HOW CHINA IS SHAPING THE AUTONOMOUS DRIVING INDUSTRY

A study on trends and driving forces reshaping the world's largest automotive market

Preface

As China actively advances a new era of communication technologies, including the industrial Internet, big data, 5G, and artificial intelligence, the spotlight on intelligent connected vehicles (ICVs) as the “intelligent mobile third space” of the future continues to intensify. Across policy-making, technological research and development, financial investment, and commercialization, China is deploying comprehensive efforts to drive the intelligent transformation of the automotive industry. The goal is to position China’s ICVs and autonomous driving technology as globally competitive.

At the 2023 World Intelligent Connected Vehicles Conference (WICV) in China, the Vice Minister of Ministry of Industry and Information Technology (MIIT) highlighted that in the first half of 2023, cars with combined driver assistance (Level-2 in Chinese Autonomous Driving Standard) contributed to an impressive 42.4% share of new passenger car sales, signifying a rapid pace in the intelligent transformation of China’s automotive industry.

In the era of intelligent transformation, traditional OEMs are breaking free from traditional structures, venturing into smart car systems and Advanced Driver Assistance System (ADAS) capabilities. Meanwhile, internet giants and tech firms leverage AI and software to delve into autonomous driving, offering complete hardware and software solutions. This inter-industry collaboration, coupled with technological advancements and supportive policies, have propelled autonomous driving in China to successfully advance in line with the Intelligent Connected Vehicle Technology Roadmap 2.0 released by China Industry Innovation Alliance for the Intelligent and Connected Vehicles (CAICV).

In this report, we present a comprehensive overview of the current landscape of China’s autonomous driving market, delving into various technologies and application scenarios. Additionally, the paper will analyse the development drivers of autonomous driving in China as well as uncover insights into the development prospects and technological trends shaping China’s autonomous driving market.

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FUELING THE FUTURE: CHINA'S ELECTRIC VEHICLE TAKEOVER AND RISE AS THE AUTONOMOUS CAR POWERHOUSE

AUTOMOTIVE MARKET OVERVIEW

China's passenger vehicle market has witnessed a decline since 2018. However, the market has rebounded quickly over the last two years with a year-on-year growth rate of 9.5% in 2022, which withstood the negative effects of the pandemic. In 2022, the sales of passenger vehicles in China accounted for 31.5% of global sales, which is two times that of Europe's proportion.[1]

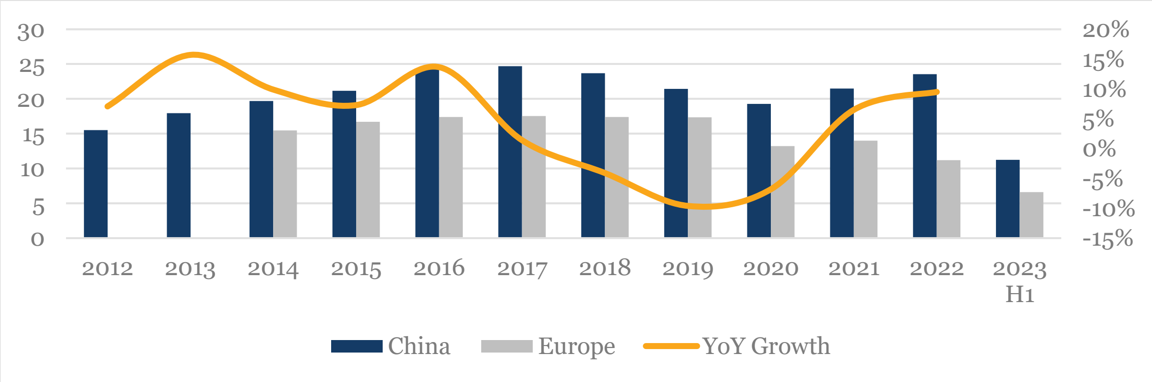

Figure 1 passenger vehicle sales and YoY growth in China (in million units)

Meanwhile, China's heavy-duty truck market has experienced negative growth since April 2021 due to weak demand and Covid control policy with a total of 672,000 units sold in 2022. As the pandemic control has been abolished and the market has started to recover to more normal levels, the performance of the heavy-duty truck market has bounced back quickly in 2023, with 621,092 units sold from January to August – almost the total number of last year.[2]

Figure 2 HDV sales and YoY growth in China (in 1000 units)

As China is calling for a green transition in the automotive industry, the electric vehicles in China have been booming over the past few years. Purchasing subsidies and incentives from the government, increased acceptance by the market, relatively comprehensive infrastructure

[1] Source: CAAM, Statista, IEA
[2] Source: CAAM

construction, and the cost-effective performance of EVs have been main driving forces of the fast-growing EV market. The sales of electric vehicles in China reached 6,887,000 units in 2022, with the penetration rate being 29.2%. [3]

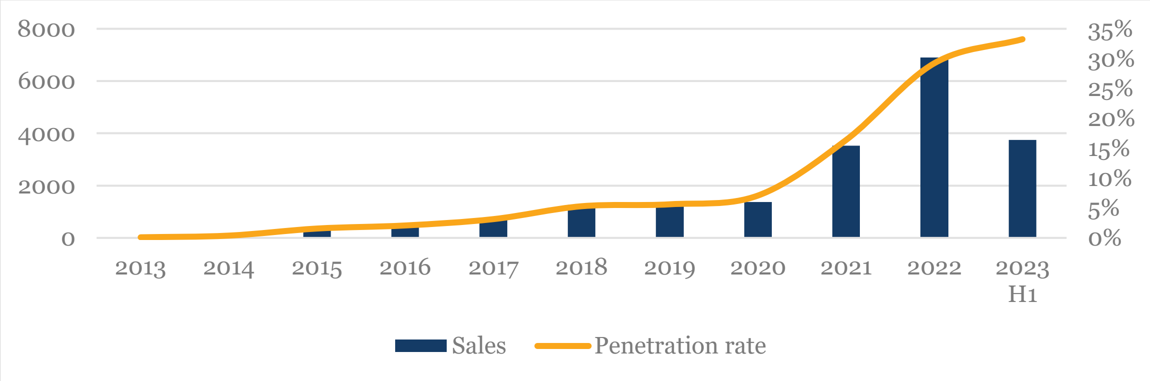

Figure 3 Sales of electric vehicles (PVs + CVs) and penetration rate of new sales in China (in 1000 units)

The rapid advancements of AI, 5G, big data, and other emerging ICT technologies have fuelled significant growth in the Intelligent Connected Vehicles (ICV) sector. China's ICV industry has experienced rapid expansion in recent years, reaching 134.2 billion yuan in 2022, marking a remarkable 21.56% year-on-year increase. As the industry continues to undergo technological enhancements, the market size of China's ICV sector is projected to surge to 222.3 billion yuan by 2025.[4]

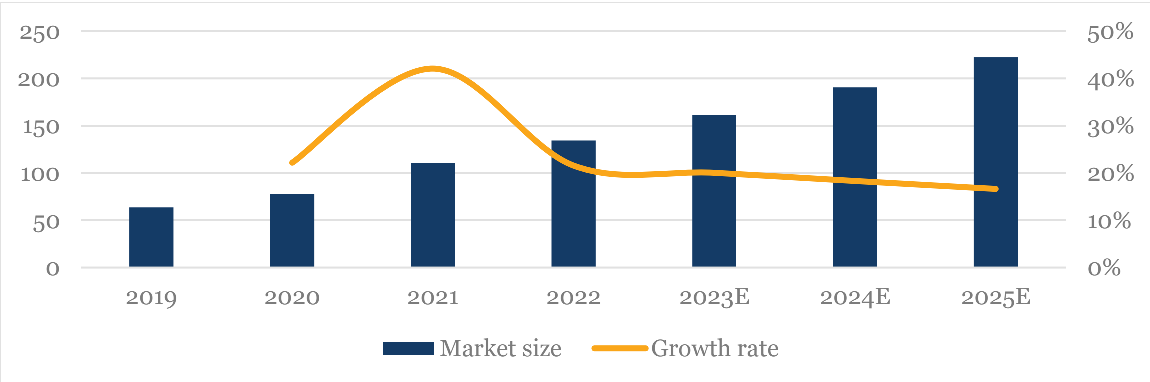

Figure 4 Market size of China's ICV industry, 2019-2025 (in billion yuan)

ROADMAP TO AUTONOMY: TECH BREAKTHROUGHS TRANSFORM DRIVING LANDSCAPE

CATEGORIZATION OF CHINA'S AUTONOMOUS DRIVING

The autonomous driving technology is categorized into different levels, with various institutions proposing grading standards. The two most commonly used industry standards are the NHTSA grading, proposed by the National Highway Traffic Safety Administration in the U.S., and the SAE

[3] Source: CAAM
[4] Source: CAICT, DongfangQB

grading, introduced by the Society of Automotive Engineers (SAE). While there are differences in the detailed grading within these systems, they share common narrative definitions. Beginning at level 3, control transitions to autonomous driving, where the vehicle takes over as the primary operator, replacing the human driver. Consequently, level 3 has become a crucial milestone in the application of autonomous driving technology.

