

# Mobility in 21<sup>st</sup> Century China: Snapshots, Dynamics & Future Perspectives



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Beijing, 2019

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# List of Abbreviations

3PL	Third Party Logistics Provider
ACEA	European Automotive Manufacturers' Association
AG	Aktiengesellschaft
AI	Artificial Intelligence
BEV	Battery Electric Vehicle
BRI	Belt and Road Initiative
BRT	Bus Rapid Transit
BMVI	Bundesministerium für Verkehr und digitale Infrastruktur
BMW	Bayerische Motoren Werke
BVL	Bundesvereinigung Logistik
BYD	Build Your Dreams
CAAM	China Association of Automotive Manufacturers
CATL	Contemporary Amperex Technology Co Ltd.
CATS	China Academy of Transportation Sciences
CCCC	China Center for Climate Communication
CGTN	China Global Television Network
CHTS	China Highway and Transportation Society
CNG	Compressed Natural Gas
CO <sub>2</sub>	Carbon Dioxide
COMAC	Commercial Aircraft Corporation of China
COSCO	China Ocean Shipping Company
CR	China Railway
CRCC	China Railway Construction Company
CSIS	Center for Strategic and International Studies
DB	Deutsche Bahn
DFS	Deutsche Flugsicherung
EUR	Euro
FAW	First Automotive Works
FYP	Five-Year Plan
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GTAI	Germany Trade and Invest
HDV	Heavy-Duty Vehicle
HEV	Hybrid Electric Vehicle
HSR	High-Speed Rail
IATA	International Air Transport Association

ICCT	International Council on Clean Transportation
ICE	Internal Combustion Engine
ICV	Intelligent and Connected Vehicle
IEA	International Energy Agency
ITF	International Transport Forum
KBA	Kraftfahrt-Bundesamt
LPG	Liquefied Petroleum Gas
LPI	Logistics Performance Index
MIIT	Ministry of Industry and Information Technology
MMT	Million Metric Tonnes
MOT	Ministry of Transport
NBS	National Bureau of Statistics
NDRC	National Development and Reform Commission
NEV	New Energy Vehicle
NOx	Nitrogen Oxides
NO <sub>2</sub>	Nitrogen Dioxide
NRDC	National Resources Defense Council
O <sub>3</sub>	Ozone
OECD	Organisation for Economic Co-operation and Development
OEM	Original Equipment Manufacturer
PM	Particulate Matter
R&D	Research and Development
RMB	Renminbi
SAE	Society of Automotive Engineers of China
SAIC	Shanghai Automotive Industry Corporation
SOE	State-Owned Enterprise
STEM	Science, Technology, Engineering and Mathematics
TEU	Twenty-foot Equivalent Units
UITP	Union Internationale des Transports Publics
UK	United Kingdom
UNCTAD	United Nations Conference on Trade and Development
US	United States
USD	United States Dollar
V2G	Vehicle-to-Grid
VDA	Verband der Automobilindustrie
VECC	Vehicle Emission Control Center
VOC	Volatile Organic Compounds
WEF	World Economic Forum
WHO	World Health Organization
WRI	World Resources Institute

# 1. Introduction

To assess, comprehend and analyse transport in a global 21<sup>st</sup> century context, it is imperative to look towards China. As China's economy grew from 178 billion USD in 1978 to around 12 trillion USD<sup>1</sup> in 2017, its transport sector has undergone a monumental mobility transformation and now leads the world in terms of sheer scale (World Bank, 2019a). While this may not be surprising with a population of 1.4 billion, the rate at which virtually every transport subsector grew over the past few decades has been nothing short of staggering. Take car ownership for example; while the entire country of China had under 20,000 registered private cars in 1985, in July 2018 Chinese consumers purchased more than 60,000 cars each day (NBS, 2019a; Li, 2018). At the same time, the country has also constructed the world's largest High-Speed Rail (HSR) and highway networks, built the world's largest metro systems and is destined to overtake the United States (US) to become the largest civil aviation market by 2022 (IATA, 2017).

