Agile Governance: A New Governance Model for Autonomous Vehicle

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Abstract. Autonomous vehicle can bring people a more efficient, safe, comfortable and energy-saving travel experience, and can also promote the overall development and progress of society in traffic safety, travel efficiency, energy conservation and emission reduction, industrial reform and other aspects. However, the risks of autonomous vehicle are highly uncertain. In addition, the technology iteration cycle is getting shorter and shorter, and the business model and innovation path are still unclear, which brings huge challenges to industrial governance, and the traditional governance model is difficult to cope with. The research shows that the agile governance model has obvious advantages in emerging technology governance. This paper introduces agile governance into autonomous vehicle, establishes an agile governance framework for autonomous vehicle, and takes China as a case to analyze how regulators achieve governance goals through agile governance. This study helps to identify the internal operating mechanism of emerging technology governance such as autonomous vehicle, and provides reference for theoretical research and practice of other emerging technology governance.

Keywords: autonomous vehicle; agile governance; emerging technologies; governance framework; innovation regulation

1 Introduction

Autonomous vehicles are regarded as the strategic direction of future automobile industry development. On the one hand, autonomous vehicles can bring people a more efficient, safe, comfortable and energy-saving travel experience. On the other hand, they can also promote the overall development and progress of society in traffic safety, travel efficiency, energy conservation and emission reduction, industrial reform and other aspects. However, from a global perspective, autonomous vehicles are still in the early stage of industrial development, and their technical routes and business models are immature and under continuous exploration. The autonomous vehicle is a double-edged sword for China's automobile industry and even the whole society. On the one hand, autonomous driving technology has a strong driving force for innovation, which not only helps to cultivate new advantages in the development of the automobile industry, but also helps to promote technological innovation in other industries in China, providing important support and powerful assistance for China to build itself into a power in automobile, transportation, manufacturing, science and technology, network and digitization. However, on the other hand, autonomous vehicles will also bring certain social risks, and the negative external effects caused by them have attracted widespread attention.

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Autonomous vehicles are formed through technological innovation and business model innovation under the guidance of market demand. The market plays a decisive role in the development process of autonomous vehicles, but government regulation is also essential to ensure normal operation of the industry and avoid possible risks. However, compared with traditional vehicles, autonomous vehicles are subversive and highly uncertain. The technical route is not yet clear, the business model is still immature, and it is difficult to predict potential risks, so the traditional regulatory mechanism cannot effectively cope with them. For the immature autonomous driving technology, government departments, research institutions, colleges and universities, and enterprises are very concerned about when to intervene and how to design regulatory ideas and requirements so as not to hinder the development of technological innovation but minimize risks.

To solve the governance problems brought by the Fourth Industrial Revolution to human society and overcome the contradiction between the lag in traditional policy formulation and the rapid iterative development of new technologies, the concept of "agile governance" was put forward in the 2018 World Economic Forum White Paper. [1]Agile governance is a governance concept and improvement method proposed for emerging technologies. It features agility, sustainability, adaptability, self-organization and inclusiveness. Compared with traditional governance methods, agile governance can better solve the problems of one-sidedness, fragmentation and lag, and effectively bridge the gap between technological innovation and policymakers' governance ability.[2]This paper summarizes the connotation of agile governance and builds an analysis framework for autonomous vehicle agile governance. In addition, it analyzes the management practice of autonomous vehicles in China, explores how to achieve regulatory objectives through agile governance among various subjects, further analyzes the operation mechanism behind, summarizes the optimization path of autonomous vehicle regulation, and promotes the healthy and orderly development of autonomous vehicles.

2 Changes in governance foundation caused by autonomous driving technology

2.1 Driving task: transition from human to automated driving system

In March 2020, the Ministry of Industry and Information Technology of the People's Republic of China (MIIT) issued the national standard Taxonomy of Driving Automation for Vehicles (GB/T40429-2021), which specifies the taxonomy of driving automation functions of vehicles. [3]With reference to the autonomous driving classification standard formulated by the Society of Automotive Engineers (SAE International), this standard divides the driving automation system into 0~5 levels.[4] Levels 3~5 of driving automation refer to autonomous driving. Unlike traditional vehicles where humans perform environmental perception, driving decision-making and vehicle control, autonomous vehicles will rely more on in-vehicle systems to complete their driving tasks. With the continuous improvement of driving automation level, the role played by human drivers is decreasing, and the driving tasks are gradually transferred to the automated driving system. Finally, all driving tasks in fully autonomous vehicles (Level 5) will be undertaken by the system.