China's grading standard is closely aligned with the industry's widely used SAE grading, except for a few differences between the Chinese and SAE standards. The major reason behind the differences is the concern of driving safety, for instance, levels 0-2 in China's system involve "target and event detection and response," which require both human drivers and the driving system to monitor road conditions and react accordingly. In contrast, the SAE grading dictates that Object and Event Detection and Response (OEDR) for autonomous vehicles at levels 0-2 is the sole responsibility of human drivers.

NHTSA	SAE	Name	Definition	Execution of steering and acceleration / deceleration	Monitoring of driving environment	DDT fallback	ODD
L0	L0	No automation	The full-time performance by the human driver of all aspects of the dynamic driving task (DDT)				N/A
L1	L1	Driver assistance	The driving mode-specific execution by a driver assistance system of either steering or acceleration/deceleration				Limited
L2	L2	Partial assistance	Part-time or driving mode-dependent execution by one or more driver assistance systems of both steering and acceleration/deceleration. Human driver performs all other aspects of the DDT				Limited
L3	L3	Conditional assistance	Driver is necessity but is not required to monitor the environment. The driver must be ready to take control of the vehicle at all times with notice				Limited
L4	L4	High automation	The vehicle is capable of performing all driving functions under certain conditions. The driver may have the option to control the vehicle				Limited
	L5	Full automation	The vehicle is capable of performing all driving functions under all conditions. The driver may have the option to control the vehicle				Unlimited

Table 1 Classification and characteristics of autonomous driving technology[5]

Note: DDT – Dynamic driving task; ODD – operational design domain

[5] Source: 36Kr Research

SAE	Name	Definition	Execution of steering and acceleration / deceleration	Monitoring of driving environment / OEDR	DDT fallback	ODD
L0	Emergency assistance	The auto-driving system alerts the driver to hazards but doesn't control DDTs or conduct OEDR continuously				Limited
L1	Partial driver assistance	The system assists the human driver in controlling the vehicle's direction and acceleration/deceleration under operational design conditions (ODCs)				Limited
L2	Combined driver assistance	The vehicle autonomously controls DDTs under ODCs				Limited
L3	Conditionally automated driving	Under ODCs, the vehicle autonomously manages the DDTs, along with road condition detection and response			DDT fallback-ready user*	Limited
L4	Highly automated driving	Under ODCs, the autonomous driving system manages DDTs as well as DDT fallback without human intervention				Limited
L5	Fully automated driving	Continuously perform all DDTs without ODC restrictions, except for commercial and regulatory factors, while automating minimal risk maneuver				Unlimited*

Table 2 China's taxonomy of driving automation for vehicles[6]

GENERAL DEVELOPMENT OVERVIEW

The adoption of ADAS (Advanced Driver Assistance Systems) is rapidly expanding, with substantial growth potential. In the Chinese automotive market, ICVs are typically equipped with ADAS (L1+L2) technology. Currently, intelligent driving technology in China is still in the development phase, with L2 driving technology already achieving mass production. Over recent years, sales of ADAS-equipped ICVs in China have been growing at an accelerated pace, increasing from 7,200,000 units in 2019 to 13,208,000 units in 2022, representing an annual CAGR of approximately 22.4%. Sales are projected to reach 14,811,000 units in 2023. [7]

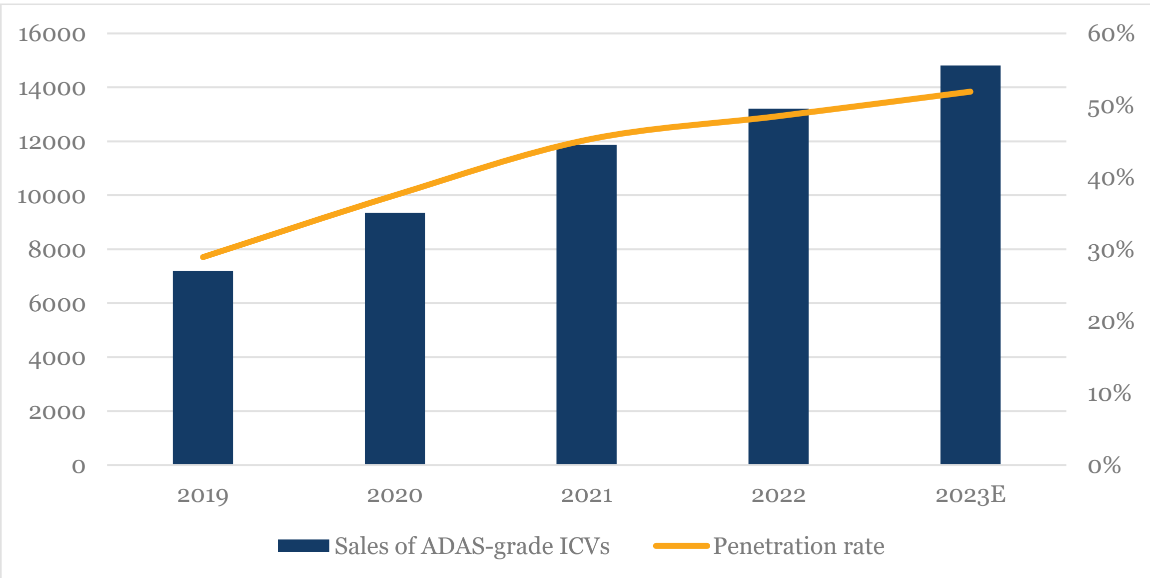

Figure 5 Sales performance of ADAS-grade ICVs (in 1,000 units) & penetration rate of ADAS technology

[6] *Note: DDT fallback-ready user: DDT fallback backup user (become driver after takeover); Unlimited ODD excludes restrictions such as commercial and regulatory factors

[7] Source: DongfangQB

Features	2020	2022E	2025E
Multi-view camera system	28.8%	40.8%	51.8%
Adaptive driving beam	25.8%	35.8%	47.8%
Lane departure warning	30.7%	40.7%	49.7%
Lane changing assist	25.2%	31.2%	36.2%
Traffic sign recognition	11.0%	21.0%	32.0%
Rear cross traffic alert	16.6%	26.6%	37.6%
Cruise control	40.5%	25.0%	5.0%
Lane keeping assist	23.3%	33.3%	48.3%
Autonomous emergency braking	41.7%	53.7%	69.7%
Adaptive cruise control	27.0%	43.0%	69.0%

Table 3 ADAS features penetration rate forecast[8]

The structure of China's autonomous driving industry value chain consists of key component suppliers, solution providers, automotive companies as well as operators and service providers across various usage scenarios. Component suppliers are expanding into software algorithms and related areas, establishing deep collaborations with automotive companies through integrated software and hardware solutions. Solution providers focus on developing and producing hardware devices, aiming to maximize profits through in-house research and development of software and hardware.

Upstream:

In the upstream of the industry, key component suppliers can be further divided into perception layer, decision layer and execution layer. Among these, sensors and high-precision maps are particularly crucial components in the perception layer, playing a vital role in the extensive and significant part of the autonomous driving industry chain. So far, the sensor market in China is still dominated by the international tier-1s including Bosch, Continental, Aptiv and Valeo, accounting for over 60% of the market share. Domestic players such as Hesai Technology, Desay SV, Hasco are gaining the market share with improved accuracy and lower cost. In terms of high-precision maps, key suppliers are mainly domestic players given strict compliant requirements on geographical information laws and regulations. In terms of market share, the high-precision map industry is concentrated among a few major players. In 2021, Baidu and NavInfo together held over 50% of the market share in China.

