ETHICAL CONSIDERATIONS AND GOVERNANCE IN VEHICLE AUTONOMY

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THE TECH INTELLIGENCE EXPERTS™

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THE CURRENT STATE OF VEHICLE AUTONOMY

The advancement of the autonomous vehicle has garnered public attention and scrutiny in recent years. Many technology vendors and end users are incredibly excited with the realization of the fully autonomous driving experience. Widescale adoption of the autonomous vehicle is expected to reduce traffic deaths and harmful emissions, thus improving quality of life and promoting sustainable growth.

Despite all the promises, the path toward vehicle autonomy is riddled with safety, security, privacy, and ethical concerns. In recent years, consumer vehicles with Level 2 autonomous capabilities were involved in fatal traffic accidents due to inappropriate driving behavior. High-profile accidents involving Uber, Tesla, and NIO indicate a poor understanding of the capabilities of autonomous vehicles by consumers. Furthermore, vehicle Original Equipment Manufacturers (OEMs) have not been entirely forthcoming regarding the limitation of vehicle autonomy.

At the same time, cybersecurity experts have also demonstrated the vulnerability of autonomous vehicles against malicious cyberattacks, casting doubt on the long-term safety and sustainability of the technology. Not surprisingly, the authorities are also increasingly wary of the data collection practices by vehicle OEMs. In January 2020, the European Data

Protection Board (EDPB) issued Guidelines 1/2020 on the processing of personal data in the context of connected vehicles and mobility-related applications. The Cyberspace Administration of China followed suit in May 2021, publishing a draft rule requiring all OEMs to store all geolocation data, road traffic images, videos, and user behavioral information domestically.

More importantly, these events have brought more attention to the lack of a systematic approach to the evaluation and governance of the technology. As of 4Q 2021, the entire industry has yet to decide on a common framework. To achieve the full benefits of vehicle autonomy, the industry must come together to create a governance framework to bridge the gap between the societal benefits and ethical pitfalls of vehicle autonomy in a collaborative and inclusive manner.

DEFINITIONS AND MARKET FORECASTS

All evaluation and governance start with the definition of the technology itself. The most commonly accepted definition for vehicle autonomy comes from J3016. First released by the Society of Automotive Engineers (SAE) and the International Organization for Standardization (ISO) in 2014, the SAE J3016, commonly referenced as SAE Levels of driving automation, defines six levels of driving automation, from SAE Level 0 (no automation) to SAE Level 5 (full vehicle autonomy).

Based on J3016, human drivers remain in charge of the vehicle from Level 0 to Level 2. Level 3 is where the complete driving task is handed over to the automated driving system, but a human driver must be ready to take over the driving task from the system within a pre-defined time. At Level 4, human control is no longer necessary under certain conditions, such as good weather. Examples of Level 4 vehicles include driverless taxis on campuses. Finally, in Level 5, the automated driving system can drive under all conditions.

Figure 1: SAE J3016 Levels of Driving Automation

(Source: SAE International)

<table>
<tr><th></th><th>Level 0</th><th>Level 1</th><th>Level 2</th><th>Level 3</th><th>Level 4</th><th>Level 5</th></tr>
<tr><td>What does the human in the driver's seat have to do?</td><td colspan="3">You are driving whenever these driver support features are engaged – even if your feet are off the pedals and you are not steering.

You must constantly supervise these support features; you must steer, brake, or accelerate as needed to maintain safety.</td><td colspan="3">You are not driving when these automated driving features are engaged – even if you are seated in 'the driver's seat'.

When the feature requests you must drive

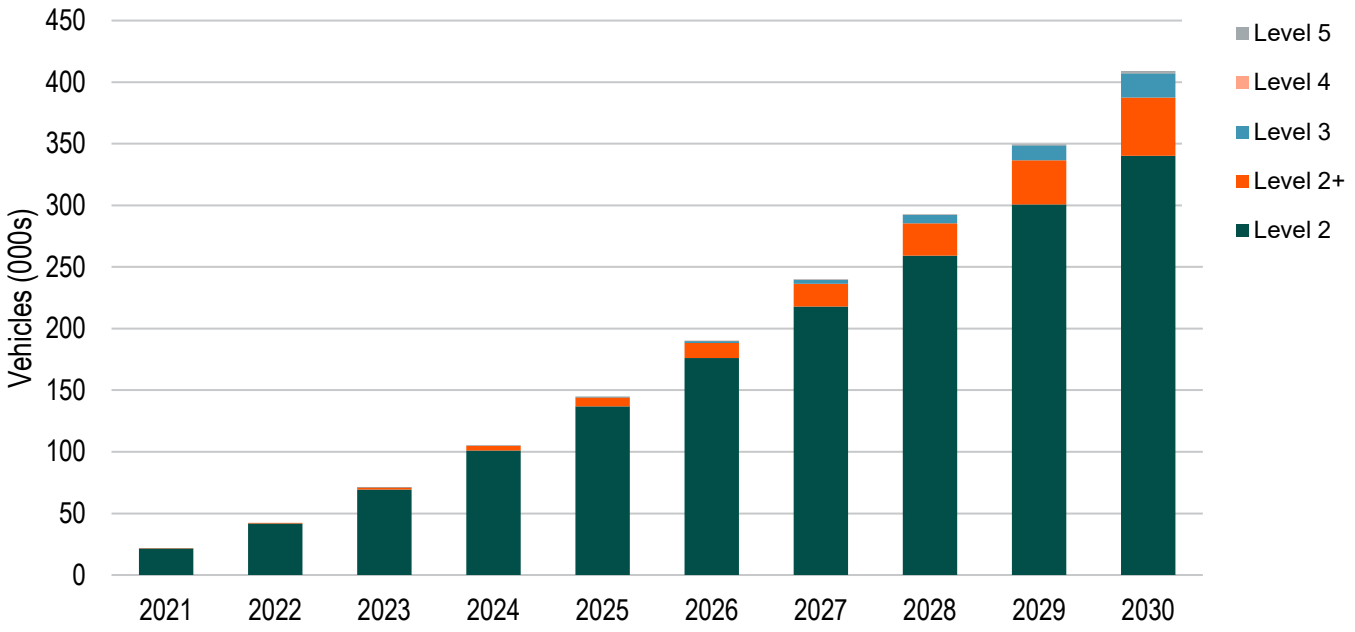
These automated driving features will not require you to take over driving.</td></tr>
<tr><td></td><td colspan="3">These are driver support features</td><td colspan="3">These are automated driving features</td></tr>
<tr><td>What do these features do?</td><td>These features are limited to providing warnings and momentary assistance.</td><td>These features provide steering or brake/acceleration support to the driver.</td><td>These features provide steering and brake/acceleration support to the driver.</td><td colspan="2">These features can drive the vehicle under limited conditions and will not operate unless all required conditions are met.</td><td>This feature can drive the vehicle under all conditions.</td></tr>
<tr><td>Example features</td><td>▪ Automatic emergency braking
▪ Blind spot warning
▪ Lane departure warning</td><td>▪ Lane centering or
▪ Adaptive cruise control</td><td>▪ Lane centering and adaptive cruise control at the same time</td><td>▪ Traffic jam chauffeur</td><td>▪ Local driverless taxi
▪ Pedals/steering wheel may or may not be installed</td><td>▪ Same as level 4, but feature can drive everywhere in all conditions</td></tr>
</table>