2.2 Technology iteration: shorter and shorter iteration cycle of autonomous driving technology

In traditional vehicles, hardware (such as the engine and transmission) is an important component of a vehicle. It has a very long iteration cycle, and is usually not much changed in 5 or 10 years. However, in autonomous vehicles, the competition for automotive products has shifted to intelligence and networking. Chips, software and algorithms have become key factors for product competitiveness. The iteration cycle of chips, software and algorithms is significantly shorter compared with that of hardware such as engines. Developers greatly reduce development costs, promote rapid iteration of autonomous vehicles, and accelerate the industrialization process through software intensification. At present, the iteration cycle of a vehicle has been shortened from 40~50 months to 12~15 months. With the continuous breakthrough of autonomous driving technology, its upgrade and iteration can be as normalized and regularized as smartphones.

2.3 Business model: lack of mature and feasible business models in the short term

In theory, all scenarios that traditional vehicles can apply can be applied by autonomous vehicles. However, in terms of the difficulty of technical realization, autonomous driving technology will be first applied in some low-speed closed scenarios, such as closed parks, airports, mining areas and docks. In contrast, it is difficult to realize safe and reliable autonomous driving technology in a short time in large-scale operation scenarios with uncertain lines, complex traffic environment scenarios and operation scenarios under extremely severe weather. Therefore, autonomous vehicles will be commercialized in the order of "low-speed closed scenario - low-speed open scenario/high-speed closed scenario - high-speed open scenario". However, from a commercial perspective, the limited number of low-speed closed scenarios, small vehicle demand, low commercial income and small market space lead to insufficient development motivation for enterprises. On the contrary, the demand for autonomous vehicles in complex scenarios is large, and the commercial income is high, but it is difficult to implement at this stage due to restrictions of technologies, policies and regulations. Therefore, the current business model of autonomous vehicles is still highly uncertain. How to find a feasible and sustainable business model is a common problem for enterprises.

2.4 Risk evolution: Internal and external risks exist simultaneously

Large-scale application of autonomous vehicles poses both internal and external risks. Among them, internal risks refer to the risks at the level of autonomous driving technology itself, and external risks refer to the potential social risks brought by large-scale application of autonomous driving technology.

First, internal risks. To make autonomous driving as smart as human beings, R&D personnel have applied deep learning algorithms in autonomous driving, greatly improving the intelligence and flexibility of autonomous driving technology. However, the application of deep learning algorithms also poses another problem: lack of interpretability of deep neural networks. [5]Although people can use deep neural networks, they do not fully understand them. The algorithm model built based on deep neural networks enables autonomous driving to make corresponding judgments and actions, but it cannot tell people the reasons and considerations for making this decision. This is the "black box" of autonomous driving technology. For

example, for a white car parked in the middle of the road, human beings can judge that it is a vehicle through various characteristics such as color, shape, volume and contour. However, autonomous vehicles may go beyond what humans can understand, recognize the car as sky and drive directly, eventually leading to traffic accidents. The "black box" of autonomous driving technology exists objectively. Although a series of intelligent operations can be completed through deep learning, it is difficult to predict internal risks, which directly affects the safety, comfort and efficiency of products.

Second, external risks. The autonomous driving technology is an emerging industry, and the external risks caused by its large-scale application are highly uncertain. Generally speaking, the development of technology needs to go through a process from birth to perfection and then to maturity. The security risks brought by new technologies are gradually emerging in this process.[6] However, at present, the global autonomous driving technology is in its early stage of development, and the innovation law and technical route are still unclear. It is difficult for regulators, R&D personnel and scientific research institutions to judge the external risks caused by autonomous driving.

2.5 Participants: multiple participants for realization of autonomous driving functions

With the development of autonomous driving technology, the boundary of the automobile industry is expanding and becoming increasingly blurred. In addition to automobile manufacturers and parts suppliers who have always been in the industrial center, on-board computing platform developers, technology companies providing new software and hardware, mobility service providers, infrastructure builders and operators will become an important part of the future automobile industry. The past chain industry chain has gradually transformed into a three-dimensional network ecosystem.