The automotive chips are in the spotlight in the decision layer, which can be divided into four major camps: traditional automotive chip manufacturers represented by NXP, solution providers represented by Mobileye, general-purpose and platform-oriented hardware and software toolchain providers with most active Chinese players such as Huawei, Horizon Robotics, and Black Sesame, and full-stack self-developed manufacturers represented by Tesla.

In the execution layer, the market is also dominated by the international tier-1s, while the domestic players for domain control units and wire-control system still being in the early stages of development.

Midstream:

[8] Source: Autohome, Soochow Securities

The automotive companies and the full-stack solution providers form the midstream of China's autonomous driving industry. The international and local automotive companies are the pillar of the autonomous driving industry, who have the capability to integrate and materialize the final products that can be delivered to the end users. In addition, the full-stack solution providers such as Baidu Apollo and WeRide are emerging who can effectively break through technological bottlenecks such as the integration of hardware and software, algorithm iteration, etc.

Downstream:

The operators and service providers across different application scenarios formulate the downstream of the autonomous driving industry. Players are actively developing solutions and accelerating the commercialization for certain usage scenarios such as logistics, Robotaxi, ports and mines. The implementation of autonomous driving will be further discussed in another section.

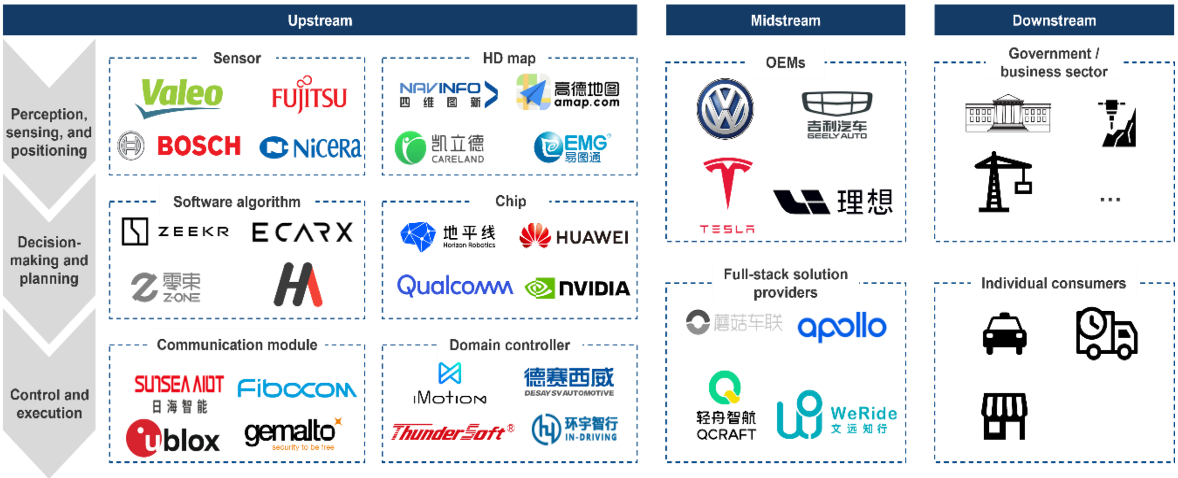

Figure 6 The industrial chain of autonomous driving[9]

Various market players with diverse development strategies engage in the competition of the autonomous driving market, leading to significant transformations in the supply chain and industry dynamics. In terms of the nature of different players, they can also be categorized as traditional automotive OEMs, emerging startups (new forces of car-making), and Internet/tech companies.

- Traditional OEMs on the international stage have chosen to pursue a stable development strategy and an evolving path of technological advancements
- Internet/tech companies have integrated their AI algorithms and software technology advantages into the autonomous driving sector, becoming a significant force comparable to OEMs that cannot be ignored
- Autonomous Driving (AD) and Vehicle-Infrastructure Cooperated Autonomous Driving (VICAD) complement each other, accelerating the adoption and implementation of autonomous driving technologies

Case study: Industry-leading provider of high-performance intelligent driving computing solutions - Horizon Robotics

Established in 2015, Horizon Robotics is a leading provider of energy-efficient computing solutions for ADAS and automated driving (AD) for consumer vehicles. As a pioneer to commercialize embedded passenger-

[9] Figure is for illustrative purpose only. Source: Oriental Securities, 36Kr Research

vehicle ADAS and AD products in China, Horizon Robotics is committed to enhancing next-generation driving experiences by integrating hardware and software, including low-power hardware computing solutions, and open software development tools. Horizon Robotics offers comprehensive chip solutions for the industry, including high-performance smart chips, hardware designs, software platforms, and reference algorithms.

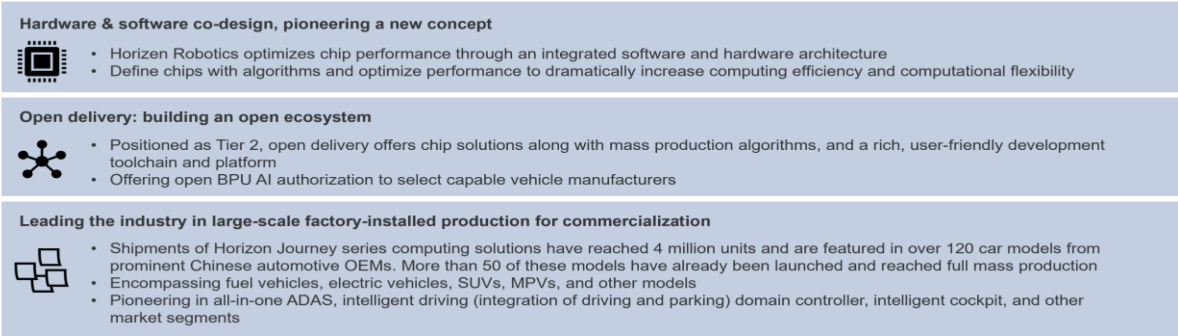

Figure 7 Core competitiveness of Horizen Robotics

TECHNICAL DEVELOPMENT & BREAKTHROUGHS

The CPU + ASIC solution is anticipated to become the mainstream architecture, with rapid development in large arithmetic chip technology

The trajectory of autonomous vehicles hinges on the adoption of a CPU+ASIC[10] architecture, a pivotal component in the realm of self-driving technology. These chips are transitioning from Microcontrollers (MCUs) to System-on-Chip (SoC) designs, catering to the demands of intelligent automobiles.

Conceptualize these chips as the central processing units orchestrating various functions in a vehicle, encompassing navigation, information processing, and more. They find applications in critical systems such as advanced driver assistance systems (ADAS) and in-car entertainment.

Presently, three primary chip configurations dominate the landscape: CPU + GPU[11] + ASIC, CPU + ASIC, and CPU + FPGA[12].

The evolution towards autonomous driving necessitates heightened computing capabilities. This is attributed to the amalgamation of multiple sensors and the handling of intricate data. Consequently, we observe an advancement in software sophistication, resulting in an augmentation of functionalities within vehicles. This burgeoning demand has spurred the development of potent chips. Exemplifying this trend are notable releases such as Huawei's Ascend910 chip and Horizon Robotics' Journey5 chip, contributing significantly to the enhanced intelligence and safety of self-driving vehicles.

The accuracy of radar systems continues to improve, accompanied by a significant increase in the number of onboard sensors

Autonomous driving, dealing with various challenges, needs precise speed estimates, all-weather navigation, and remote monitoring. This has led to the development of radar-based sensors, essential for the auto-driving system. These sensors, using cameras, lidar, ultrasonic radar, and millimetre-wave radar, analyse the surroundings in real-time and gather accurate object information.

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[10] ASIC: Aplication Specific Integrated Circuit
[11] GPU: Graphics Processing Unit
[12] FPGA: Field Programmable Gate Array

In technology, autonomous driving takes two paths: visual and radar. Vision relies on cameras with lower costs but demands complex algorithms and extensive training data. On the other hand, radar, focused on lidar, requires less complex algorithms and integrates with various sensors. Both approaches play a crucial role in autonomous driving.

