Identifying opportunities to govern how autonomous vehicles communicate

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Abstract

Stakeholders throughout the world use alternatives to regulation, in the form of soft law, as a tool to dynamically manage the design, development, and deployment of AI applications. One of these applications, autonomous vehicles (AVs) above SAE level 4, promises to transport individuals and goods safely and efficiently at scale. For this to happen, it is critical that society develop governance mechanisms that adapt to the wide variety of scenarios confronting how AVs communicate with the rest of the world. To examine this issue, this working paper has two objectives. First, it proposes a framework to characterize the range of communication-centered behaviors that an AV is capable of performing: information security, safety, infrastructure support, and profit motivated. Second, it examines the potential or existing role of soft law in managing these capabilities in a proactive and pro-social manner.

Introduction

The operation of road vehicles requires a combination of abilities (visual perception, reasoning, manual handling of instruments, etc.) to deliver a person and their cargo from point A to B. In addition to moving in all directions, critical tasks include the gathering of information and communicating with one's surroundings to express an intended course of action. Doing so appropriately increases the safety of people and property in a vehicle's vicinity.

Traditionally, this two-way information exchange has relied exclusively on a human operator. Licensed individuals are trained to become situationally aware and communicate through verbal or visual cues directed at individuals sharing the road in different modalities of travel (bicycle, foot, train, motorcycle, among others). In fact, these behaviors are covered by regulated and non-regulated means. Regulated ones include specific rules on the size and light intensity of turn signals.¹ Non-regulated ones exist as social norms that involve the usage of gestures and eye contact, among other behaviors, to indicate intent.

Increasingly, autonomous vehicles (AVs) are expected to challenge the long-standing governance of vehicle navigation. This is especially the case for SAE level 4 and above vehicles that release humans from all responsibilities over their operation.² In effect, the deployment of this technology is becoming a reality in a small number of countries, like the United States (US). In cities like San Francisco, authorities have approved the commercialization of taxi services for AVs without operators.³ At an SAE level of 4, these vehicles cross the threshold of no longer depending on an individual for their operation.⁴ Thus, society faces novelty in terms of replacing the role of humans and managing unknown scenarios of varying complexity.⁵

Coping with this novelty involves identifying adaptable and responsive governance mechanisms. While enacting regulation or hard law is effective in mandating a desired output, less so is its creation process. This is because it requires significant stakeholder bandwidth and can be difficult to modify in the long-term. On the other hand, the use of programs that create substantive expectations that are not directly enforced by government, also known as soft law, serve as a dynamic means of managing the growing expectations of AVs. ⁶ In fact, this is the

¹ Federal Register, *Federal Motor Vehicle Safety Standards; Lamps, Reflective Devices and Associated Equipment,* FEDERAL REGISTER (2004), https://www.federalregister.gov/documents/2004/08/11/04-18297/federal-motor-vehicle-safety-standards-lamps-reflective-devices-and-associated-equipment (last visited Sep 14, 2023).

 ² Society of Automotive Engineers, SAE Levels of Driving AutomationTM Refined for Clarity and International Audience, https://www.sae.org/site/blog/sae-i3016-update (last visited Jun 14, 2022).

³ California Public Utilities Commission, *CPUC Approves Permits for Cruise and Waymo To Charge Fares for Passenger Service in San Francisco*, (2023), https://www.cpuc.ca.gov/news-and-updates/all-news/cpuc-approves-permits-for-cruise-and-waymo-to-charge-fares-for-passenger-service-in-sf-2023 (last visited Sep 15, 2023).

⁴ California Public Utilities Commission, *ADDENDUM: Operational Design Domain - Driverless Deployment in California*, (2022), https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/consumer-protection-and-enforcement-division/documents/tlab/av-programs/cruise-driverless-deployment-odd-2023-08.pdf.

⁵ Lyria Bennett Moses, *Recurring Dilemmas: The Law's Race to Keep up with Technological Change*, U. ILL. JL TECH. & POL'Y 239 (2007); Carlos Ignacio Gutierrez, *The Unforeseen Consequences of Artificial Intelligence (AI) on Society: A Systematic Review of Regulatory Gaps Generated by AI in the US* (2020).