3 Governance challenges of autonomous driving technology

3.1 Breaking the traditional legal framework

Historical experience has shown that subversive technologies are often excluded and constrained by conventional ideas and established rules, including autonomous vehicles. The existing automobile-related laws and regulations in China are constructed based on the logic of "human-driven vehicle", and the corresponding system design is centered on "human". However, the biggest characteristic of autonomous vehicles is "system-driven vehicle", which will inevitably lead to the current laws and regulations not applicable to autonomous vehicles. For example, if a road traffic accident occurs when the automated driving system is activated, how should it be imputed, and who shall be responsible for compensation? Another example is whether the automated driving system needs to obtain a driver's license as well. In addition, autonomous vehicles will also face ethical issues such as the "trolley problem". It can be predicted that autonomous vehicles will have a profound impact on automobile product forms, industrial forms, traffic forms and even social forms, and will also become the key area of international competition in automobile and related industries. However, the inapplicability of current relevant laws and regulations to autonomous vehicles exists objectively, and the industry has an urgent need for adjustment and optimization of relevant systems.

3.2 Difficulty in accurately predicting internal and external risks of industrial development

The traditional automobile governance in China is mainly based on the pre-governance model of risk prevention, that is, regulatory authorities intervene before potential risks evolve into actual damages to realize risk prevention.[7] A typical example is the access system for automobile products. The "prior" review method is adopted for automobile product access in China, which requires that automobile products meet national mandatory standards and technical specifications, so as to reduce risks of automobile products and maintain public safety and social security[8]. From the perspective of applicable scenarios, the pre-governance model should be established based on the mature automobile industry and clear safety risks. However, the internal and external risks of autonomous vehicles are uncertain, difficult to predict and unable to cope with, which brings great challenges to traditional governance models, specifically in the following aspects:

Firstly, the governance model should coordinate development and security. Autonomous driving technology has great potential to promote social change, but there are internal and external risks that are difficult to predict at this stage. To this end, regulators need to strike an effective balance between development and safety. They can neither "ban it" nor "let it go"[9]. Second, the countermeasures of pre-governance model are lagging behind. Since risks cannot be predicted in advance, it is difficult for regulators to formulate countermeasures in advance, and they can only explore governance models in the process of technological innovation and application, which leads to a lag in countermeasures. Third, the governance method needs to be constantly adjusted. With the development of autonomous driving technology, the connotation and manifestation of risks are also constantly changing. Regulators need to dynamically adjust their supervision methods and means according to industrial development.

3.3 It is difficult for traditional governance to keep up with the iteration of the technical updates.

Generally, timeliness and economy shall be considered in the formulation of policies and regulations. For example, the law is used as an explanation here. In terms of timeliness, China's legislation has a strict and complex process that usually takes 3~5 years.[10] However, the iteration cycle of autonomous driving technology is generally 12~15 months. It is difficult for the formulation and revision of policies and regulations to keep up with the iteration of technical updates, and there may a dilemma "being outdated or about to be obsolete once released". In terms of economy, legislation is both political and economic. When discussing the necessity and timing of legislation, it is necessary to consider both expected benefits and legislative costs.[11] Legislation will only be made when the expected benefits outweigh the legislative costs. The formulation of laws and regulations on autonomous vehicles not only costs a lot of manpower, material resources, financial resources and time, but also needs publicity, interpretation and implementation after release. In addition, as the iteration cycle of autonomous driving technology is short, laws will be constantly adjusted and revised after release.

3.4 Interests of multiple parties need to be balanced in the industrial governance

Autonomous vehicles drive technological and business model innovations and lead to disruptive changes in the automotive industry, creating new opportunities but threatening the interests of

existing participants as well. In terms of industrial governance, it is necessary to achieve industrial fairness and rebalance interests. The first is to rebalance the regulatory authorities. Autonomous driving technology has expanded the scope of vehicles. National Development and Reform Commission, Ministry of Industry and Information Technology, Ministry of Transport, Ministry of Public Security, State Administration for Market Regulation, Ministry of Natural Resources, Ministry of Housing and Urban-Rural Development, Ministry of Science and Technology, National Energy Administration, Ministry of Finance, Cyberspace Administration of China, Ministry of Ecology and Environment, etc. have assumed certain responsibilities in the governance over autonomous vehicles, so it is necessary to improve the coordination between the regulatory authorities. The second is to rebalance the interests of participants. In addition to automobile manufacturers and parts suppliers, on-board computing platform developers, technology companies providing new software and hardware, mobility service providers, infrastructure builders and operators will also join the game of regulatory policy. The third is to balance the central government and local governments. The central government mainly plays the role of top-level design in autonomous vehicle governance, and local governments conduct the implementation.

