self-regulatory model based on an "AI Code." This code would outline ethical standards for the deployment of AI technology across multiple industrial sectors.[75] These kinds of interventions signal regulatory guidance to operators and manufacturers about legal responsibility for the vehicles themselves.

On the other side of the globe, Korea became one of the first countries to release safety standards on the manufacturing and commercialization of SAE Level 3 AVs. The legislative amendments led by Korea's Ministry of Land, Infrastructure, and Transport (MOLIT) helped create a regulatory framework and mandatory consumer-training regimes which came into force in the summer of 2020.[76] In contrast to the EU, Korea adopted a technology-push approach, focusing on making AVs available to the public, ultimately promoting domestic industrial growth.[77] Their neighbour, Japan, is taking a mixed approach, focusing on the combination of social and technology regulations given its decreasing, aging population and strong economic ties to the automotive industry. In March 2021, Japanese manufacturer Honda launched the world's first level 3 self-driving car. In anticipation of this technological advancement, the Japanese government introduced a revised legal framework in April 2020 to ensure that the vehicle and its manufacturer were primarily responsible for the driving. Before approval, Honda conducted over 10 million situational simulations and 1.3 million kilometres of automatic testing, which were approved by Japan's Ministry of Land, Infrastructure, Transport, and Tourism in November 2020.[78]

Focusing on the vehicle itself, and the associated demands on the manufacturer, raises questions of manufacturer's liability. Honda's recent Level 3 vehicle launch emphasizes how government regulations can guide manufacturer behaviour: with clear guidance that the vehicle and manufacturer maintain legal responsibility, comprehensive testing was conducted to ensure that safety threshold. Absent such direction, liability could arise in a variety of ways, including tort, contract, or class action contexts.

In Canada, the nature of the automotive industry, and especially the impact of automotive insurance,[79] constrain the likelihood of potential litigation. The tort of negligence is sometimes viewed as the only possible avenue of recovery for technology-related injuries and damages in Canada, through imposing a duty of care on manufacturers. Designers, creators, and distributors

[73] Thomas O'Leary & Taylor Armfield "Adapting to the Digital Transformation" (2020) CanLIIDocs 3296 at 267.
[74] *Ibid*; see also Brandon W Jackson, "Artificial Intelligence and the Fog of Innovation: A Deep-Dive on Governance and the Liability of Autonomous Systems" (2019) 35 Santa Clara Comp & High Tech LJ at 42–44.
[75] https://publications.parliament.uk/pa/ld201719/ldselect/ldai/100/10014.htm
[76] http://www.molit.go.kr/english/USR/BORD0201/m_28286/DTL.jsp?id=eng_mltm_new&mode=view&idx=2905
[77] Jeehoon Ki, Fondation France, Korea Institute of Science and Technology Evaluation and Planning, FFJ Discussion Paper #20-02 at page 46.
[78] https://www.hondanews.ca/en/news/release/Honda-launches-next-generation-Honda-SENSING-Elite-safety-system-with-Level-3-automated-driving-features-in-Japan
[79] Canadian litigation approaches would vary by province, given the differences between public and private automotive insurance providers in different jurisdictions.

normally accrue liability for harm caused by the use or misuse of their products.[80] Typically, a software designer or AI manufacturer should owe a *prima facie* duty of care to the public and its consumers. However, questions persist on how the limitations of regulations imposed on these developers, manufacturers, vendors, and users of AI systems in Canada will unfold.[81] Relatedly, in contract law, there is ongoing debate on whether AI-powered technologies are considered under the *Sales of Goods Act* (SGA) and its principles on product warranties.[82] The SGA provides no remedy against the manufacturer or designer that may be at fault regarding product quality or defect. Although the definitions vary across Canadian jurisdictions, it is implied that under a relevant market, goods will be reasonably fit and accepted for the general purposes they serve.[83] Due to the reliance on the seller's judgement of goods, consumers examining products for defects are rarely protected by statutory warranty claims. Thus, the consumers typically turn to tort law to obtain remedies against a manufacturer.[84]

No significant cases have been litigated in these spaces so far, leaving open questions as to how courts will allocate legal risk for the operation of ADAS. In one interesting analogy, a provincial court in Alberta considered a dangerous driving violation of the Criminal Code, where the driver was driving a manual transmission despite being unfamiliar with its operation.[85] Extrapolating from this view, unfamiliarity with a vehicle's operations—including its technological systems—may be cited in support of a reckless state of mind. With such uncertainty around the allocation of legal risk, robust regulatory frameworks could assist with flagging the new complexity introduced by sharing driving tasks with ADAS.

Part IV. Policy Proposals

To best approach ADAS driver training and regulation, policy makers must acknowledge the disconnection between automation bias and complacency studies and the unstated and questionable assumption that introducing ADAS to consumer vehicles necessarily improves safety outcomes. Because Canadian approaches to technology regulation have allowed technology companies to set the agenda, government regulation in this space is especially scant. This generates what is often referred to as a pacing problem, where innovation outstrips possible regulation. In the case of driver licensing, the regulatory scheme need not be directed at technology companies directly. However, intervention in driver licensing regimes with clear evidence-based policy could assist in calibrating driver trust and reliance appropriately, to avoid the automation bias and complacency outcomes identified in Part II, and to explicitly and effectively address the risks and hazards associated with ADAS. Further, clear direction to manufacturers through unified regulatory approaches that prioritize testing and safety data will avoid the patchwork liability outcomes discussed in Part III.