The Chinese transport and mobility space is in a state of constant evolution and is continuing to evolve and adapt to challenging realities. First, due to the gargantuan size of the country's population, the sector will continue to expand to meet the population's growing mobility demands. Indeed, the sector is still rife with inefficiencies and in many ways, is not sufficiently developed on a per capita basis. Second, with the rapid development of China's transportation system and the associated increases in energy consumption and carbon emissions, major environmental and health concerns continue to trouble the country. In 2016, the Chinese transport sector alone emitted more tonnes

of carbon dioxide (CO<sub>2</sub>) than all of Germany's sectors combined and no Chinese city currently conforms to World Health Organization (WHO) pollution guidelines (IEA, 2018a). Indeed, the magnitude of Chinese emissions makes the overhaul of the Chinese transport sector of critical importance for reducing global carbon emissions.

China, the world's second largest economy, is also flexing its industrial muscles and is proving itself to be incredibly ambitious in becoming a transport and mobility powerhouse. Today, the Chinese state is throwing its weight behind the development of an excellent transportation sector underpinned by a world-class mobility industry. Chinese state ambitions are epitomized by various state strategies and action plans such as the 'Made in China 2025' plan, the 13<sup>th</sup> Five-Year Plan (FYP) and the 'Blue Sky Action Plans', central government plans which have set key strategic industrial and environmental targets for a multitude of transport sectors. Indeed, in part due to state intervention, China is busy developing disruptive mobility innovations and has become somewhat of a cauldron of innovation in the development of New Energy Vehicles (NEVs), Intelligent and Connected Vehicles (ICVs), Shared Mobility and digitalized transport innovations; developments which are set to have global reverberations.

It is in this sense that ignoring developments in the Chinese transport sector would be fatal, not only in the fight against climate change and carbon emissions, but also for countries with well-established mobility industries such as Germany. Indeed, in many ways the Chinese and German transport sectors provide a valuable comparison. Germany

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<sup>1</sup> Current USD

has a highly developed transport sector underpinned by a globally leading transport industry. In contrast, China has, in what seems like the blink of eye, built the world's largest transport system and is putting the 'pedal to the metal' as it aims to develop powerful mobility industries. Similarly, in the domain of emissions, the German transport sector is no angel either. The share of emissions attributable to transport in Germany has doubled since the 1980s, making the transport sector Germany's second largest carbon-emitting sector. Thus, with Chinese transport being a major contributor to global carbon emissions, and German transport also significantly contributing to global emissions, Germany and China are confronted with the mutual challenge of cutting, or ideally eliminating, transport emissions. As such, due to their positions within the wider transport sector, Germany as a well-established industrial leader and China as a large, highly dynamic, innovative and disruptive newcomer, both China and Germany can become testing grounds for a reconfiguration of global transportation structures.

Thus, this report is intended to showcase the throbbing dynamism of the Chinese transport sector and to convey the notion that what happens in China will, due to the sheer size of the sector, have reverberations and repercussions throughout the world. While the comparison with Germany will be drawn to put Chinese transportation dynamics into perspective, the report will focus on the trends, dynamics and future of Chinese transportation. Furthermore, this report also seeks to emphasize the notion that there is much to learn from the Chinese experience and the study of Chinese transport dynamics can provide vital insights for transportation stakeholders around the world.

To analyse and explore the current trends, challenges and potentials of the Chinese transportation sectors, it is first necessary to develop a holistic understanding of the nature of both the Chinese and the German transport sectors. To capture the relevance of the sectors, **Chapter 2** will begin by illustrating the disconcerting environmental and health ramifications caused by the Chinese and German transport sectors. The chapter will then proceed to compare and contrast the key pillars of their wider transportation systems, depict how passengers and goods move, as well as highlight the economic relevance of their underpinning industries.

**Chapter 3** will then turn towards China and discuss contemporary mobility trends. The chapter will illustrate and discuss the political drivers of China's transport upheaval, assess key exogenous economic and social factors that are defining the trajectory of Chinese mobility, as well as explore relevant technical and legal developments.