4 Agile governance framework for autonomous vehicles

4.1 Connotation and characteristics of agile governance

Agile governance is a dynamic governance method that quickly adapts to changes in scenarios. It has the advantages of rapidity, flexibility, adaptability and inclusiveness, and can effectively deal with regulatory challenges caused by high uncertainty of new technologies.[12] Existing research has introduced agile governance into digital government[13], urban governance[14], metaverse[15], artificial intelligence[16], digital healthcare[17] and face recognition[18]. These fields are generally emerging industries or use many emerging technologies. Agile governance not only improves the response speed of governance, rethink and design policy processes, but also takes maintaining public safety, reducing industrial risks and improving social well-being as top-level objectives to guide and standardize the development and application of emerging technologies.[19] Agile governance includes the following characteristics:

First, agility. In agile governance, it is necessary to make continuous preparation is required for rapid changes, and quickly respond to risks in the process of finding problems, studying countermeasures and making decisions. Second, collaboration. The regulatory objects of agile governance are generally highly uncertain in terms of technology, business model and risk, so it is difficult for regulators to do it alone. Therefore, the construction of the supervision system under the agile governance no longer relies on the government alone, but introduces stakeholders such as enterprises, industry institutions and universities into the decision-making process to improve the scientificity and agility of decision-making through collaborative integration. Third, flexibility. In the face of highly uncertain governance objects, it is difficult for the government to formulate targeted regulatory policies. This requires the government to make flexible adjustments in supervision systems, processes, methods, means and objects to constantly adapt to industrial changes. Fourth, tentativeness. Agile governance advocates the principle of "concise design and continuous improvement"[20], and advocates the intervention method of "fast process and light force". "Fast process" is conducive to quickly clarifying the

government's regulatory attitude and providing guidance for enterprises so that they can make quick adjustments. "Light force" means tentative and experimental, which minimizes the impact on enterprises and avoids great losses caused by excessively aggressive regulatory policies in the process of industrial development.

4.2 Agile governance framework for autonomous driving

Agile governance is different from traditional governance in terms of agility, collaboration, flexibility and tentativeness, which helps solve the regulatory dilemma faced by autonomous vehicles. Specifically, the agile governance framework for autonomous vehicles includes five dimensions: governance concept, governance objectives, governance process, governance structure and governance tools, as shown in Figure 1.

In terms of governance concept, the government needs to actively accept changes, have an in-depth understanding of the current situation of the industry and the interest demands of various participants, make predictions in advance based on the governance environment and governance scenarios, adjust governance ideas and means in a timely manner, and change from passive response to active response.

In terms of governance objectives, the objectives of agile governance for autonomous vehicles are more diversified. It is necessary to promote industrial development and technological innovation, improve social efficiency, and control industrial safety risks caused by the large-scale application of autonomous driving technology.

In terms of governance process, the agile governance of autonomous vehicles requires a flexible and responsive governance process with efficient connection and closed-loop coupling, so as to provide institutional support for the efficient solution and timely response of autonomous vehicle governance.

In terms of governance structure, the agile governance of autonomous vehicles requires a multi-collaborative governance model. In the development process of autonomous driving technology, industry institutions and enterprises have a better understanding of the current situation, route and trend of technology development, which can make up what the regulators do not know to some extent. Therefore, compared with the traditional automobile industry, the dependence of government regulatory authorities on industrial institutions and enterprises in the autonomous vehicle industry is more in-depth. It is necessary to establish a cross-border cooperation mechanism where government departments, industrial institutions and enterprises participate together. For the regulatory authorities, through communication with industry institutions and enterprises, they can better understand the development status and trend of autonomous vehicle industry, correctly assess industrial risks and formulate a reasonable supervision system. Under specific circumstances, they should also actively participate in industrial development to guide the direction and path selection of industrial development. For enterprises, through cooperation with regulatory authorities, they can have an in-depth understanding of industrial governance ideas and carry out activities such as enterprise capacity building, product development, production and operation in line with government governance objectives to minimize compliance risks. For industry institutions, they will participate in governance activities as the link between government regulatory departments and enterprises, playing their roles of "making teams", "building standards", "building platforms" and "building bridges".