⁶ Gary E Marchant & Brad Allenby, *Soft Law: New Tools for Governing Emerging Technologies*, 73 BULLETIN OF THE ATOMIC SCIENTISTS 108 (2017).

approach currently championed by the US government through the publication of several of its AV frameworks.⁷

This paper has two goals. First, it proposes a framework that characterizes the communication capabilities of AVs, incoming and outgoing, based on the following dimensions: information security, safety, coordination, and profit-motive. Secondly, it identifies existing or opportunities for governing these capabilities through soft law mechanisms. The expectation is that this document can serve transportation stakeholders in the public and private sector to improve their proactivity in terms of managing this technology. One with capabilities that will likely alter the social norms of individuals traveling from point A to B in the same way that the first mechanized vehicle changed how individuals accustomed to horses perceived the risks from transportation technologies.

Communication Capabilities of AVs

In the operation of non-AVs, the exchange and usage of information is completely reliant on a driver. These individuals can gather data through their senses and communicate their intention to act via: sound using a car's horn or voice, visually through headlights and turning signals, and non-verbal cues from their posture, facial, or hand gestures. Many of these interactions are regulated, where there is an expectation for a particular place and time to communicate (e.g., a turn signal when changing lanes). Meanwhile, others are not subject to statutory requirements and wide discretion is given, such as when to honk a horn or gesticulate approval or disapproval over another person's behavior. Overall, society affords vehicle operators with relative flexibility over how and when these communication mechanisms are engaged.

AVs differ from their human-driven counterparts in two ways, those above SAE level 4 may lack a human driver and a significant expansion of communication capabilities are possible.⁸ Such increase is both an opportunity to improve the utility of vehicles and a risk that requires the management of behavior that may introduce new harms. This article proposes a framework to characterize the communication capabilities of AVs and identify the soft law programs that exist or should be proposed for their governance (see Table 1). It divides the information exchanges AVs make possible into four dimensions: information security, safety, infrastructure support, and profit motive.

Table 1: Communication Capabilities of AVs			
Dimension		Description	
Information security	Safety	Avoid scenarios where an AV can directly or indirectly cause harm to an individual or infrastructure.	
	Infrastructure support	Generate and transmit information that improves the situational awareness of an entity for the benefit of a group of vehicles, an individual, or society.	

⁷ Department of Transportation, *Automated Vehicles Activities*, (2023), https://www.transportation.gov/AV (last visited Sep 15, 2023).

⁸ Based on the classification of the SAE, drivers are charged with supervising the decisions of vehicles under automation levels 0 to 3. In other words, there is an expectation that an individual should take over vehicle control if a complex situation arises. There are several opportunities for the management of this relationship via soft law, including standards for the visual, sound, and haptic cues needed in the successful transition between the AV and human. Nevertheless, the focus of this document are vehicles with an SAE level 4 and 5 and discussion of semi-AV will not be emphasized throughout this text.

Profit motive	Create opportunities that harness AV sensors and the data they
r ront mouve	generate with the intention of monetizing them.

The following sections will describe the proposed dimensions. The intent of this exercise is to emphasize opportunities and challenges to manage this technology. The examination of a range of scenarios and behaviors emanating from AV capabilities will demonstrate that stakeholders can benefit from flexible and agile consolidation of governance through soft law to improve prosocial outcomes.

Information security

Security is an overarching element of this framework. Without the protection of data, any effort to communicate between and with AVs is subject to a long list of attack vectors that can exploit supply chain vulnerabilities, remotely disable fleets, disrupt sensors, facilitate theft, etc.⁹ A compromised information network is a clear indicator of a technology that cannot be trusted by consumers to perform any of its expected or desired tasks related to safety, infrastructure support, or a profit motive.

