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The emerging intelligent and connected vehicle industry in China

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1. Introduction

Benefiting from digitalisation which allows vehicles to be connected with their surroundings and the drivers, intelligent and connected vehicle (ICV) has the potential to solve congestion, decrease the number of road accidents and improve access to mobility. The ICV industry involves a whole new ecosystem of services, operations and infrastructures formed by a wide variety of actors and stakeholders, which not only generates transformation in the industries but also has direct impact on the social security and sustainability (ENISA, 2021).

Meanwhile, ICV systems are very complex, which require the integration and interaction of multiple elements such as people, vehicles, roads and clouds, and more importantly the elaboration of dedicated industrial norms and regulations. As many related functions are still in a stage of rapid development and continuous iteration, ICVs also face challenges such as network safety and data security (ENISA, 2021). Currently, some countries and regions have adopted methods such as ‘exceptions and exemptions’ and case-by-case handling to impose restrictive conditions on the access of ICV products and services while continuing to explore innovative safety supervision methods.

China has become the global leader in new energy vehicle (NEV) production and consumption since 2015, and is so far the only country that has developed a vertically integrated full value chain of mass production of electric vehicles (Wang et al., 2022). With its NEV industry becoming increasingly mature and competitive, China has reoriented its industrial policy to forge the emergence of the next-generation ICV industry and its full value chain development.

Our paper will investigate the national and industrial strategies that have allowed the recent fast development of the new industry of ICV in China, as well as the innovation of business models related to ICV applied in new competitive niche markets. By documenting key policies and announcements by relating Chinese authorities, we analyse the crucial role of industrial policies in sustaining the take-off of ICV industry. Under the guidance of relevant national policies, all major provinces and cities in China have been actively promoting the implementation of ICV for transporting people and goods. Our study underlines the indispensable role played by local governments in encouraging innovative projects and coordinating demonstrative applications, by providing close supervision and follow-up. These governments are highly motivated also because the industrial chain of ICV is long and involves a lot of actors, and ICV can become an important driver of transformation and upgrading of local industries and economies. Many new business models have been developed for both public and private applications, from traffic management to commercial cargo to city services. Specific scenarios such as ports and mining areas have taken the lead in

launching pilot operations; and in some limited areas in cities, self-driving taxis, unmanned logistics and unmanned sanitation have also started road demonstration.

2. National strategy and policies to promote ICV industry development

ICV is not a new innovation of the 21st century. The United States has supported since the early 1990s the development of ICVs through the ‘Intelligent Transportation System (ITS)’ project. In 2009 and 2014, it released strategic studies on connectivity and autonomous driving and published autonomous vehicle policy guidelines in 2016. The European Parliament officially launched the ‘Dedicated Road Facilities for Vehicle Safety (DRIVE)’ project as early as 1988, and continues to fund the R&D, and application of technologies related to ICVs. In 2015, the European Union released the GEAR 2030 strategy, which brings together the automotive, IT, communications, insurance and government sectors, focusing on promotion and cooperation in the fields of highly automated and connected driving. The Japanese government also regards autonomous driving and vehicle-to-vehicle communications as important directions and goals, and financed projects such as Vehicle Information and Communication Systems (VICS) and Advanced Safety Vehicles (ASV). In 2014, Japan released the ‘Strategic Innovation and Creation Project (SIP)’, listing autonomous driving as one of the ten strategic areas.

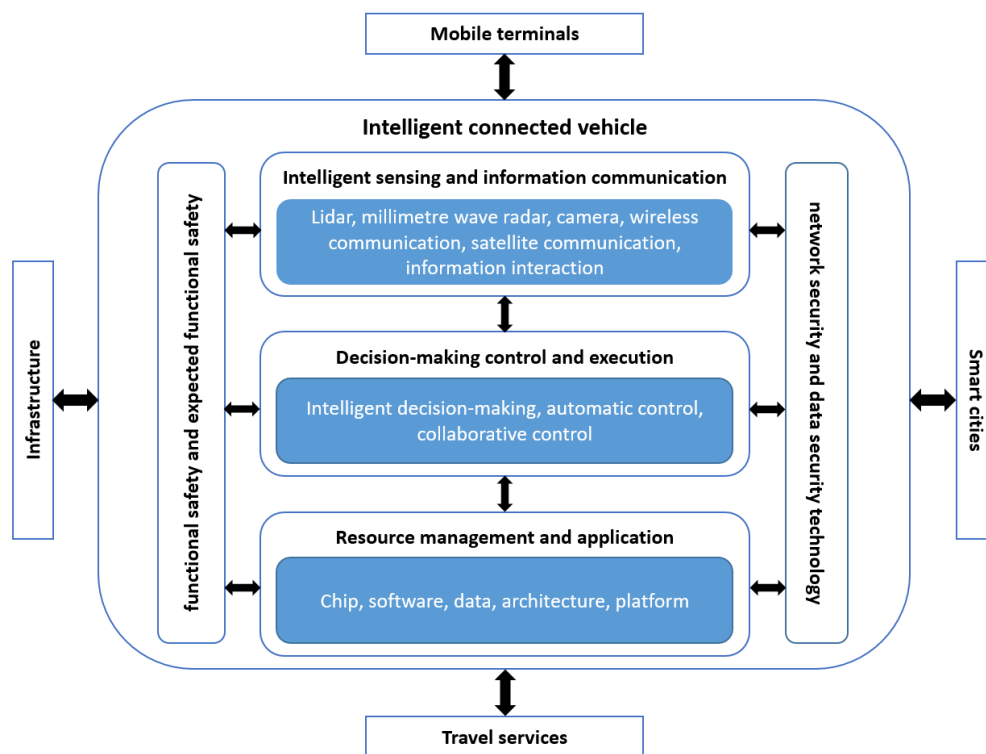
At present, the United States is in a dominant position regarding core technologies related to ICV, with balanced strength in different segments of the industrial chain; Europe has strong OEMs and suppliers with long industrial tradition and expertise; while Japan is relatively advanced in the application of intelligent safety technology. Global leading auto makers such as Mercedes-Benz, BMW, Volvo, General Motors, Ford, Tesla, Toyota and Nissan, are all heavily investing and promoting the commercialisation of PA-level autonomous driving products while some high-end brands have also launched CA-level autonomous driving products.