In terms of governance tools, agile governance of autonomous vehicles should give full play to the advantages of technical and policy tools. In terms of technical tools, advanced technologies such as software Internet and big data can be used to build a monitoring platform, carry out big data analysis, deeply grasp the development data of autonomous vehicle industry, analyze industrial development risks, and provide strong support for the construction of supervision system. In terms of policy tools, it is necessary to explore ways to establish local pilot and Regulatory Sandbox, so as to create an institutional environment conducive to the innovation and development of emerging technologies.

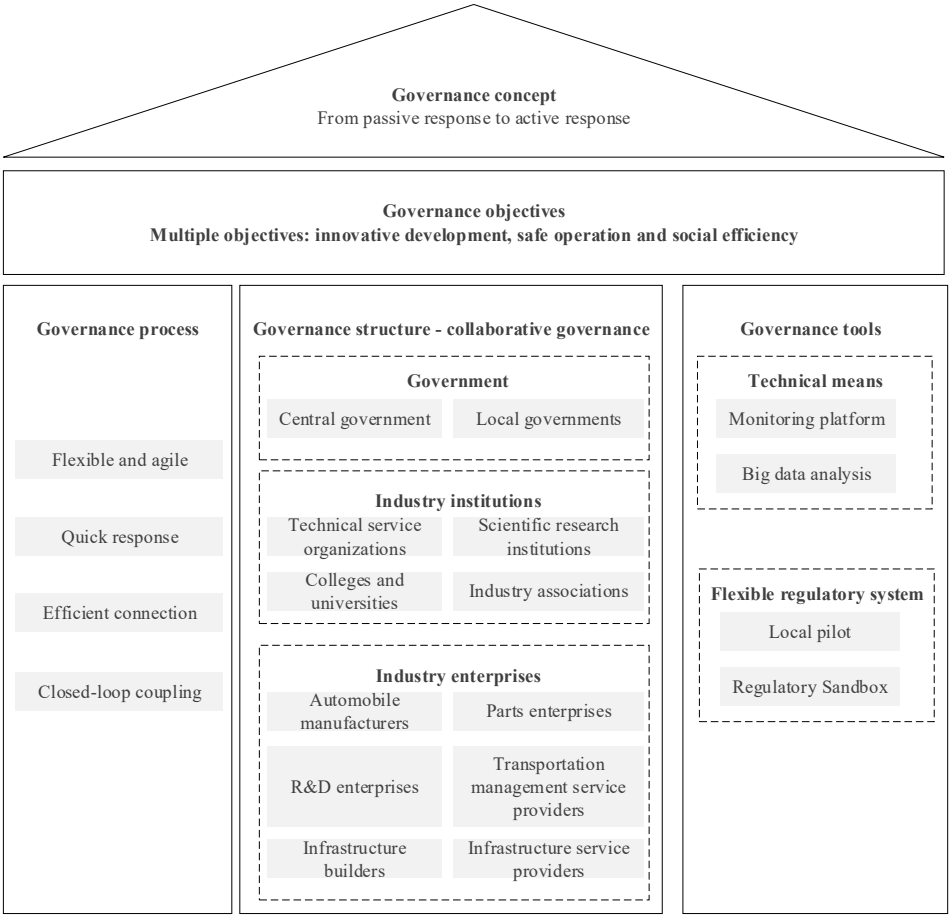

Figure 1. Agile Governance Framework for Autonomous Vehicles

5 Analysis on agile governance practice of autonomous vehicles in china

Compared with traditional vehicles, the technical route, product structure and use mode of autonomous vehicles have undergone subversive changes. The current management system will

inevitably be unsuitable for autonomous vehicles in some aspects, which delays the industrialization process of autonomous driving technology to a certain extent. China attaches great importance to the development of autonomous vehicles, innovates its management system in combination with the characteristics of autonomous driving technology, and has initially established an agile governance system for autonomous vehicles with Chinese characteristics. With the joint efforts of the government and industry, the development of autonomous driving technology in China has entered the fast lane. Over 20,000 kilometers of test roads have been opened up in China, with a total test mileage exceeding 70 million kilometers. Several enterprises are accelerating the R&D of autonomous vehicles, and some products have already met the conditions for mass production and are about to enter the market. The following analysis of the agile governance mode for autonomous vehicles in China, from the perspectives of top-level planning (governance concept and objectives), governance process, governance structure, and governance tools, aims to assist government departments, academia, and industry in carrying out theoretical research and application practice of agile governance.