To combat potential attacks, stakeholders have access to several existing soft law mechanisms. For one, the National Highway Traffic Safety Administration dedicates significant bandwidth to educate industry about cybersecurity through workshops and the publication of a best practices document.¹⁰ Industry alliances, such as those of the Alliance of Automobile Manufacturers and the Association of Global Automakers, have developed consumer privacy protection principles to align manufacturer efforts.¹¹ Lastly, ISO/SAE 21434:2021 is a global standard developed to specify "engineering requirements for cybersecurity risk management regarding concept, product development, production, operation, maintenance and decommissioning of electrical and electronic (E/E) systems in road vehicles, including their components and interfaces."¹²

Safety

The promise of AVs represents a hopeful future. One where safety does not depend on the capacity, awareness, state of intoxication, or reflexes of an error-prone driver.¹³ Even in complex environments, there is an acknowledgement that machines are likely to capture, analyze, and make decisions on information at a higher and more consistent rate than humans. To deliver on this promise, a fundamental component of AV safety is its effectiveness in gathering and communicating information. This section explores three scenarios where communication is critical to mitigate the direct or indirect harm caused by an AV.

⁹ Cybersecurity & Infrastructure Security Agency, *AUTONOMOUS GROUND VEHICLE SECURITY GUIDE: Transportation Systems Sector*,

https://www.cisa.gov/sites/default/files/publications/CISA_AV_SecurityGuide_508.pdf.

¹⁰ NHTSA, *Cybersecurity Best Practices for the Safety of Modern Vehicles - Updated 2022*, (2022), https://www.nhtsa.gov/sites/nhtsa.gov/files/2022-09/cybersecurity-best-practices-safety-modern-vehicles-2022-tag.pdf.

¹¹ Alliance for Automotive Innovation, *Consumer Privacy Protection Principles*, (2022),

https://www.autosinnovate.org/innovation/Automotive%20Privacy/Consumer_Privacy_Principlesfor_VehicleTechn ologies_Services-03-21-19.pdf.

¹² ISO/SAE, *ISO/SAE 21434:2021*, ISO (2021), https://www.iso.org/standard/70918.html (last visited Nov 18, 2023).

¹³ Nidhi Kalra & Susan M. Paddock, *Driving to Safety: How Many Miles of Driving Would It Take to Demonstrate Autonomous Vehicle Reliability?*, 94 TRANSPORTATION RESEARCH PART A: POLICY AND PRACTICE 182 (2016).

Pedestrians and individuals in other non-AVs

One of the complexities in maneuvering a vehicle is interacting with humans in the form of pedestrians and other motorized or non-motorized vehicles operated by them.¹⁴ If AVs are to value the safety of this group over their navigational objectives, these individuals will live in a world where the likelihood of harm due to an AV encounter is very small. This scenario describes a status quo of "pedestrian supremacy," where technology will behave conservatively to avoid harming individuals outside the vehicle at all costs.¹⁵

Optimizing pedestrian supremacy does not account for the full spectrum of safety issues. People inside of AVs also face risks when a technology favors the well-being of those outside its enclosure. This is why effective communication serves as a vector to minimize risk-inducing interactions.¹⁶ There are two areas within the interaction of AVs with individuals and non-AVs where soft law can enhance vehicle safety: distinguishing AVs from other vehicles and communicating intent to people. For both, widely adopted soft law programs have yet to emerge.

Improving safety requires the communication of AV capabilities. At present, there are no clear indicators for identifying an AV able to perform at a SAE level 4 or above. Even vehicles performing below a SAE level 4, such as Tesla's "autopilot" or General Motor's "supercruise," lack any method to indicate that these systems are engaged. Pedestrians and other drivers are left to assume that a vehicle's equipment (e.g., radar), branding, or the visible lack of a driver might be a sign of autonomy.

Automakers would benefit from normalizing how vehicles publicize that a human is not in charge of decision-making. Doing so, would allow people to exercise the necessary caution with how they interact with this technology. In this respect, the state of California has clear requirements for identifying AVs that are being tested (§ 227.16).¹⁷ However, these guidelines are limited to information provided to local authorities on the model make, license plate, and vehicle identification number. Unfortunately, none of these improve the public's awareness of AVs.

The second step to improve safety is standardizing how intent is communicated. AVs can theoretically process data consistently and continuously, but if their sensors are blocked by incoming traffic, a tree, or other sources of "signal pollution," then their ability to mitigate harms could be inadequate. For this purpose, the academic literature is home to a large market of ideas for visual and auditory cues to message pedestrians.¹⁸ In addition, researchers have evaluated

¹⁴ Non-motorized AVs refer to vehicles that share the road and are operated by humans such as bicycles, skateboards, among others.