Despite the lack of governance in general, autonomous vehicle technology is maturing steadily at the moment. In May 2021, the SAE and ISO updated J3016 to provide more granular technology definitions and incur more recent examples for additional context. Currently, only 1.75% of the registered passenger vehicles will have an automated driving system in 2021, with the majority featuring Level 1 autonomy. However, this is going to change very quickly. Level 2 autonomy is already widely available in vehicles from selected OEMs, including Tesla, Audi, Ford, GM, and Toyota. Most autonomous vehicle developers, such as Aurora, Baidu, Pony.ai, and Waymo, are working toward Level 3 and Level 4, with a few aiming to solve Level 5 by 2025.

By 2030, ABI Research forecasts that a total of 408 million registered cars will feature an automated driving system, accounting for 29.2% of the total registered passenger vehicles. The majority of the vehicles will have Level 2 automation. Commercial deployment of Level 4 and Level 5 will remain restricted to campus areas and pilot programs.

Chart 1: Total Registered Passenger Vehicles by SAE Levels of Driving Automation

(Source: ABI Research)



ETHICAL CHALLENGES IN VEHICLE AUTONOMY

Unlike other emerging technologies, such as next-generation cellular and Wi-Fi technology, autonomous vehicle technology adoption remains concentrated in large volume markets like the United States, the European Union (EU), China, and developed nations like Japan, South Korea, and Singapore. The limitation in adoption is primarily due to the following aspects:

- **Cost of Ownership and Legacy Business Model:** A passenger vehicle with an automated driving system is more expensive than its non-automated counterparts because it features various high-tech components, including an embedded supercomputing platform, ultrasonic, Light Detection and Ranging (LiDAR) and radar sensors, cameras, and connectivity gateways. There is a lack of user-friendly business models apart from traditional car ownership or car leasing. New business models are needed to enable OEMs to benefit from advancements introduced by autonomous vehicle technologies. Examples of these models include car subscriptions or Car-as-a-Service (CaaS).

- **Lack of Adaptability:** Autonomous vehicle technology is Artificial Intelligence (AI)-driven and only as good as the data used for training and validation. While an autonomous vehicle can handle normal weather conditions very well, it struggles in environments with unusual weather patterns or extreme weather conditions. The regional difference in traffic regulations and norms also hinders the worldwide rollout of autonomous vehicles in different markets.
- **Low Physical Infrastructure and Legal Framework Maturity in the Rest of the World:** The implementation of vehicle autonomy requires widespread availability of high-bandwidth connectivity, traffic infrastructure, and alternative energy supply, lacking in developing and emerging markets. Likewise, many countries still lack new road traffic rules and regulations aligned with autonomous driving technology. The rules and regulations in these markets are still designed to govern the use of non-autonomous vehicles. These markets will take at least a decade to catch up with the key markets mentioned above.

More importantly, there is still a gap in governing the ethics of autonomous vehicles. The lack of clarity around the design and development of the technology itself creates anxiety and reluctance among end users. Moreover, vehicle OEMs are not fully open about their approach to the decision-making process associated with autonomous vehicles. Unlike a human driver, however, most automated driving systems are black boxes that cannot communicate and explain their decision-making process and choices in a step-by-step manner that less tech-savvy users can easily understand. In addition, the authorities are concerned with the data collected by vehicle OEMs, such as information on real-time traffic and surrounding critical infrastructure, as well as personal data. These data can be mishandled for political gains, commercial intelligence, and unfair competitive advantages if no governance or universal regulation is in place to prevent such unethical practices.

Table 1 indicates the ethics gap across all six levels of driving automation.

Table 1: Ethical Gap Analysis for SAE Levels of Driving Automation

(Source: ABI Research)

SAE LEVELS	ETHICAL RISKS WITHOUT GOVERNANCE
Level 0	No ethical risk because there is no vehicle autonomy. Fully controlled by the human driver.
Level 1/2	Minimal ethical risk due to low autonomy. Mainly controlled by the human driver with steering or brake/acceleration support. Data collected are processed locally. No sensitive data are shared with the cloud.
Level 3	Low ethical risk. Full level of control of the human driver. The driver can make a conscious decision to delegate complete control to the vehicle under very limited circumstances like traffic jams and parking. The vehicle uses AI for almost all its decision-making, from a simple Machine Learning (ML) model handling a single task to multimodal AI handling sensor fusion, navigation, and driving. Bias in training data could lead to poor prediction and vehicle handling. The human driver remains fully liable for all at-fault collisions. Data are processed locally and sent to the cloud. Legitimate concerns over data ownership and cybersecurity
Level 4	Medium ethical risk. Full vehicle autonomy under certain circumstances like a driverless taxi on a campus. Bias in training data could lead to poor prediction and vehicle handling, endangering the driver and the passengers. Data are processed locally and sent to the cloud. Legitimate concerns over data ownership and cybersecurity. Vehicle OEMs are liable for collisions in limited conditions. However, the human driver remains responsible for collisions outside of approved conditions.
Level 5	High ethical risk. Full vehicle autonomy under all conditions. Bias in training data could lead to poor prediction and vehicle handling, endangering the driver and the passengers. Data are processed locally and sent to the cloud. Legitimate concerns over data ownership and cybersecurity. The vehicle OEMs are liable for all at-fault collisions.

If poorly handled, these ethical gaps can affect the well-being of passengers and other road users, even leading to national security risk. ABI Research argues that ethical risk comes from five main areas of concern: biases in training and testing data, conflict of interest, data governance, degree of complexity, and level of control.