Globally, many automotive companies are exploring millimetre-wave radar for vehicles. Operating in bands like 24GHz, 60GHz, and 77GHz, these radars gained prominence in China, especially the 77GHz and 79GHz bands, known for higher integration and accuracy. Regulations released by the Ministry of Industry and Information Technology (MIIT) in December 2021 allocated the 76-79GHz frequency band for automotive radar[13]. This frequency band supports various ADAS features, such as adaptive cruise control, collision prevention, blind spot detection, parking assistance, rear vehicle warning, pedestrian detection, and more. In ACC adaptive cruise scenarios, a 77GHz millimetre-wave radar is one-third the size of a 24GHz radar, and its detection accuracy is three to five times higher. As of the data for the first eleven months of 2022, the Chinese market witnessed 7.56 million factory-installed millimetre-wave radar units in new passenger vehicles (excluding imports and exports), a year-on-year increase of 24%[14].

Technical areas	Developing trends
Frequency band	• 77/79GHz mm-wave radar has begun to evolve towards small size and high precision, and the cost is gradually approaching 24GHz products; 24GHz will be phasing out • "Interim Provisions on the Administration of Automotive Radar Radios" clarified that the frequency used for automotive radar is in the range of 76-79GHz frequency band • 77 GHz mm wave Radar market is still dominating by international companies such as Bosch, Continental and Denso, accounting for over 80% of the market share; the domestic brands including Hasco and Desay SV started to supply the 77 Ghz mm radar with mass production. The market share of domestic brands is expected to grow in the coming years
Product performance	• The number of receiving and transmitting antennas of MIMO system keeps increasing, and the radar performance continues to improve • The accuracy, resolution and detected distance of the radar are expected to be improved to cope with the higher requirement of L3/L4 implementation
4D radar	• The radar system will transform from single chip solution to multi chip solution • It is expected that the number of factory-installed 4D millimetre-wave radars in the Chinese passenger vehicle market will exceed one million unit in 2023, the proportion of 4D radar in all forward-looking millimetre-wave radars is expected to exceed 40% • Major players includes traditional tire 1 supplier such as Continental AG, ZF Friedrichshafen AG, Aptiv, Mobileye, and new entrants such as Oculii, Huawei, Arbe, Vayyar, etc.
Multi-scenario usage	• Automotive: millimetre-wave radar is well known used in obstacle detection, and the usage will expand to intelligent cabin for monitoring Vital Signs and controlling gestures • Other areas: with the increasing demands for automation in other industry, millimetre-wave radar will be used in other fields such as smart city, smart transportation, intelligent building, medical, etc.

Table 4 Technical trends of millimetre-wave radar

Irrespective of the technology route, the promotion of high-level autonomous driving has led to a significant increase in the number of sensors mounted on vehicles, encompassing both visual and radar routes. Notably, the number of sensors integrated into L3 vehicles is expected to reach 17-34, more than doubling the count of L1 sensors. Anticipated sensor requirements indicate a continued expansion.

Types of sensor	L1	L2	L3	L4	L5
Camera	1-3	3-11	3-14	3-14	3-14
Millimetre-wave sensor	1-3	1-3	5-7	5-7	5-7
Ultrasonic sensor	4-8	8-12	8-12	8-12	8-12
Lidar	0	0	1	2	4
Total	6-14	14-26	17-34	18-35	20-37

Table 5 Estimation of the required number of on-board sensors for autonomous driving across all levels in China[15]

[13] Source: MIIT, Interim Provisions on Radio Management of Automotive Radar
[14] Source: Gaogong Industry Institute (GGII)
[15] Source: Audiowell prospectus

The V2X is maturing as it finds application in multiple scenarios

Furthermore, the industrial environment of automotive networking (V2X) is gradually maturing and is being applied in various scenarios, including ICVs and traffic management. The concept of V2X originates from the Internet of Things (IoT), specifically the Vehicle Internet of Things, wherein vehicles become information-aware objects. Leveraging the next generation of information and communication technology, V2X enables network connectivity between vehicles, vehicles and people, vehicles and roads, and vehicles and service platforms. V2X is more than just a networked technology or an intelligent product application; it represents a fusion of networked, intelligent, and service-oriented new business models with cross-disciplinary characteristics.

V2X has two main implementation routes: DSRC and C-V2X. DSRC[16], standardized by the IEEE and developed since the end of the last century, has matured over more than two decades, predominantly led by Europe and the United States. On the other hand, C-V2X[17], led by 3rd Generation Partnership Project (3GPP) and dominated by China, includes LTE-V2X and 5GNR-V2X. Currently, the DSRC route has largely been phased out, and C-V2X is emerging as the mainstream technology for automotive networking. C-V2X technology is grounded in the evolution of cellular communication technology, supporting a broad spectrum of automotive networking applications. It offers advantages for future evolution, particularly in supporting high-level autonomous driving—referred to as 5G-V2X—by facilitating direct connection communication and cellular communication between different interfaces. Presently, China has clearly chosen the C-V2X technology route as the direct communication technology for automotive networking.

STATUS OF IMPLEMENTATIONS (COMMERCIALIZED OPERATION) IN PASSENGER & COMMERCIAL VEHICLES

Autonomous driving technology offers a wide range of applications, but when categorized by vehicle type, they primarily include Robotaxi services for passenger vehicles and autonomous driving for commercial purposes, such as heavy-duty trucks used in trunk logistics, container trucks used in ports, dump trucks in mining areas, and last-mile distribution vehicles. Among these, Robotaxi services and autonomous driving in trunk logistics are anticipated to have the most significant market size and public interest in the future.

Autonomous driving technology is rapidly advancing toward level 3 (L3). Currently in China, the autonomous driving capability in mass-production passenger vehicles is transitioning from L2 to L3 and beyond. L2 capabilities are becoming a must-have pre-installation for new cars thanks to the maturation of the hardware platform and software algorithms. In 2022, the penetration rates for L2 and L3 in China were 35% and 9%, respectively. These figures are expected to rise to 51% and 20% in 2023. Some technology companies are even developing L4 autonomous driving, which is being tested in specific urban sections or scenarios. However, high-level autonomous driving still faces policy, safety, and technology maturity challenges. In 2022, the L4 penetration rate in China was 2%, expected to reach 11% in 2023.[18]

[16] DSRC, namely dedicated short-range communications, is a U.S. Department of Transportation (DoT) project based on the Communications Access for Land Mobiles (CALM) architecture for vehicle-based communication networks. DSRC utilizes IEEE 802.11p, an approved amendment to the IEEE 802.11 standard, to add wireless access in vehicular environments (WAVE). It permits low-latency (2-ms) communication of basic safety messages between vehicles and between vehicles and roadside infrastructure.

[17] Cellular-vehicle-to-everything (C-V2X) is a 3GPP standard for V2X applications such as self-driving cars. It is an alternative to 802.11p, the IEEE specified standard for V2V and other forms of V2X communications. C-V2X uses 3GPP standardised 4G LTE or 5G mobile cellular connectivity to exchange messages between vehicles, pedestrians, and wayside traffic controls devices such as traffic signals. It commonly uses the 5.9GHz frequency band, which is the officially designated intelligent transportation system (ITS) frequency in most countries.

[18] Source: Gonyn.com

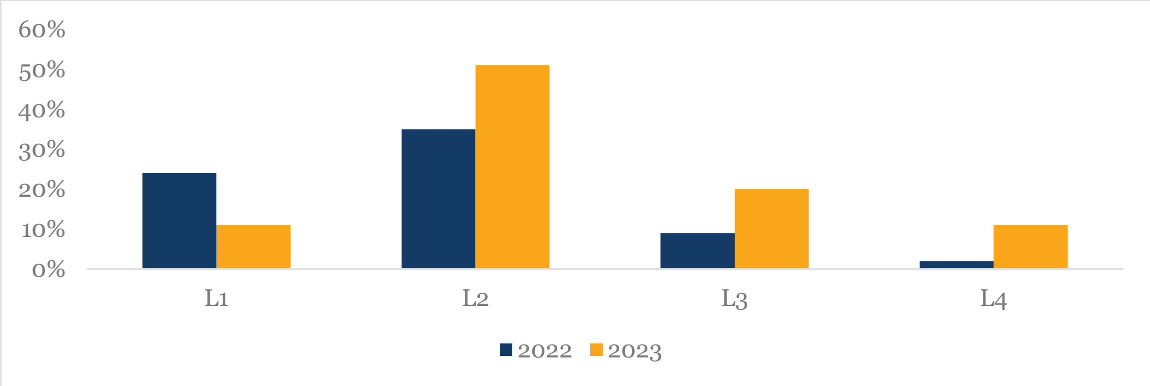

Figure 8 Projected penetration rate of autonomous driving function in new cars on sale in China

1. Robotaxi is in the commercial testing phase

Various cities, including Beijing, Shanghai, Guangzhou, and Shenzhen, are actively advancing the Robotaxi and the ICV sector through legislation, establishing pilot zones, and extensive road testing. However, in terms of Robotaxi commercialization, different local governments have adopted diverse approaches, combining inclusivity and caution in their business operations.