In ‘Made in China 2025’ (2015), the development of ICV was first officially elevated to a national strategic level, and driverless driving was listed as one of the important directions for the future transformation of the automotive industry. According to the ‘Intelligent Vehicle Innovation and Development Strategy’, the development of intelligent vehicles brings multiple benefits: ‘1) improve the fundamental industrial capabilities, achieve key technology breakthroughs, and enhance the ability to lead a new round of technological revolution and industrial transformation; 2) accelerate the transformation and upgrading of the automotive industry, cultivate the digital economy, and strengthen new economic growth momentum; 3) accelerate the construction of a manufacturing power, a technology power, a connectivity power, a transportation power, a digital China, and a smart society, and enhance China’s comprehensive strength in the new era; 4) ensure life safety, improve transportation efficiency, promote energy conservation and emission reduction, and improve people’s well-being’ (NDRC, 2020). Very strong ambition and high expectation are evident from the wordings.

China has been learning from the success of its NEV industrial policy, applying the method of ‘learning from experimentation’, gradually putting into place different guidelines and management directives for the ICV industry (Wang et al., 2022). ICV systems are very complex, which not only need advanced technological equipment but more importantly require the integration and interaction of multiple elements such as people, vehicles, roads and clouds. Dedicated industrial norms and regulations are a must to allow the testing and demonstration of ICV applications. In order to accelerate the construction of ICV industry, since 2015, relevant Chinese government departments have issued a series of policy standards and opinions to guide and regulate the ICV industrial development (see Table 1).

In 2017, the MIIT issued the ‘Guidelines for the Construction of the National Intelligent Connected Vehicles Industry Standard System’, which announced China’s objective to develop ICV and provided phased targets for establishing a national standard system. The Guidelines have been revised several times since. The current standard system is based on a core technical architecture of ‘three horizontals and two verticals’, as showed in Figure 1 (MIIT, 2023). There are three horizontal levels: intelligent sensing and information communication, decision-making control and execution, and resource management and application; and two vertical dimensions: functional safety and expected functional safety, network security and data security technology. This architecture fully presents the technical logic and clarifies the status and role of each standard in the ICV technology system. At the same time, it combines the technical relevance of ICVs with mobile terminals, infrastructure, smart cities, travel services and other related elements to reflect the characteristics of cross-industry collaboration.

Figure 1 - The ICV standard system developed by China (2023)



Source: 国家车联网产业标准体系建设指南 Guidelines for the Construction of the National Intelligent Connected Vehicles Industry Standard System (MIIT, 2023)

In 2018, the MIIT released ‘Intelligent Connected Vehicles Industry Development Plan’, which set a roadmap for 2020 and beyond, structuring key development plans including technological breakthroughs, standard making, pilot projects and demonstrations areas, infrastructure, ecosystem and international cooperation.

In 2020, the NDRC and other 10 Chinese ministries jointly published the ‘Intelligent Vehicle Innovation and Development Strategy’, a crucial document which provided strategic visions for 2025, 2035 and 2050, and set up key tasks and detailed policies for reaching these goals, regarding: 1) open innovation system: financial support, demonstration applications, testing valuation system, pilot policy; 2) cross-industry ecosystem: cluster of key suppliers, brand development, resource integration

and alliance, military technology to civilian applications; 3) infrastructure system: central and local financial support, diversified market financing tools, co-development by companies from transportation, communications and network; 4) regulations and standard system: network safety, data management, responsibility determination, regulation trial, modification and implementation; 5) ICV product supervision system: product quality, safety, R&D, manufacturing, import & export, accident tracing and liability investigation, network access licence, software and hardware upgrades and updates, commercial insurance; 6) network security system: multi-layered security system combining software and hardware, security situational awareness platform to improve emergency response capabilities. The Strategy laid a cornerstone for the development of ICV in China, providing a comprehensive and operational framework, underlining in particular the importance of open innovation, ecosystem, infrastructure, regulation, standardisation and supervision.