KEY CONCERNS

Figure 2: Five Main Areas of Concern in Autonomous Vehicle Technology

(Source: ABI Research)

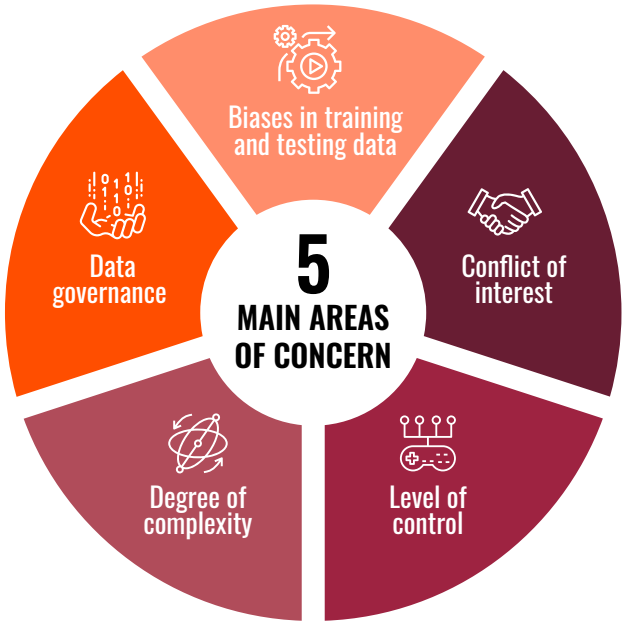


Table 2: Main Areas of Concerns for Trustworthiness in Self-Driving Technology

(Source: ABI Research)

CRITERIA	KEY POINTS
Biases in ML training and testing	An automated driving system consists of several algorithmic models hosted in a vehicle with constant updates from the cloud. These models assist the vehicle in making decisions by processing unlabeled data based on pre-defined rules (known as classical AI) and/or automatic detection and discovery of patterns without human intervention (known as ML). During the development phase, the ML models are exposed to simulated and real-world environments. These models are often trained and tested with a large amount of data collected from different settings, including all types of road and weather conditions, traffic patterns, and emergencies. Any inherent bias in the dataset or data contamination (malicious data that mimic the characteristics of a situation to induce a biased outcome) will significantly impact the autonomous vehicle's accuracy, performance, and ethical judgment. At the same time, the decision-making processes are tested and tuned using a combination of data and expert opinions. Any bias in the expert opinions will also influence the ethical judgment of the vehicle. With the deployment of more autonomous vehicles, specific ML models may become obsolete due to changing traffic patterns or user behaviors, leading to concept drift, where the patterns the model learned are no longer relevant. Therefore, the models need to be updated. Otherwise, this will lead to accidents and fatalities.
Conflict of interest	While traffic safety remains the top priority, conflict of interest still exists between end users, autonomous vehicle solution providers, and regulators. For example, the driver and the passengers of autonomous vehicles no doubt prioritize the vehicle's safety and privacy. Meanwhile, solution providers may prioritize the production speed and time-to-market through the data gathering and sharing practices that may infringe on end users' interests. In addition, solution providers may be hesitant to adopt industry-wide benchmarks to evaluate their AI capabilities' performance, accuracy, safety, and security.

CRITERIA	KEY POINTS
Data operation and governance	Autonomous vehicles collect a large amount of data, such as personal information, geospatial data around the vehicle, road traffic and logistic information, in-vehicle videos and photos taken by onboard cameras, and operational data on real-time traffic and charging stations. The data it collects enables the ML models to make a decision. Some data may even be shared with an authorized third party for further processing and analysis. However, the collection, storage, and transfer of these data create concerns around proprietary data operation for mission-critical data, data sovereignty, and cybersecurity concerns.
Degree of complexity and transparency	The autonomous vehicle relies on a series of sensors for data collection and complex ML models for various sub-functions, ranging from safety to localization, navigation, infotainment, and personalization. These ML models are trained and tested with datasets before being ready for commercial deployment. These data need to be cleaned and pruned to mitigate any concerns of contamination originating from sensors' accuracy or malicious simulations. Most importantly, these sub-functions are expected to learn and anticipate the driver's and passengers' intentions and adapt to changes in these intentions over time. This leads to an inherently complex system with a certain level of unpredictability and uncertainty. As a result, questions remain on the explainability and transparency of the safety features, accuracy, the maintenance and update framework, frequency, and responsibility.
Level of control	Generally, the more control that end users have over a system, the more trustworthy a system becomes. In vehicle autonomy, a human driver is delegating control over the vehicle to an automated driving system. As the system's autonomy increases across the driving automation spectrum, the responsibility, liability, and accountability shift from drivers to OEMs and sub-systems suppliers. To date, the industry has not introduced universal regulatory and legal approaches to handle any issue caused by an autonomous vehicle.

At the moment, industrial players, including vehicle OEMs, automated driving system developers, automotive part suppliers, and regulators, have yet to introduce a harmonized approach to govern the ethical development and deployment of an autonomous vehicle. As a result, all vehicle autonomy solution providers develop their solutions in a siloed manner, with limited transparency and oversight.

For instance, Tesla, Waymo, and previously Uber ATG (now sold to Aurora) have developed their vehicle autonomy software in-house. Legacy vehicle OEMs, such as GM, Ford, and Toyota, opt to work with autonomous vehicle technology startups, such as Cruise, Argo AI, and Pony.ai, but there is no interaction between these players. Apollo, Baidu's autonomous vehicle program, is the most popular open-source solution with many prominent industrial partners, but the adoption and discussion are limited to the Research and Development (R&D) phase.

Because the technology will have a widescale societal impact across national borders and jurisdictions, the industry faces an urgent need to develop a universal and transparent framework for ethics governance.

EXISTING ETHICAL AI FRAMEWORK FOR VEHICLE AUTONOMY

In recent years, academia, industry associations, and regulators have proposed different governance frameworks to address the aforementioned ethical dilemmas and gaps. Prominent examples include those from the Institute of Electrical and Electronics Engineers (IEEE) and the EU.

IEEE

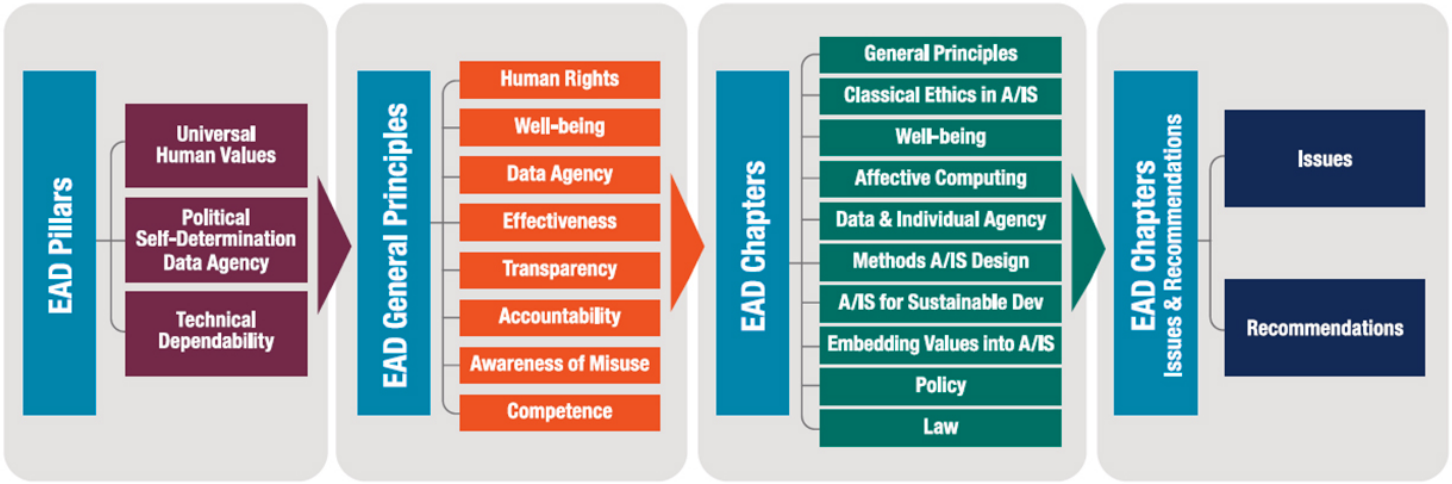
A key influencer in the ethical AI framework is IEEE. As a professional association for electronic and electrical engineering, IEEE has introduced an ethics framework for Autonomous and Intelligent System (A/IS) since 2016. Vehicle autonomy is considered a key part under the umbrella term of A/IS.