Finally, **Chapter 4** will turn towards the future and provide an outlook as to where China's transportation sector is heading. By interviewing experts and stakeholders within the Chinese transport industry, the chapter will assess and discuss possible future directions within the sector and outline challenges that China might face on its way to building sustainable transport systems of the future. While a wide variety of transportation domains will be explored, special attention will be given to electrification and NEVs. This is due to the industry's highly dynamic and disruptive nature, its impact on wider transport sustainability as well as the Chinese state's explicit ambitions in developing the sector. The chapter will also highlight important mobility lessons that can be drawn from the Chinese experience.



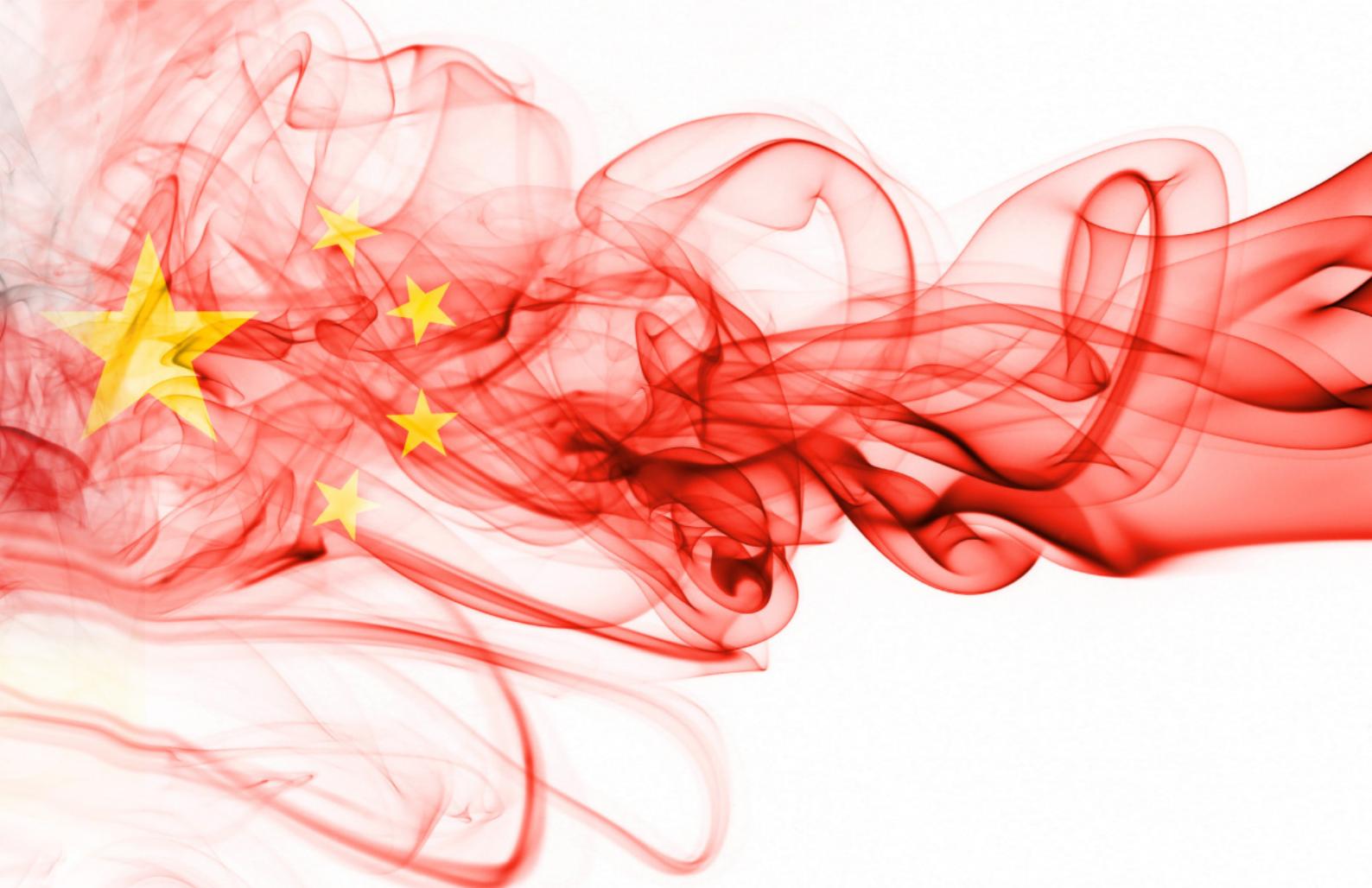
## 2. Facts and Figures: Chinese and German Mobility Landscapes