¹⁵ Adam Millard-Ball, *Pedestrians, Autonomous Vehicles, and Cities*, 38 JOURNAL OF PLANNING EDUCATION AND RESEARCH 6 (2018).

¹⁶ Brian Mason et al., *Lighting a Path for Autonomous Vehicle Communication: The Effect of Light Projection on the Detection of Reversing Vehicles by Older Adult Pedestrians*, 19 INTERNATIONAL JOURNAL OF ENVIRONMENTAL RESEARCH AND PUBLIC HEALTH 14700 (2022).

¹⁷ California Department of Motor Vehicles, *Article 3.7. Testing of Autonomous Vehicles*, (2022), https://www.dmv.ca.gov/portal/file/adopted-regulatory-text-pdf/.

¹⁸ Ola Benderius, Christian Berger & Victor Malmsten Lundgren, *The Best Rated Human–Machine Interface Design for Autonomous Vehicles in the 2016 Grand Cooperative Driving Challenge*, 19 IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS 1302 (2017); Lex Fridman et al., *To Walk or Not to Walk: Crowdsourced Assessment of External Vehicle-to-Pedestrian Displays*, ARXIV PREPRINT ARXIV:1707.02698 (2017); MICHAEL

CLAMANN, MILES AUBERT & MARY L. CUMMINGS, Evaluation of Vehicle-to-Pedestrian Communication Displays for Autonomous Vehicles, (2017); Tobias Lagström & Victor Malmsten Lundgren, AVIP-Autonomous Vehicles'

several efforts with respect to their inclusiveness. Meaning, that they have examined how individuals with different demographic characteristics (varying cultures, ages, and capabilities) interpret the information displayed by AVs to safeguard their well-being.¹⁹

Interaction with authorities and their signals

Personnel representing a public authority (e.g., first responders, police, firefighters, etc.) have privileges over roadways. In some scenarios, these individuals are charged with altering standard operating traffic procedures so that the flow of vehicles can adjust to an emerging situation. To fulfill their remit, it is evident that the capability to interact with AVs must not only exist but should be widely available and trained for.²⁰ Particularly, these individuals might require AVs to perform a specific set of actions for an indeterminate temporality. Such circumstance can be faced in a variety of conditions such as construction work, torrential rain during a hurricane, a medical emergency, a riot, a situation involving a firearm, among others.

Reception of orders from formal authorities is one element of this equation. Another is individuals who serve as informal authorities. A pedestrian or another driver may want to modify the flow of traffic to protect an individual or a group from harm. In these cases, AVs must have the capability to follow instructions from formal and informal authorities. Informal authorities may appear in the designation of a civilian as a temporary holder of power during an accident or unusual road conditions.

In terms of US policy, the federal government acknowledges the need for law enforcement to interact with AVs in its proposed model template for states. This document declares that there "will be a growing need for the training and education of law enforcement regarding their interaction with drivers/operators in both the testing and deployment of these technologies."²¹ As of today, these interactions currently generate inconveniences for public officials.²²

To address the above, entities testing and deploying these vehicles have developed mechanisms named law enforcement interaction plans. In states such as CA, these are mandatory based on a vehicle's permit, while in other states no such requirements are in place.²³ Depending on the

Interaction with Pedestrians-An Investigation of Pedestrian-Driver Communication and Development of a Vehicle External Interface (2016).

¹⁹ Mark Colley et al., *Towards Inclusive External Communication of Autonomous Vehicles for Pedestrians with Vision Impairments, in* PROCEEDINGS OF THE 2020 CHI CONFERENCE ON HUMAN FACTORS IN COMPUTING SYSTEMS 1 (2020); Vicky Charisi et al., *Children's Views on Identification and Intention Communication of Self-Driving Vehicles, in* PROCEEDINGS OF THE 2017 CONFERENCE ON INTERACTION DESIGN AND CHILDREN 399 (2017); Mirjam Lanzer et al., *Designing Communication Strategies of Autonomous Vehicles with Pedestrians: An Intercultural Study, in* 12TH INTERNATIONAL CONFERENCE ON AUTOMOTIVE USER INTERFACES AND INTERACTIVE VEHICULAR APPLICATIONS 122 (2020); N. Charness et al., *Final Report: Aging Driver and Pedestrian Safety: Parking Lot*, FLORIDA STATE UNIVERSITY: TALLAHASSEE, FL, USA (2012).