KEY RECOMMENDATIONS

After 3 years of industry consultation, the association published Ethically Aligned Design (EAD) - First Edition. The publication provides a complete framework to guide universal human values, technical dependability, and political self-determination data agency into the AI design process. The framework is guided by eight general principles: 1) human rights; 2) well-being; 3) data agency; 4) effectiveness; 5) transparency; 6) accountability; 7) awareness of misuse; and 8) competence.

Figure 3: Ethically Aligned Design Conceptual Framework: From Principles to Practice

(Source: IEEE)



KEY INITIATIVES

Leveraging the key ideas proposed in EAD, IEEE has also launched the following initiatives looking at sustainable development, personal data rights, legal frameworks for accountability, and policies for education and awareness:

Table 3: Key Initiatives by IEEE

(Source: IEEE)

IEEE INITIATIVES	SUMMARY
IEEE P7000 series of approved standardization projects	IEEE launched P7000 series of standard projects with a specific focus on addressing ethical concerns during system design. The relevant ones for vehicle autonomy are: • IEEE P7000: Model Process for Addressing Ethical Concerns During System Design • IEEE P7001: Transparency of Autonomous Systems • IEEE P7002: Data Privacy Process • IEEE P7003: Algorithmic Bias Considerations • IEEE P7007: Ontological Standard for Ethically Driven Robotics and Automation Systems • IEEE P7008: Standard for Ethically Driven Nudging for Robotic, Intelligent, and Automation Systems • IEEE P7009: Standard for Fail-Safe Design of Autonomous and Semi-Autonomous Systems
Training courses on AI and ethics in design	These 10 training courses are designed for global professionals using content in EAD and taught by experts who helped create EAD.
A/IS ethics glossary	The Glossary features more than two hundred pages of terms that help to define the context of A/IS ethics for multiple stakeholder groups.
Global Initiative on Ethics of A/IS	The mission of the Global Initiative on Ethics of A/IS was to ensure every stakeholder involved in the design and development of autonomous and intelligent systems is educated, trained, and empowered to prioritize ethical considerations so that these technologies are advanced for the benefit of humanity.

IEEE INITIATIVES	SUMMARY
Open community for A/IS developers	The Open Community for Ethics in Autonomous and Intelligent Systems (OCEANIS) is a global forum for discussion, debate, and collaboration for organizations interested in developing and using standards.
Ethics certification program for A/IS	The Ethics Certification Program for Autonomous and Intelligent Systems (ECPAIS) aims to create specifications for certification and marking processes that advance transparency, accountability, and reduction in algorithmic bias in A/IS.
Consultation with key influencers	The Council on Extended Intelligence (CXI) was launched in partnership with the Massachusetts Institute of Technology (MIT) Media Labs. It consists of a group of high-profile individuals to increase the ideals of ethical design, data agency, and metrics of economic prosperity, prioritizing people and the planet over profit and productivity.
Engagement with universities	The EAD University Consortium (EADUC) was established to educate every engineer at the beginning of their studies on the ethical challenges of AI.
A framework for community engagement	AI Commons was launched to connect all AI developers and users, connecting problem owners with the community of solvers to create solutions with AI collectively. The goal is to implement a framework for participation and cooperation.

Through these initiatives, IEEE creates an ecosystem that fosters the adoption of ethics in the design of A/IS. These efforts are designed to address the most pertinent questions in developing, implementing, and monitoring ethical designs by laying down fundamental principles, highlighting key issues, and providing recommendations for engineers and governments. However, these initiatives are more like guidance and suggestions instead of enforceable items. This puts IEEE in a weaker position in influencing the implementation of AI ethics governance in autonomous driving.

EUROPEAN UNION

In September 2017, the Second High-Level Meeting of EU Transport Ministers recommended creating an expert group to discuss ethical issues raised by Connected and Automated Vehicles (CAVs) at the European level. As a result, the work of a 14-member independent expert group started in June 2019 to provide practical support to relevant researchers, policymakers, and CAV manufacturers and deployers in the safe and responsible transition to connected and automated transition mobility.

KEY RECOMMENDATIONS

The work was summarized in a report published in June 2020, titled Ethics of connected and automated vehicles. The report builds upon existing materials, such as the AI High-Level Expert Group Guidelines for Trustworthy AI (AIHLEG), the European Group on Ethics in Science and New Technologies (EGE) statement on Artificial Intelligence, Robotics and Autonomous Systems, and the Expert Group report on Liability and New Technologies.

The report focused on three main aspects: 1) road safety; 2) data, AI, and algorithms; and 3) responsibility. In the report, the expert group proposed 20 recommendations. These recommendations can be categorized into four main principles:

Table 4: Key EU Recommendations for the Ethics of Connected and Automated Vehicles

(Source: EU)

KEY PRINCIPLES	RECOMMENDATIONS
Safety	Ensure that CAVs reduce physical harm to persons. Prevent unsafe use by inherently safe design. Define clear standards for responsible open road testing. Consider revision of traffic rules to promote the safety of CAVs and investigate exceptions to non-compliance with existing rules by CAVs. Identify and protect CAV-relevant high-value datasets as public and open infrastructural resources Safeguard informational privacy and informed consent.
Equality	Redress inequalities in vulnerability among road users. Develop measures to foster the protection of individuals at the group level. Prevent discriminatory differential service provision. Ensure accountability for the behavior of CAVs.
Transparency	Develop transparency strategies to inform users and pedestrians about data collection and associated rights. Audit CAV algorithms Reduce opacity in algorithmic decisions.
Responsibility	Identify the obligations of different agents involved in CAVs. Promote a fair system for the attribution of moral and legal culpability for the behavior of CAVs. Promote a culture of responsibility with respect to the obligations associated with CAVs. Create fair and effective mechanisms for granting compensation to victims of crashes or other accidents involving CAVs.
Empowerment	Manage dilemmas by principles of risk distribution and shared ethical principles. Enable user choice, seek informed consent options, and develop related best practice industry standards. Promote data, algorithmic, AI literacy, and public participation.

