



Defining the Future of Mobility: Intelligent and Connected Vehicles (ICVs) in China and Germany

Opportunities, Challenges and the Road Ahead

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List of Abbreviations

AD	Automated Driving
BMVI	German Federal Ministry for Transport and Digital Infrastructure
BMWi	German Federal Ministry for Economic Affairs and Energy
CAAM	China Association of Automobile Manufacturers
EV	Electric Vehicle
FPS	Frames per second
GBA	Greater Bay Area
GHG	Greenhouse Gas
GIVE	Greater Bay Area Intelligent Vehicle Eco-Partnership
ICV	Intelligent and Connected Vehicle
IoT	Internet of Things
JV	Joint Venture
LiDAR	Light Detection and Ranging
MIIT	Ministry for Industry and Information Technology
MPS	Ministry of Public Security
MOFCOM	Ministry of Commerce
MOT	Ministry of Transport
MoU	Memorandum of Understanding
MOST	Ministry of Science and Technology
NASG	National Administration of Surveying, Mapping and Geoinformation
NDRC	National Development and Reform Commission
NEV	New Energy Vehicle
OEM	Original Equipment Manufacturer
PS	Progressive Scan
SWOT	Strengths, Weaknesses, Opportunities, Threats
UN ECE	United Nations Economic Commission for Europe
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-Everything
WEF	World Economic Forum
WHO	World Health Organization



1. Introduction to Intelligent and Connected Vehicles (ICVs) in China

In 2017, 29 million new vehicles were sold in China – more than in the United States, Japan and India combined. This figure is expected to increase to at least 37 million by 2025, assuming a 3 % annual growth rate.^{1,2} Given this vast market potential, the same question comes up time and again within the global automotive industry: What proportion of these vehicles will be so-called Intelligent and Connected Vehicles (ICVs)?

China's determination to become the world's leading automotive nation is matched by their desire to shape the future of mobility. Together with the rapid increase in New Energy Vehicles (NEVs), the development of its ICV industry lies at the heart of this ambition. After some initial hesitation, China has undertaken numerous steps to

accelerate the development of ICVs in 2018. Following recent legislative changes, the adoption of national strategies, as well as improvements in its connectivity-based technologies, it is fast closing the gap with leading ICV competitors, such as Germany.³ However, the road to a future in which ICVs predominate is long, and both countries face complex challenges in meeting their ambitious targets. This report seeks to shed light on these challenges, as well as the numerous opportunities associated with the development of ICVs in China. To this end, a comprehensive overview of the present ICV landscape in China will be provided, including a detailed analysis of the latest market and policy developments. To give some perspective to the Chinese developments, comparisons with Germany will be selectively highlighted throughout.

Following a brief discussion of the key terminology and drivers of ICV development in China, chapter two will review the current state of the Chinese ICV market. This will include an introduction to the key players and their business models, as well as development targets. Particular emphasis will be placed on the existing collaboration formats between Chinese and German firms. Chapter three will study the most important policy and legislative developments relating to ICVs in China. This will include a survey of the chief public regulators, an analysis of the legal framework, and an overview of the key ICV strate-

gies, guidelines and standards. Chapter four will provide a comparative analysis of the Strengths, Weaknesses, Opportunities and Threat (SWOT) for ICVs in China and Germany. An argument will be made to the effect that while Germany currently has the upper hand in terms of ICV development, China has the potential to rapidly catch up, not least due to its unique approach to public policymaking. Finally, the chapter five will present a critical summary of the research findings and offer an outlook for ICV developments in both countries.

1.1 What are Intelligent and Connected Vehicles (ICVs)?

The international discussion surrounding ICVs contains a high degree of ambiguity regarding terminology. While terms such as *autonomous*, *automated*, *intelligent* or *connected* are universally applied, there is no commonly accepted definition of these concepts.

The terminology also differs significantly between countries. In Germany, for instance, the terms *automated* and *connected* are predominant.⁴ However, these terms are generally used separately, and refer to distinct concepts. In Germany, *automated* refers to vehicles with some degree of automation, and *connected* usually refers to vehicles' ability to communicate either with each other (V2V) or with the external infrastructure (V2I). In China, contrastingly, the term "Intelligent and Connected Vehicle (ICV)" has been established in official documents. The most concrete definition to date appears in the *Draft Strategy for Innovation and Development of ICV*.⁵ Released in January 2018

by the National Development and Reform Commission (NDRC), this document forms the core of China's ICV ambitions. According to the Draft Strategy, ICVs are defined as a future generation of vehicles that (1) are able to achieve the exchange and sharing of information between vehicles and other factors such as individuals, vehicles, roads and the cloud (V2X); (2) allow awareness of complex surroundings as well as intelligent decision making; (3) are able to realize "safe, efficient, comfortable, energy-saving" driving; and (4) may carry out driving operations independently of human beings.

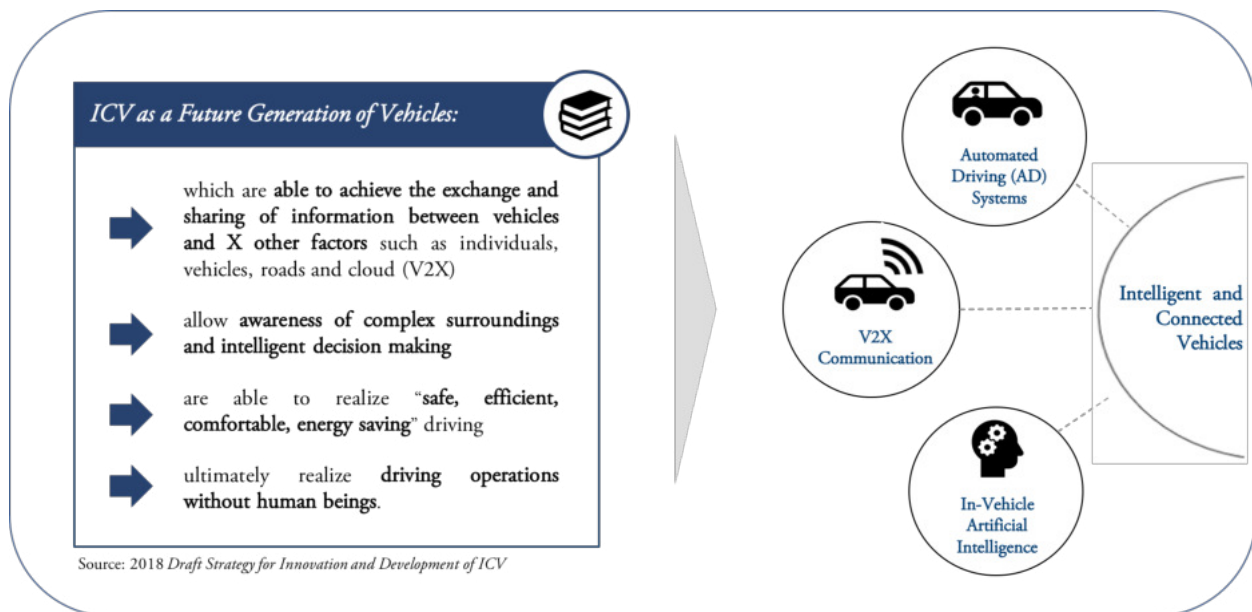
This broad definition encompasses: (1) Automated Driving (AD) Systems; (2) Vehicle-to-Everything (V2X) Communication; and (3) In-Vehicle Artificial Intelligence (AI), such as voice and motion recognition. In contrast to the German approach, the concept of the ICV in China is hence understood in a wider and more holistic sense. From

a long-term perspective, the term ICV encompasses both automated and connected vehicles, with no clear distinction between the two concepts. This integrative approach is also in line with China's definitive vision to create an *intelligent transport eco-system*, as recently expressed by sev-

eral Chinese officials at the 2018 Global Intelligent Vehicle (GIV) Summit held in Shenzhen.⁶

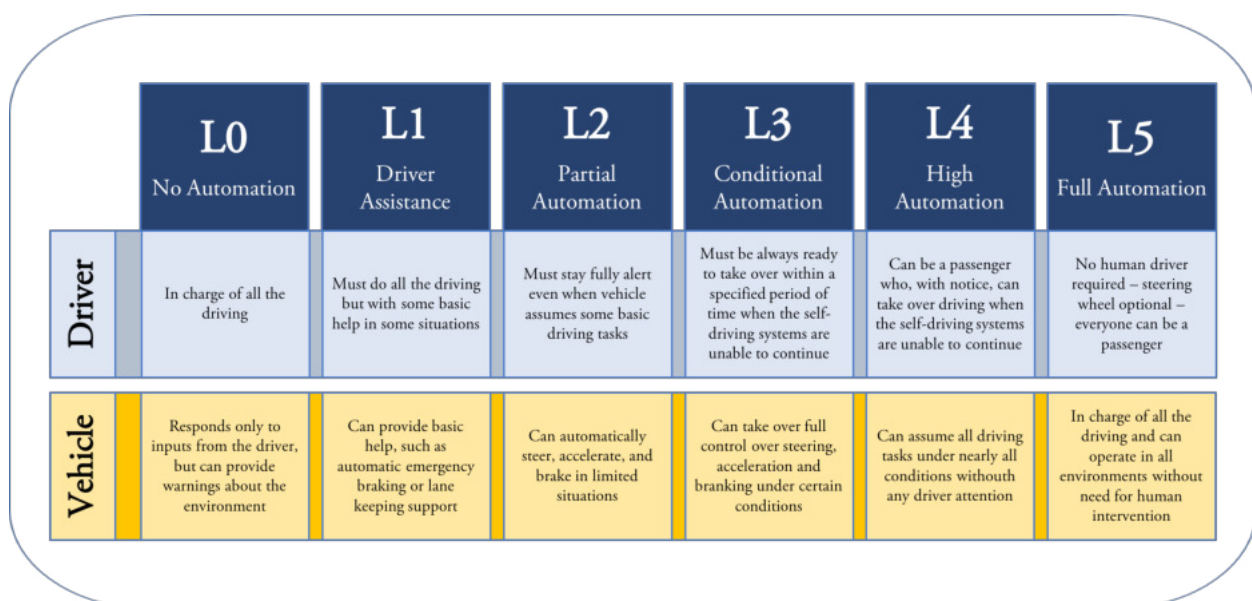
While imprecise terms are frequently used in debates surrounding ICVs, some clarity has nevertheless been

Figure 1: Definition of Intelligent and Connected Vehicles (ICVs) in China



Source: Own illustration

Figure 2: The Six Levels of Automated Driving (AD)



Source: Own illustration, based on SAE⁷

established with regards to automation functions. In 2014, the Society of Automotive Engineers (SAE) published a classification system based on six different levels of automation.⁷ This classification has since been adopted by most firms and governments, including those in Germany and China. As shown in Figure 2 below, Level 0 refers to the case of “driver only”; Levels 1-4 refer to “automated” driving with some degree of human supervision; and Level 5 refers to “fully automated” or “autonomous” driving, with

no human driver required at all.

Under this classification system, the term “autonomous” driving only refers to Level 5. However, it is sometimes (incorrectly) used in by the media in reference to lower levels of automation. In the interest of accuracy and consistency, any form of self-driving function will be referred to herein as “automated” driving (i.e., ranging from Level 1 to Level 5).

1.2 ICV Action Fields and Dimensions

The development of ICVs is not merely a technological challenge. Societal, environmental and legal considerations are also involved in the construction of the type of intelligent transport eco-system to which China aspires. While these action fields and dimensions are relevant to all participants in the ICV “race”, respective governments allocate different importance to each.

• Legal and Liability Issues

One of the most decisive factors in ICV development is the design of the corresponding legal and regulatory framework. First and foremost, the use of ICVs requires legal certainty, both for consumers and manufacturers. However, as road traffic legislation is often governed both by domestic and international laws, providing this certainty is a complex undertaking. Concerns regarding liability in the event of an accident are a potential stumbling block for ICV development. To forestall these issues and prevent the emergence of a legal grey zone, both China and Germany

have recently introduced new legislation for automated vehicles (see section 3.2).

• Safety

Concerns surrounding liability are inseparable from issues relating to ICV safety, particularly the automated driving function. Following two high-profile crashes in the United States involving Uber and Tesla in March 2018, the safety of automated vehicles has been at the forefront of public discussion. In response, several manufacturers have toned down their highly ambitious development targets, and the authorities in both China and Germany are more eager than ever to stress safety as their top priority in the development of these technologies. Paradoxically, safety is also one of the main drivers of ICV development, as proponents argue that these vehicles have the potential to vastly reduce the 1.25 million people killed each year in car accidents worldwide.⁸

• Physical and Digital Infrastructure

The successful implementation of automated and connected driving depends on the capacity of a country's physical and digital infrastructure. This implies changes to the road infrastructure, including on-road telematics, signage, crash barriers, lane widths and curbs. In addition to excellent road conditions, a high-performing cellular network is essential to support the connectivity functions of ICVs. Vehicle manufacturers are seeking to introduce higher levels of automated driving on public roads as soon as 2020; however, the minimal requirements for the digital infrastructure lack clear definition. As a result, vehicle manufacturers are coming up with their own solutions, and road operators and service providers are hesitant to renew or replace existing infrastructure and services. One example of this is high-definition (HD) mapping, which is required for automated vehicles to maneuver in complex road environments. Despite the importance of this technology, no common standards exist for HD mapping, and manufacturers use non-uniform technologies. This could potentially lead to safety issues if different automated vehicles are using different mapping systems to navigate public roads. The development of ICVs may also affect existing public transport schemes, which will need to integrate these new vehicles.¹²

• Ethical Dimension

The development of automated driving functions entails sophisticated ethical questions about how the vehicle should behave when faced with a moral choice. How, for instance, should it decide between the lives of its passengers and the lives of pedestrians? To address these questions, Germany's Federal Ministry of Transport and Digital Infrastructure (BMVI) deployed its own Ethics Commission on Automated and Connected Driving in 2016.