²⁰ SEAN E. GOODISON ET AL., Autonomous Road Vehicles and Law Enforcement, (2020); Seong Hee Lee et al., Safe to Approach: Insights on Autonomous Vehicle Interaction Protocols with First Responders, in COMPANION OF THE 2023 ACM/IEEE INTERNATIONAL CONFERENCE ON HUMAN-ROBOT INTERACTION 399 (2023).

²¹ Department of Transportation, *Federal Automated Vehicles Policy: Accelerating the Next Revolution in Roadway Safety*, (2016), https://www.nhtsa.gov/sites/nhtsa.gov/files/documents/av_policy_guidance_pdf.pdf.

²² Dara Kerr, *Why Police and Firefighters in San Francisco Are Complaining about Driverless Cars*, NPR, Aug. 10, 2023, https://www.npr.org/2023/08/10/1193106866/why-police-and-firefighters-in-san-francisco-are-complaining-about-driverless-ca (last visited Sep 21, 2023).

²³ California State Transportation Agency, Re: Rulemaking 12-12-011, (2023),

https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M516/K901/516901046.PDF.

deployer, these documents provide critical information to facilitate the disabling, towing, opening, and disconnecting the battery of an AV.²⁴

Non-road AVs

This document has thus far described scenarios concentrated on road-faring AVs. An emerging market segment in the US are vehicles that autonomously deliver goods using the sidewalk.²⁵ They generally exist in the form of mobile rectangular boxes that share pedestrian spaces at slow speeds. Because of this context, these AVs are in continuous contact with humans. But, unlike road AVs, there is clarity about the lack of a human physically in the driver seat of this technology.

Relevant in this scenario is the distribution of transit space that was mainly devoted for commuting via walking.²⁶ Therefore, the sidewalk is a context where pedestrians might be less accustomed to interacting with a technology that is crowding out a public space to complete "last-mile delivery."²⁷ Here, communication is targeted at two entities. Pedestrians and vehicles (AV and non-AV), particularly during crosswalk interactions, need to be given a clear understanding of this AVs intended direction.

Local governments throughout the US have generated hard law to manage how sidewalk space is managed or shared with AVs, in some cases denoting delivery robots as "pedestrians."²⁸ More importantly, soft law initiatives in the form of ISO 4448 have been created to standardize the behavior of this technology and serve as a reference for deployers and government stakeholders.²⁹

Infrastructure support

To function, AVs require several sensors (cameras, radar, LiDAR, ultrasonic, etc.) to understand and interact with their surroundings. In addition to enabling autonomy, this technology generates data that allows the coordination of vehicles for the benefit of a user, group, or society at large.

Realizing this advantage hinges on interoperability. Without it, each AV is limited to function as an independent entity incapable of distributing real-time information for the purpose of cooperating with other systems. This section discusses two scenarios for using the information generated by AVs to improve traffic flows through platooning and increasing the situational

²⁴ Autox, AutoX Driverless Vehicle Test: Law Enforcement Interaction Plan,

https://www.autox.ai/files/law_enforcement_interaction_plan.pdf; Waymo, *Servicios de primera respuesta*, WAYMO, https://waymo.com/intl/es/firstresponders/ (last visited Nov 18, 2023); Cruise, *First Responders*, https://getcruise.com/firstresponders/ (last visited Nov 18, 2023); Pony.ai, *Pony.Ai: Law Enforcement Interaction Plan*, (2022), https://pony.ai/firstresponders.

²⁵ Starship Technologies: Autonomous robot delivery, STARSHIP TECHNOLOGIES: AUTONOMOUS ROBOT DELIVERY, https://www.starship.xyz/ (last visited Sep 18, 2023).

²⁶ Millard-Ball, *supra* note 15.