In the same year, the State Council released the ‘New Energy Vehicle Industry Development Plan (2021-2035)’, which provided strategic guidance for the next 15 years, making NEVs the carrier for the application of intelligent connected technology, supporting cross-industry collaboration among enterprises, developing key technologies and products include high-precision mapping and positioning, V2X communication, and wire-controlled execution systems, promoting ICV demonstration and scale-up through specific business scenarios, including urban driverless logistics, municipal sanitation, bus rapid transit systems (BRT) and automatic valet parking. Meanwhile, accelerate the improvement of policies and regulations on road traffic, accident liability and data use of ICVs.

Consequently, an increasing number of demonstration zones and pilot projects have established over the whole nation; the Chinese government also felt the necessity to provide clearer guidance for ICV market entry and product supervision. In 2021, ‘Opinions on Strengthening the Access Management of Intelligent Connected Vehicle Manufacturers and Products’ was released, which specified that ICV manufacturing enterprises should assume the main responsibilities on the management of data security, network security, software upgrades, functional safety, and ensure product quality and production consistency.

Table 1 - Key national ICV policies and regulations in China (2017-2023)

Year	Title	Released by	Main contents
2017	国家车联网产业标准体系建设指南 Guidelines for the Construction of the National Intelligent Connected Vehicles Industry Standard System	Ministry of Industry and Information Technology, National Standardization Administration Committee	<ul style="list-style-type: none"> It established China’s objective to develop intelligent vehicles with network connectivity. The proposed standard system includes 95 standards, covering basics, general specifications, product and technology applications, and related standards. In the next 2 to 3 years, priority will be given to the formulation of the following standards: 1) basic and general standards that support the entire standard system, such as system terms and definitions, level classification standards; 2) relatively mature and widely applied technology product and functional standards, such as automatic emergency system standards and commercial vehicle electronic stability control system standards; 3) technology and product standards related to national strategic planning, such as general technical specifications for automotive information security.
2018	车联网（智能网联汽车）产业发展行动计划 Intelligent Connected Vehicles Industry Development Plan	Ministry of Industry and Information Technology	<ul style="list-style-type: none"> By 2020, breakthroughs will be made in cross-industry integration of the intelligent and connected vehicle industry. Vehicles with high-level autonomous driving functions will be applied in specific scenarios on a large scale; a comprehensive application system will be basically established; and user penetration will be greatly increased. The level of smart road infrastructure will be significantly improved.

			<ul style="list-style-type: none"> • Policies, regulations, standards and safety guarantee systems that adapt to industrial development will be initially established.
2020	智能汽车创新发展战略 Intelligent Vehicle Innovation and Development Strategy	National Development and Reform Commission and other 10 ministries	<ul style="list-style-type: none"> • It consists of four parts: development situation, overall requirements, main tasks, and safeguard measures. • Strategic Vision: By 2025, the technological innovation, industrial ecology, infrastructure, regulations and standards, product supervision and network security systems of China's intelligence vehicles will be basically formed.
2020	新能源汽车产业发展规划（2021-2035 年） New Energy Vehicle Industry Development Plan (2021-2035)	State Council	<ul style="list-style-type: none"> • By 2025, highly autonomous vehicles will be commercially available in limited areas and specific scenarios; large-scale application will be achieved in 15 years. • Use NEVs as the first carrier for the application of intelligent connected technology, support cross-industry collaboration among enterprises, and develop key technologies and products include high-precision mapping and positioning, V2X communication, and wire-controlled execution systems. • Promote the integrated development of NEVs and information communications and carry out demonstration applications in specific scenarios, regions and roads. • Support urban driverless logistics and distribution, municipal sanitation, bus rapid transit systems (BRT), automatic valet parking and specific scene demonstration applications using intelligent connected vehicles as the carrier. • Accelerate the improvement of policies and regulations on road traffic, accident liability, data use, etc. that adapt to the development requirements of intelligent connected vehicles.
2021	智能网联汽车道路测试与示范应用管理规范 Intelligent Connected Vehicle Road Testing and Demonstration Application Management Specifications	Ministry of Industry and Information Technology, Ministry of Public Security and Ministry of Transport	<ul style="list-style-type: none"> • It is a revision of the old version of the 'Specification' in April 2018. • The first aspect is to add demonstration application scenarios and extend test demonstration roads to highways and urban roads. • Second, special utility vehicles have been added to the range of test vehicles, and requirements for the test demonstration subjects have been increased in terms of network security and data security, etc. • Third, improve the general testing projects for the autonomous driving functions of intelligent connected vehicles and promote the unification of testing projects and standards. • Fourth, cancel the issuance requirement of road test/demonstration application notice and simplify the application procedures.
2021	关于加强智能网联汽车生产企业及产品准入管理的意见 Opinions on Strengthening the Access Management of Intelligent Connected Vehicle Manufacturers and Products	Ministry of Industry and Information Technology	<ul style="list-style-type: none"> • Intelligent connected car manufacturing enterprises should assume the main responsibilities on the management of data security, network security, software upgrades, functional safety, and ensure product quality and production consistency. • Make clear regulations on the data of intelligent connected cars from the aspects of data security and network security. • Enterprises that produce automotive products with online upgrade functions should establish compatible management capabilities. • Enterprises producing automotive products with driving assistance and automatic driving functions should clearly inform the vehicle functions and performance limitations, driver responsibilities, human-computer interaction equipment instructions, function activation and exit methods and conditions, etc. • Improve safeguard measures. Enterprises should establish a self-examination mechanism.
2022	车联网网络安全和数据安全标准体系建设指南 Guidelines for the Construction of Internet of Vehicles Network Security and Data Security Standard Systems	Ministry of Industry and Information Technology	<ul style="list-style-type: none"> • It is proposed that by the end of 2023, a network security and data security standard system for the IoV will be initially established. • Focus on research on basic commonalities, terminal and facility network security, network communication security, data security, application service security, security assurance and support, and other standards. • The development of more than 50 urgently needed standards.
2023	国家车联网产业标准体系建设指南	Ministry of Industry and	<ul style="list-style-type: none"> • Construct an intelligent connected vehicle standard system, including intelligent connected vehicle foundation, technology,