### 2.1 Energy Consumption and CO<sub>2</sub> Emissions

Both China and Germany are major emitters of CO<sub>2</sub> and Greenhouse Gas (GHG) emissions. The rapid growth of the Chinese economy and the associated growth in energy consumption has seen Chinese carbon and GHG emissions increase in virtually every economic sector. China has had the world's largest carbon footprint since 2004 and in 2017 was responsible for a staggering 28.3 % of global CO<sub>2</sub> emissions (CSIS, 2018). This is in part due to the country's reliance on coal as its primary energy source; even today China continues to burn more coal

than the rest of the world combined, with coal combustion accounting for 70 % of total Chinese CO<sub>2</sub> emissions (CSIS, 2018). Nevertheless, while Chinese emissions have experienced gargantuan levels of growth, German per capita CO<sub>2</sub> emissions from fuel combustion remain noticeably higher than their Chinese counterparts; in 2016 China emitted 6.57 t/CO<sub>2</sub> per capita, while Germany emitted 8.88 t/CO<sub>2</sub> per capita (IEA, 2018b). This can be explained by Germany's significantly higher per capita income<sup>2</sup> and associated consumption demand, and China's highly

<sup>2</sup> In 2017, China had a per capita GDP of 8,826 USD while Germany had a per capita GDP of 44,469 USD (current USD). (World Bank, 2019b).

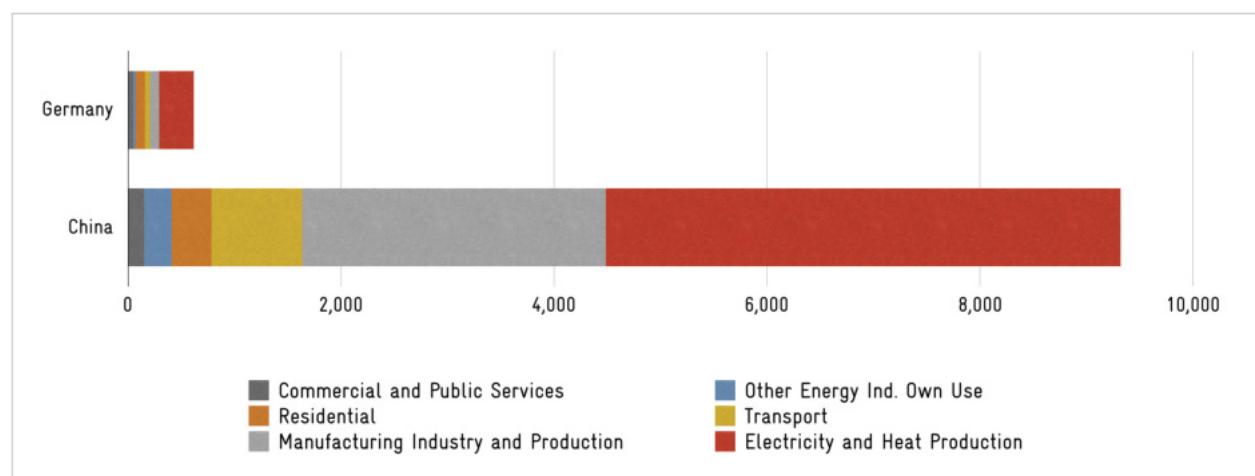


unequal income distribution across unequally developed regions and provinces.