 ²⁷ Dylan Jennings & Miguel Figliozzi, Study of Sidewalk Autonomous Delivery Robots and Their Potential Impacts on Freight Efficiency and Travel, 2673 TRANSPORTATION RESEARCH RECORD 317 (2019); Mason Marks, Robots in Space: Sharing the Sidewalk with Autonomous Delivery Vehicles, AVAILABLE AT SSRN 3347466 (2019).
²⁸ Eli Stein, Autonomous Robot Delivery Legislation, GENERAL CODE (Mar. 15, 2022),

https://www.generalcode.com/blog/autonomous-robot-delivery-legislation/ (last visited Sep 21, 2023). ²⁹ Harmonize Mobility, *Robots on City Streets and Walkways*, (2018),

https://harmonizemobility.com/sidewalkandcurb/ (last visited Sep 21, 2023); Harmonize Mobility, *Sidewalk and Kerb Operations for Automated Vehicles: Arriving, Stopping, Parking, Waiting, and Loading*, (2020), https://www.mwcog.org/file.aspx?&A=uVGonCP0WvdxJ5Ear9Xf3Q5yLXwfsnCK3WZR5Dfzf%2FM%3D.

awareness of road conditions for public authorities. Both outputs have been identified by US policymakers as examples of potential benefits from this technology.³⁰

Platooning of AVs

Individually, non-AVs are chaotic and inefficient in terms of navigation and energy usage. As a group, AVs are capable of exchanging information to coordinate movements for the optimal allocation of space considering road conditions. In the literature, the term of reference for this behavior is platooning.³¹

In practice, platooning involves the synchronization of sensors and the communication of data. As AVs enter the market in the US, there is an opportunity to harmonize the exchange of information as networking (e.g., 5G or 6G) or vehicle hardware (e.g., Lidar) technology improves. In this respect, there are several soft law programs attempting to set common protocols. In Europe, there is the ENSEMBLE project where manufacturers pool their expertise to test and roll-out this functionality among heavy-duty vehicles.³² Internationally, standards have been developed to securely communicate vehicle-to-vehicle data.³³

Data for the public benefit

Gathering information from the physical world requires significant infrastructure. For instance, several metropolitan areas in the US have dedicated sensors to monitor conditions, while a minority, like Los Angeles, invest in dedicated hardware to optimize traffic.³⁴ For governments of diverse sizes and budgets, the sensors and communication capabilities of AVs are an opportunity to outsource the systematic gathering and transmission of information on road conditions.

The public benefit of these sensors need not stop at the gathering of data on road conditions. The combination of demographic, geographic, and meteorological information, among other sources, can serve public officials concerned with improving their community (e.g., its health outcomes). Although this prospect sounds beneficial, this data could provoke direct and indirect harm that aggravate the rights and civil liberties of individuals if careful consideration is not undertaken regarding its use.

For AV data to become a net positive contribution to the public, there are a few issues to consider. Interoperability needs to be established between how different manufacturers capture information and how this is relayed to authorities. Through soft law in the form of standards,

³⁰ Department of Transportation, *A Framework for Automated Driving System Testable Cases and Scenarios* (2018), https://www.nhtsa.gov/sites/nhtsa.gov/files/documents/13882-automateddrivingsystems_092618_v1a_tag.pdf.

³¹ Maryam Kamali et al., Formal Verification of Autonomous Vehicle Platooning, 148 SCIENCE OF COMPUTER PROGRAMMING 88 (2017); Keqiang Li, Jiawei Wang & Yang Zheng, Cooperative Formation of Autonomous Vehicles in Mixed Traffic Flow: Beyond Platooning, 23 IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS 15951 (2022); TIM TIERNAN ET AL., Test and Evaluation of Vehicle Platooning Proof-of-Concept Based on Cooperative Adaptive Cruise Control, (2017).

³² Ensemble, ENSEMBLE: Platooning Together, (2022),

https://platooningensemble.eu/storage/uploads/documents/2022/03/22/Ertico-ENSEMBLE-digital-brochure-final-HQ compressed-(1).pdf.