	南 Guidelines for the Construction of the National Intelligent Connected Vehicles Industry Standard System	Information Technology, National Standardization Administration Committee	products, test standards, etc., and guide the formulation and revision of relevant standards. <ul style="list-style-type: none"> • In the first phase, by 2025, an intelligent connected car standard system will be formed that can support common functions of assisted driving and autonomous driving. • In the second phase, by 2030, an intelligent connected vehicle standard system will be fully formed that can support the coordinated development of single-vehicle intelligence and network empowerment.
2023	开展智能网联汽车准入和上路通行试点工作 Carry out pilot projects for access and on-road access of intelligent connected vehicles	Ministry of Industry and Information Technology, Ministry of Public Security, Ministry of Housing and Urban-Rural Development, Ministry of Transport	<ul style="list-style-type: none"> • For intelligent and connected vehicle products that have obtained access, pilot projects will be carried out on the road in limited areas. • The pilot projects concern L3 and L4 autonomous driving according to the national standard "Automotive Driving Automation Classification" (GB/T 40429-2021). • Companies must provide full description of their self-driving system (a total of 59 technical parameters in 9 categories), as well as satisfy multiple product testing and safety assessment requirements. • Five phases of implementation: pilot application, product access pilot, on-road pilot, pilot suspension and withdrawal, evaluation and adjustment.
2023	自动驾驶汽车运输安全服务指南 Guide to autonomous vehicle transportation safety services	The Ministry of Transport	<ul style="list-style-type: none"> • Specific requirements in terms of scope of application, basic principles, application scenarios, autonomous driving transportation operators, transportation vehicles, staffing, safety assurance, supervision and management, etc. • Roboshuttles or robotrucks need to have in-car safety operators, while robotaxis can use remote operators. The ratio of robotaxis to remote operators cannot exceed 3:1, and operators need to pass certain skill tests.

Source: Chinese government and ministries' announcements, with authors' elaboration

By 'learning from experimentation', these policies have kept adapting and evolving with the deepening of the ICV industrial development. Now the development of ICV in China is moving from initial testing to a new stage of multi-scenario demonstration and application, which requires continuous improvement in regulations and standards making. The policy 'Carry out pilot projects for access and on-road access of intelligent connected vehicles', released in November 2023, fully demonstrates the point. The new directive, regarding the most advanced L3 and L4 autonomous driving, outlines detailed rules and technical parameters for companies participating in pilot projects and the five main phases of implementation. The latest policy in December 2023 'Guide to autonomous vehicle transportation safety services', which is China's first regulation on commercial operation of autonomous vehicles, further confirms that China is accelerating the regulatory system building to adapt to the scale-up phase.

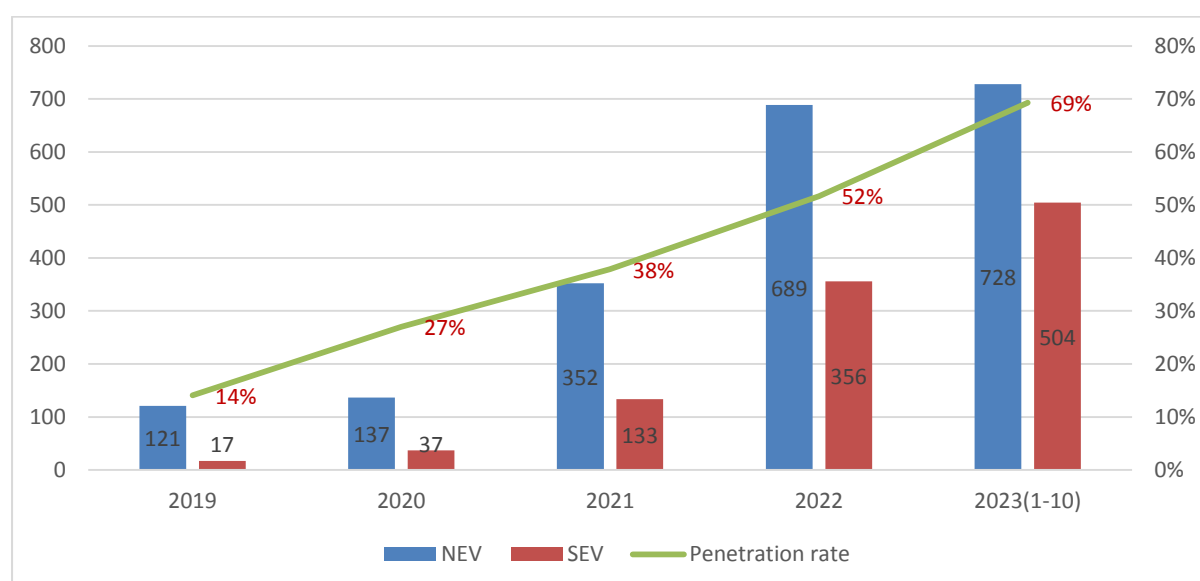
These national policies, together with other closely related industrial strategies (NEVs, AI, chips, automation, etc.), form a comprehensive and structured framework for local governments and firms, and all stakeholders, to carry out innovations and applications, to experiment, correct and scale up. They also facilitate the allocation of financial resources which are much needed for the technology-intensive and rapidly iterative ICV products and services.