The transportation sector has long been a major contributor to global CO<sub>2</sub> and GHG emissions. In 2016, the global transportation sector emitted 7,866 million tonnes of CO<sub>2</sub>, or approximately 25 % of total global CO<sub>2</sub> emissions (IEA, 2018a). Between 2000 and 2013, global transport

emissions grew at an annual average of 2.6 % and while a multitude of member states of the Organisation for Economic Co-operation and Development (OECD) managed to reduce their transport emissions, China saw its transport emissions nearly triple in that period (IEA, 2018a). By 2016, the country was responsible for 35 % of Asian CO<sub>2</sub> transport emissions (IEA, 2018b). As shown in **Figure 1**, in China the transport sector was the third

**Figure 1:** CO<sub>2</sub> Emissions from Fuel Combustion 2016, Million Metric Tonnes (MMT) CO<sub>2</sub>, Germany, China, (IEA, 2018a)



**Table 1:** CO<sub>2</sub> Emissions from Fuel Combustion 2016, MMT CO<sub>2</sub>, Germany, China, (IEA, 2018a)

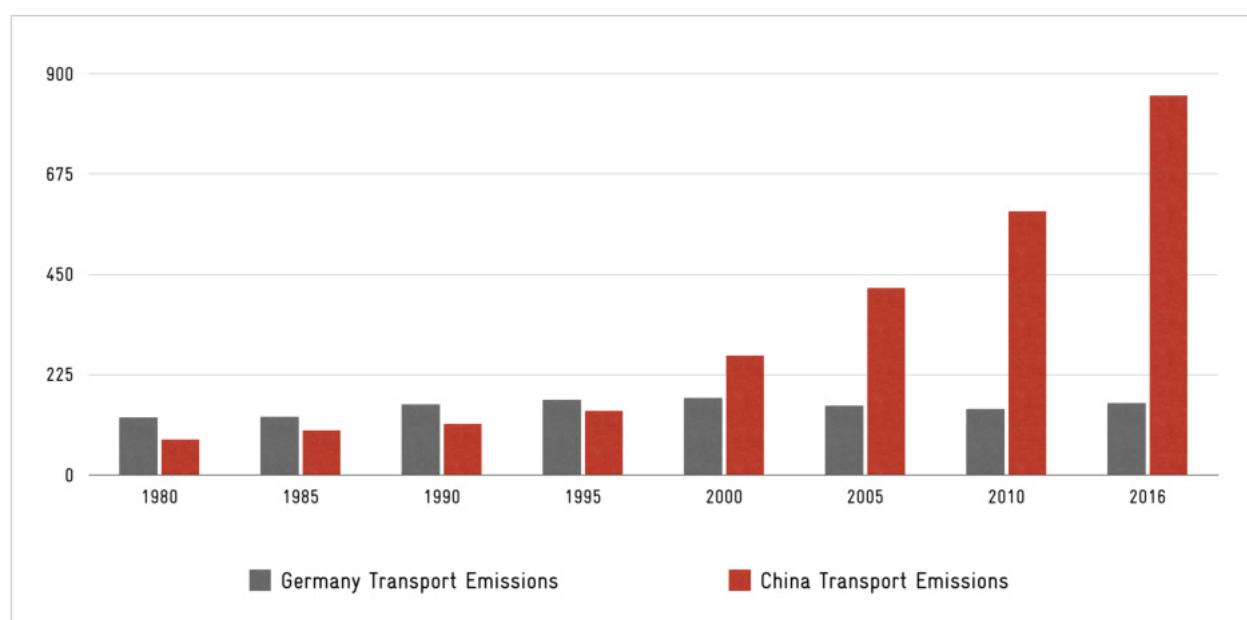
Emitters of CO <sub>2</sub> emissions	China	Germany
Commercial and Public Services	151.8	46.0
Other Energy Ind. Own Use	258.8	24.1
Residential	374.9	89.1
Transport	<b>851.2</b>	<b>161.0</b>
Manufacturing Industry and Production	2,849.7	89.2
Electricity and Heat Production	4,836.4	321.8
Total CO <sub>2</sub> emissions from fuel combustion	<b>9,101.5</b>	<b>731.6</b>

largest emitter of CO<sub>2</sub> emissions in 2016, behind the electricity and heat production and manufacturing and production sectors, while in Germany the transport sector was the second highest emitting sector.