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[80] *Lambert v Lastoplex Chemicals Co*, [1972] SCR 569 at 574–75; see also *Linden & Feldthusen, supra* note 59 at paras 16.6, 16.13-16.
[81] O'Leary & Armfield.
[82] *Sale of Goods Act*, RSO 1990, c S.1.
[83] *Sale of Goods Act*, RSO 1990, s 15.2.
[84] O'Leary & Armfield.
[85] The defendant was charged with dangerous driving under s. 249(1)(a) of the Criminal Code; in addition to his lack of familiarity with the manual transmission, the evidence included that he was traveling 208 kmph (more than triple the speed limit) and was not a fully licensed driver. *R v Routh*, 2016 ABPC 26.

Policy approaches are best informed by first-hand accounts of the experience of driving ADAS-equipped vehicles. The KOTI/ORI dataset from the quantitative public survey on knowledge regarding ADAS offers meaningful engagement with the deployment of these technologies and public attitudes. Importantly, vehicle default settings impact their usage rates: drivers are most likely to use lane-keeping (71.2%); followed by parking assist (63.2%); adaptive cruise control (45.1%); and regular cruise control (36.6%). These results mirror how the technologies are deployed within new vehicles: LKAs and parking assist functions are often on by default, different from traditional cruise control systems that require drivers to manually engage the system. This underscores how driver familiarity with system architectures and options are critical for interacting with ADAS—and even turning off undesirable system elements.

Across the range of ADAS technologies, a significant proportion of drivers reported feeling more unsafe when SAE Level 1 or 2 systems are engaged, as compared with Level 0 systems. Parking assist systems were most maligned, with 40.7% of respondents reporting feeling as though they compromised driver safety "most or all of the time." Meanwhile, 37% of respondents felt safety was compromised either most or all of the time with lane keeping assist; with 30.4% of respondents feeling this way for adaptive cruise control. These reports are contrasted quite evenly against traditional cruise control: only 41.1% of respondents report feeling cruise control compromised their safety. These reports on drivers' subjective experiences underscore concerns that ADAS systems do not necessarily improve vehicle safety. Studies attempting to quantify ADAS safety impacts have generated mixed results. Vehicles operating autonomously are struck from behind in crashes more often than human-operated vehicles,[86] but LKA technologies have been found to reduce severity of police-reported crashes by 18% (as compared to vehicles without LKA).[87]

Drivers' safety concerns with ADAS signal the need for more research into safety and driver education and training. When asked about what kinds of training or learning contributed to their knowledge of ADAS, respondents were clear that training efforts were meagre and variable. Only 7.7% of respondents confirmed that their driving courses offered some kind of training on ADAS, with another 5.78% reporting that the driver licensing authority did offer some basic information. Meanwhile, most respondents obtained their information either from reading the car manual (37.4%) or trying the feature out while driving (37.9%). Neither of these methods qualify as meaningful training experiences, nor are they likely to counteract the psychological effects described in HAI literature—automation bias and complacency—that undermine effective user behaviour.

ADAS operation should therefore be adopted into driver's education and training courses across Canada. Because driver training is provincially administrated, federal guidance should be issued on how to best achieve these goals. Proper guidance would include identifying key system components, distinguishing between alerts and recommendations, and appropriate interventions for both commission and omission errors. Training recommendations should harness the UTAUT model to acknowledge levels of over-trust and overcompliance commonly associated with HAI, with specific warnings about common issues, like feeling "switched off" or driver drowsiness. Data from testing centres could be collected to develop insights for new frameworks for RTI

[86] NJ Goodall, "Comparison of automated vehicle struck-from-behind crash rates with national rates using naturalistic data" (2021) 154 Accident Analysis & Prevention 106056.
[87] JB Cicchino, "Real-world effects of rear automatic braking and other backing assistance systems" (2019) 68 Journal of safety research 41 at 47.

processes, which might better inform. Care would need to be taken to ensure training centres and programmes had access to vehicles equipped with commonly available ADAS.

In this scenario, ADAS-familiarity could also be acknowledged in formal testing environments, although since most driving candidates provide their own vehicle for driver testing, this may require a minimum ADAS requirement or the provision of a specific test car to achieve a driving credential. In the alternative, ADAS testing could be separately administered, with drivers mandated to complete a specific ADAS course within a particular time period of their other licensing exam. Governments would need to make the training centres accessible, with appropriate attention given to equity-seeking groups. In addition, standards organizations must help manufacturers coordinate the nature of user interfaces associated with various ADAS features, since a sense of interface uniformity from vehicle to vehicle will become more essential as more drivers engage in car sharing over car ownership.

Part V. Conclusion

Ultimately, a critical distinction is missed by unduly focusing on SAE levels as a measure of where liability issues arise: what complicates liability is the distinction between drivers directly controlling critical driving tasks *versus* monitoring the automated performance of critical driving tasks. Concurrent research about driver awareness, knowledge, and use of ADAS demonstrates significant shortcomings with their implementation. Review of the literature demonstrate that drivers were unsure about how some systems work in combination with others and how they are distinguishable from one another. Uncertainty and confusion may impact a driver's usage, comfort, and reliance on the technology.[88] Few survey respondents reported seeking information about technologies from any sources beyond the dealership, owner's manual, and their own experience via trial and error; only about 1 in 10 reported seeking information on the Internet and hardly any reported visiting government safety websites. More research is needed to determine how best to reach drivers with important information about how to safely use these technologies. Allocation of legal risk remains a thorny question for automotive manufacturers, who endeavour to secure global supply chains despite radically different regulatory regimes across the globe. Comprehensive training on HAI best practices could offer guidance to legal regulators seeking to predict human performance when interacting with automated systems.

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[88] McLeod *et al*.