To further accelerate the R&D and implementation of ICV through multi-layered collaboration, the 'China Intelligent Connected Vehicle Industry Innovation Alliance' (CAICV) was founded in 2017, guided by the MIIT. The alliance has very soon developed into an innovative institution that not only supports government decision-making but also promotes industry development, giving full play to the important driving force of cross-industry, government-industry-university-research-application collaborative innovation platform. This institutional organisation has strongly contributed to policy and strategic research, key technology development, standards and regulations, testing demonstrations, academic exchanges and international cooperation.

With a clear strategic vision and strong policy pushes, China's ICV industry is catching up fast with pioneer countries such as the United States and is aligned with the global technological advancement (CADA, 2021). And based on the national strategy to reach technology independency and supremacy, the ICV supply chain is also becoming more and more localised. Assisted driving systems have been mass-produced in China and about 55.3% of the NEVs sold in 2023 have installed L2 and above assisted driving functions (CPCA, 2024). LIDAR and vision chips used in ICVs have been mass-produced domestically (e.g. Hesai, RoboSense). A variety of self-developed autonomous driving computing platforms and chips have been installed (e.g. Huawei and Horizon Robotics aim to gradually replace Nvidia and Qualcomm). High-precision maps (Baidu, Gaode) based on Beidou satellite system have been commercialised and have reached international advanced levels. ICVs have been demonstrated and applied in closed and semi-closed scenes such as parks, airports and mines; and mobility services such as robotaxi and last mile delivery are also commercially operational in several pilot cities. No surprise: now about 43% of the world's autonomous driving invention patents come from China.

Since 2019, the market penetration of ICV in the NEV overall demand in China has keep growing fast. Figure 2 shows that the market share of smart electric vehicle (SEV) among NEVs has increased from 14.1% in 2019 to 27.0% in 2020, 37.9% in 2021, 51.7% in 2022 and 69.3% for the first 10 months of 2023 (EO Intelligence, 2023). This impressive market penetration of intelligent and connected technology is confirmed by the rapid growth of some leading ICV manufacturers in China, many of them EV new comers. Table 2 shows the sales of leading SEV brands in China for the first 10 months of 2023. Among them, only 3 brands are fully and partially foreign-owned; other brands are all Chinese brands. EV new comers, such as Tesla, NIO, XPeng and Li Auto, are leading the advanced levels of intelligent and connected offers for passenger cars, thanks to their ability to design a more open and scalable hardware and software architecture and agility to launch disruptive functions (Alochet et al., 2021). Other mainstream OEMs, such as BYD, Changan, GAC, Great Wall and Geely, are also accelerating the launch of ICV models. These data indicate that the ICV-based mobility in China is expanding in a steady pace.

Figure 2 - Fast increasing penetration rate of SEV in China



Source: EO Intelligence (2023)

Table 2 - Sales numbers (10,000) of the Top 15 SEV brands in China (January to October 2023)

1	BYD	201,7
2	Tesla	46,2
3	Aion (GAC)	39,7
4	Li Auto	27,8
5	NIO	12,6
6	Leapmotor	10,7
7	Denza (BYD Daimler)	10,3
8	XPeng	10,1
9	Neta (Hozon)	9,9
10	Deepal (Changan)	9,6
11	Zeekr (Geely)	9,2
12	BMW Brilliance	7,9
13	Ora (Great Wall)	7,2
14	Hongqi (FAW)	6,4
15	Haval (Great Wall)	5,6

Source: EO Intelligence (2023)