Roughly one year later, in June 2017, the Commission released the world's first ethical guidelines⁹ for automated vehicles. Among others, the 14 scientists and legal experts recommended that human life should always have priority over property or animal life. Ethical questions connected to ICV technology are thus a high priority in Germany, while in China they remain a more tangential consideration. In March 2017, however, Eric Hilgendorf, a legal expert at the University of Würzburg who also served on the Ethics Commission, informed Reuters that he had been invited to lecture in China. He also stated that China could follow Germany's lead and introduce similar rules in the future.¹⁰

• IT-Security and Data Protection

The digitalization of mobility will bring about a significant increase in the amount of data produced, in particular in large markets such as China. This poses new challenges for vehicle safety and digital infrastructure, as well as the protection of privacy rights. For instance, as the number of ICVs increases, so does their vulnerability to remote attack. And these risks are not merely theoretical. In 2015, the American car company, Chrysler, announced the recall of 1.4 million vehicles after hackers demonstrated that they could remotely gain access to their Jeep's digital systems via the internet.¹⁴ Both manufacturers and governments must hence address the key question of how these vehicle systems can be protected and how users' personal data can be secured.

• Government Support and Public Funding

The successful development of ICVs requires strong governmental support, both in terms of facilitating testing on public roads and also promoting the relevant research. Effective coordination among all regulatory bodies is essential, particularly across different spheres of responsibilities,

regions, and levels of administration (see section 3.1). Funding these developments also requires sufficient budgetary leeway, despite the fact that the development of ICVs may have a negative impact on government revenues. At present, governments receive billions of dollars from taxes on fossil fuels, while NEVs often receive subsidies.¹² Governments must then consider how the lost revenues from the transition to IVCs could be compensated, for instance through road pricing.

• Environment and Cities

Assuming they do not simply replace privately owned cars but are rather deployed as a fleet of shared automated vehicles, ICVs have the potential to significantly reduce greenhouse gas (GHG) emissions.¹³ Moreover, ICVs will likely not be equipped with conventional combustion engines but instead be powered by electric drive, heightening the potential positive environmental impacts. The reduced need for on- as well as off-street parking and the more efficient movement of traffic mean that fleets of automated

vehicles could drastically alter the appearance of our cities.¹⁴ All of which could generate new opportunities for alternative uses of scarce urban spaces.

• Social Inclusion and Economic Impact

Automated vehicles may also offer mobility solutions to rural populations, whose lives are often impacted by insufficient public transport options.¹⁵ Similarly, they may benefit individuals unable to drive, including the elderly, the disabled, and those who simply do not own a car. The development of ICVs could also have economic implications that extend beyond the multi-billion-dollar potential of the industry.¹⁶ On a positive note, time currently spent driving a car could be used in a productive manner, resulting in significant economic benefits.¹⁷ A negative impact, conversely, may be that many workers in the trucking and taxi industries find their livelihoods in jeopardy. To offset this loss, public policy aimed at creating new employment opportunities in the automotive and supply chain industries may well be required.

1.3 Drivers of ICV Development in China

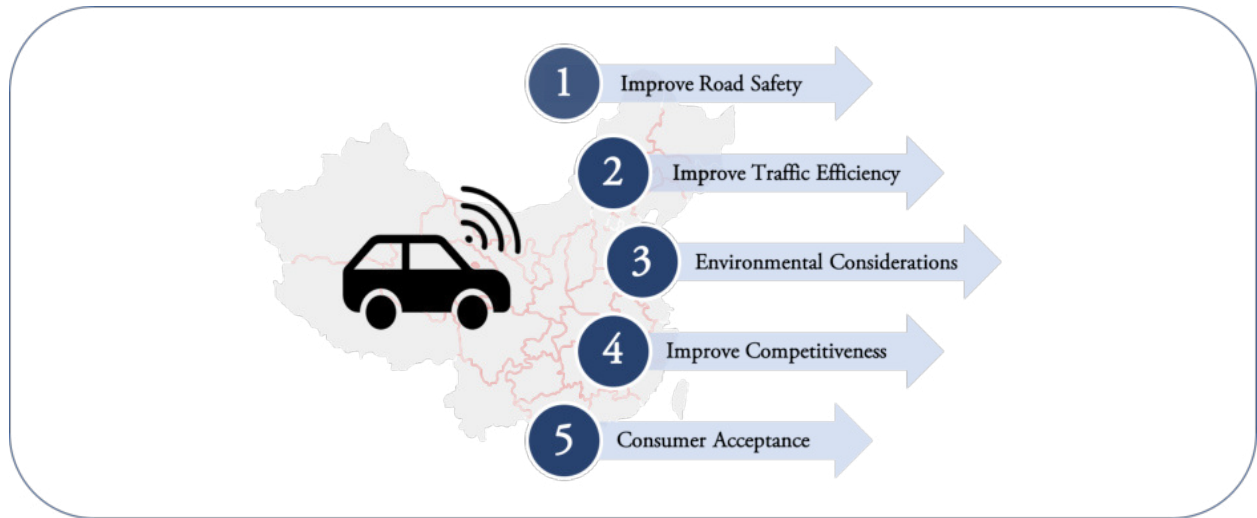
ICV development in China is driven by societal, environmental and economic considerations. First, the Chinese government views these vehicles as a pivotal opportunity to improve road safety. According to the World Health Organization (WHO), there are 18.8 traffic-related deaths per 100,000 people each year in China, with up to 90 % of all car accidents caused by human error. This is more than double the average rate in developed countries (in Germany, the figure is 4.3 deaths per 100,000).¹⁸ Second, authorities in China hope to improve traffic efficiency and prevent congestion through an increase in driving efficiency and navigation, as well as a reduction of inter-vehicle space. Third, the transport sector is one of the largest contributors to air pollution in China, a significant portion of which is attributable to passenger cars. Given the near-certainty that ICVs will be driven electrically, this represents a vital opportunity to reduce both pollution and energy consumption.

Fourth, China's aim of strengthening the competitiveness of its automotive industry forms part of a broader shift from a production-based towards an innovative economy. China has realized that it will not catch up with Western manufacturers when it comes to conventional combustion

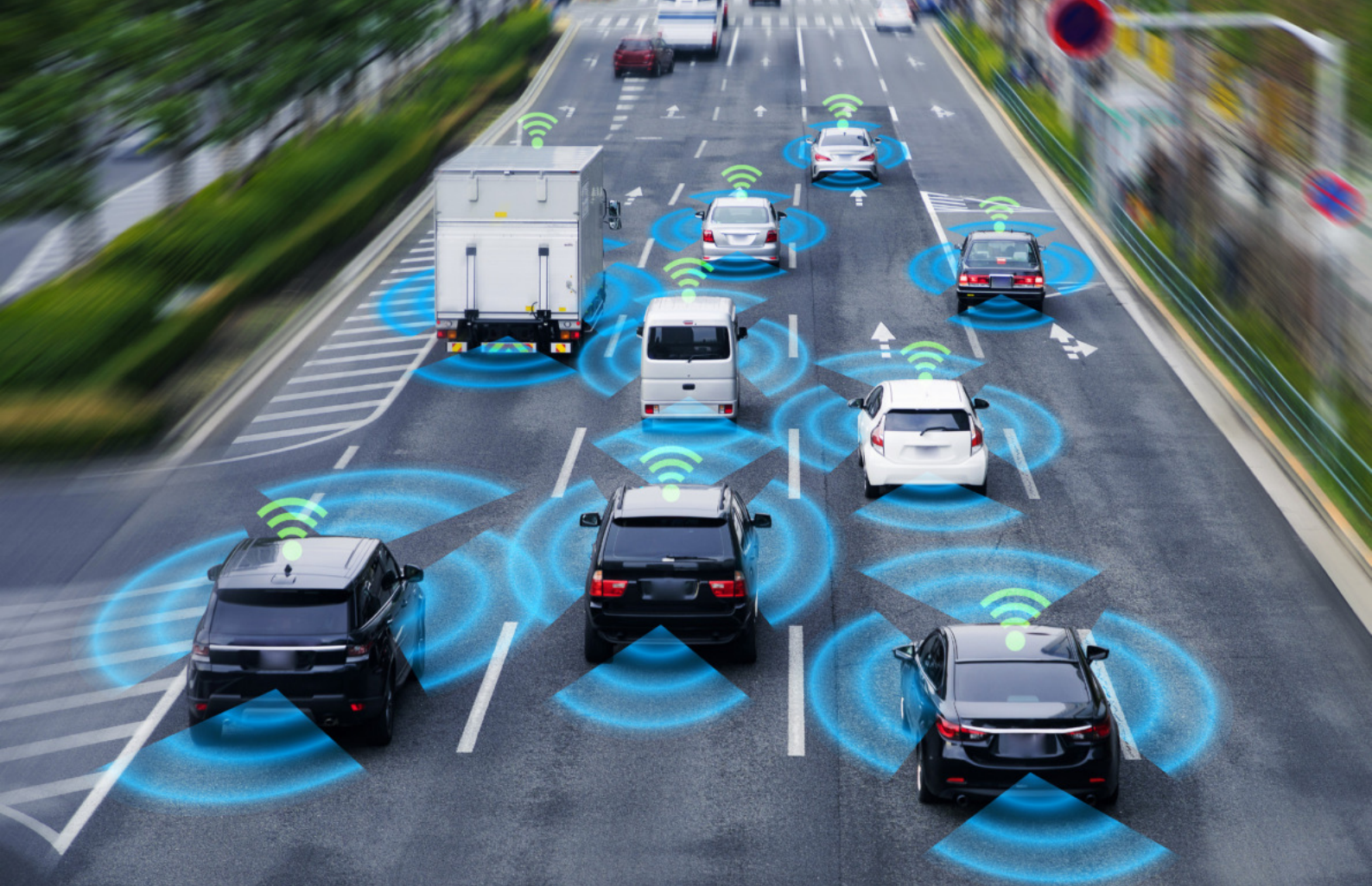
engines. However, it has legitimate ambitions to become a world leader in ICVs and NEVs. Lastly, the enthusiasm for new and innovative technologies is significantly greater in China than elsewhere. A survey conducted by the World Economic Forum (WEF) in 2015 found that 75 % of Chinese consumers would be willing to ride in an automated vehicle. In the United States, this figure was significantly lower at 53 %, and less still in Germany, where only 42 % answered yes to the same question.¹⁹

Clearly, the development of ICVs is a controversial issue. Not all experts share the enthusiasm of car manufacturers and tech companies about the benefits of ICVs, particularly with regard to their automated driving functions. Professor Daniel Sperling from the University of California Davis, for instance, has stated that the potential benefits of ICVs will only materialize in the event of a shared solution. The simple replacement of privately-owned vehicles with ICVs, he argues, would merely lead to an increase in traffic, as people will spend more time in their vehicles.²⁰ Similarly, the debate surrounding the claim that ICVs will make traffic safer, ease congestion and free up urban spaces is ongoing.²¹

Figure 3: Drivers of ICV Development in China



Source: *Own illustration*



2. Overview of the Chinese Market

2.1 The ICV Industry in China

The huge potential of the Chinese market attracts an ever-increasing number of companies to the domestic ICV industry. The transformative nature of the mobility industry in general and the continuous technological disruptions relating to ICVs means that these companies are difficult to classify. Indeed, many firms which are active in the Chinese ICV market have a substantial presence across various industries, offering a wide range of services and operating in numerous countries.

To provide a structured account of the ICV industry in China, this report will differentiate, on a very basic level, between traditional automotive OEMs and emerging tech companies. Tech companies are further classified into (1) platform and mobility service; (2) vehicle construction; and (3) manufacturers of LiDAR technology and AI chips.

“Platform and mobility service” companies offer a broad range of services, tools, and products. “Vehicle construction” firms, meanwhile, focus on full-stack solutions for automated and connected driving. On the OEM side, Chinese firms focusing exclusively on constructing electric vehicles make up a further subcategory.

• Tech Companies

Platform and Mobility Service Companies

Baidu, Tencent, JD.com and Didi Chuxing have all announced their own automated vehicle projects. Most recently, on 16 April 2018, Alibaba also confirmed that it is testing its own automated vehicle technology. All of the Chinese internet giants are hence investing heavily in ICV-related technology, albeit for somewhat different

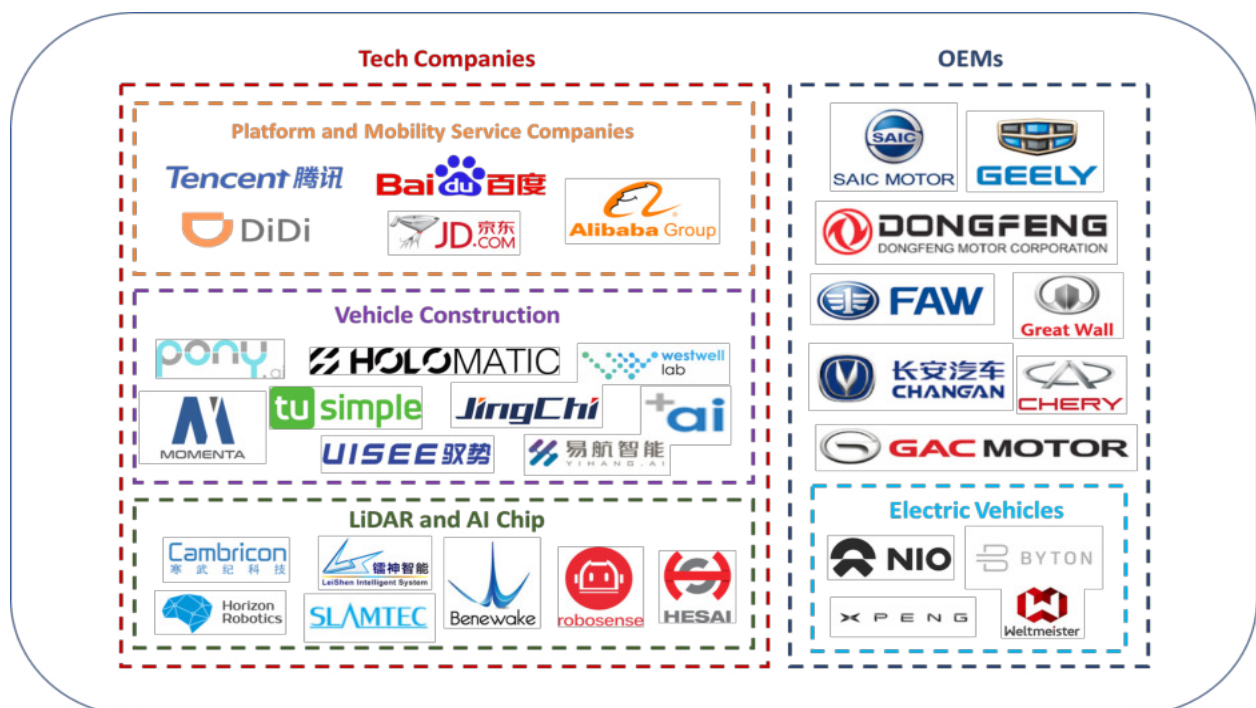
reasons. While Baidu, Didi and Tencent are most interested in developing automated passenger cars, the two e-commerce companies, JD.com and Alibaba, are developing the technology mainly for their warehouse and delivery services.