Taking Beijing as an example, in September 2023, Chinese autonomous driving solution provider, Pony.ai, received the first batch of commercial pilot notices for fully-unmanned Robotaxi commercial services in the Beijing Intelligent Connected Vehicle Policy Pilot Zone. This approval allows Pony.ai to launch its Robotaxi service with only remote monitoring and no safety operators onboard while charging fees in Beijing's Yizhuang area. As of July 2023, there are 116 unmanned test vehicles with a total test mileage of nearly 2 million kilometres.

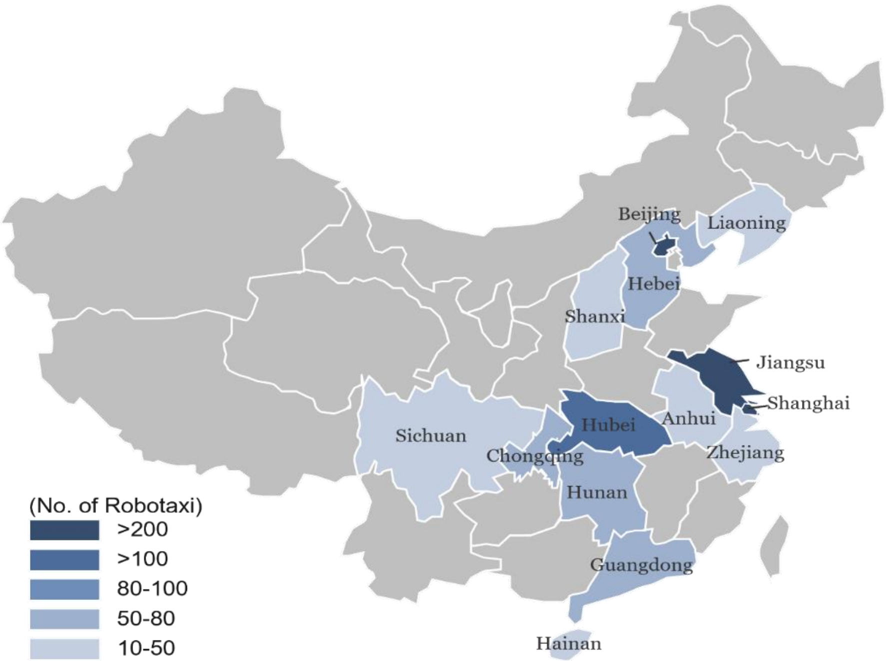

Figure 9 Deployment of Robotaxi operations across multiple cities in China[19]

[19] Source: China SAE, CICV, CAICV. Data as of February 2023

Commercial vehicle autonomous driving has entered the commercialization stage primarily due to reduced price sensitivity, higher willingness to pay in the B2B sector, simpler operational scenarios, and supportive policies. Sectors such as mining, port logistics, trunk logistics, airports, and logistics parks are witnessing the emergence of new markets for high-level autonomous driving. Notably, trunk logistics, mining, and port operations, where labour shortages and safety concerns are prevalent, are experiencing rapid commercial adoption. Leading companies have already entered the commercial operational phase due to significant cost savings and efficiency improvements in these areas.

1. The last-mile delivery sector has facilitated the small-scale mass production of autonomous distribution vehicles. Numerous companies like JD.com, Cainiao, Meituan are testing AD delivery vehicles in closed environments on small scales, while some technology companies establish cooperations with express companies and testing operation across several scenarios. For instance, HDeliver 2.0, a last-mile unmanned distribution vehicle produced by Haomo.AI, has launched more than 1,000 units to the market by the end of 2022, delivering more than 130,000 courier orders.

2. Autonomous driving in trunk logistics and sanitation sectors are more likely to get commercialized due to plenty of participants and fierce competition. Inceptio Technology, Plus. AI (Zhijia Technology) and other technology companies have begun mass production of L3 class autonomous driving trucks, and started commercial operation. On October 31, 2023, the initial shipment of 10 intelligent HDV JAC K7+ equipped with the Plus. AI's autonomous driving system was officially handed over to Zhongtong Express and deployed for the Double 11 express service[20].

3. The mining autonomous driving sector is currently in its initial testing phase, but as it progresses towards commercialization, it has the potential to reach a market size of hundreds of billions. To support the industry, the government has published several policies in favour of the development of mining AD applications. Further, the government has established a target to transform all mining operations to intelligent mines by 2035[21].

   In 2021, the CHN Energy Baorixile Project marked a significant milestone by successfully implementing China's first unmanned driving transformation project, involving 5+200/higher-tonnage mining trucks. The achievement included the successful marshalling operation of mining trucks in an extremely cold environment (below -40 ℃). In 2023, Waytous has announced the launch and deployment of China's first autonomous mining robot, "Zaishan Carmo", making it a truly full-time autonoums driving mine transport device.

4. Multiple ports test self-driving container trucks in trial operations. In January 2022, Fabu. AI's unmanned container truck in the Meishan Port Area of Ningbo Zhoushan Port Group successfully completed 40 loading/unloading box-level transportation cycle operations by removing safety staff and relying on precise field equipment perception. In July of the same year, Shanghai designated the two-way outermost third lane of the Donghai Bridge as a dedicated lane for autonomous driving testing, marking the transition of Port of Shanghai's driverless container trucks into a substantial "unmanned" commercial operation phase.

[20] Source: Zhijia Technology
[21] Source: China's National Development and Reform Commission, Guideline for Intelligent mining, February 2020

DRIVER ACCEPTANCE/CUSTOMER ACCEPTANCE

According to J.D. Power's May 2021 survey, Chinese consumer confidence in autonomous driving stands at 50%, surpassing the 36% in the United States. The positive sentiment is driven by widespread acceptance of Advanced Driver Assistance Systems (ADAS) in current vehicle models. However, acceptance drops to 9% for Robotaxis, revealing a notable gap between embracing autonomous features and viewing them as a complete transportation mode.[22]

Meanwhile, a customer survey conducted by Yiche Research in late 2021 reflects that a rising share of customers are willing to pay for autonomous driving features[23]:

1. Approximately 30% of customers express a willingness to pay extra for features related to autonomous driving
2. Over half of customers are in a wait-and-see mode regarding the development of autonomous driving technology, signalling a potential shift to becoming future customers once the technology matures and becomes safer

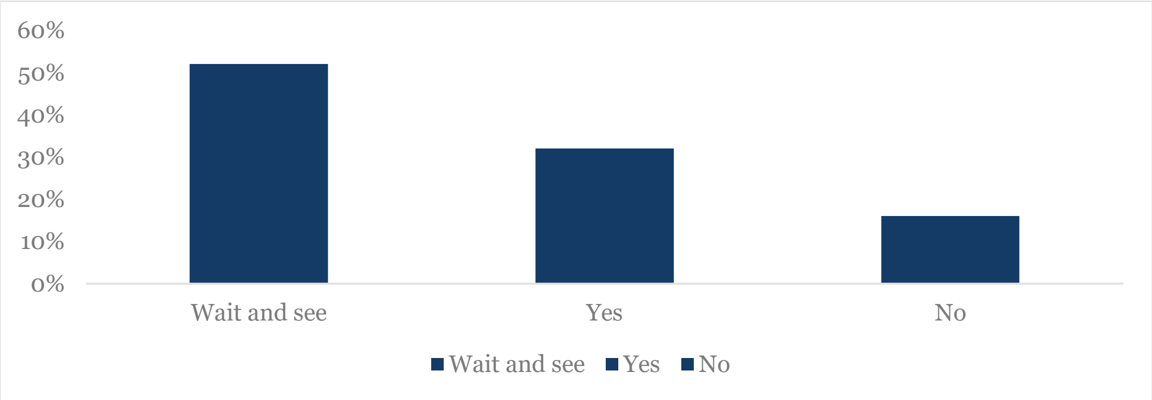

Figure 10 Customer willingness to pay for vehicles with AD features

However, it's essential to note that even when autonomous driving cars reach technological maturity, there will be a wait-and-see period from the initial vehicle launch to widespread consumer adoption. Many consumers are inclined towards a more flexible approach to utilizing autonomous driving features. Monthly subscriptions or pay-per-use based on mileage or duration of use are payment methods that are generally more acceptable to consumers compared to the one-time purchase of an entire car with autonomous driving feature.[24]