KEY INITIATIVES

The research on ethics for CAVs was funded by Horizon 2020, the EU's eighth framework program funding research, technological development, and innovation. From 2014 to 2020, around €350 million was allocated to support CAV-related projects through Horizon 2020. Moving forward, Horizon Europe, the successor to Horizon 2020 with a budget of €95.5 billion, will continue to prioritize the research on CAVs. In addition, The European Parliament and the European Council have approved the Connecting Europe Facility (CEF) proposal, worth €33.7 billion. The CEF consists of three major components, namely CEF Digital, CEF Energy, and CEF Transport. The ethics for CAVs falls under CEF Transport, which will invest €25.8 billion in transportation-related projects in the EU Member States.

The EU is also fully committed to developing frameworks for the overall AI ethics governance. The European Commission strongly believes that a clear European regulatory framework is essential in building trust among consumers and businesses in AI, which will speed up the adoption rate. Therefore, the Commission proposes the Ethics Guidelines for Trustworthy AI and Trustworthy AI Assessment List published in 2019. Coupled with Guidelines 1/2020 on processing personal data in the context of connected vehicles and mobility-related applications issued by EDPB in January 2020, the EU can be seen as the current leader in AI ethics governance.

REST OF THE WORLD

There are no specific regulations designed for ethics governance in vehicle autonomy in the rest of the world. Nonetheless, governments are becoming more aware of the importance of governance in personal information, national security data, and AI ethics in general. ABI Research believes that the autonomous vehicle-related plans, guidelines, and regulations published by a handful of countries will significantly impact the development of a global ethical framework for vehicle autonomy.

Table 5 highlights some of the plans, guidelines, and regulations in major markets.

Table 5: Plans, Guidelines, and Regulations Related to Autonomous Vehicle World Market: 2017 to Present

(Source: ABI Research)

COUNTRY	DOCUMENT TITLE	RELEASE DATE
Australia	Changing driving laws to support automated vehicles (Discussion Paper)	Oct-17
	National Enforcement Guidelines for Automated Vehicles (Guidelines)	Nov-17
	The Safety Assurance for Automated Driving Systems: Decision Regulation Impact Statement	Nov-18
	Innovating Transport across Australia	Mar-19
Canada	Pan-Canadian Artificial Intelligence Strategy	Jan-17
	Testing Highly Automated Vehicles in Canada	Jun-18
	Safety Assessment for Automated Driving Systems in Canada	Jan-19
	Vehicle Cyber Security Guidance	Jan-20
	Connected and Autonomous Vehicle Readiness Plan	Feb-21
China	Medium- and Long-term Development Plan of Automobile Industry	Apr-17
	The Regulations on the Administration of Road Testing of Autonomous Vehicles (for Trial Implementation)	Jan-18
	Guidance to the Standard System Construction of National Connected Vehicle Industry (Autonomous Vehicles)	Feb-18
	Regulations on the Administration of Road Testing of Autonomous Vehicles (for Trial Implementation)	Apr-18
	Temporary Administrative Regulations on the Direct Connected Communication Use of 5905-5925MHz Spectrum on Car Networking (Autonomous Vehicles)	Dec-18
	Action Plan on Car Networking (Autonomous Vehicle) Industry Development	Dec-18
	The Governance Principles for New Generation Artificial Intelligence - The Development of Responsible Artificial Intelligence	Jun-19
	Innovative Development Strategy of Intelligent Vehicle	Feb-20
	Taxonomy of Driving Automation for Vehicles	Mar-20
	Data Security Law	Sep-21
South Korea	Autonomous Vehicle Act	May-20
	The Ethics Guideline for AVs and Stakeholders	Dec-20
	Guideline for the Manufacture/Safety of Level 4 AVs	Dec-20
	Cross-ministry R&D plan for Commercialization of Level 4 AVs	Jan-21
United Kingdom	Automotive Technology and Aviation Act	Feb-17
	Automated and Electric Vehicles Act 2018	Jan-18
United States	Autonomous Driving System 2.0: Safety Vision	Sep-17
	Automated Vehicles Comprehensive Plan	Jan-21

A GLOBAL ETHICS GOVERNANCE FRAMEWORK FOR VEHICLE AUTONOMY

ABI Research believes that the definition of ethics should be universal, similar to human rights. Key markets must set aside their differences, adopt a more collaborative and conciliatory approach, and develop universal frameworks based on common consensus.

While the EU is the first region to introduce a regional ethics governance framework, imposing the EU's framework on the other areas will be undemocratic and unrealistic. Developing and emerging markets are still playing catch-up. On the one hand, China, the EU, and South Korea are looking at top-down, government-led initiatives to govern and audit AI solutions. On the other hand, the U.S. federal government is deferring the responsibility entirely to the private sector. As a result, it will take some time before all the major markets have their own ethical AI framework for vehicle autonomy, which will significantly slow down the widescale deployment of autonomous vehicles.

ABI Research hereby proposes the following framework for ethics governance in vehicle autonomy. This framework leverages seven principles of ethics governance presented in our previous whitepaper on ethics governance in AI:

Figure 4: Seven Principles of Ethics Governance

(Source: ABI Research)

Table 6: Global Ethical Governance Framework for Vehicle Autonomy

(Source: ABI Research)

KEY PRINCIPLES	DESCRIPTIONS
Human-centricity	The development of vehicle autonomy must align with common societal values that are well accepted and perfectly aligned with the universal moral values upheld by all humankind. • The decision made by an autonomous vehicle must only be based on traffic safety. • The decision-making must also accommodate the views of all traffic users, including motorists, cyclists, pedestrians, and vulnerable traffic users who are physically challenged or speech and vision-impaired. • The outcome must serve as the betterment of society and meet the present and future traffic needs.