At present, Baidu is considered the leading ICV firm in China. This is due in no small part to its pioneering spirit: Baidu began developing automated vehicles in 2013, when few other Chinese companies were investing in the technology. Best known for its search engine, Baidu was also the first Chinese firm to be granted licenses to test automated vehicle technology on public roads in both China (Beijing) and the United States (California). Its aim is to achieve fully automated (Level 5) driving on highways and certain city roads by the end of 2020. Baidu's most successful ICV project is Apollo – an open-source platform for automated vehicle technology launched in April 2017.²³

More than 100 companies have since joined the platform, which seeks to build an ecosystem allowing firms to integrate resources and share data. Members of the project include several Chinese manufacturers, American firms such as Ford and Intel, and a number of German industry leaders including Daimler, Bosch, Continental and BMW, which was recently granted a seat on the board under the July 2018 initiative.²⁴

Other Chinese platform and mobility service companies entering the ICV market are making great efforts to narrow the gap with Baidu. Didi Chuxing, China's leading ride-hailing service, announced its automated vehicle project in 2017. In the same year, it opened a research center in Silicon Valley (Didi Labs) to accelerate the development of its technology. Located not far from Google's headquarters, the facility housing around 100 researchers and AI specialists is Didi's first physical presence outside of China.²⁸

Figure 4: Overview of the ICV Industry in China



Source: Own illustration, based on data from Shi²²

Moreover, Didi, along with Baidu, is the only Chinese tech company to receive testing licenses in both the United States and China. Tencent – a Chinese investment holding conglomerate specialized in internet-related services and products – also set up an automated vehicle lab in Beijing in 2016. In May 2018, it was the first company to receive permission to test automated vehicles in Shenzhen.

Given the breadth of technology required for the development of ICVs, a large number of other Chinese tech companies have quickly emerged, with different areas of focus. These can broadly be grouped into two different categories: (1) vehicle construction; and (2) LiDAR and AI Chip.

Vehicle Construction






While most companies seeking to build automated passenger vehicles are rather young (most were founded in the past two years), they have nevertheless raised large sums of capital and, in some cases, formed partnerships with OEMs. Most commonly, these companies are founded by former employees of China's tech giants (e.g., Pony.ai, Jingchi, and Holomatic, all of which were founded by for-

mer Baidu employees). Similar to Baidu, these companies focus on highly automated solutions for the direct development of Level 4 vehicles. Several other Chinese companies are focused on commercial vehicles. While these firms have raised significantly less money than their passenger vehicle equivalents, it remains likely that the first successful Chinese-built automated vehicle will be of the commercial variety. This is mainly because it is much easier to build automated vehicles that operate in a controlled environment (e.g., trucks for use in ports) than, say, the automated taxi-fleet envisioned by Didi.²²

LiDAR and AI Chip

One of the most crucial technologies for automated driving is Light Detection and Ranging (LiDAR). In a similar way to radar, which sends out radio waves, LiDAR emits pulses of infrared light and measures how long they take to come back after hitting nearby objects. The results are aggregated into a so-called "point cloud," which works like a real-time 3D map of the world.²⁹ At present, LiDAR technology for automated vehicles is dominated by Velodyne, a Silicon Valley-based company that currently works with 25

Figure 5: Chinese Platform and Mobility Service Companies in the ICV Industry

	 Baidu 百度	 Tencent 腾讯	 JD 京东 .COM	 DiDi	 Alibaba Group
Major Business	Search Engine	Social Media and Gaming	E-Commerce	Ride-Hailing	E-Commerce
Valuation	\$90 billion	\$540 billion	\$60 billion	\$56 billion	\$500 billion
Start Automated Vehicle Project	2013	2016	2016	2017	2018
Focus	Passenger Cars	Passenger Cars	Delivery Robots	Passenger Cars	Delivery Robots
US Testing Permit	Yes (2016)	No	No	Yes (May 2018)	No
China Testing Permit	Yes (Beijing, March 2018))	Yes (Shenzhen, May 2018)	No	Yes (Beijing)	No

Source: Based on data from State of California²⁵, South China Morning Post²⁶, Shi²⁷

automated vehicle programs around the world. In 2016, Velodyne opened a branch in Rüsselsheim, a city in the Rhein-Main region of Germany.³⁰ Velodyne's dominant position within the LiDAR industry makes it difficult for Chinese companies to compete. However, demand for LiDAR in China remains low, giving these companies time to develop next-generation products.

In terms of AI chips, the most well-known and best-funded companies in China are Horizon Robotics and Cambricon. Founded by Kai Yu, a former Baidu employee, Horizon Robotics focuses on the development of embedded computer vision processors for automated vehicles. In 2017, the company announced Journey, its first computer vision chip capable of recognizing up to 200 objects at 30 fps for 1080 p videos. Cambricon, meanwhile, is working on more general-purpose AI chips for use with voice recognition and natural language processing software. The

company has announced that it is working on a chip for automated vehicles; however, it has yet to confirm a launch date.²²

• OEMs

Unsurprisingly, Chinese OEMs are dedicating vast resources to the development of their own ICVs. China's largest OEM, SAIC Motor, which together with Volkswagen formed the Joint Venture (JV) SAIC Volkswagen in 1984, is leading the way in terms of automation technology. To achieve its goal of being the first company to launch a Level 3 vehicle in China by the end of 2018, SAIC Motor is working closely with several tech companies, including China's Momena, the US firm DeepMap, and the Israeli company Mobileye. Along with Changan Automobile, SAIC Motor is the only Chinese OEM to be granted test licenses in both China and the US.

Figure 6: Chinese OEMs in the ICV Industry

	SAIC MOTOR	DONGFENG	FAW	CHANGAN	BAIC	SAC MOTOR	GEELY	Great Wall	CHERY
Market Share	24%	14%	12%	10%	9%	7%	5%	4%	2%
ICV Partners	DEEPMAP ALMOTIVE Mobileye	Baidu 百度	Baidu 百度 + ai	Baidu 百度	Baidu 百度	pony Visteon	Autoliv	Baidu 百度	Baidu 百度
Development Targets	Level 3 (end of 2018)	Self-driving Bus (2019)	Self-driving Truck (Date Unknown)	Level 2 (2nd Half of 2018)	Level 3 (2019)	Level 3 (2020)	Level 2 (Volvo Pilot Assist)	Level 3 (End of 2020)	Level 3 (2020)
Apollo Participant?	No	Yes	Yes	Yes	Yes	No	No	Yes	Yes
US Testing Permit	Yes (June 2017)	No	No	Yes (Nov. 2017)	No	No	No	No	No
China Testing Permit	Yes (March 2018)	Yes (March 2018)	Yes (March 2018)	Yes (March 2018)	Yes (April 2018)	Yes (March 2018)	Yes (March 2018)	No	No

Source: Based on data from State of California²⁵, Shi²⁷

To catch up, other OEMs such as BAIC or Great Wall generally subscribe to Baidu's Apollo platform. Some OEMs have also partnered with start-ups as they strive to keep pace. GAC, for instance, decided to work with Pony.ai, and Geely chose Autoliv as its preferred partner. In April 2017, Autoliv and Volvo (which is owned by the Chinese manufacturer Geely) formed Zenuity, a JV seeking to develop automated vehicles.

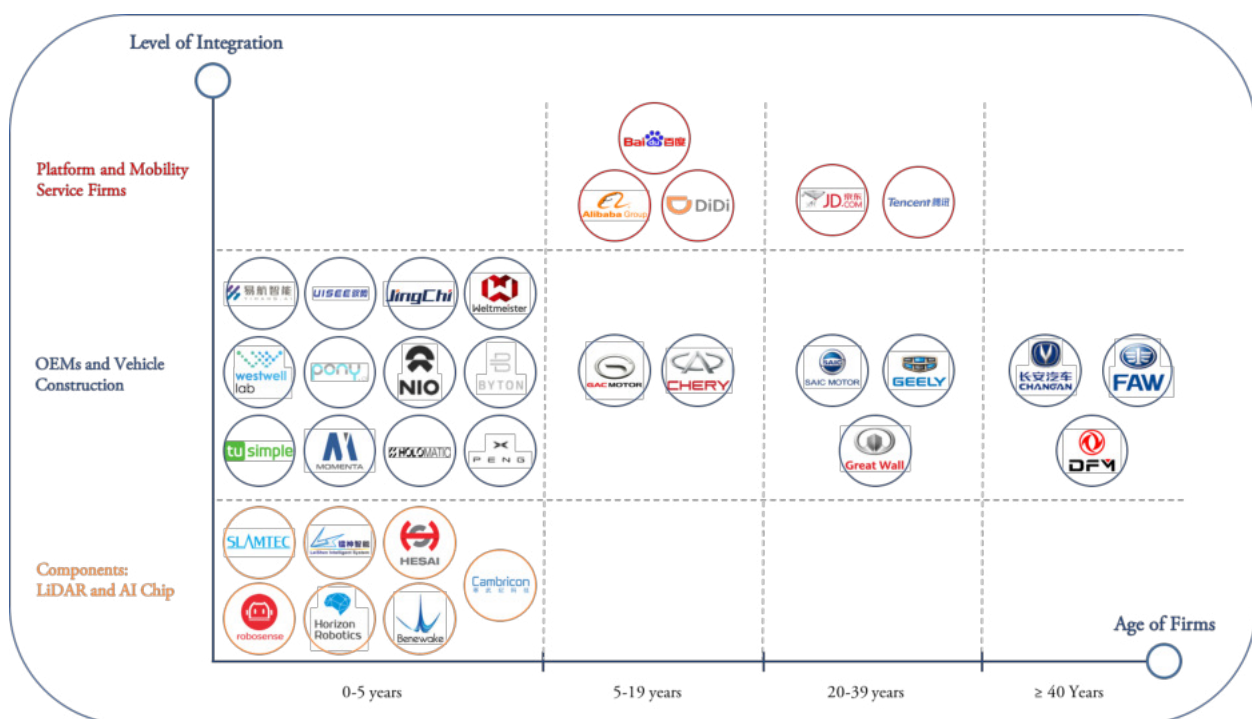
Electric Vehicles (EVs)

China is a global leader in electro-mobility. It is hence no surprise that Chinese EV manufacturers view automated driving technology as an integral part of their business models. As is the case for traditional OEMs, however, EV companies come under pressure to launch their products onto the market as quickly as possible. Unable to simply wait until Level 4 technology is ready for commercial use,

these firms tend to focus on incrementally developing their automated driving technologies (starting with Level 2). In December 2017, an EV company, NIO, became the first Chinese firm to launch a vehicle (the ES8) with Level 2 automation functions. However, competitors' vehicles contained these functions as early as 2014, when Daimler introduced the Distronic Plus Adaptive Cruise Control System (ACC) for its Mercedes E-Class.

Figure 7 below provides a concluding summary of China's ICV industry. The structure of the overview is based on the founding date of the various firms as well as their level of integration. As evident from the figure, there is a broad range of firms active in the construction of ICVs, whereas companies specializing in the necessary components are very young, with none of the firms being older than 5 years.