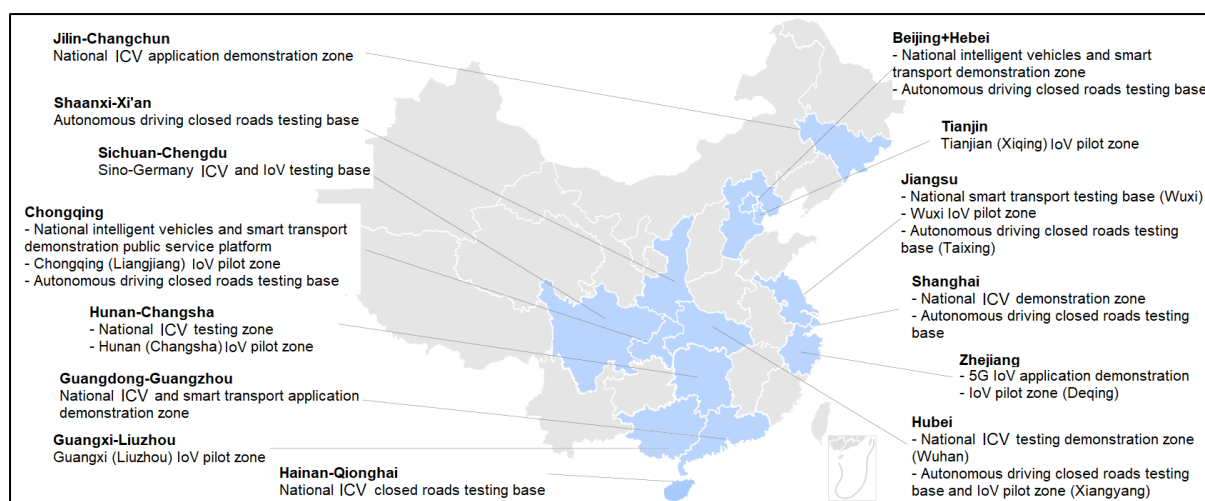
In the field of commercial vehicles, 5G smart heavy and light duty trucks have been used in port transportation scenarios, by carmakers such as FAW, Dongfeng, Shaanxi Auto and Foton; bus companies such as Yutong, Golden Dragon, Higer, CRRC Electric and Ankai have launched intelligent connected buses. Sinotruck has recently started the mass production of intelligent connected heavy trucks.

With the development of technology and large-scale construction, C-V2X test demonstration activities in China have also gradually developed into the exploration stage. More than 3000 sets of roadside infrastructure have been installed across the country; more than 1.425 million 5G base stations have been opened; and multiple demonstration areas have realised map data coverage. Some car companies have already launched mass production models equipped with C-V2X technology in China (GAC, FAW, BAIC, SAIC, Great Wall, Geely, NIO, Ford, Buick, Audi).

3. Regional ICV policy and development

Under the guidance of national policies, all major provinces and cities in China have launched promoting programs for the application of ICVs. Specific scenarios such as ports and mining areas have taken the lead in pilot operations; demonstrations on open road and in limited areas such as robotaxis, driverless logistics fleet, and driverless municipal sanitation have also been carried out. As of the end of 2023, more than 20,000 kms of ICV test roads have been opened in China, and a total of 17 national-level test demonstration zones, 7 Internet of Vehicle (IoV) pilot zones, and 16 smart cities have been selected for developing ICV industry (Figure 3).

Figure 3 – National ICV testing & demonstration zones and IoV pilot zones (2024)



Source: CAICV & Foresight Industry Research Institute (2024)

Since 2015, the MIIT has begun to lay out and establish ICV demonstration zones across the country. In May 2021, Beijing, Shanghai, Guangzhou, Wuhan, Changsha and Wuxi were selected as the first batch of ‘Double Smart’ pilot cities for the coordinated development of smart city infrastructure and ICVs. In December the same year, the second batch of “Double Smart” pilot cities were announced, including Chongqing, Shenzhen, Xiamen, Nanjing, Jinan, Chengdu, Hefei, Cangzhou, Wuhu and Zibo. These 16 pilot cities are distributed over different Chinese regions, covering a large geographic zone. They all have a solid automotive industry foundation and have different economic and social needs. Very soon, a good number of ICV pilot projects were set up in these cities, mainly by major OEMs like SAIC, Changan and Dongfeng and leading internet/software companies like Baidu, Didi, Pony.ai, WeRide and Inceptio (Table 3). As of the first half of 2023, more than 2,800 ICV test licenses have been issued nationwide.

Table 3 - Major ICV demonstration cities and development (2022)

ICV demonstration city (province)	Opened mileage (km)	Tested mileage (km)	No. of licences issued	Main test subjects
Shanghai	1289.83	656.20	325	Didi, SAIC, AutoX
Beijing	1027.88	391.18	170	Baidu, Pony.ai, Didi
Wuhan (Hubei)	321.00	200.00	54	Dongfeng, Baidu, Deepblue
Changsha (Hunan)	263.00	176.00	57	Deepblue, Inceptio
Chongqing	176.85	96.80	50	Changan, Foton, Baidu
Guangzhou (Guangdong)	135.30	400.00	142	Baidu, Pony.ai, WeRide, Didi, GAC, Deepblue, AutoX
Hainan	129.20		1	FAW
Xiangyang (Hubei)	111.40		3	Dongfeng Trucks, Yutong Bus
Zhejiang	70.60	50.00	18	Youxing, Leapmotor
Chengdu (Sichuan)	50.00		12	Baidu

Source: CAICV (2022)