KEY PRINCIPLES	DESCRIPTIONS
Process orientation	A process-based governance framework is critical to the implementation of ethics governance. The framework must be able to do the following: • Identify the roles and responsibilities of all relevant stakeholders involved in the automated driving system's creation, implementation, validation, and commercialization process. • Establish clear guidelines and mechanisms to support end-to-end audits. • Provide a clear time frame for any evaluation, correction, re-assessment, and continuous monitoring.
Transparency and auditability	Ideally, all AI models must be capable of explaining to their users the existing limitations of training and testing data, the logic behind all AI training and inference processes, and the role of each neural network layer, feature, and parameter. This is impossible with the existing technologies. Therefore, the following steps must be taken: • All AI developers must develop AI models that can explain themselves, if possible. • Since the likelihood of the Explainable AI (XAI) is extremely low, all AI developers must prepare documentation/a manual that explains the entire decision-making mechanism and processes, information on data sources used for training, algorithms and frameworks used, etc. • This process may vary drastically from entity to entity, so a universal regulatory framework may resolve the difference and create a uniform approach. • To ensure compliance, the audit can either be conducted by a regulatory body made up of key industry stakeholders authorized to issue a certificate of compliance for AI ethics.
Responsibility and accountability	Based on the outcome of the audit, the developers of an automated driving system must be held accountable for their decision-making: • All developers will abide by all these ethical cultures and values and be responsible for all malicious actions and decisions that fail to ethical culture and values. • Continuous improvement must be made for AI models that fail to adhere to ethical culture and values, via the use of fair and equitable dataset with reasonable features, the introduction of a continuous chain of responsibility and oversight mechanism, and constant communication on the real-world impact. • The consequence and implications of unethical decision-making must be communicated clearly to all entities to ensure fairness.
Collaborative and inclusiveness	All stakeholders in the R&D of automated driving systems should be included in the formulation, implementation, and assessment of ethics governance, including vehicle OEMs, hardware and software solution suppliers, regulators, international standard organizations, government departments, and academia: • Encourage cross-disciplinary, cross-field, cross-regional, and cross-border exchanges and cooperation. • Educate and train researchers and developers from the early stage of their career on the importance of ethics. • Industry-wide consultation must be held when implementing new changes or methods. • Regulatory bodies must agree on a similar, if not identical, set of rules to prevent confusion and misinterpretations.
Safety and robustness	The safety of an automated driving system is the utmost concern. The system must be able to handle all traffic conditions in compliance with safety rules and regulations, regardless of traffic conditions. However, due to the unlimited variability of the driving conditions, developers and implementors need to ensure the system they design can learn and improve with future updates: • The system must be able to address all traffic conditions regardless of weather, terrains, geographical regions, and country-specific traffic laws. • All developers must introduce the mechanisms for future improvement to accommodate emerging safety challenges.
Data integrity, privacy, and sovereignty	Data integrity and sovereignty are critical to ethical decision-making because all advanced automated driving systems rely on data. All stakeholders must ensure the data used for ML training and testing must be ethical, free of bias, and stored securely: • All developers must incorporate transparent and auditable processes for data collection, processing, storage, and update, with detailed documentation. • Bias minimization and elimination must form a critical part of the data operation. • All implementors must demonstrate formidable cybersecurity expertise to prevent hacking. They also need to ensure that no sensitive data can be shared with unauthorized entities and/or stored outside the country border.

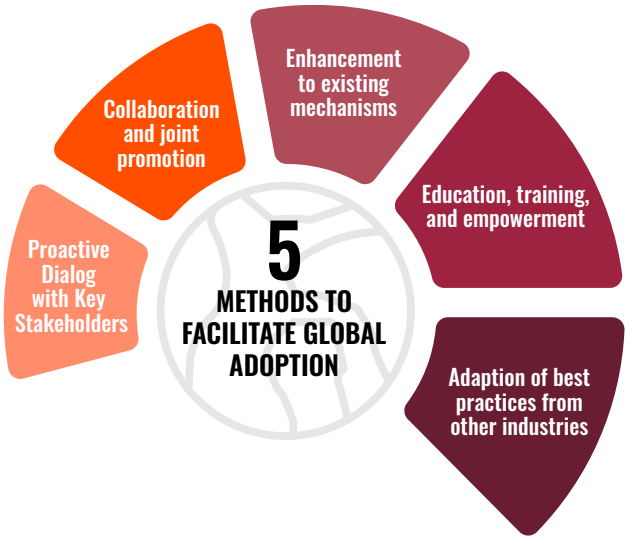
METHODS TO FACILITATE ACCEPTANCE AND ADOPTION

For the framework to gain global acceptance, key stakeholders in vehicle autonomy must be willing to buy into the principles, identify the appropriate methods to develop a globally accepted ethics governance process under the framework, and promote it to the rest of the industry. In addition, active participation in global framework development allows participants to influence product and service development to align with the ethics governance framework.

ABI Research believes there are five main ways to facilitate global acceptance and adoptions, as shown in Figure 5.

Figure 5: Five Best Practices to Facilitate Global Adoption

(Source: ABI Research)



PROACTIVE DIALOG WITH KEY STAKEHOLDERS

The ethical decision-making of an autonomous vehicle has the most significant impact on technology developers, road users, and regulators. The international body that formulates the ethical governance framework must involve all vehicle OEMs, Tier One to Tier Three suppliers, transportation system integrators, road users and traffic associations, technology influencers, and regulators. In addition, the international body must have frequent meetings to discuss various regional ethics governance frameworks and ways to harmonize them, whitepapers and proposals from industrial players and regulators, and additional challenges and strategies to overcome them.

When making the final decision, all members shall be given equal participating and voting rights in all technical meetings to ensure fairness and consensus-building. Most importantly, public consultation must be held to collect constructive feedback from the general public, academia, and industrial experts before finalizing the framework. This will help further improve the relevancy and the acceptance of the framework.

An excellent example of this will be The 3rd Generation Partnership Project (3GPP). The organization has 16 working groups covering all aspects of cellular communication technology. All working groups work in a distributed, piecemeal manner with limited end-to-end supervision. Overall progress is achieved through a col-

laborative approach, with all members working toward creating technical specifications for next-generation cellular technology. While the global ethics governance framework is not a technical specification, a similar process can be adopted to ensure equal participation, common consensus, and zero discrimination.

COLLABORATION AND JOINT PROMOTION WITH STANDARD BODIES AND REGULATORS

Standards and regulations are both essential to ensure vehicle safety and consumer rights. Ethics governance is only one part of the overall safety mechanism of an autonomous vehicle, so collaboration with key international standard bodies and national regulators is a must. The list of partners must include the International Electrotechnical Commission (IEC), ISO, SAE, and regulators in the first-adopter markets. Together, both standard bodies and national regulators can actively drive awareness, championing the framework to governments, developers, and end users. Such collaboration and joint promotion are vital in democratizing the global governance framework for ethics in vehicle autonomy.

ENHANCEMENT TO EXISTING MECHANISMS

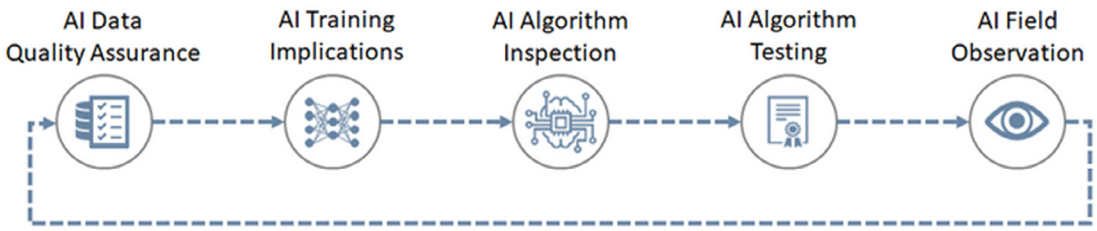
The global ethics governance framework must also build upon existing practices, including open standards, regulatory frameworks, and third-party certification to expand its sphere of influence. An excellent example of this is openGENESIS.

Jointly created by TUV SUD, Incenda AI, and the German Research Centre for Artificial Intelligence, openGENESIS is a collaborative platform that provides knowledge, methods, and tools for assessing AI used within autonomous driving applications. openGENESIS drives and supports the investigation of an understandable, verifiable, and certifiable AI. This includes adopting functional safety approaches to symbolic and sub-symbolic AI, and developing new methods and metrics for the verification of neural networks.