Figure 7: ICV Firms in China According to Level of Integration and Founding Date



Source: Own illustration

2.2 Collaboration with German Firms

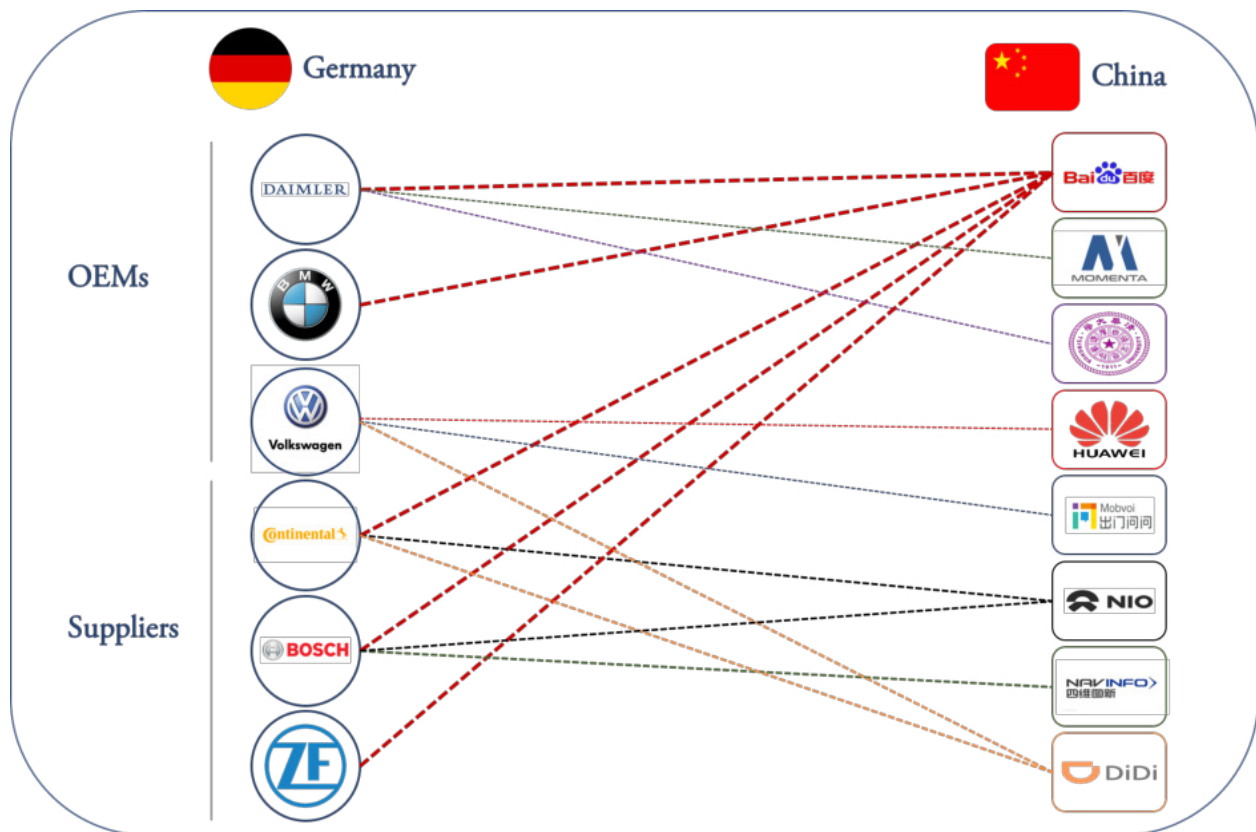
In their quest to spearhead the worldwide ICV “race”, numerous Chinese companies have forged ties with firms across the globe. Given the strategic role that leading German OEMs and suppliers play in the Chinese market, it is no surprise that Sino-German cooperation in this field has been particularly strong. Both the formats and the themes of these partnerships are broad, spanning research collaborations, JVs, vehicle construction and HD mapping.

As the Chinese firm with the most advanced ICV technology, Baidu also enjoys some of the strongest global partnerships. In the case of Germany, the company has partnership agreements with all German OEMs aside from

Volkswagen. Baidu is able to maintain close ties with companies such as Daimler, Bosch, Continental and BMW, primarily via its Apollo platform.

Most recently, Daimler announced its enhanced strategic cooperation with Baidu in the field of automated driving and vehicle connectivity. In July 2018, the two firms signed a Memorandum of Understanding (MoU) to expand their partnership through the Apollo platform. The partners will also integrate Baidu’s vehicle connectivity services into the Mercedes-Benz infotainment system, MBUX. In the context of a recent Sino-German MoU signed between the German Ministry of Transport and Digital Infrastructure

Figure 8: Sino-German Cooperation on Intelligent and Connected Vehicles (ICVs)



Source: Own illustration

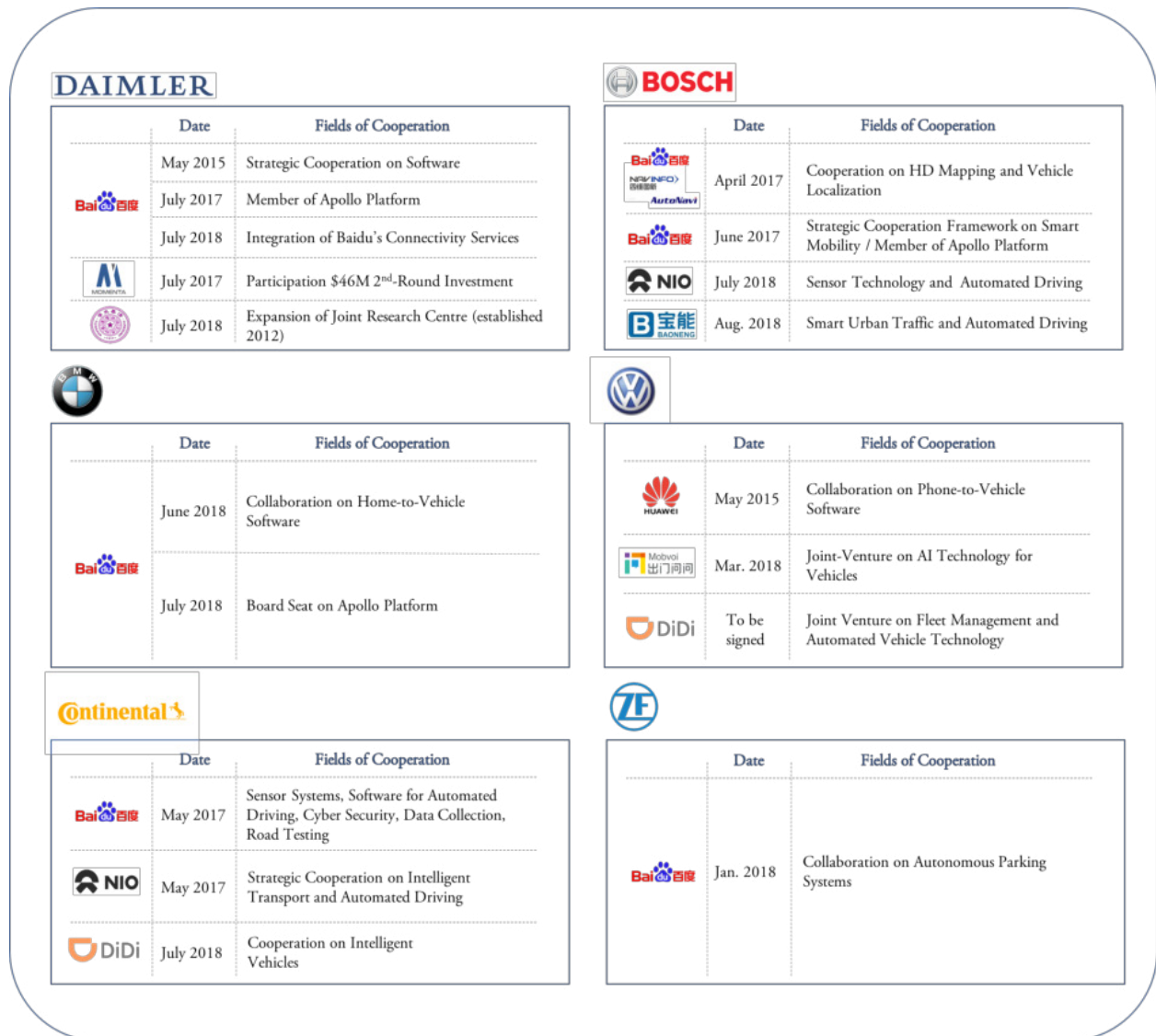
(BMVI), the German Ministry for Economic Affairs and Energy (BMWi) and China's Ministry for Industry and Information Technology (MIIT) on 9 July 2018, Daimler also widened the scope of its partnership with Tsinghua University. With an annual multi-million CNY investment, the partners will seek to sharpen the focus of their Joint Research Center for Sustainable Transportation, established in 2012, and intensify their research efforts in the fields of automated driving technology and intelligent mobility.

Several other German companies have also used the Sino-German MoU on automated driving as a stepping stone to establish ICV partnerships with Chinese firms. For instance, Didi Chuxing signed an agreement with German automotive supplier Continental to jointly develop connected vehicles and purpose-built EVs for services provided by Didi. Continental had previously also signed cooperation agreements with Baidu and NIO in the field

of automated driving technology. At the time of writing, Didi is also reported to be in talks with Volkswagen to form a JV, the aim of which is to manage part of Didi's fleet and help develop purpose-built ride-hailing vehicles. Another important area of cooperation concerns HD mapping. In April 2017, Bosch signed agreements with AutoNavi, Baidu and NavInfo. Together, the four companies are working on a solution that will allow them to use information collected by Bosch's vehicle-mounted radar and video sensors to generate and update maps.

Regarding the present state of Sino-German cooperation on ICV, it is striking that the overwhelming majority of partnerships were formed between German OEMs/suppliers and Chinese Tech Companies. As far as Chinese OEMs are concerned, only the automobile manufacturer NIO has signed agreements with Bosch and Continental. Instead, as outlined in section 2.1, most of China's OEMs are relying on cooperation with Baidu to advance their ICV plans.

Figure 9: Fields of Sino-German ICV Cooperation



Source: Own illustration



3. Legislation and Policy

3.1 Actors and Regulators of ICVs in China

Regulation of ICV-related matters in China is overseen by multiple authorities with partially overlapping responsibilities. The situation is further complicated by the fact that officials at both national and provincial levels are responsible for the relevant policy-making.

As is typical of the Chinese system, the central government provides top-down guidance and control. At the highest level, the NDRC is responsible for issuing general strategies and guidelines for the entire Chinese automotive industry, such as the *Draft Administrative Rules on Auto Industry Investment* circulated in May 2018. The NDRC also publishes implementation schemes for the industrialization of key technologies and has initiated the creation of the National ICV Innovation Platform (see section 3.3). Macro-level policy-making is complemented by the State

Council, whose high-profile *Made in China 2025* strategy, issued in 2015, seeks to transform the country into an innovation hub in a variety of sectors, including the automotive industry.

Beneath the NDRC and the State Council, the Ministry of Industry and Information Technology (MIIT), the Ministry of Transport (MOT) and the Ministry of Public Security (MPS) form the key pillars of ICV regulation in China. Crucially, these three national ministries have emerged as competent regulators for the road testing of automated vehicles, having jointly issued their respective national guidelines in April 2018 (see section 3.3). Of these three, the MIIT has the highest degree of responsibility regarding ICV regulation. Aside from being accountable for industrial policy, and thus the administration of the automobile

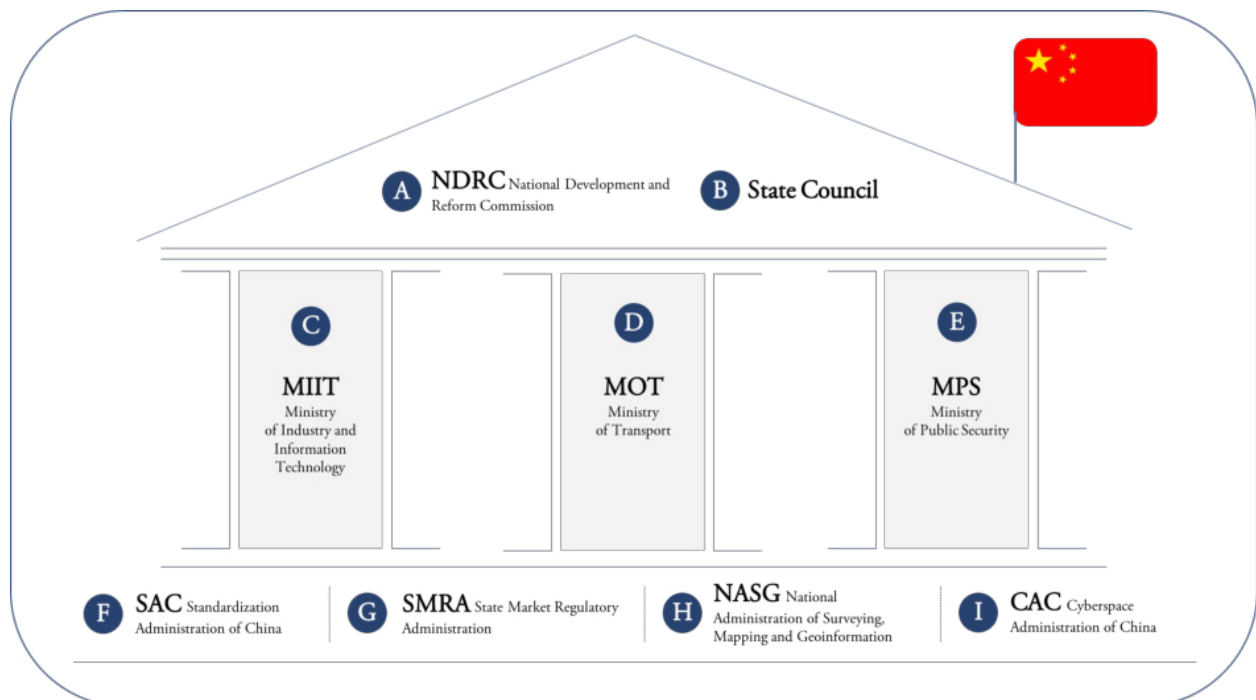
industry, the MIIT is also in charge of issuing type-approval or homologation for vehicle products. Regulations on communication technology, such as the access to radio frequencies, also fall within its scope of responsibility. The MOT, for its part, is responsible for all matters related to digital transport infrastructure, intelligent transport systems and road transportation supervision. The MPS, meanwhile, administers road traffic safety and is in charge of vehicle registration.

The national ministries are supported by various government agencies that work on specific aspects of ICV regulations. The State Market Regulatory Administration (SMRA), created in March 2018 as part of a government restructuring plan, is the responsible agency for compulsory certification in China. The National Administration of Surveying, Mapping and Geoinformation (NASG) man-

ages all matters related to surveying and mapping, and as such is the most relevant policy-making body in the field of HD mapping. The Standardization Administration of China (SAC) merged recently with the SMRA following government restructuring, although it will keep its own name and office and remain entrusted with the crucial task of establishing an ICV standards system. Lastly, the Cyberspace Administration of China (CAC) monitors and regulates all aspects of cybersecurity relating to the connectivity aspects of ICV.