5.1 Strengthen top-level planning, clarify the direction and goal of industrial development, and actively deal with industrial risks in advance

In order to promote the innovative development of autonomous vehicles, 11 Bureaus such as the National Development and Reform Commission, MIIT and the Ministry of Science and Technology jointly issued the Innovative Development Strategy in Intelligent Vehicles on February 24, 2020 [21], which pointed out China's autonomous vehicle governance concept, governance objectives and regulatory system construction direction, and clarified the main tasks for a period of time in the future with wide coverage and strong guidance. According to the Innovative Development Strategy in Intelligent Vehicles, the autonomous vehicle regulatory system shall adhere to the "scientific and standardized, inclusive, and safe and controllable" principle. The Strategy encourages bold innovation, particularly in the early stages of the development of autonomous vehicles, to create an inclusive development environment with cautious regulation as much as possible. The relationship between accelerating development and ensuring safety shall be properly handled, promoting the product application and industry development. At the same time, it considers safety and controllability as the regulation bottom line to standardize the development of autonomous vehicles.

5.2 Innovate the regulatory system and establish an efficient and tightly integrated governance process

The core of agile governance for autonomous vehicles is to establish an agile "inspection and adjustment" feedback loop process, so as to maintain flexible adaptability, respond quickly to emergencies in time, efficiently coordinate the interests and resources of all stakeholders, and intervene in cases of government behavior deviations or inefficiencies, which is manifested in the following aspects:

First, continuous monitoring and timely feedback. Continuous monitoring and timely feedback are the basis for achieving agile governance, which helps to quickly identify problems and risks in the autonomous vehicle industry and ensure the effectiveness and adaptability of governance. Taking the sector of autonomous vehicle data security as an example, China requires enterprises to strengthen the building of data security monitoring and early warning capabilities. They must monitor data security incidents in real-time and respond promptly. Relevant information needs

to be reported to provincial-level telecommunications authorities and industrial and information technology authorities, supporting government departments to continuously optimize their policy systems.

Second, rapid adjustment. In China, the management of autonomous vehicles has formed a closed management loop of "continuous monitoring - timely feedback - rapid adjustment" to ensure the continuous effectiveness of governance methods and means through self-adjustment and continuous iteration. Take Jiangsu Province as an example. Jiangsu Province has established a statistical monitoring indicator system for the development of autonomous vehicles. It carries out timely evaluations of the development of autonomous vehicle industry and promptly optimizes policies and measures to ensure the sustainability and scientificity of the policies.

5.3 Strengthen departmental collaboration, industry cooperation, and vertical coordination to form a collaborative governance structure across departments, industries, and sectors

(1) Establish diversified communication channels

First, communication channels between the government and enterprises, universities and industry institutions. For example, the National Innovation Center of Intelligent and Connected Vehicles was officially established in 2017. It is composed of automobile enterprises, industry organizations, universities and research institutions, with more than 200 member units covering many sectors such as automobiles, electronic communication and transportation. The Center is committed to building industrial communication channels and platforms for coordinated promotion, and carrying out cooperation in industrial strategies, policies and regulations, R&D of common technologies, industry promotion, and domestic and foreign industry exchanges. These channels play a bridging role, enabling relevant stakeholders to stay updated on the latest advancements in the autonomous vehicle industry. Moreover, they can drive innovation in regulatory methods for government departments and foster a conducive interaction between the government and the industry.

Second, social communication channels, such as conferences, forums, roundtable discussions and autonomous vehicle events. These channels aim to promote the interaction between relevant stakeholders of autonomous vehicles and the public, which are not only conducive to technical exchanges and industry discussions among different stakeholders, but also help to popularize autonomous vehicles. These channels include the World Intelligent Connected Vehicles Conference, Innovative Development Forum on Intelligent Connected Vehicle Industry, and Theme Forum on Intelligent Connected Vehicles and Cybersecurity.

Third, science popularization activities for public education. For example, the National Intelligent Connected Vehicle (Shanghai) Pilot Demonstration Zone has set up the Science Popularization Experience Zone (E-Zone) in Shanghai Automobile Expo Park, which provides autonomous vehicle experience activities for the public. For another example, Wuhan Economic & Technological Development Zone hosted the Intelligent Connected Vehicle Technology Innovation and Science Popularization Forum, which invited several academic and expert scholars to engage in face-to-face exchanges with primary and middle school students.