FAST LANE TO AUTONOMOUS DRIVING: HOW CHINA'S POLICIES AND INVESTMENTS STEER INNOVATION

GOVERNMENT SUPPORT POLICIES

Autonomous driving has emerged as a pivotal development direction in the automobile industry. The Chinese government recognized its significance as early as 2015 when the State Council

[22] Source: J.D. Power
[23] Source: Yiche Research
[24] Source: J.D.Power

introduced "Made in China 2025." This guideline and plan laid the groundwork for the development and implementation of autonomous vehicles over the following decade.

To stimulate economic growth, enhance core competitiveness, and expedite the development of intelligent connected vehicles in China, on February 10, 2020, 11 national ministries including the National Development and Reform Commission (NDRC) and Ministry of Industry and Information (MIIT) etc., collectively promulgated “the Innovative Development Strategy of Intelligent Vehicle”. The strategy initiated to accelerate the development of high-level autonomous driving, and proposes that by 2025, the large-scale production of L3 vehicles and the market launch of L4 vehicles in selected scenarios will be realized; long-term evolution vehicle-to-everything (LTE-V2X) area coverage will be realized, and fifth generation-V2X (5G-V2X) network coverage featuring high-precision space-time benchmarks will be enabled in some cities and on some highways; a set of Chinese standards for autonomous driving will be fairly comprehensive. By 2035, China’s standard intelligent vehicle system will be fully completed.

In the same year of 2020, the State Council issued the New Energy Vehicle Industrial Development Plan (2021-2035), which clearly proposed the goal of “developing highly autonomous vehicles to achieve commercial application in limited areas and specific scenarios by 2025, and to achieve large-scale application by 2035.”

The outline of the 14th Five-Year Plan (2021-2025) for National Economic and Social Development and Long-term Objectives for 2035, the country’s highest-level initiatives for social and economic development published in March 2021[25], set targets for autonomous driving and intelligent mobility. In July 2021, The MIIT and other ministries issued the Good Practice for the Administration of Road Tests and Demonstrative Application of Intelligent and Connected Vehicles to establish requirements and further regulate autonomous driving testing. These documents established the foundation for the advancement of ICVs and the requisite infrastructure.

In August 2022, the Ministry of Transport released the “Safety Service Guide for Autonomous Vehicle Transport (Pilot)” (draft for comment). This initiative is designed to align with the advancements in autonomous driving technology and foster the commercial utilization of autonomous vehicles. Simultaneously, cities like Beijing, Shenzhen, and Chongqing have implemented policies and regulations to facilitate the commercial deployment of autonomous vehicles. By the end of 2021, local government had built more than 20 new ICV test zones and had designated more than 3,500 kilometres of road for autonomous-car testing. Government also created regulatory pilots that integrate market access, data security, accident handling, and design specifications in their test.

As the regulatory system is getting more sophisticated, to develop autonomous-driving laws and regulations, central governments subsequently use the information gathered in pilot cities to create policies, while local governments can take a pragmatic approach when promoting and optimizing regulatory systems. For example, when Shenzhen Municipal People’s Congress passed the first law in China regarding autonomous driving[26], it ensured end-to-end regulatory coverage during testing and provided a yardstick for determining responsibility in traffic accidents. This approach has led to greater legislative support: on August 1, 2022, Shenzhen permitted self-driving cars on the road, a milestone in the development of autonomous-driving technology.[27]

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[25] Source: NDRC

[26] Draft for Comments of the Regulations of Shenzhen Special Economic Zone on the Administration of Intelligent and Connected Vehicles (the “Shenzhen Draft Regulations”)

[27] Source: McKinsey & Company

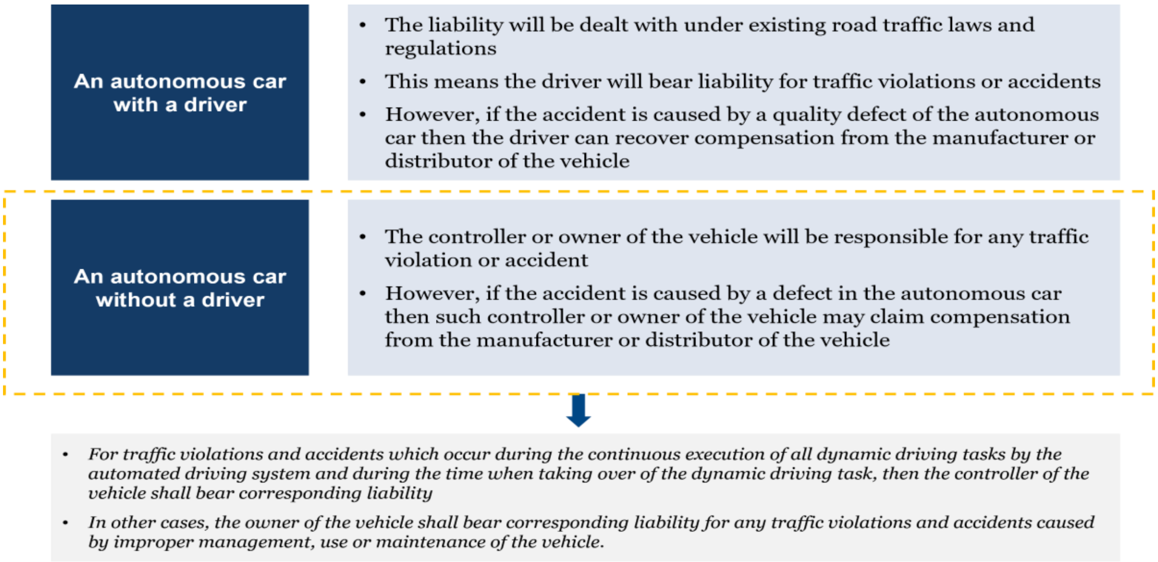

Figure 11 Case study - liability distinguishment for autonomous cars according to Shenzhen's regulation

FINANCIAL SUPPORT & INVESTMENT

In addition to direct investments in ICVs and autonomous driving technologies, China also attaches great importance to "new infrastructure" which supports autonomous driving. Information infrastructure such as 5G, AI, cloud computing, data centres, as well as intelligent transportation infrastructure are the core supporting technologies to help achieve systems through perception, behaviour prediction and planning to achieve full autonomous driving.