In addition to these national-level administrative agencies, provincial- and municipal-level authorities are involved in ICV regulation, in particular regarding vehicle testing approval. The following section will examine the corresponding legal frameworks in China and in Germany.

Figure 10: Regulators of ICV in China



Source: *Own illustration*

3.2 Legal Framework in China and Germany

A decisive factor shaping the development of ICVs in different countries is the national legal framework for test vehicles and the type approval given to automated vehicles. This legislative aspect will become even more crucial as the technology continues to evolve and the focus shifts from testing vehicles in enclosed facilities to conducting tests on public roads.³¹

The most progressive legal framework for automated vehicles is currently in the United States – the only country to date that has legalized the testing of fully automated (Level 5) vehicles, such as Alphabet's Waymo, on public roads. As a result, the majority of road tests for automated vehicles take place in California, including those of Chinese and German manufacturers. However, both countries are undertaking rapid steps to modernize their own legal frameworks to allow them to compete with the United States. In this context, it is important to recognize that both international and domestic law are relevant to the regulation of automated vehicles.

Several international agreements currently govern national road traffic legislation, including the 1968 Vienna Convention on Road Traffic. Under this convention, highly automated driving (Level 4) has been permitted since the last amendment in March 2016. However, fully automated driving (Level 5) is not yet possible as the agreement specifies that human drivers must be present in the vehicle. Germany – unlike the United States and China – is one of the 73 countries to have ratified the convention, and as such is currently prohibited by international law from testing fully automated vehicles on public roads. Also relevant are the technical standards of the United Nations Economic Commission for Europe (UN/ECE), which regulate the type of approval granted for automated vehicles in

various European countries, including Germany. According to ECE-Rule 79, automated steering systems are only allowed up to a speed of 10 km/h. Evidently, these rules prevent vehicles with conditional or highly automated driving systems (Levels 3 and 4) from obtaining road approval in Germany. To prepare for higher levels of automation in the future, Germany is actively working to develop the Vienna Convention and revise ECE-Rule 79. At the domestic level, both China and Germany have recently introduced new legislation aimed at facilitating the testing and development of ICVs.

• Germany

On 21 June 2017, the Bundestag (German federal parliament) passed an amendment to the German Road Traffic Act permitting automated driving up to Level 4 on public roads.³² Under these new terms, the driver may take his/her eyes off the road while the vehicle takes over. However, he/she is obliged to remain aware of the traffic situation to be able to react in case of malfunction or any other situation which cannot be handled by the automated driving system. Furthermore, the driver must use the automated driving function in the manner intended by the manufacturer (e.g., a function intended for use on highways may not be used in a town). This new legislation certainly represents a big step forward for Germany, although fully automated driving (Level 5), where all vehicle occupants are merely passengers, remains prohibited.

If the driver fails to properly monitor the vehicle and traffic environment while the automatic function is engaged, he/she may be held liable in the event of an accident. If the accident is caused by a system malfunction, however, liability may fall upon the manufacturer. The question of fault is

ultimately determined by the in-built black box that each vehicle is obliged to contain. Under German car ownership laws, however, the vehicle's owner will always be held liable vis-à-vis the accident victim, even if the data from the black box absolves the driver of blame. In light of this rapid technological progress, the German government has announced its intention to further review the amendment to the Road Traffic Act in 2020.

Despite this new legislation, German manufacturers are not yet allowed to introduce automated driving technology beyond Level 2 to the commercial market. This is due to the fact that while the new law (*Straßenverkehrsgesetz*) governs driver behavior, it does not affect the type of approval granted to new vehicles with automated driving systems (*Zulassungsrecht*). As outlined above, this domain is predominantly governed by international law (UN/ECE),

which currently prohibits such systems. Thus, while the testing of automated vehicles with Level 3 and 4 technology is allowed on public roads in Germany, the same does not apply to commercial use. An example of this is the "Traffic Jam Pilot" function that Audi introduced for its new A8. This Level 3 system is capable of driving automatically up to 60 km/h in traffic jams, without the need for constant human supervision, as currently required by other Level 2 systems. However, the system³³ has yet to be launched on German roads as Audi have not obtained the necessary legal approval.

• China

For a long time, China was characterized by a highly restrictive regulatory framework when it comes to automated vehicles were completely prohibited on public roads, even

Figure 11: Road Test Licenses in China as of August 2018



Source: Own illustration

for testing purposes. In April 2018, however, to much international attention, the Chinese government announced its *Administrative Rules on ICV Road Testing*³⁴ that allow automated vehicles up to Level 4 to be tested on specified public roads. This step was widely seen as a reaction to the adoption of local testing regulations in previous months by municipal authorities in Beijing, Shanghai, Shenzhen and Chongqing.

The first Chinese city to issue such guidelines was Beijing in December 2017. Although Shanghai lost out in the race to be the first city to publish road-testing rules for automated vehicles, it was the first to issue test permits. On 1 March 2018, the Shanghai authorities granted their approval to two companies: the Chinese OEM SAIC Motor and the EV start-up NIO. Beijing was quick to follow suit, granting its first test permits to Baidu on 22 March 2018 and one permit each to NIO and BAIC on 25 April 2018. On 14 May 2018, BMW became the first foreign manufacturer to be granted a testing permit in China (Shanghai), followed closely by Daimler, which received its Beijing license in July 2018.

The new national regulations on the testing of automated vehicles were released jointly by MIIT, MPS and MOT and entered into force on 1 May 2018. As outlined in section 3.1, these three national ministries will also be the regulators for future automatic driving road testing. While local authorities are granted a high degree of autonomy in organizing road tests for automated vehicles, they are still obliged to submit reports to the regulators, including any accidents that may occur.

According to Chinese legislation, testing is subject to prior regulatory approval and various requirements. Any applicant for road testing must be an independent legal entity, registered in China, that has successfully conducted tests

in enclosed facilities prior to their application. Moreover, tests can only be conducted on designated roads, which are selected by the local authorities and made known to the public. The applicant must also be able to record, analyze and reconstruct the testing procedure – a prerequisite similar to the use of the black box in Germany.

In terms of the actual testing, national regulations specify that a test driver must always be present to monitor the status of the test vehicle and the driving environment. Again, similar to the requirements in Germany, the regulations state that the test driver must be able to take over if he/she notices that the vehicle is not suitable for use in automated mode or if the system requests that the driver intervene. These national requirements are stricter than earlier local regulations, with safety highlighted as a top priority. This is likely a reaction by the Chinese authorities to the high-profile crashes involving Tesla and Uber in the United States in March 2018.















• Comparison of the Legal Frameworks

Comparing the legal frameworks in China and Germany reveals some similarities, as well as several striking differences. In terms of similarities, both countries require a driver to be present at all times and ready to take control of the vehicle. Consequently, fully automated driving technology (Level 5) is currently not permitted. All automated vehicles must also be equipped with a black box to determine fault in the event of an accident. With respect to their differences, Chinese regulations are generally more conservative than those in Germany. Significantly, Chinese national guidelines only specify rules for testing on public roads, not the commercial use of automated vehicles. Testing is also only possible on selected public roads. However, China is not a signatory to the 1968 Vienna Convention on Road Traffic, nor is it committed to the UN/ECE

approval regulations. The authorities in Beijing could hence enact legislation in the future with greater ease than their German counterparts – legislation that could potentially include fully automated driving (Level 5). Progress in Germany, by contrast, is limited by the international

agreements to which it adheres. Therefore, while it remains true that the legal framework is currently more progressive in Germany, China has the potential to swiftly shift this balance in its favor in the near future.

Figure 12: Comparison of the Legal Frameworks on ICVs in Germany and China

	 Legal Framework on ICV in Germany	 Legal Framework on ICV in China
Testing		
<i>Permitted?</i>	 Yes, on <u>all</u> public roads	 Yes, on <u>selected</u> public roads
<i>Which Levels?</i>	 Up to level 4. Level 5 is prohibited.	 Up to level 4. Level 5 is prohibited.
<i>Requirements?</i>	 Human Driver present at all times	 Human Driver present at all times
	 Black Box to record, analyze, reproduce	 Black Box to record, analyze, reproduce
Commercial Use	 <ul style="list-style-type: none"> Only permitted up to level 2 Further automation prohibited by <u>international</u> law 	 <ul style="list-style-type: none"> Only permitted up to level 2 Further automation prohibited by <u>domestic</u> law
Liability	 <ul style="list-style-type: none"> Driver always responsible May exclude liability if system fails, then manufacturer may be held liable Vehicle's owner remains liable vis-à-vis accident's victims, even if system fails 	 <ul style="list-style-type: none"> Test Driver and Applicant responsible Applicant must have financial capability to compensate damage during testing Within 24h of accident, black box must be sent to authorities

Source: Own illustration

3.3 ICV Strategies, Standards and Policies in China

In addition to the regulations on road testing, the Chinese government has recently released a series of strategies, standards and policies whose aim is to accelerate the development of ICVs. These “strategies” refer to documents that are somewhat general in nature and define overarching development targets. Contrastingly, “standards” are highly specific and vital to ensuring that the systems of different manufacturers can effectively communicate not only with each other but also with the external infrastructure. “Policies” sum up all further measures taken by the Chinese government to advance the development of ICVs, notably the establishment of various coordination bodies.

• Strategies

The development of ICVs combines elements of all three of China’s current key national technology strategies: (1) *Made in China 2025*; (2) *Internet Plus*; and the (3) *Artificial Intelligence (AI) Strategic Plan*. The promotion of both the automotive industry in general and innovative technologies in particular at the highest level of government shows China’s strong potential in the international ICV “race”, and the determination of the government to shape this process.

The *Made in China 2025* strategy released by the State Council in May 2015 identifies the automotive industry as one of the ten strategic areas to be developed between now and 2025. Specifically, China has set itself the following targets, which can be seen as closely related to ICV development: (1) reducing traffic accidents by more than 30 % and traffic deaths by at least 10 %; (2) setting the driving speed of automated vehicles at 120 km/h; (3) reducing energy consumption by more than 10 % and emissions by more than 20 %, compared to regular vehicles.

In March 2015, China’s Premier, Li Keqiang, proposed *Internet Plus* – a five-year plan to integrate cloud computing, big data and the Internet of Things (IoT) in various industries. The initiative’s ambitious goal is to transform, modernize and equip traditional industries in China to join the modern economy. Among other things, the Chinese government seeks to increase funds for research and development to 2.5 % of GDP through 2020, to ensure that 98 % of the population has access to broadband, and to provide 100 MB/s internet connections in large cities.

On 8 July 2018, the State Council released its *Artificial Intelligence (AI) Strategic Plan*. The plan will proceed in three stages: 1) by 2020, China aims to bring the country’s AI up to global standards and to develop an AI industry worth at least CNY 150 billion; 2) by 2025, the AI industry will be worth CNY 400 billion, including the automotive sector; and 3) by 2030, China will have become the world’s primary AI innovation center.

As well as these rather general industry plans, the Chinese government has released various documents specifically related to the development of ICVs. In terms of strategy, the most important of these is the *Draft Strategy for Innovation and Development of Intelligent Vehicles* announced by the NDRC on 5 January 2018. Specifically, the Draft Strategy lays out a 3-phase vision for the development of ICVs in China. By 2020, the Chinese authorities aim to have set up a systematic regulatory framework for ICVs. Moreover, ICVs with partial or fully automated functions should account for 50 % of all new cars in China. Wireless telecommunication networks for vehicles (LTE-V2X) will be available on 90 % of highways in big cities. By 2025, almost 100 % of all new vehicles produced will be intelligent, and a new generation wireless telecommunication network for vehicles

(5G – V2X) will be operational. By 2030, China aims to become the world leader for ICVs.

These goals are also in line with China's *Medium- and Long-Term Automotive Industry Development Plan*, issued by the NRDC in conjunction with the MIIT and the Ministry of Science and Technology (MOST) on 6 April 2017. This plan was further refined in July 2018, when the MIIT approved eight more concrete projects after review by an expert group comprising leading figures from both academia and the automotive industry.³⁵

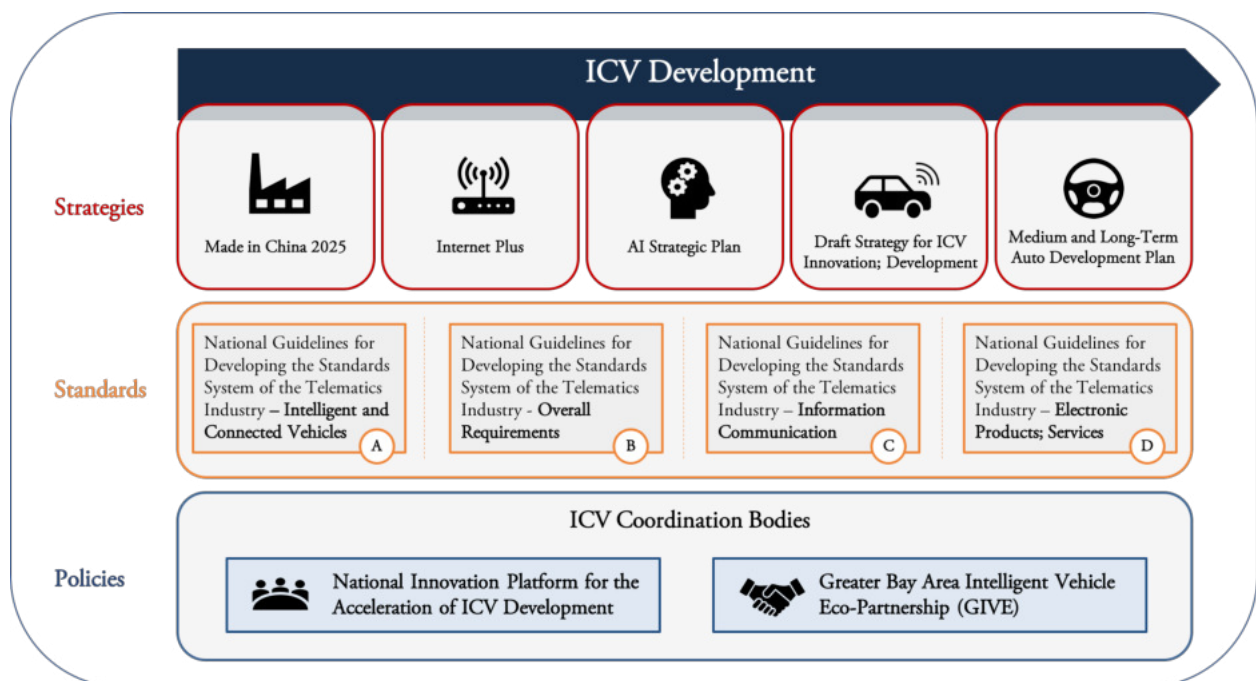
• Standards

Beginning in December 2017, MIIT, in collaboration with SAC, issued a comprehensive set of four national guidelines to provide the framework for the development of an ICV standards system in China. The plan is to establish

this system in two phases: by 2020, a standards system featuring 30 ICV key standards should be in place to support automated driving Levels 1-3; and by 2025, a standards system featuring more than 100 ICV key standards should be in place to support automated driving Levels 1-5. Specifically, the four guidelines are as follows:

- i. *December 2017*: National Guidelines for Developing the Standards System of the Telematics Industry (ICVs) 《国家车联网产业标准体系建设指南（智能网联汽车）》
- ii. *June 2018*: The National Guidelines for Developing the Standards System of the Telematics Industry (Overall Requirements) 《国家车联网产业标准体系建设指南（总体要求）》
- iii. *June 2018*: The National Guidelines for Developing the Standards System of the Telematics Industry (Information Communication) 《国家车联网产业

Figure 13: ICV Strategies, Standards and Policies in China



Source: Own illustration

标准体系建设指南（信息通信）》

iv. June 2018: The National Guidelines for Developing the Standards System of the Telematics Industry (Electronic Products & Services) 《国家车联网产业标准体系建设指南（电子产品和服务）》

While these guidelines offer a high degree of detail, they remain “only” guidelines; i.e., a pathway for the future development of binding standards. Figure 13 below summarizes the key targets for ICV development in China as set out in the described strategies and standards goals.

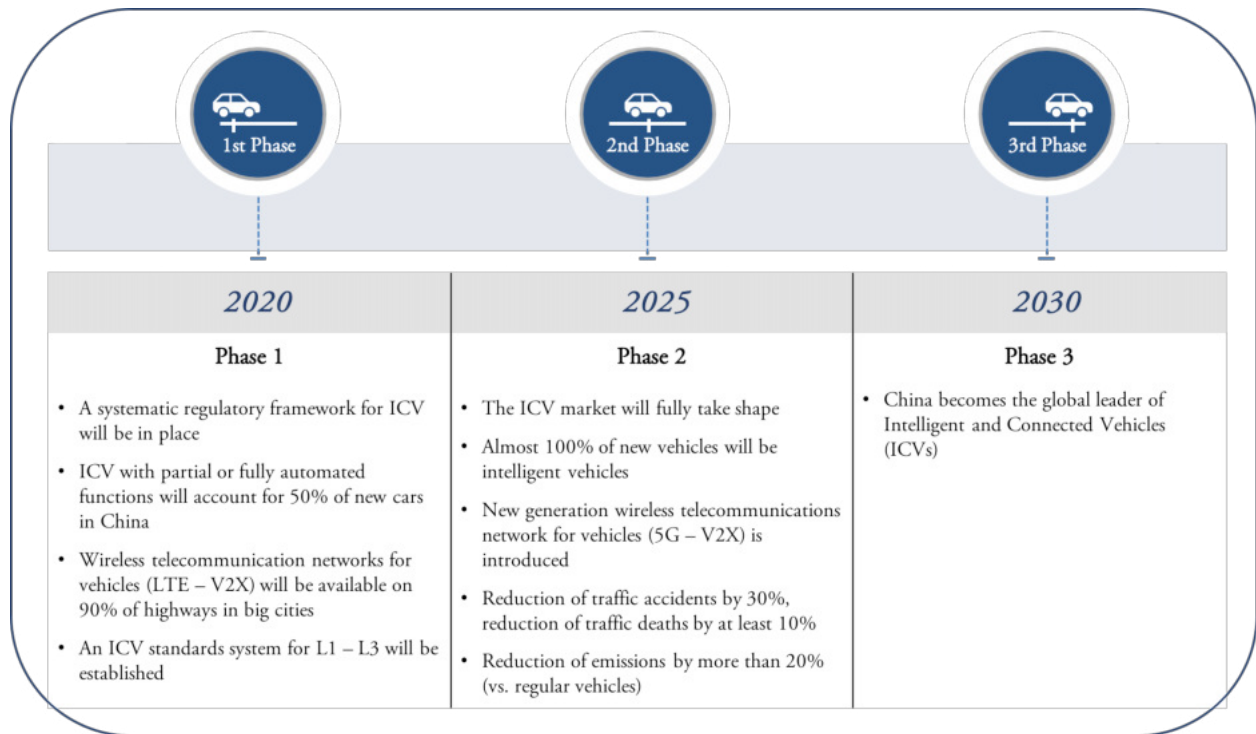
• Policies

In addition to the strategies and guidelines for standards development, the Chinese government has taken concrete steps to foster the creation of an ICV ecosystem. Notably, this includes the establishment of two coordination bodies for ICV development. In December 2017, the NDRC set up a National Innovation Platform for the Acceleration of ICV Development. The platform was established to

address obstacles in the development of ICVs and to ensure the effective implementation of national strategies. Its role is also to facilitate policy-making and promote R&D relating to ICVs.³⁶ The platform consists of a council, an advisory committee, and a platform institute (National ICV Institute Co. Ltd., founded on 19 December 2017 by MIIT, comprising 21 ICV enterprises).

Most recently, the Shenzhen Municipal Government, together with the prestigious think-tank China EV100 and the Green and Low-Carbon Development Foundation (GDF), launched the Greater Bay Area Intelligent Vehicle Eco-Partnership (GIVE). The objective of this high-level platform is to accelerate the formation of the ICV industry ecosystem, specifically in the Greater Bay Area (GBA) including Hong Kong, Macau, and province of Guangdong. To date, more than 100 members from business and academia have joined GIVE. Companies represented include Tesla and Bosch, and, since July 2018, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH.

Figure 14: 3-Phase Vision for ICV Development in China



Source: Own illustration



4. SWOT-Analysis

As indicated in previous chapters, China has the potential to be at the forefront of the global “race” for Intelligent and Connected Vehicles (ICVs). However, this report has also touched upon the many challenges linked to the successful development of these technologies. This chapter contains a comparative SWOT-Analysis of China and Germany, the aim which is to provide a better understanding of the

advantages (strengths and opportunities) and disadvantages (weaknesses and threats) of ICV development in the two countries. “Strengths and weaknesses,” in this context, will pertain to ICV development as it stands at present, while “opportunities and threats” will focus on future potential. The analysis will draw on previously discussed insights, as well as introducing some new perspectives.

4.1 SWOT-Analysis for China

• Advantages

Strengths

China’s ICV development strengths include aspects relating to both policy and the market. While Chinese authorities were initially reluctant to accelerate ICV development, the topic now enjoys strong national- and local-level gov-

ernment support, as evidenced by the numerous ICV-related strategies and guidelines released in recent months (see section 3.3) as well as the liberalization of road-testing regulations (see section 3.2). China also benefits from its relatively advanced digital infrastructure. In particular, the country maintains a high-performing cellular network, with 4G coverage reaching 74 % of the population in 2016

(for comparison, the coverage rate in Germany was 57.1 % over the same period).³⁷

China's position as a world leader in connectivity-based technologies and internet-related services drives the rapid development of the country's ICV industry. It is no coincidence that the leading ICV firms in China are tech companies such as Baidu, which possess strong capabilities in many related fields (see section 2.1). One reason for the large number of successful tech companies in China is the high degree of openness on the part of Chinese consumers towards new and innovative technologies. This widespread attitude could be a great advantage for a mobility future defined by ICVs. As previously mentioned in section 1.3, studies have found that the acceptance rate towards automated vehicles is significantly higher in China than in competitor countries such as the United States or Germany.

Opportunities

China's strengths form the basis for its ICV development opportunities. First and foremost, China's unique political system has the potential to greatly accelerate ICV development. At present, most ICV policymaking takes place at the national level (see section 3.1). This top-down approach could significantly simplify complicated regulatory processes that may prove an impediment to competing federal systems. Moreover, China is not restricted by international agreements on road safety and traffic legislation, such as the 1968 Vienna Convention and ECE Rule-79 (see section 3.2). While Germany is beholden to the potentially tedious process of amending these rules at an international level, China could pass new legislation permitting automated driving on public roads in a very

short time span.

In addition to these potential policy advantages, China's clearest opportunity lies in the sheer size of its market. China is currently the largest automotive market in the world, both in terms of production volumes and sales figures. These numbers are expected to grow even further in coming years, as the rate of vehicle ownership (121 vehicles per 1,000 people in 2015) is still well below the levels of, for instance, Germany (555 vehicles per 1,000 people in 2016). China is also the world's largest market for New Energy Vehicles (NEVs). The pace of NEV development in China is remarkable: in the first half of 2018 alone, NEV sales had already reached 412,000, up from 195,000 vehicles sold in the first half of the previous year. In comparison, NEV sales in Germany in the first six months of 2018 stood at 33,917, up from 22,453 in the first half of 2017.³⁸ Given that ICVs will most likely be NEVs, China will be able to leverage its strong NEV industry for the further development of ICVs. The country also has a relatively high ratio of electric vehicles to charging points (3.8:1)³⁹, reflecting its willingness to update its road network for new technologies. In comparison, Germany's ratio is one charging point to roughly 10 electric vehicles.⁴⁰

Valued at USD 23 billion, China's ride-hailing market is larger than that of the rest of the world combined. China also features some of the strongest industry players. Didi Chuxing, for instance, provides more than 30 million rides per day – roughly twice as many as its main American competitor, Uber. Given that fleets of shared automated vehicles are one of the most likely future uses of ICVs, China's ride-hailing industry offers huge potential for the successful deployment of ICV technology.

• Disadvantages

Weaknesses

While China's top-down approach to public policymaking allows for the swift installation of a highly progressive regulatory framework, current ICV regulations still constitute a weakness. Despite recent changes, China's regulatory environment is still less progressive than that of competitors such as Germany or the United States. While the public road testing regulations passed in April 2016 represent a big step forward, the testing of fully automated vehicles (Level 5) remains prohibited, and testing is only allowed on selected roads (see section 3.2). In terms of ICV standards, China has only issued guidelines; these have yet to be transferred into binding legal texts and regulations (see section 3.3). Likewise, strict regulations with regards to HD mapping for automated vehicles remain in place. Companies require special licenses from the National Administration of Surveying, Mapping, and Geo-Information (NASG) to collect data about road conditions and the height or weight limits of bridges. In particular, they are forbidden to collect any road data around military districts. For foreign companies, rigid restrictions apply to the collection, storage and processing of data. According to the Surveying and Mapping Law, foreign-invested entities are not eligible for the highest-level license allowing for wide-ranging data collection and processing for survey and mapping activities. Moreover, under the Cybersecurity Law, personal information collected or generated in China must be assessed before being transferred overseas. This creates an effective restriction for foreign companies seeking to transfer data outside of China.

The regulatory system in China is still characterized by a relatively fragmented dispersion of responsibilities (see section 3.1). Multiple ministries are in charge of ICV regulations, and manufacturers seek greater clarity re-

garding who regulates what and how these regulations are applied. For China to fully realize its policymaking advantages, ministries and agencies must be able to communicate effectively.

China also faces several challenges in terms of infrastructure. While the country is equipped with a high-performing cellular network, there is no comprehensive smart infrastructure that would enable wireless communication with vehicles. Another obstacle is the complexity of the traffic environment, particularly in large cities, while road conditions in rural areas are often not ideal.

Threats

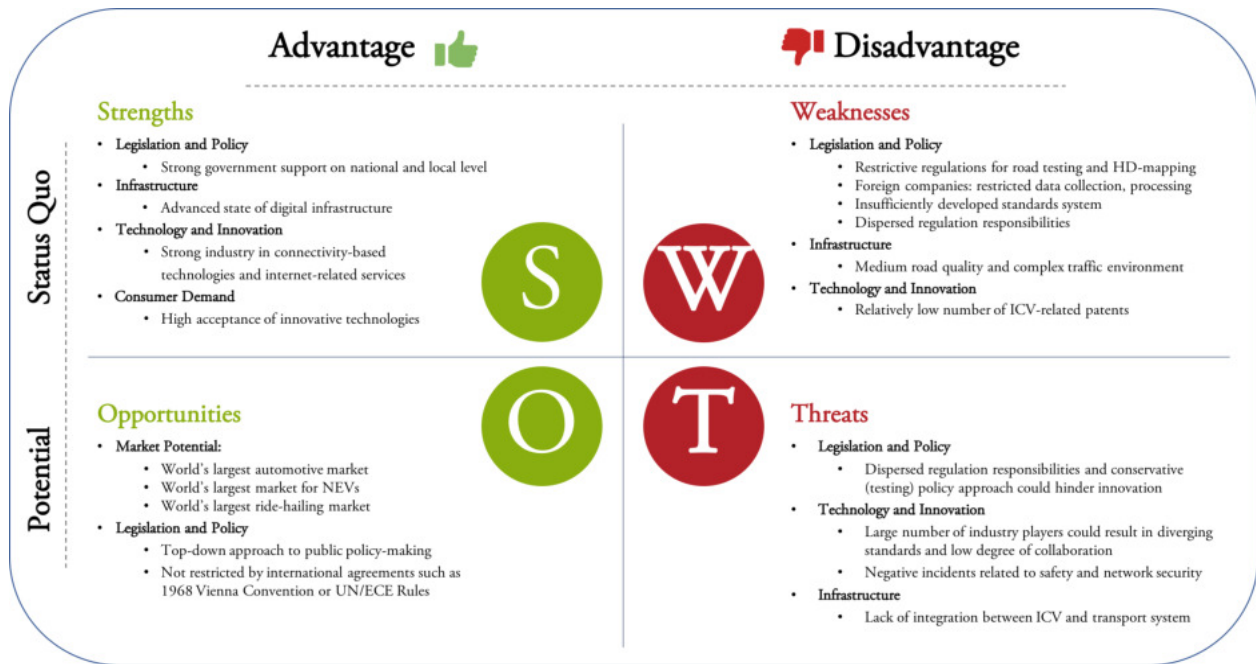
The above-mentioned weaknesses are the foundation for possible "threats" to ICV development in China. With regards to legislation and policy, the dispersed regulatory responsibilities and the rather conservative approach to public road testing could hinder long-term innovation. On the market side, the large number of firms currently active in China's ICV industry (see section 2.1) could result in diverging standards and a low degree of collaboration. The reference case in this regard is the Chinese NEV industry, where high government subsidies led to an increasing number of companies flooding the market with often low-quality vehicles. Moreover, as evident from the cases involving Uber and Tesla, negative incidents calling into question the safety of ICVs could significantly delay development.