Chinese transport emissions have grown rapidly. As shown in **Figure 2**, Chinese transport emissions have increased more than tenfold since 1980, rising from about 80 Million Metric Tonnes (MMT) of CO<sub>2</sub> in 1980 to around 850 MMT of CO<sub>2</sub> in 2016, the latest year where robust

data is available. While German transport emissions were higher than Chinese transport emissions until the mid-1990s, today Chinese transport emissions are more than five times as large as Germany's, larger than Germany's entire CO<sub>2</sub> emissions from fuel combustion.

German territorial emissions have steadily declined since 1990, with CO<sub>2</sub> emissions from fuel combustion falling from 940 MMT of CO<sub>2</sub> in 1990 to 731.5 MMT of CO<sub>2</sub> in 2016, a reduction of 22.2 % (IEA, 2018a). However,

**Figure 2:** CO<sub>2</sub> Emissions from transport fuel combustion, MMT of CO<sub>2</sub>, 1980-2016, (World Bank, 2019c; IEA, 2018b), Author's own calculations

as shown in **Figure 2**, German transport emissions have undergone pronounced growth over the past few decades, growing from 128 MMT of CO<sub>2</sub> in 1980 to 161 MMT of CO<sub>2</sub> in 2016. That same year, approximately 97 % of CO<sub>2</sub> emissions attributable to transport were emitted by road vehicles (IEA, 2018a). This increased share of emissions attributable to transport has been largely driven by growth in the volume of goods and passengers transported by the German transport system. As shown in **Figure 3**, the transport share of CO<sub>2</sub> emissions has grown from just over 10 % in 1971 to a historical maximum of 21.8 % in 1999 before levelling off to hover at approximately 20 %.

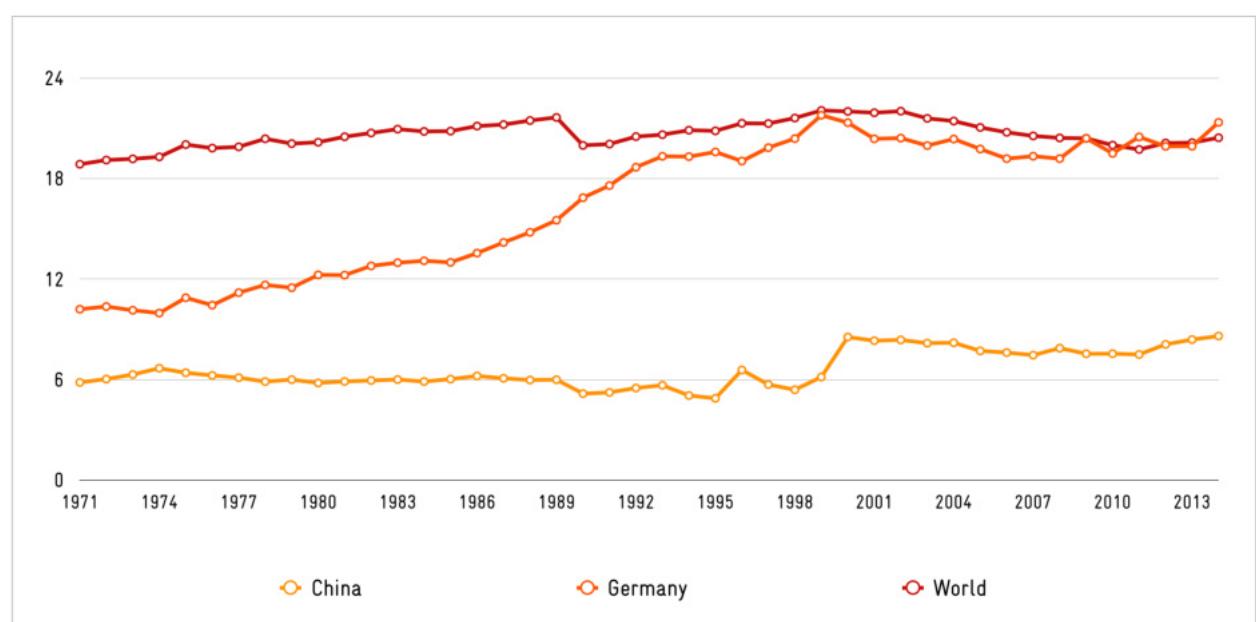
In the context of a rapidly industrialising China, where virtually every major economic sector has seen stark growth in associated emissions, rapid growth in transport emissions has not dramatically increased the ratio of transport emissions to total emissions from fuel combustion. As shown in **Figure 3**, the share of transport CO<sub>2</sub> emissions as a percentage of total fuel combustion has hovered at around 6 % between 1971 and 1989, before