Supporting technology	Investment or market size	Growth
5G	0.9 to 1.5 trillion yuan of investment between 2021 and 2025	-
AI	77.7 billion yuan of private investment between 2013-2021	CAGR approx. 43%
Cloud infrastructure services	455 billion yuan market size by 2025	2021 to 2025 CAGR 25%
Data centres	231 billion yuan market size by 2025	2020-2025 CAGR 19.2%

Table 6 Financial indicators on AD supporting technologies[28]

In 2022, there were 153 domestic autonomous driving-related investment events with a total disclosed financing of nearly 30 billion yuan. While the number of investment events increased compared to 2021, the overall financing levels decreased significantly. In 2022, there were only eight investment events that raised more than 500 million yuan, compared to 19 in previous year. This shift in investment trends suggests a more rational approach in the capital markets. Additionally, investment is moving from a diversified approach to focus on commercialization, hardware integration, and mass production.[29]

[28] Source: China Academy of Information and Communications Technology, Stanford 2022 AI Index Report, Canalys Research on Cloud Spend 2021, Shibuya Data Count Data Centre Market, KPMG analysis
[29] Source: 36Kr Research

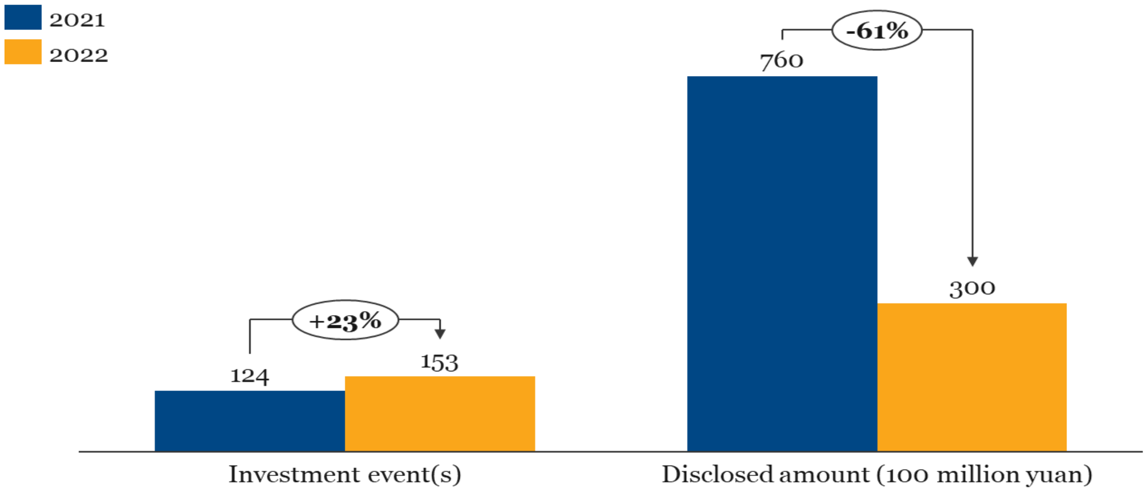

Figure 12 Comparison of investment and financing in China's autonomous driving in 2021 and 2022[30]

MARKET DEMAND

Autonomous driving promises a safer, more efficient, energy-conserving, and comfortable mode of transportation. Its significance goes beyond altering human driving habits; it plays a vital role in advancing overall societal development and progress, particularly in areas such as traffic safety, travel efficiency, energy conservation, and industrial transformation.

Each year, China witnesses over 60,000 fatalities due to traffic accidents[31], making road traffic injuries the leading cause of death in the country. Autonomous vehicles offer a solution to this grave issue by employing intelligent control and standardized driving to prevent safety accidents, thereby ensuring traffic safety. Furthermore, traffic congestion remains a significant challenge in urban areas, with approximately 75% of congestion occurring during peak hours in major cities. Self-driving vehicles, equipped with onboard sensors, can collaborate with intelligent traffic systems to optimize intersection flow, enhance traffic efficiency, and alleviate congestion. As a result, more precise vehicle control and reduced traffic congestion can effectively minimize resource wastage and contribute to energy conservation and emission reduction.

The automotive industry is shifting towards unified computing platforms, embracing software-defined vehicles as a prominent trend. These vehicles are transforming from stand-alone cars into adaptable mobile spaces driven by users needs, with self-driving technology serving as a key enabler.

WHERE IS CHINA'S AUTONOMOUS DRIVING HEADING?

FUTURE TREND IN COMING 5-10 YEARS

In November 2020, the State Council issued the New Energy Automotive Industry Development Plan (2021-2035), outlining primary objectives for new energy vehicles and presenting development goals for ICVs and autonomous driving:

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[30] Source: Cyber-Car, 36Kr Research
[31] Data reference: Ministry of Transport, Ministry of Public Security, Chinese Center for Disease Control and Prevention

1. Commercialize autonomous driving in specific areas and scenarios by 2025
2. Scale-up the application of highly autonomous ICVs by 2035

In addition, the China Industry Innovation Alliance for Intelligent and Connected Vehicles (CAICV) unveiled the 'Intelligent Connected Vehicle Technology Roadmap 2.0' (hereinafter referred to as Roadmap 2.0) during the 2020 World Intelligent Connected Vehicle Conference. The roadmap outlines the next 15 years of development for Intelligent Connected Vehicles (ICVs), categorizing them into three stages: the development period (2020-2025), promotion period (2026-2030), and maturity period (2030-2035)

In terms of the market, by 2025, more than 50% of new car sales in China will involve PA-level[32] and CA-level[33] ICVs, with a 50% new car assembly rate for C-V2X terminals. Highly autonomous vehicles (HA) are expected to be commercially deployed in restricted areas and specific scenarios. By 2030, In China, PA-level and CA-level vehicles constitute 70%, while HA-level accounts for over 20%. New cars equipped with C-V2X terminals are widely adopted. By 2035, HA-level autonomous driving is anticipated to be widely embraced across most areas in China.

In recent years, the ICV industry has experienced rapid development, with intelligent and network-connected convergence gaining an international consensus. Numerous countries and regions, including the EU, the U.S., Japan, South Korea, and others, have implemented relevant policies to foster ICV development. This has led to the emergence of a plethora of new technologies and trends in the field. The development of China’s Roadmap 2.0 further incorporates perspectives from experts in diverse fields such as communication, AI, and electronics.

[32] PA-level: partial assistance, may refer to L2 in SAE Standard
[33] CA-level: conditional assistance, may refer to L3 in SAE Standard

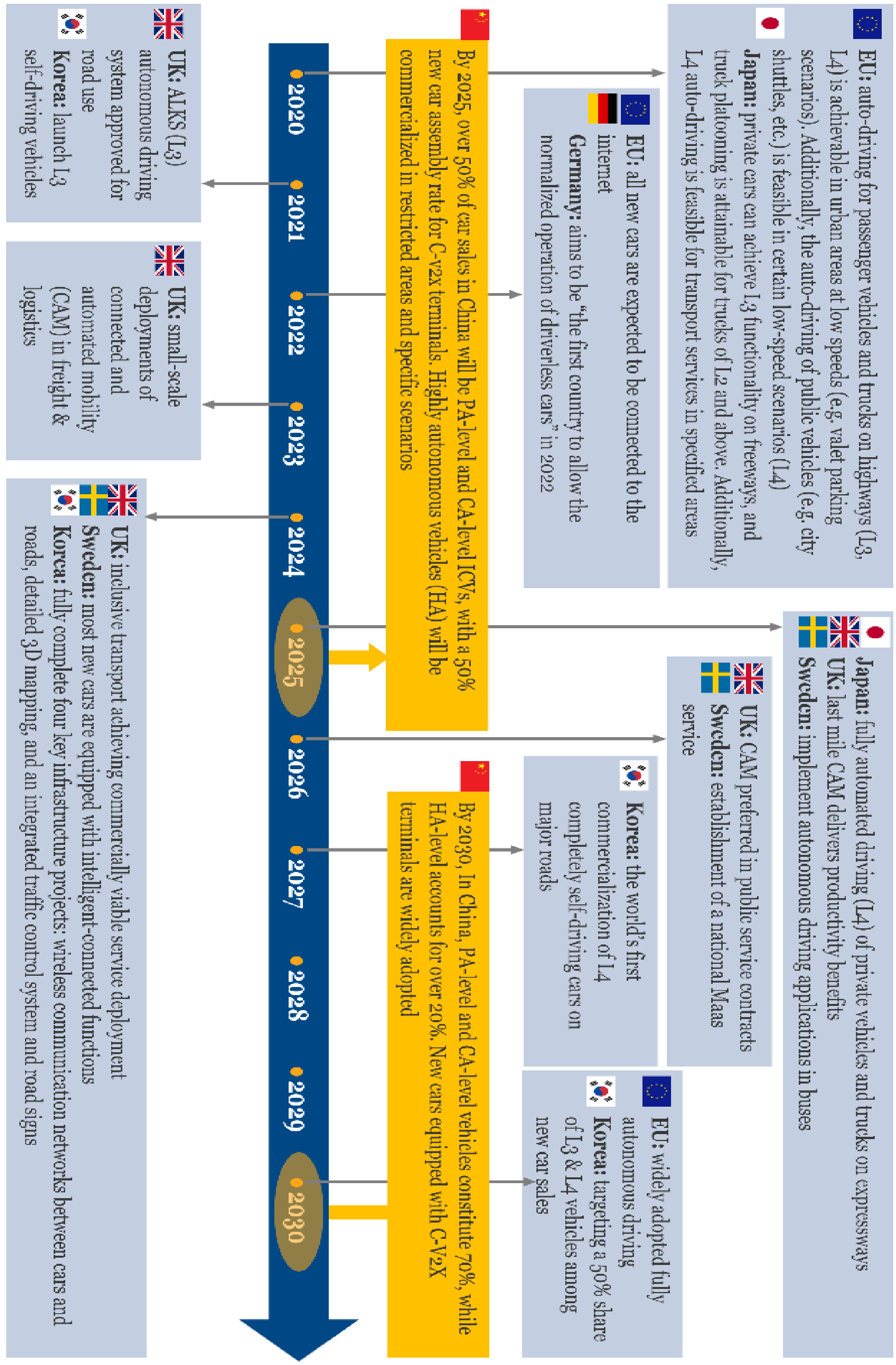

Figure 13 Key milestones of autonomous driving development roadmaps by countries/region[34]