Lastly, the successful development of ICVs encompasses more than the technological challenge of automated driving. Ultimately, China aspires to create an "intelligent transport eco-system" that integrates ICVs as one of its key components. In addition to the question of how best to connect and coordinate ICVs, the integration of ICVs into

the present transport system remains a central concern. To fully realize the potential of ICVs, three sets of challenges must be addressed: (1) the integration of ICVs with

non-intelligent vehicles; (2) the integration of ICVs with non-motorized vehicles; and (3) the integration of ICVs with the existing transport infrastructure (roads etc.).

Figure 15: SWOT-Analysis for ICV in China



Source: Own illustration

4.2 SWOT-Analysis for Germany

• Advantages

Strengths

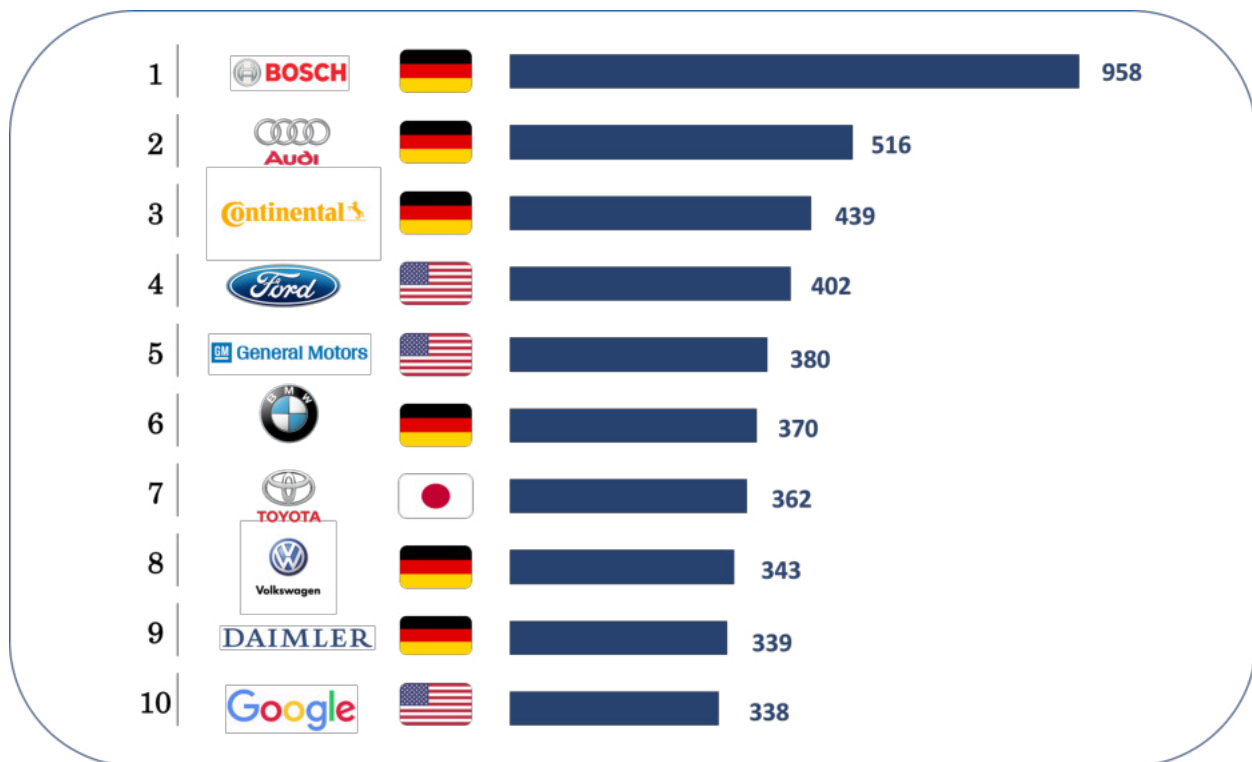
As for China, Germany's strengths apply to both policy and the market. One of Germany's main assets is its well-developed legal framework, which was revised in June 2017 to prepare the country for a future in which automated vehicles play an integral role (see section 3.2). Testing automated driving technology under real-life conditions is a crucial component when it comes to achieving full automation, and Germany currently offers one of the best international environments to conduct such tests. The German government has already indicated that it will revise the existing law in 2020 to account for the latest

technological developments.

Physical infrastructure also plays an important role in the development and testing of ICVs. In this regard, the high quality of Germany's road infrastructure and the conditions of the overall traffic environment provide a solid foundation. The relatively high population density also allows for tests that encompass a broad range of different traffic situations – highways, country roads, city traffic – within a relatively small space.

Another distinct advantage lies in Germany's long automotive tradition. The German automobile industry is regarded as one of the most competitive and innovative in

Figure 16: Worldwide Patent Filings related to Automated Driving (January 2010 – July 2017)



Source: Own illustration

the world, and this status is reflected in the field of ICV technology. Notably, Germany's automotive industry is the world's leading provider of driver assistance systems and technologies,⁴³ such as radar systems and actuator technologies. As such, the country is well prepared to play a leading role in the quest for higher degrees of automation – an intent that is evidenced by its high number of ICV-related patents and publications. According to the Cologne Institute for Economic Research, six out of the top ten automated driving patent holders worldwide are of German origin. Of these, Bosch is leading the field with 958 relevant patents filed between January 2010 and July 2017.⁴⁴

Opportunities

German automotive manufacturers sell the majority of their vehicles in the premium and luxury segments. Given that both automation and connectivity functions are generally introduced top-down (i.e., as optional equipment in higher priced vehicles), there is great potential for German OEMs to bring their systems to the global market while benefiting from economies of scale. Additionally, Germany's status as a key automotive player means that the requisite sophisticated research and investment environment is already in place. German OEMs have a large pool of highly qualified engineers and staff at their disposal, with up to one-eighth employed in R&D.⁴⁵ In the same vein, the research clusters of automotive manufacturers are closely interlinked with leading universities and public research facilities. This strong technological know-how among German OEMs could potentially be leveraged by, and transferred to other sectors involved in the development of ICVs.

Germany's road infrastructure is well suited not only to the testing of automated vehicles but also to their future commercial use. Significantly, the German Autobahn, as

well as the country's other highways, are equipped with continuous lane markings and uniform road signs. This will likely minimize the cases in which automated systems will ask the driver to take over as the limits of the system have been reached.

German OEMs and suppliers are also in a good position to develop overarching backend solutions for ICVs. In the past, German OEMs deployed different backend systems to support their automated driving technology. In August 2015, however, BMW, Audi and Daimler collectively acquired Nokia's mapping division, HERE, for USD 3.2 billion.⁴⁵ This presents German OEMs with the opportunity to offer consolidated backend solutions that span several companies, improving traffic and vehicle safety.

• **Disadvantages**

Weaknesses

One of the biggest obstacles for the general adoption and operation of ICVs in Germany are unresolved legal issues. While Germany has modernized its road traffic legislation (*Straßenverkehrsgesetz*) to account for the possibility of automated driving up to level 4, the laws governing vehicle type approval (*Zulassungsrecht*) currently still prohibit the use of systems above level 2 for commercial use. This is mainly due to the fact that vehicle type approval in Germany is in turn dependent on international law, which currently prevents road approval for such systems (see section 3.2). This could prove to be a major stumbling block for Germany as revising such regulations at the international level is a complicated and often time-intensive process.

Alongside a well-developed legal framework, a powerful mobile data network covering the entire autobahn network and the progressive implementation of a smart transportation infrastructure are key requirements for automated

driving. There is significant potential for improvement in both of these areas in Germany. A recent analysis by the wireless company OpenSignal found that Germany features amongst the lowest rated countries in Western Europe for 4G experience, with an average LTE speed of just 22.7 Mbps. Its 4G availability was little better with a score of 65.7 %.⁴⁶ In comparison, 4G availability stood at 92.2 % in Norway, 89.6 % in the Netherlands and 87.4 % in the Czech Republic.⁴⁷ Moreover, so far, there are no concrete plans in Germany to equip its Autobahn network with the relevant technology to enable V2X communication.

Ultimately, the success of ICVs hinges on the question whether consumers accept the related technology. However, as several studies have highlighted, consumers in Germany appear to be rather skeptical towards automated driving technology. For instance, a survey conducted by the World Economic Forum (WEF) found that less than half of respondents in Germany (44 %) would be willing to ride in an automated vehicle. This stands in stark contrast to the 75 % of consumers in China who answered yes to the same question.⁴⁸

Threats

In the past, the automotive industry was characterized by relatively high access barriers. However, as the importance of traditional automotive technology declines, and connectivity-based technologies become more vital, start-ups and tech companies are becoming ever more relevant. While German automakers currently hold a leading position at the lower levels of automated driving (Levels 1-3), they can anticipate tremendous competitive pressure from emerging, government-backed players in competitor countries such as China. Indeed, when it comes to supporting its own emerging players, Germany seems to be lagging behind. Venture capital investments in ICV are compar-

atively low, and investments by German OEMs in ICV technology is most often overseas – for instance, in California. Also, competitor countries such as China often view the topic of “intelligent mobility” in a more comprehensive way, considering higher levels of automation as well as smart infrastructure (see section 1.1).

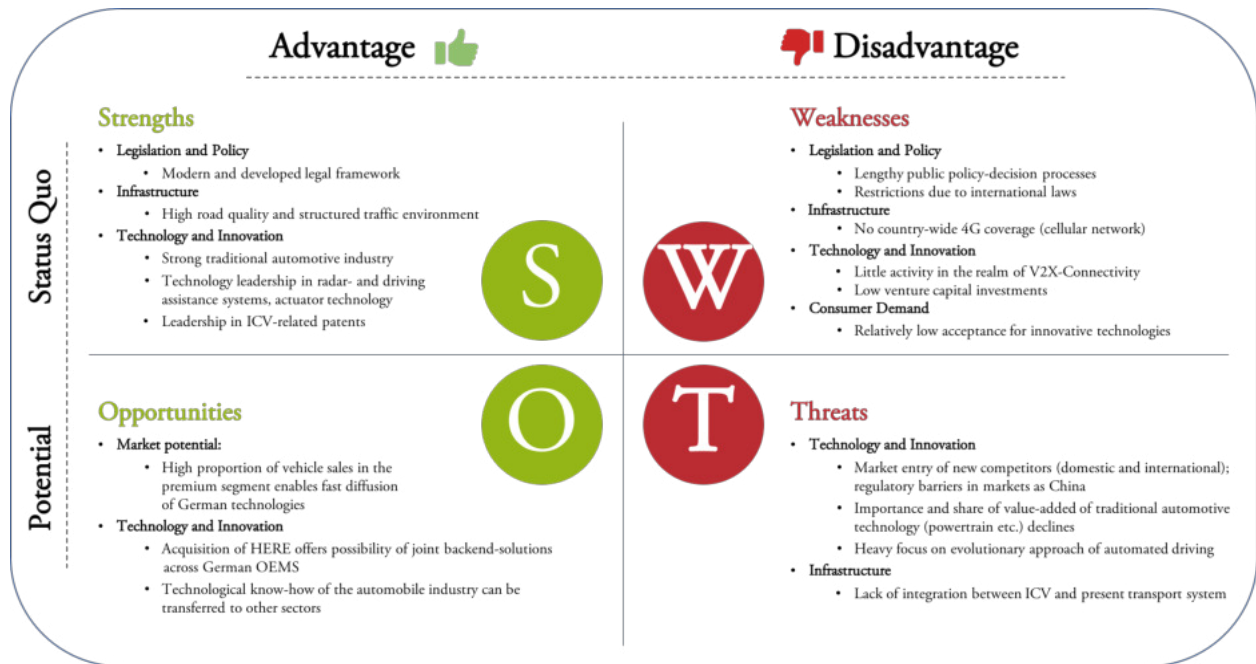
German OEMs rely heavily on an evolutionary development approach to automated driving technology. New technologies and more advanced driving assistance systems are incrementally introduced, leading to higher degrees of automation. This stands in contrast to the development approach of both American (e.g. Waymo) and Chinese (e.g. Baidu) tech companies, who seek to build fully-automated (Level 5) vehicles from scratch. There is hence a risk that German OEMs may miss out on opportunities presented by, for instance, driverless shuttle systems in urban areas.