falling to under 5 % in 1995 and then growing to 8.5 % in 2000 and 8.6 % in 2015. In this sense, while the share of transport emissions in Germany has gradually converged with the global average, the share of transport emissions in China remains considerably below the global average.

Moreover, while Chinese transport emissions dwarf those of Germany in absolute terms, per capita CO<sub>2</sub> emissions from transport remain considerably higher in Germany. In 2016, German per capita CO<sub>2</sub> emissions from transport were 1,995 kg of CO<sub>2</sub>, more than three times China's 614 kg of CO<sub>2</sub> and almost double the global average of 1,050 kg of CO<sub>2</sub> per capita (IEA, 2018a).

In sum, with the share of emissions attributable to transport having grown substantially in Germany and with the Chinese transport sector continuing to grow at a staggering pace, China and Germany are confronted with the same critical question: **How to successfully transform transport through decarbonisation and sustainable mobility?**

**Figure 3: CO<sub>2</sub> Emissions from transport, % of total fuel combustion, 1971-2014, (World Bank, 2019c)**



## 2.2 Air Pollution and Environmental Impact

Transport emissions are not only contributing to climate change but are also amplifying air pollution problems in both countries, leading to alarming public health concerns. Urban air pollution increases the risks of lung cancer, respiratory and cardiovascular diseases, cancer, adverse birth outcomes and premature death. Air pollution related illnesses and deaths are primarily linked to exposure to small particulate matter (PM) of less than 10 (PM10) and 2.5 (PM2.5) microns in diameter. The microscopic size of these particulates allows them to bypass the body's defence mechanisms against dust and penetrate deep into the body's respiratory system. They also comprise a toxic mixture of substances including heavy metals, sulphurs, carbon compounds and carcinogens such as benzene derivatives (WHO, 2019).

Air quality guidelines from the World Health Organisation (WHO) stipulate that a country's annual mean PM2.5 and PM10 concentrations should not exceed 10 µg/m<sup>3</sup> and 20 µg/m<sup>3</sup>, respectively (WHO, 2005). In China, however, air pollution continues to plague cities, with PM2.5 concentrations consistently being more than four times higher than WHO guidelines; the 2016 annual mean PM2.5 exposure in China came in at 56 µg/m<sup>3</sup> (World Bank, 2019d). Indeed, no Chinese city currently conforms to the WHO recommended annual guideline levels. In 2017, Beijing had an average annual PM2.5 concentration of 58 µg/m<sup>3</sup>, a value almost six times higher than stipulated by the WHO guidelines (Feng, 2018). Moreover, in 2014 researchers from Berkeley University found that 92 % of the Chinese population was exposed to more than 120 hours of unhealthy air over a four-month period (CSIS, 2018). A recent study also estimates that 1.6 million Chinese die each year from heart, lung and stroke disorders

linked to poor air quality (Rohde & Muller, 2015).

While no robust national data is available, estimates indicate that throughout China 15 % to 30 % of total PM2.5 concentrations are attributable to emissions from the transport sector. While these figures vary throughout the country, according to the Ministry of Environmental Protection, in 2014 in Beijing, approximately one third of PM2.5 concentrations could be attributed to vehicle exhaust emissions alone (Duggan, 2014). After the power generation sector, road vehicles were the second largest source of PM2.5 concentrations in most Chinese cities in 2018 (Kao, 2018). In Beijing, vehicle emissions also account for 58 % of nitrogen oxide (NOx) and 40 % of volatile organic compounds (VOC) concentrations, both of which are linked to serious health concerns (Song, 2014).