(2) Establish a multi-stakeholder collaboration mechanism for the commercialization promotion of autonomous vehicles

Autonomous vehicles have remarkable cross-sector characteristics and require in-depth cooperation and collaborative promotion among governments at all levels, industry and academia. In 2017, the MIIT took the lead in cooperating with more than 20 government departments to set up a special committee for the development of IoV industry under the National Leading Small Group for Building a Strong Manufacturing Country. The special committee coordinated and solved key problems that need to be solved across sectors in the industry from many aspects such as policy formulation, standard innovation, and test and verification, and promoted the continuous improvement of top-level designs and laws and regulations. In March 2021, the MIIT organized relevant industry institutions and enterprise experts to set up an Intelligent Connected Vehicle Promotion Group (ICV-2035), under which an expert group composed of experts from industries related to industry, university, research and application was set up to solve major key problems faced in the development of autonomous vehicles by gathering experts and promote the commercialization of autonomous vehicles. The coordination and promotion mechanism established by the government, which involves cross-departmental, cross-industry, and cross-institutional cooperation, has played a crucial role in promoting the improvement of China's policy and regulatory system for autonomous vehicles and supporting industry development.

5.4 With inclusive and cautious regulation, create a governance toolbox for autonomous vehicles

(1) Innovate technical regulation means

Compared with traditional vehicles, autonomous vehicles need more flexible technical regulation means to quickly and accurately understand the current situation of industry development and analyze the trend of industry development. In order to effectively support the full life cycle management of autonomous vehicles, China has set up a number of national and local data regulation platforms for autonomous vehicles. At the national level, in 2020, the MIIT took the lead in building the "Public Service Platform for Data Interaction and Comprehensive Application of Intelligent Connected Vehicles". The overall architecture of the platform is divided into three layers: national management center, territorial center and enterprise platform. Once completed, the platform will have the capability to serve the data collection and storage needs of "millions" of autonomous vehicles, which can play an important supporting role in China's autonomous vehicle data standards and full life cycle management, and help to build a new ecosystem of autonomous vehicle data integrating multiple functions such as operation monitoring, safety early warning, and test and evaluation. At the local level, taking Shenzhen City as an example, Shenzhen City has built a "Shenzhen Intelligent Connected Transportation Test Demonstration and Regulation Platform", further horizontally connects the business application and system data of municipal departments such as industry and information technology, transportation, traffic police and municipal supervision departments on the basis of this platform, refines and integrates the regulation business needs of various business departments for intelligent connected vehicles, and forms an integrated safety regulation and monitoring platform in Shenzhen.

(2) Establish flexible regulatory system

1) In the early stage of industry development, encourage local pilots to form a number of replicable and promotable experience and practices

First, encourage local governments to carry out public road tests and demonstration applications of autonomous vehicles according to local conditions. The system in an autonomous vehicle undertakes most or even all of the driving tasks. In order to ensure that the vehicle can operate safely and reliably under various scenarios, R&D personnel not only need to carry out lots of tests and verification in the laboratory, but also need to place the product in a real road traffic environment for repeated tests. Through public road test and demonstration application, the autonomous driving function is fully systematically verified to ensure the adaptability and coordination between vehicles, between vehicles and people, between vehicles and transportation facilities and among participants. From a global perspective, it is a common practice in various countries around the world to carry out public road tests and demonstration applications of autonomous vehicles. The practice can not only control risks within a limited range, but also help regulatory authorities understand new problems and challenges faced by autonomous vehicles in product access, registration, on-road traffic, transportation operation, circulation, after-sales and other links, providing policy practical experience for subsequent establishment of a new governance system.

Second, explore autonomous vehicle regulation solutions through local legislation. On the one hand, China's autonomous vehicles are in the early stage of development, and there are significant uncertainties in technical routes, business modes and industrial risks. Therefore, it is difficult to make unified legislation at the national level at this stage. On the other hand, China has a vast territory and significant regional gap. The R&D and industrialization of autonomous driving technology have distinctive geographical characteristics. Autonomous driving technology solutions need to be adaptively adjusted according to different regions. In view of the above, implementing local legislation as a pilot program is the best method at this stage to explore autonomous vehicle regulation solutions. In June 2022, Shenzhen City issued the Regulations on the Administration of Intelligent Connected Vehicles in the Shenzhen Special Economic Zone, which made comprehensive regulations on the autonomous vehicle regulation, covering the full life cycle links of autonomous vehicles such as road test and demonstration application, product access, registration, use management, vehicle-road coordination, data security and cybersecurity, and traffic violations and accident handling. The Regulations is an important piece of legislation in Shenzhen's emerging industry sector, and also the first regulation to standardize the administration of autonomous vehicles in China. It sets a benchmark for exploration of autonomous vehicle legislation at the local level, and accumulates local pilot experience for subsequent legislation at the national level.