 ³³ Feifei Liu et al., Secure Vehicle Platooning Protocol for 5G C-V2X, in 2021 IEEE INTL CONF ON PARALLEL & DISTRIBUTED PROCESSING WITH APPLICATIONS, BIG DATA & CLOUD COMPUTING, SUSTAINABLE COMPUTING & COMMUNICATIONS, SOCIAL COMPUTING & NETWORKING (ISPA/BDCLOUD/SOCIALCOM/SUSTAINCOM) 868 (2021).
³⁴ LADOT, Los Angeles Signal Synchronization, https://ladot.lacity.org/sites/default/files/documents/ladot-atsacsignals-_-fact-sheet-2-14-2016.pdf.

associations representing local departments of transportation and manufacturers can formalize the linkages necessary for the reception and sending of data.

In parallel, priorities on what type of information to classify, catalog, and distribute must be considered a multi-stakeholder process that can be formalized through soft law. On the one hand, agreement could be found on having AVs assist in generating reports on accidents, potholes, micro-weather conditions, natural disasters, and energy use. On the other hand, the monitoring and characterization of individual behavior can lead to major disagreements on how to balance privacy and the recovery of information that should exclusively be used for the public benefit.

Profit-motive

The safety and infrastructure support categories of this framework dealt with AV functionalities with a primary motivation that contributes to the common good (e.g., improve traffic, minimize accidents, etc.). This category emphasizes incentives that are less altruistic and centered on the monetization of AV capabilities for the benefit of individuals or firms. Its inclusion in this framework stems from the desire to catalyze debate on the guardrails necessary to balance profit motivations with the respect of civil liberties.

Information sponge

Inherent to how they function, AVs are data magnets. Their sensors capture, process, classify, and transmit their surroundings to maneuver through the world. What if these sensors were given the ability to monitor data that does not serve a navigational purpose? Potential secondary targets could serve an almost infinite number of objectives. For example, market research firms could identify the demographics of pedestrians in specific geographies and count the number of vehicles in a business parking lot. Less desirable objectives include having a private investigator purchase access to this stream of information with the purpose of surveilling an individual or group of people.

In the US, the first amendment protects the ability of individuals and firms to collect information in public. Arguably, this includes data gathered by AVs through their sensors. Enacting hard laws to control this information intake and processing may result in legal controversies that, eventually, have no effect in deterring this activity. In this scenario, soft law may represent an effective alternative to setting norms that limit such surveillance. It is important to note, that prior efforts related to this type of monitoring have faced difficulties in the recent past.³⁵

Despite the legal hurdles to control the behavior of private actors, soft law can serve as a mechanism to limit unwanted outputs of a profit-motivated actor. For instance, the public can reveal their preferences against behavior that generates some sort of "automotive red-lining." By expressing these social norms and translating them into consumer choices, society can generate incentives against behaviors that pose risks and harms that would be difficult to regulate or take a significant amount of time to fight in court.

Conclusion

The emergence of AVs at SAE levels 4 and 5 necessitates new approaches for governing their capabilities. This is especially true for how AVs can communicate and interact with their

³⁵ Privacy Multistakeholder Process: Facial Recognition Technology | National Telecommunications and Information Administration, (2016), https://ntia.gov/other-publication/privacy-multistakeholder-process-facial-recognition-technology (last visited Sep 21, 2023).

surroundings beyond the status quo of turn signals and horns. This document proposed a framework that characterized AVs' communication across four dimensions: information security, safety, infrastructure support, and profit-motives.

Each dimension presents novel scenarios requiring governance. Information security tackled the dichotomy of trust versus protected communication paradigms through standards or best practices. For safety, AVs should have standardized mechanisms for identifying themselves and signaling intent to pedestrians. They must also interpret instructions from authorities in dynamic situations. Regarding infrastructure support, this technology presents opportunities for platooning and relaying road conditions. However, interoperability is key for these capabilities to benefit society. Lastly, profit-driven communication should be scrutinized to prevent misuse of personal data or distracting advertising.

Overall, regulating AV communication solely through traditional, rigid rules would be difficult given the technology's rapid evolution. Thus, governance through flexible soft law mechanisms can enable dynamic oversight by stakeholders. Examples include voluntary standards, pilot programs, safety certifications, corporate social responsibility efforts, and more. Moving forward, AV communication governance should promote safety, equity, transparency, and accountability. With appropriate soft law guardrails on these emerging technologies, AVs benefits can be realized, while risks are proactively addressed.