To achieve those goals, openGENESIS will develop and compile assessments for performance, robustness, and comprehensibility. In addition, the organization also plans to share an open dataset to enable research based on real cases and safety-relevant challenges. Finally, openGENESIS will provide both public and regulatory authorities with approaches to help them deal with AI approval and certification challenges.

Figure 6: AI Assessment Process

(Source: openGENESIS)



EDUCATION, TRAINING, AND EMPOWERMENT

Another effective way to influence ethical governance in autonomous vehicle technology is through education, training, and empowerment. The developers of an automated driving system must undergo education and training on the benefits of the global ethical governance framework. Education and training can also be made compulsory during undergraduate study or on-the-job training. Therefore, partnerships with educa-

tion institutions and training agencies are critical in ensuring the success of these education and training programs. Upon graduation, all participants must be presented with proper certification, which will serve as an essential accreditation for those involved in designing and developing autonomous vehicle technology. In addition, developers that have gained accreditation in ethics governance practices must be empowered to drive ethical practices within the development process.

As mentioned earlier, IEEE has been an active proponent of this. The organization has established a university consortium, ethics certification program, and training courses for professionals on AI and ethics in design. These initiatives will help create industrial awareness on ethics governance in autonomous vehicle technology through continuing education and a professional development approach.

ADAPTATION OF BEST PRACTICES FROM OTHER INDUSTRIES

Very few industries have introduced iteration after iteration of next-generation standards as successfully and consistently as the wireless connectivity industry, particularly cellular and Wi-Fi technology. Standard bodies, such as 3GPP and IEEE, have been very active in introducing new global standards, while being mindful of backward compatibility and interoperability. At the same time, telco operators, infrastructure vendors, OEMs, chipset suppliers, system integrators, and industrial associations are constantly collaborating and communicating with the standard bodies and regulators to ensure that regulatory frameworks are not prohibitive to the development of these technologies.

As compared to cellular and Wi-Fi technology, autonomous vehicle technology is still in a nascent stage. When implementing the global ethic governance framework, early proponents need to be visionary and practical at the same time. While the framework needs to be comprehensive enough to account for most, if not all, future ethical challenges, it must be agile enough to allow innovation to thrive. Most importantly, the framework must be launched on time to supervise commercial deployment that is ramping up quickly across major markets.

REGULATORY APPROACH AS THE POTENTIAL END GOAL

As a document created through consensus and collaboration, the universal ethic governance framework will command a great level of respect and adherence from the industry. However, to create a long-lasting impact and influence, ABI Research believes that the entire industry needs to consider making the framework into either a technical standard or a regulatory framework to ensure industry-wide adoption.

A NEED FOR A UNIVERSAL REGULATORY APPROACH

The automotive industry is no stranger to global and regional standards. These standards greatly facilitate the global rollout as vehicles that adhere to these standards are fully recognized and accepted by every jurisdiction in the world. Without a global technical standard, a vehicle OEM needs to put a lot of effort into the trialing and testing phase if it decides to adopt the solution from a different supplier. Global standards level the playing field for technology suppliers, as vehicle OEMs can adopt and onboard solutions from other vendors with less effort, driving the international competitiveness of these technology suppliers.

Likewise, the automotive industry is very familiar with global and regional regulations. While conformity with standards is voluntary, regulations are mandatory. Designed to protect consumer interest and promote fair

competition, these regulations are typically agnostic toward the technology used to complete the process or achieve the end goals. Instead, they focus on governing and controlling the outcomes of a process or deployment. In addition, as compared to a global standard, regulatory governance in automotive is primarily a regional practice led by regional authorities. Finally, note that some regulators use regulations and standards interchangeably, but unlike industrial or technology standards, these standards introduced by regulators are mandatory and should be considered regulations.

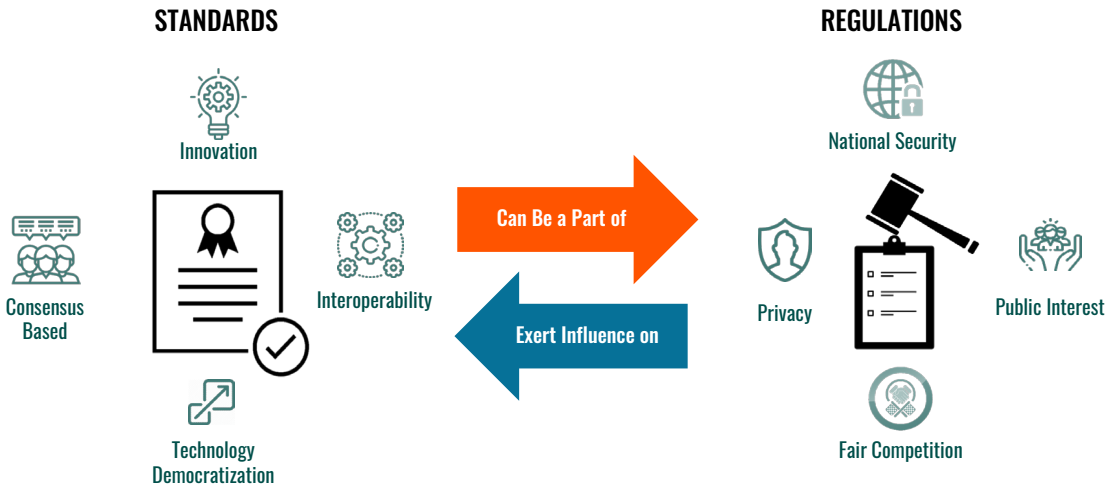
Table 7: Differences between Standards and Regulations

(Source: ABI Research)

	STANDARDS	REGULATIONS
Definition	A set of technical design specifications and requirements approved through consensus by a recognized standardization body.	A rule of order that has the force of law prescribed by a superior or competent authority.
Geographical scope	International. Could be national on some occasions.	Either national or regional.
Objective	Aim to encourage interoperability, promote scalability and maximize addressable market opportunities. May also lead to commoditization of products and services and concentration of R&D efforts.	Aim to regulate and govern specific product characteristics, process outcomes, or risk levels, while being technology agnostic. Also aim to ensure fair competition and protect the interests of citizens.
Conformity	Voluntary. Vendors that do not adopt the standard will not face legal consequences, but will lose out on end users that demand standardized and interoperable solutions.	Mandatory. Vendors will face legal consequences and commercial bans for not complying with national regulations.
Key examples	International Automotive Task Force (IATF) 16959: Automotive Quality Management Systems, Automotive Electronics Council (AEC) Q100: Failure Mechanism Based Stress Test Qualification For Integrated Circuits, and AEC Q200: Stress Test Qualification For Passive Components.	European Union (EC Directives), U.S. Federal Motor Vehicle Safety Standards (FMVSS), China National Standards, Indian Automotive Standards (AIS), and California Emission Control CCR 13.