2) Based on the local pilot experience, carry out "Regulatory Sandbox" nationwide to promote industry development and improve policies and regulations through pilot projects

The exploration of legislation and policy breakthroughs at the local level have laid a good foundation and accumulated practical experience for the construction of China's autonomous vehicle regulatory system. In order to fully prevent and control risks, China has explored the governance methods of autonomous vehicles through "Regulatory Sandbox" on the basis of local pilot. Regulatory Sandbox is an innovative test mechanism led by the government, which refers to delimiting a scope to form a "sandbox". The regulatory authorities will actively relax administration requirements and build a safe and controllable test environment through interactive consultation with enterprises on the premise of protecting consumers' rights and interests and preventing risk spillover. Pilot subjects are encouraged to test innovative products, services and business modes in the real market environment. During the test process, the

regulatory authorities will carry out regulation and final evaluation on the whole test process, so as to accumulate experience for exploring the innovation of regulatory system. Regulatory Sandbox is essentially a government-led test mechanism with the main purpose of promoting the commercial application of innovative achievements. It primarily addresses the challenges arising from the transition between old and new regulatory systems, including the risk of failure spreading due to lax regulation, the suppression of innovation caused by strict regulation or regulatory arbitrage, the difficulty of balancing innovative applications and effective regulation, and the inadequacy of traditional regulatory system in addressing the professional, technical, and forward-looking aspects of emerging industries.

In November 2023, the MIIT, the Ministry of Public Security, the Ministry of Housing and Urban-Rural Development and the Ministry of Transport jointly issued the Notice on Carrying out ICV Access and Road Traffic Pilot Work (hereinafter referred to as "the Notice")[22], and determined to launch the access and on-road traffic pilot work of autonomous vehicles. The pilot work follows the principle of "starting with small-scale experimentation and implementing according to conditions", essentially adopting the approach of "Regulatory Sandbox". The system design for the pilot work covers the following aspects:

First, clarify the access threshold. The Notice requires that a consortium composed of automobile manufacturers and user entities shall jointly apply for the pilot project, allowing qualified autonomous vehicle products to be sold in the market and put into operation on the real road. The Notice imposes exceptionally high requirements on automobile manufacturers, user entities, and autonomous vehicle products used for pilot, aiming to identify pilot schemes that demonstrate a combination of safety and innovation[23].

Second, limit the applicable area. The pilot products of autonomous vehicles can only be operated in cities with good basic conditions such as policy guarantee, infrastructure and safety management, and the operation areas and use scenarios shall be strictly limited.

Third, limit the number of pilots. The pilot work strictly limits the number of pilot products of autonomous vehicles. In the initial stage of the pilot, a small number of automobile manufacturers with advanced technology, comprehensive systems, and effective safety measures, along with their thoroughly tested and validated autonomous vehicle products, will be selected for the pilot.

Fourth, strictly limit the user type. The pilot products of autonomous vehicles can only be sold to user entities, and shall be managed by user entities in a unified manner. It is forbidden to sell these products to individual consumers.

Fifth, adhere to a bottom-line mindset. Automobile manufacturers, user entities, and pilot products are still required to comply with relevant laws, administrative regulations, and other regulations that have been promulgated. They must not endanger social security or harm public interests.

6 Conclusion

Autonomous vehicles serve as a crucial driver for the transformation and upgrading of China's automotive industry and the entire economic and social sectors. They will play an increasingly

significant role in implementing China's innovation-driven development strategy. As an emerging industry, the development and safety of autonomous vehicles shall be considered as a whole in the design of regulatory system, and the regulation intensity and scale shall be well controlled. It is essential to avoid excessively strict regulations that impede technology development, while also being vigilant against lax regulations that may pose safety risks. Agile governance combines agility, collaboration, flexibility, and exploratory approaches, enabling effective responses to the governance challenges faced by emerging industries like autonomous vehicles. This paper analyzes and sorts out the practical path of agile governance for autonomous vehicles in China, which is helpful to provide reference for other emerging industries.

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