When looking at the detailed development made in each pilot city on the subject of ICV application, a certain degree of differentiation is obvious among these cities. In 2022, CAICV collected information on the ICV application scenarios by city (see Table 4). The data show that there are overall 10 business scenarios that are currently under pilot development: robotaxi, AVP (autonomous valet parking), commuter bus, robobus, high speed truck, ports, mines, sanitation, patrol and last mile

delivery. Among them, commuter bus, last mile delivery and robobus are the most popular pilot projects, followed by municipal sanitation, robotaxi and patrolling. There are clear rationales behind these choices. Commuter bus and robobus make point to point fixed itinerary, which is easier for ICV system to manage. Pandemic-induced lockdowns and customer desires for contactless transactions, as well as increasing labour cost, have led to a rapid increase in the adoption of driverless delivery services in China. Using ICVs for municipal sanitation and patrolling is promoted by local governments as a public purchase tool to accelerate CAM implementation. Robotaxi has almost become a city's best business card in smart city development. On the contrary, scenarios such as AVP, high speed truck, ports and mines are very specific and highly dependent on the surroundings, which requires tailored project design and dedicated fleet management, therefore their application is much more complex.

Table 4 - CAM application scenarios by city (2022)

City/province	Robotaxi	AVP	Commuter Bus	Robobus	High speed truck	Ports	Mines	Sanitation	Patrol	Last mile delivery	Total
Shanghai	√		√	√	√	√	√	√	√	√	9
Guangzhou (Guangdong)	√	√	√	√	√	√		√	√	√	9
Beijing	√	√	√					√	√	√	6
Wuhan (Hubei)	√		√	√				√	√	√	6
Zhejiang			√	√		√		√	√	√	6
Wuxi (Jiangsu)	√		√	√				√		√	5
Changsha (Hunan)	√			√	√			√		√	5
Jinan (Shandong)			√	√	√	√	√				5
Tianjin				√		√				√	3
Chongqing			√		√				√		3
Chengdu (Sichuan)			√	√						√	3
Xi'an (Shaanxi)			√							√	2
Hainan			√								1
Total	6	2	11	9	5	5	2	7	6	10	

Source: CAICV (2022)

Alochet et al. (2021) have identified three major transition pathways for the new ICV based mobility: 1) Reconfiguration (mobility service added to product), in which case hardware and software allowing intelligence and connectivity are integrated into the vehicle, and the lead actor is still the automaker; 2) Substitution (robotaxi), where a future mobility is totally replacing the current vehicle + driver travel modality, and automaker and technology companies can both be leaders of this transition; 3) Territorialised open mobility platform (robobus, municipal services), where public authorities have the capacity to steer the design of mobility service in upstream phases. Applying this analysis in the case of China, we observe that all the three pathways are showing important dynamics, indicating a balanced development in all the key potential business models for ICVs.

Looking at regional level development, data from CAICV (2022) show that among the pilot cities, Shanghai, Guangzhou, Beijing and Wuhan are leading the implementation of ICV, with stronger involvement of key players and more diversified application scenarios. These leading cities have all adopted strong supporting policies and offered favourable conditions for experimentation and commercialisation.

During the year of 2023, Shanghai has released at least 5 key policies regarding ICV development¹. In April 2023, Shanghai officially issued the first batch of ICV rental demonstration operation certificates. Currently, a total of 160 vehicles from 8 companies or consortia are carrying out regular operation of ICV rental, smart heavy trucks and robobus, with cumulative travel services exceeding 92,000 times and freight transportation volume exceeding 66,000 TEU. Shanghai also launched the first legislation-based road test license for driverless ICV, and issued driverless test licenses to 7 companies and 30 vehicles, with a cumulative test mileage of 94,700 km. According to ‘Shanghai ICV Development Report (2023)’, by the end of 2023, Shanghai has a total open test area of 912 square km; a total of 32 companies and 774 vehicles have been issued road test and demonstration application licenses; autonomous driving reached a total testing mileage of 7.44 million km; 6 companies have invested in 46 units of driverless equipment, completed 50,000 smart delivery orders and 54,000 hours of smart cleaning operations.

The newly released ‘Guangzhou ICV Road Testing and Application Demonstration Operation Annual Work Report (2023)’ shows that as of the end of 2023, Guangzhou has opened 797 test roads, involving Baiyun, Huadu, Panyu, Huangpu, Nansha and Haizhu 6 administrative districts. A total of 415 ICVs from 15 testing entities (including company consortia) have obtained road test licenses, reaching a total testing mileage of 17.19 million km. In terms of infrastructure construction, the city has installed 460 sets of roadside equipment, 897 sets of sensing equipment, 343 computing units and 96 modified traffic lights dedicated to ICV. It has designed and developed 120 IoV application scenarios, and launched pilot projects with L4 fleets. It has also established a CA certification system.