In the realm of ICV industry, key technology trends include:

1. Ecosystem collaboration will be poised to play a pivotal role in the success of auto-driving companies, serving as a catalyst for promoting ecological reconstruction within the automotive industry.[35]

   The evolving dynamics among vehicle plants, Tier1 and Tier2 manufacturers, internet/technology giants, and solution providers are reshaping the industrial chain. Cross-disciplinary collaborations and communication persist, and individual entities face challenges in consistently and efficiently overcoming the current developmental obstacles in autonomous driving. Thus, for autonomous driving enterprises, the ability to establish an ecosystem platform and engage in mutually beneficial cooperation with ecosystem partners is increasingly crucial. This involves creating an open ecosystem model for diverse scenarios, introducing distinctive products and functionalities, and decoupling autonomous driving toolchains to benefit ecological partners.

   For instance, in the realm of chips, China's Horizon Robotics, a developer of artificial intelligence chips for smart cars, is linking arms with a number of Chinese auto manufacturers including SAIC Motor, BYD and Li Auto to build an open hardware and software ecosystem for use by the whole industry in order to speed up the development of the domestic semiconductor sector as well as the autonomous driving sector. AWS, Azure, and Huawei Cloud offer solutions for the automotive industry and autonomous driving. In terms of safety compliance, they facilitate every data-driven process in autonomous driving research and development, providing convenient out-of-the-box tools and security compliance services for automotive companies. This support helps companies cut costs and expedite the implementation of autonomous driving technology.

2. Integration of ICVs with smart cities and intelligent transportation systems

   The increasing complexity of road traffic scenarios poses challenges for achieving unmanned driving using single-vehicle intelligence alone in mass-production vehicles. By adopting the direction of development that integrates intelligence and networking, this development path is not just about the networked communication with infrastructure but involves more in-depth network collaboration such as V2V (Vehicle-to-Vehicle), V2I (Vehicle-to-Infrastructure), V2P (Vehicle-to-Pedestrian). This approach can effectively address the capability blind spots and sensing deficiencies present in single-vehicle intelligence. Additionally, intelligent roadside infrastructure enhances real-time interaction, precision in the positioning of road participants, and the efficiency of information interaction. Moreover, alongside the road, machine intelligence algorithms, with traffic data flow integration as the core, could support the integration of intelligent transportation IoT and information networks. This initiative aims to construct a comprehensive dynamic traffic control system and an intelligent data-driven collaborative control system, ensuring the comprehensive and dynamic nature of the intelligent transportation system.[36]

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[34] Source: CAICV. Roadmaps including On The Road to Automated Mobility: An EU Strategy for Mobility of The Future, South Korea's Future Vehicle Industry Development Strategy, Japan's ITS Roadmaps, UK Connected and Automated Mobility Roadmap to 2030, Drive Sweden, as well as China's New Energy Automotive Industry Development Plan (2021-2035) and Roadmap 2.0

[35] Source: 36Kr Research

[36] Source: CAICV

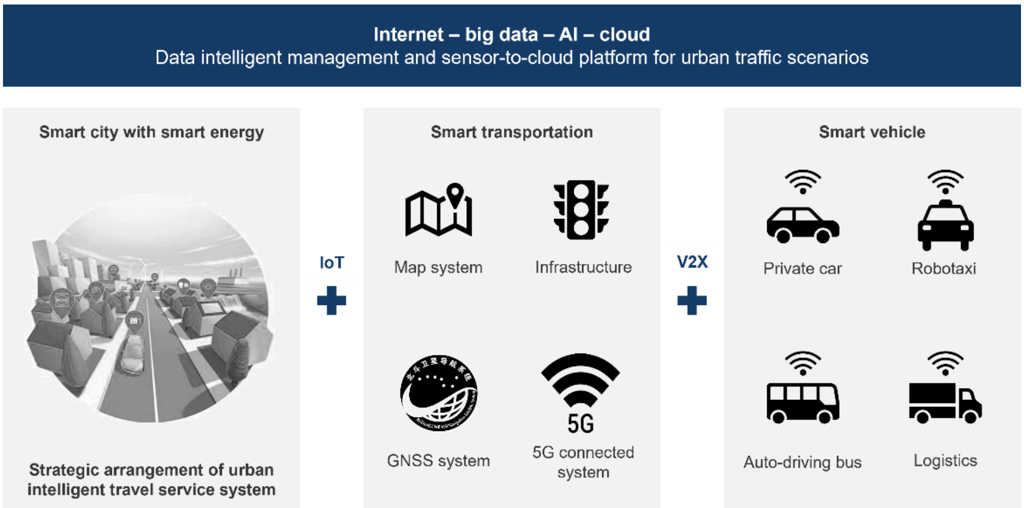

Figure 14 Integration of ICVs with smart cities and intelligent transportation systems[37]

3. The advancement of autonomous driving propels the evolution of new electronic and electrical architectures, with software-defined and data-driven vehicles emerging as future trends[38]

   The defects in traditional automotive electronic systems are evident, making it challenging to meet the future demands of automotive software. The emerging trend is toward a domain controller and central computing platform-based electrical/electronic architecture (EEA). The advantages of this approach allow for the separation of vehicle hardware and software, maximizes hardware performance utilization, enhances software reuse rates, and reduces overall costs. Simultaneously, automotive enterprises can take the lead in developing and implementing core algorithms and autonomous software systems and strengthening vehicle OTA (Over-the-Air) upgrade capabilities. This enables continuous optimization and iterative updates to enhance vehicle performance and functionality.

[37] Source: Roadmap 2.0
[38] Source: CAICV

CONCLUSION

The intelligent transformation of the automotive sector is a key component of smart cities and infrastructure development, offering benefits such as improved transport efficiency, enhanced safety, and reduced energy consumption. In China, L2 autopilot has rapidly achieved a 40% penetration by the first half of 2023, driven by breakthroughs in core technologies like car perception systems, chips, and algorithms. Despite the dominance of international tier-1 companies in the sensor market, domestic chip manufacturers are gaining ground with features like low power consumption and cost-effectiveness. While the full emergence of Chinese companies in autonomous driving will take time, their progress is noteworthy.

While Chinese consumers generally express more optimism towards autonomous driving technology compared to their counterparts in the United States, many passenger car users in China still exhibit caution, preferring to observe rather than pay for the autonomous driving technology immediately, influenced by considerations of technology maturity and transport safety. In the realm of commercial vehicles, persistent challenges such as safety concerns, limited operational efficiency in enclosed environments, and high labor costs have spurred the development of autonomous driving technology in specific application scenarios. This targeted approach aims to address pain points in commercial settings, including autonomous driving in mining and ports and last-mile delivery in specific areas.

For the widespread application of autonomous driving across various scenarios and regional boundaries in China, concerted efforts are essential. This entails not only bolstering government-level policy support and financial backing but also fostering collaboration at the corporate level. Increased investment in research and development, coupled with a commitment to technological innovation, is crucial. Moreover, actively involving the public in accepting and embracing autonomous driving technology is paramount. With these efforts, China has the potential to advance autonomous driving into a highly intelligent new stage, paving the way for the establishment of a sophisticated smart transportation network system in the future.

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