Figure 6: Relationship between Standards and Regulations

(Source: ABI Research)



Autonomous vehicle technology is still nascent, so industrial players are still finding better ways to create advanced autonomous vehicle technology that is high-performing and ethical. Adopting the right approach will spur innovation and encourage investment in the technology, while the wrong level could hurt or delay it. Making ethics governance a technical standard will stifle innovation, as it forces all vendors to adopt an identical technological approach to ethical governance, leaving very little room for them to innovate and differentiate. From this perspective, regulatory governance that is technology agnostic and does not interfere with technology development, standardization, and implementation is the most sensible choice. The vehicle OEMs' abilities to meet the regulatory requirements can fulfill critical regulatory criteria, including protecting the user interest, privacy, fair competition, and national security, which should be the only consideration for gaining regulatory approval, regardless of the fundamental technologies.

Furthermore, the industry is already witnessing more countries enacting laws and regulations to govern the design, development, and deployment of vehicle autonomy. It is essential to realize that vehicle autonomy is a new technology. While country-specific regulations have worked well for Level 0 vehicles, the successful approach in the past does not guarantee future success. Country-level or regional ethics regulations for vehicle autonomy will likely result in fragmentation and potential confusion among end users and system integrators.

There is a need for the entire industry to champion global ethics regulation for vehicle autonomy. A universal regulatory approach can bridge different interests based on the governance principles for ethical autonomous vehicle technology. Furthermore, it helps to evaluate the technology's safety, security, and ethical concerns in a consistent and unbiased manner, eliminating the fears and uncertainties of end users, minimizing excessive regulatory oversights, and facilitating autonomous vehicle deployment.

BEST CANDIDATE FOR UNIVERSAL REGULATION

Considering the current politically charged climate, formulating a new supergroup with technical understanding, regulatory responsibility, and oversight to implement universal regulation is unlikely and unobtainable. ABI Research believes that a more practical alternative is for an existing internationally recognized group to take on this responsibility. To play the role effectively, said international organization must meet the following criteria:

- **Good International Reputation:** The organization must have an excellent reputation among all the member states, including proven track records of developing regulations openly and transparently, capable of achieving consensual decision-making, zero or minimal geopolitical influence or plan, etc. They should also maintain a good relationship with standard bodies and regulators, with constant communications and dialogs to promote understanding.
- **Relevant to AI and Autonomous Vehicle Industry:** The organization must be relevant to both industries and constantly engage with the technology supply chain, and ecosystem on the trends and advancements. The forms of engagement can be conferences, seminars, workshops, publications, whitepapers, and consultations on standards and regulations, particularly on AI ethics.
- **Solid Mastery of Technology:** The organization must display a strong understanding of AI and autonomous vehicle technology. A robust technical knowledge will lead to appropriate regulation that encourages innovation and compliance, thus earning respect and appreciation from the industry.
- **Future-Looking and Visionary:** The organization also needs to be bold and showcases good visibility on market demands and future technology trends. Also, the organization must be able to foresee the future economic, societal, and technological impacts of vehicle autonomy.

At the moment, it appears that more technically-oriented international organizations, such as SAE International, ISO, and the International Telecommunication Union (ITU), are in a better position to take into this role and develop the universal regulation for vehicle autonomy. This is because these organizations have played the leading roles in the vision, design, development, and deployment of various technical standards, while maintaining a good relationship with national governments and regulatory bodies.

To develop a universal regulation, said organization should follow the following steps. First, it needs to collaborate among the current standards programs openly and transparently. Second, it should harmonize and unify all regional regulatory frameworks on ethics, while strictly adhering to the above-mentioned universal ethics governance framework. Third, it should publish discussion papers, hold public consultations, and host regional and international meetings to decide on every aspect and detail of the regulation. Finally, it needs to ensure that major markets accept the regulation before seeing it widely adopted by all countries.

INDUSTRIAL ROADMAP

Based on the current market development in the United States, the EU, and China, ABI Research foresees a realistic roadmap to be as follows:

1 to 2 years	The EU and China to launch regional regulatory frameworks for autonomous vehicles, driven by top-down initiatives.		
2 to 4 years	The United States to launch a federal regulatory framework for autonomous vehicles. Conversations on ethics around autonomous vehicles in the United States will start with commercial entities that exercise their influence on the government and regulators. The framework will be developed through a collaborative effort between technology providers, state governments, and the Department of Transportation. While the top three markets have their respective frameworks, the rest of the world will continue to debate the right approach. This will lead to two scenarios:		
4 to 7 years	**Scenario 1** Rest of the world to develop its own country-specific ethics governance framework. A more straightforward approach, but will lead to inconsistency and discrepancy that hinders global rollout.	**Scenario 2** Massive effort among key stakeholders to consolidate and harmonize the regional differences, leading to a global ethics governance framework. More time-consuming, but beneficial for global deployment. Vendors only need to adhere to a common framework, facilitating R&D efforts.	
7 to 10 years	**Scenario 1** Most countries are still developing their ethics governance frameworks. The lack of collaboration will lead to more confusion, unnecessary regulatory red tape, and duplicated efforts.	**Scenario 2** Global ethics governance framework for vehicle autonomy will be introduced through a worldwide ethics governance body for vehicle autonomy (potentially by existing entities or by a newly-created International Ethics Organization). A common framework provides the proper foundation for the stakeholders to continue improving ethical governance methods as the technology matures.	
10 to 15 years	**Scenario 1** Select countries are still developing their ethics governance framework. Most countries to focus on national regulations. Fragmentations in global vehicle autonomy adoption.	**Scenario 2A** Introduction of national regulations based on global ethics governance framework. Some unnecessary regulatory red tape and duplicated efforts.	**Scenario 2B** The birth of a universal ethics regulation based on global ethics governance framework. Widespread confidence in the ethics of vehicle autonomy.

The most obvious shortcoming of the roadmap is the duration. Autonomous vehicle technology is still a nascent technology, so it will take a few years to mature. Therefore, even the early adopter markets will take several years to determine the optimal regulatory framework. However, ABI Research expects that once the industry can agree on a universal regulatory approach, this will significantly accelerate the rollout of vehicle autonomy across the world.

CONCLUSIONS

Given the enormous potential and growing concerns around vehicle autonomy, introducing a global ethics governance framework will be a significant milestone for the autonomous driving industry. Specifically, the framework will have three major influences.

First, the framework will ensure the autonomous vehicle system's ethical design and development process with continual review, clear accountability, and complete transparency. Second, the acceptance of the framework indicates a resounding acknowledgment and commitment to upholding the safety and personal privacy of all road users in an inclusive and non-discriminatory manner. Finally, responsible data usage and secure storage minimize national security threats, protecting countries from selfish and malicious individuals and entities.

Ultimately, the global ethics governance framework bridges the gap between the societal benefits and ethical pitfalls of vehicle autonomy, making vehicle autonomy safe for everyone by reducing traffic deaths and harmful emissions, quality of life improvement, and promoting sustainable growth.

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