In April 2021, Beijing established the first ICV pilot zone in China and issued the first batch of road test licenses to Baidu, Didi, Pony.ai and other companies. The policy priority area includes the 225-square-km of Yizhuang New Town, Daxing International Airport, and six expressways surrounding Yizhuang. In November 2021, Beijing opened China’s first commercial pilot program for autonomous driving travel services. In May 2023, Beijing released China’s first autonomous driving data security management regulations, ‘Beijing ICV Policy Pioneer Zone Data Security Management Measures (Trial)’. In February 2024, driverless travel from Daxing International Airport became operational, making Beijing the world’s first capital to run autonomous passenger vehicles between urban areas and the airport. In parallel, in 2020 Beijing Shunyi district targeted to build a ‘global low-speed unmanned delivery demonstration zone’, and established relevant management systems. Meituan unmanned delivery has completed more than 3 million orders and served more than 100 communities since 2021 and other unmanned players include Neolix, Haomo.ai, JD Logistics and Rino.ai.

Wuhan is also leading in implementing ICV projects. Wuhan is the first city in China to issue pilot licenses for the commercialisation of ICVs and construction specifications for intelligent connected roads, and the first to open public test roads to central urban areas and airport autonomous driving shuttle services. By the end of 2023, the total test mileage run by autonomous vehicles in the city has exceeded 3,378.73 km. Apollo Go (Baidu) currently operates a fleet of 500 robotaxi in Wuhan, including 300 fully driverless vehicles, with over 3.3 million cumulated orders from the public. Wuhan has gathered more than 130 core enterprises in the ICV industry chain such as Dongfeng Yuexiang, ECARX and Siengine, and has united 195 enterprises to form the ‘Smart Car and Smart

¹ Including: 1) ‘Shanghai ICV Highway Testing and Demonstration Implementation Plan’ (January), 2) ‘Implementation Rules for the Provisions on Promoting the Innovative Application of Driverless ICV in Pudong New Area’ (March), 3) ‘Jiading District Action Plan for Building a World ICV Innovation Highland (2023-2025)’ (April), 4) ‘Three-Year Action Plan for the High-Quality Development of the ICV Industry in Pudong New Area (2023-2025)’ (July), and 5) ‘Several Policies for Promoting the Development of ICV in the Lingang New Area Pilot Free Trade Zone’ (November).

City Collaborative Development Alliance’, building a ‘R&D + Testing + application’ closed loop ICV industry ecosystem.

The above cases of leading pilot cities show that local governments, who make local rules and programs under the strategic guidance of national policies, have strong negotiation power in the starting phase in particular by giving access to funding and promoting the transfer and capitalisation of experience, and could play an important role of aggregators and accelerators of territorial initiatives (Alochet et al., 2021).

4. Conclusions and discussions

Having made ICV a national strategy and set up a series of pilot cities and projects have been decisive in accelerating the development and implementation of ICV in China. The central government has been providing strategic guidance and setting up regulations and standards to promote a comprehensive development framework, allowing local governments, industrial players and all stakeholders to carry out projects and experimentations. The local governments have also been crucial in implementing local rules and pilot projects, aggregating technological capabilities, industrial experience and financial resources to accelerate territorial initiatives. Under strong national ambition and policy push, Chinese companies have been catching up on core technologies and operating systems, and have entered into different segments in the ICV industry, constantly increasing the localisation of supply chain. These dynamics recall the way a fully-fledged industrial value chain for electric vehicle batteries has emerged in China within a short period of time (Wang et al., 2022).

Looking at the global landscape, there is growing cooperation between countries across the entire industrial chain. Mutual shareholdings, M&As and alliances are becoming increasingly common. And industries such as communications, information, electronics and automobiles are increasingly integrated. In their case study of Shanghai Intelligent and Connected Vehicle R&D Center, Mello et al. (2021) observe that OEMs do not act any more as the leaders of the new ICV ecosystem, but collaborate with many other stakeholders (suppliers, network providers, public authorities, etc.) and operate in more complex relations, which require different management capabilities and institutional arrangements.

With the disruptive changes in vehicle’s electronic and electrical architecture, a large number of internet companies have also entered the ICV industry through cross-industry cooperation, targeting ICV as their future growth contributor. In March 2024, Xiaomi’s first EV SU7 was officially released, positioning itself as a ‘C-class high-performance ecological technology sedan’. Huawei has been building its own ‘ICV ecosystem’, co-developing SEV models through strategic cooperation with several major OEMs. Huawei does so in three cooperation methods: 1) Tier 1 mode, in which Huawei provides core component support while OEMs still take the lead in R&D and the commercialisation (e.g. GAC, SAIC and Geely Geometry); 2) HI (Huawei Inside) mode, in which Huawei jointly develops along OEMs, providing core system solutions (e.g. Arcfox of BAIC, Avatr of Changan & CATL, and Voyah of Dongfeng); 3) Huawei-led mode, in which Huawei is not only deeply involved in the R&D but also puts its own sales network at disposition, while using the car company’s existing model development platforms (e.g. Aito of Seres & Huawei, Luxeed of Chery & Huawei, and Stelato of BAIC & Huawei) (Li, 2023). Huawei is a good example of how disruptive technologies can change innovation management and ecosystem, leading to the reconfiguration of the OEM dominating automotive industry.

While the discussion is going on about if OEMs are really losing control on the innovation and supply chain management with the automotive industry facing CASE (connected, autonomous, smart and electric) transition, we are only certain that under the new ICV ecosystem, national strategy guidance and industrial policy support are becoming a universal and indispensable tool for any country with the ambition to lead the future trend.

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