Lastly, success in China is critical to the success of the German automotive industry as a whole. China is by far the most important foreign automotive market: in 2016, 4.9 million German cars were sold here, up from 1.5 million in 2009.⁴⁹ Given the strategic importance of the Chinese automotive market for German OEMs, a level playing field for ICV development is crucial. However, the development of new ICV standards in China may potentially create access barriers for German firms. The first signs of this appeared on 28 June 2018, when the NDRC and the Ministry of Commerce (MOFCOM) released a 2018 version of the *Negative List for Foreign Investment*.⁵⁰ While the number of items on the list was reduced from 63 to 48, and opening-up measures in sectors including finance and energy were introduced, the list includes investment restrictions for several fields that are closely related to ICV development, including telecommunications, internet services and mapping technology. On 4 July 2018, in addition to these general restrictions, the NDRC released the

second *Draft Administrative Regulations on Investment in the Chinese Automotive Industry*, which focuses on the automotive sector. To date, the investment restrictions

presented in this document apply mainly to conventional vehicles and NEVs. However, these examples show that similar restrictions could be implemented for ICVs.

Figure 17: SWOT-Analysis for ICV in Germany



Source: Own illustration

The background of the page features a cityscape with a network overlay. A large, glowing blue Wi-Fi symbol is positioned in the upper right, with lines radiating from it to connect to various points across the city. Another smaller, glowing blue circle with a white laptop icon is located on the left side. The city itself is shown in a hazy, blue-tinted style, with a highway curving through the lower right portion of the image.

5. Outlook and the Road Ahead

The world stands on the verge of a mobility revolution. Technology is transforming the way we get from A to B, and the pace of innovation is accelerating. The development of automated and connected driving in the form of ICVs is an integral part of this transformation, both in China and in Germany. On the one hand, this megatrend has the potential to redefine markets, business models and customer relationships. On the other hand, it will force us to think about the safety, ethics and the legal boundaries of technology in a new way.

As this report has shown, China and Germany are at the forefront of these developments. Both countries have undertaken a series of measures to accelerate the development of ICVs, with ambitious targets being set by the respective

governments. The two countries' common ambition to lead the ICV "race" is driven in part by societal considerations, such as the promised benefits for road safety, and in part by the economic implications of this multi-billion-dollar reconfiguration of the automotive landscape. China and Germany each bring unique capabilities and players to the table, be it the strong automotive industry in Germany or the high-performing tech companies in China. At present, Germany, with its more sophisticated regulatory environment, seems to have an upper hand in the development of ICVs, particularly for lower levels of automation. However, China has the potential to rapidly catch up given its strengths in digital technologies and smart infrastructure, the vast resources of its tech companies, and its top-down approach to public policy.



Despite all the potential benefits, opportunities and ambitious targets, this report has also shown that the road to a future in which ICVs predominate is complex and full of challenges. While some of these challenges are country specific, many obstacles on the path to automated and connected driving apply across the board. In particular, a well-thought-out legal framework for ICVs will need to be implemented, as well as basic standards of interoperability across countries and continents. The Chinese and the German governments will have to think about how to integrate these vehicles into the broader eco-system of smart transportation. This will require large investments in both physical and digital infrastructure, neither of which are presently able to support the mass use of ICVs in either country.

By highlighting the mutual opportunities and challenges for ICV development in China and Germany, this report seeks to open dialogue and illustrate the strong potential for Sino-German cooperation. The recent Sino-German MoU on automated driving, signed on 9 July 2018 in Berlin, marks an important first step in this direction. However, the commitments undertaken to achieve a level playing field, equal treatment and transparent cooperation need to be followed up by concrete initiatives. This report hopes to have shed some light on areas that may be best suited for the next steps in this Sino-German cooperation, and to have offered some encouragement to both sides moving forwards.

6. References

- [1] Statista (2018): Car sales (passenger and commercial vehicles) in China from 2008 to 2018. URL: <https://www.statista.com/statistics/233743/vehicle-sales-in-china/>
- [2] Reuters (2017): China targets 35 million vehicle sales by 2025. URL: <https://www.reuters.com/article/us-china-autos-electric/china-targets-35-million-vehicle-sales-by-2025-nevs-to-make-up-one-fifth-idUSKBN17R086>
- [3] Roland Berger (2018): Automated Vehicles Index Q4 2017. URL: https://www.rolandberger.com/en/Publications/pub_automated_vehicles_index_q4_2017.html
- [4] Bundesministerium für Verkehr und digitale Infrastruktur (2015): Strategie Automatisiertes und Vernetztes Fahren. URL: https://www.bmvi.de/SharedDocs/DE/Publikationen/DG/broschuere-strategie-automatisiertes-vernetztes-fahren.pdf?__blob=publicationFile
- [5] National Development and Reform Commission (2018): Draft Strategy for Innovation and Development of ICV. URL: www.ndrc.gov.cn/yjzq/201801/t20180105_873146.html
- [6] GIZ (2018): The 2018 Global Intelligent Vehicle (GIV) Summit. URL: <http://www.sustainabletransport.org/archives/6102>
- [7] Society of Automotive Engineers (2016): Classification of Automated Driving. URL: https://www.sae.org/standards/content/j3016_201609/
- [8] World Health Organization (2018): Road Traffic Injuries. URL: <http://www.who.int/news-room/fact-sheets/detail/road-traffic-injuries>
- [9] BMVI (2017): Report of the Ethics Commission on Automated and Connected Driving. URL: https://www.bmvi.de/SharedDocs/EN/publications/report-ethics-commission.pdf?__blob=publicationFile
- [10] Reuters (2017): China may adopt some of Germany's laws on self-driving cars. URL: <https://www.reuters.com/article/us-autos-autonomous-germany-china/china-may-adopt-some-of-germanys-law-on-self-driving-cars-expert-idUSKCN1GR2TJ>
- [11] Wired (2015): The Jeep Hackers are back to prove car hacking can get much worse. URL: <https://www.wired.com/2016/08/jeep-hackers-return-high-speed-steering-acceleration-hacks/>
- [12] KPMG (2018): 2018 Autonomous Vehicles Readiness Index. URL: <https://home.kpmg.com/xx/en/home/insights/2018/01/2018-autonomous-vehicles-readiness-index.html>
- [13] International Transport Forum (2015): Urban Mobility System Upgrade. How shared self-driving cars could change city traffic. URL: https://www.itf-oecd.org/sites/default/files/docs/15cpb_self-drivingcars.pdf
- [14] Fraunhofer-Gesellschaft (2017): Wie sieht die Zukunft des autonomen Fahrens aus? URL: https://www.morgenstadt.de/de/aktuelles/interview_schaufler.html
- [15] Roland Berger (2018): Reconnecting the Rural: Autonomous Driving. URL: https://www.rolandberger.com/en/Publications/pub_reconnecting_the_rural_autonomous_driving.html
- [16] Intel (2017): Accelerating the Future: The Economic Impact of the Emerging Passenger Economy. URL: <https://preview.tinyurl.com/ycps9xgh>
- [17] KPMG (2018): 2018 Autonomous Vehicles Readiness Index. URL: <https://tinyurl.com/yabrebpl>

- [18] World Health Organization (2018): Road Traffic Deaths. Data by Country. URL: <http://apps.who.int/gho/data/node.main.A997>
- [19] World Economic Forum (2015): Are we ready for self-driving cars? URL: <https://www.weforum.org/agenda/2015/11/are-we-ready-for-self-driving-cars/>
- [20] Washington Post (2017): Driverless cars could be a solution to climate change – but two major things have to happen. URL: <https://www.washingtonpost.com/sf/brand-connect/ucdavis/driverless-cars-could-be-a-solution-to-climate-change/?noredirect=on>
- [21] Medium (2018): The future of mobility belongs to people, not self-driving cars. URL: <https://medium.com/@parismarx/the-future-of-mobility-belongs-to-people-not-self-driving-cars-625c05b29692>
- [22] Shi, Jianyu (2018): Breakdown of China's Self-Driving Car Industry. URL: <https://medium.com/@fisher.jianyu.shi/breakdown-of-chinese-self-driving-car-industry-dd20deea7e73>
- [23] Baidu (2018): Apollo Autonomous Driving Platform. URL: Apollo.auto
- [24] BMW (2018): BMW and Baidu join Forces to Accelerate the Development of Autonomous Driving. URL: <https://www.press.bmwgroup.com/global/article/detail/T0282944EN/bmw-group-and-baidu-join-forces-to-accelerate-the-development-of-autonomous-driving-in-china?language=en>
- [25] State of California (2018): Testing of Autonomous Vehicles. URL: <https://www.dmv.ca.gov/portal/dmv/detail/vr/autonomous/testing>
- [26] South China Morning Post (16.04.2018): Alibaba confirms Self-Driving Car Tests. URL: <https://www.scmp.com/tech/china-tech/article/2141954/alibaba-confirms-self-driving-car-tests-joining-baidu-and-tencent>
- [27] Shi, Jianyu (2018): Breakdown of China's Self-Driving Car Industry. URL: <https://medium.com/@fisher.jianyu.shi/breakdown-of-chinese-self-driving-car-industry-dd20deea7e73>
- [28] GIZ (2018): Didi Chuxing. How China's ride-hailing leader aims to transform the future of mobility. URL: <http://www.sustainabletransport.org/archives/6317>
- [29] Wired (2018): What is LiDAR, why do self-driving cars need it, and can it see nerf bullets? URL: <https://www.wired.com/story/lidar-self-driving-cars-luminar-video/>
- [30] Hessen Trade and Invest (2016): US-amerikanisches Unternehmen Velodyne LiDAR kommt nach Hessen. URL: <https://www.invest-in-hessen.de/dynasite.cfm?dsid=501864&newsid=27167&skipfurl=1>
- [31] Roland Berger (2018): Automated Vehicles: Legal Framework Will Decide Which Automakers Win the Race to Full Automation. URL: <https://www.rolandberger.com/en/Media/Automated-Vehicles-Legal-Framework-Will-Decide-Which-Automakers-Win-the-Race-to.html>
- [32] Bundesanzeiger Verlag (2017): Aches Gesetz zur Änderung des Straßenverkehrsgesetzes. URL: <https://preview.tinyurl.com/ybrclbru>
- [33] Audi (2018): Audi A8. Audi AI Traffic Jam Pilot. URL: <https://www.audi-technology-portal.de/en/electrics-electronics/driver-assistant-systems/audi-a8-audi-ai-traffic-jam-pilot>
- [34] MIIT (2018): Administrative Rules on Intelligent and Connected Vehicle Road Testing. URL: <http://www.miit.gov.cn/n1146295/n1652858/n1652930/n3757018/c6128243/content.html>
- [35] MIIT (2018): Implementation Plan for Key Projects in the Medium and Long-Term Development Plan of the Automobile Industry. URL: <http://www.miit.gov.cn/n1146290/n1146402/n1146455/c6248497/content.html>

- [36] United States Information Technology Office (2018): NDRC releases Intelligent Vehicle Innovation and Development Strategy. URL: <http://www.usito.org/news/ndrc-releases-intelligent-vehicle-innovation-and-development-strategy>
- [37] OpenSignal (2016): The State of LTE in November 2016. URL: <https://opensignal.com/reports/2016/11/state-of-lte>
- [38] Center for Automotive Management (2018): Absatztrends von Elektroautos in wichtigen Märkten 2017/18. URL: http://auto-institut.de/index_html_files/E-Absatz_1.HJ._18.png
- [39] Zheng (2018): EV Charging Network to Expand. URL: <http://www.chinadaily.com.cn/a/201801/19/WS5a613492a3106e7dcc1352f8.html>
- [40] Cohrs, Alexander (2018): Ladestationen für Elektroautos: Gibt es genug Stromtankstellen? URL: <https://aiomag.de/ladestationen-fuer-elektroautos-gibt-es-genug-stromtankstellen-7303>
- [41] Bain and Company (2018): China's Mobility Industry Picks Up Speed. URL: <https://www.bain.com/insights/chinas-mobility-industry-picks-up-speed/>
- [42] International Transport Forum (2015): Urban Mobility System Upgrade. How shared self-driving cars could change city traffic. URL: <https://preview.tinyurl.com/yafmsdjx>
- [43] Fraunhofer IAO (2015): Automated driving is a huge opportunity. URL: <https://www.iao.fraunhofer.de/lang-en/about-us/press-and-media/1252-automated-driving-is-a-huge-opportunity.html>
- [44] Institut der deutschen Wirtschaft Köln (2017): Deutschland hält Führungsrolle bei Patenten für autonome Autos. URL: https://www.iwkoeln.de/fileadmin/publikationen/2017/356331/IW-Kurzbericht_55_2017_Patente_autonomeAutos.pdf
- [45] Mirani, Leo (2015): Why three German car makers just bought a mapping company from Nokia. URL: <https://qz.com/470264/why-three-german-car-makers-just-bought-a-mapping-company-from-nokia/>
- [46] OpenSignal (2018): State of the Mobile Network in Germany. URL: <https://opensignal.com/reports/2018/05/germany/state-of-the-mobile-network>
- [47] OpenSignal (2018): Europe's 4G speeds rise while the rest of the world stalls. URL: <https://opensignal.com/blog/2018/02/20/europes-4g-speeds-rise-while-the-rest-of-the-world-stalls/>
- [48] World Economic Forum (2015): Are we ready for automated cars? URL: <https://www.weforum.org/agenda/2015/11/are-we-ready-for-automated-cars/>
- [49] EY (2017): Der PKW-Absatzmarkt China 2009 bis 2016. URL: [https://www.ey.com/Publication/vwLUAssets/ey-auto-absatzmarkt-china-2017/\\$FILE/ey-auto-absatzmarkt-china-2017.pdf](https://www.ey.com/Publication/vwLUAssets/ey-auto-absatzmarkt-china-2017/$FILE/ey-auto-absatzmarkt-china-2017.pdf)
- [50] NDRC (2018): Negative List for Foreign Investment. URL: http://www.ndrc.gov.cn/xwzx/xwfb/201806/t20180628_890757.html



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