Smog and air pollution also have economic ramifications. A study from the Chinese University of Hong Kong found that smog-inducing fine particulates and ozone (O<sub>3</sub>) concentrations may be shaving an estimated 38 billion USD, or 0.7 % of GDP, off the Chinese economy from associated public health damage, work absences and crop losses (Kao, 2018). O<sub>3</sub>, a compound closely linked to chronic respiratory diseases, also adversely affects crop production by reducing or stunting photosynthesis in plants and is estimated to result in the loss of 20 million tonnes of rice, wheat, maize and soybeans each year in China (Kao, 2018).

Germany is also confronted with air pollution related issues. In 2015, the average German was exposed to a PM2.5 level of 13.48 µg/m<sup>3</sup>; research by the European Environmental Agency revealed that 80,767 deaths in

Germany were attributable to air pollution<sup>3</sup> in 2014 (Siehn, 2017; World Bank, 2019e). A key difference between China and Germany in this domain is Germany's continued reliance on diesel vehicles that, as shown in **Section 2.3.1**, still accounted for almost 39 % of vehicle registrations in 2017. In comparison to cars with petrol

motors, diesel motors emit larger amounts of NOx and particulate matter, making diesel vehicles a key contributor to pollution and related health issues in German cities. This notion has sparked widespread debate in Germany with a number of cities threatening to limit or ban older diesel engines from their roads.

## 2.3 Passenger Transport

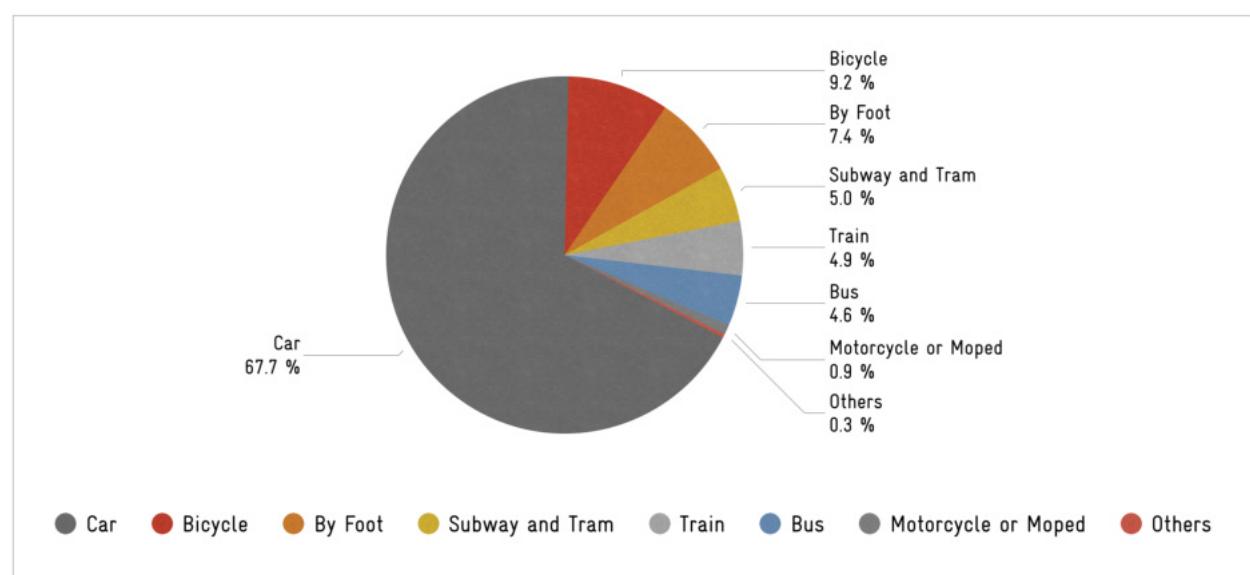
### 2.3.1 Road

A key reason for the growth of German transport emissions is that for most Germans the car remains the dominant mode of transportation. According to research by the Pew Research Centre, in 2014 an estimated 85 % of German households owned at least one car (Poushter, 2015). With 610 passenger cars for every thousand inhabitants in 2016, Germany has one of the highest car ownership densities in the European Union (ACEA, 2019). Moreover, as shown in **Figure 4**, in 2016, 67.7 % of Germans relied on their

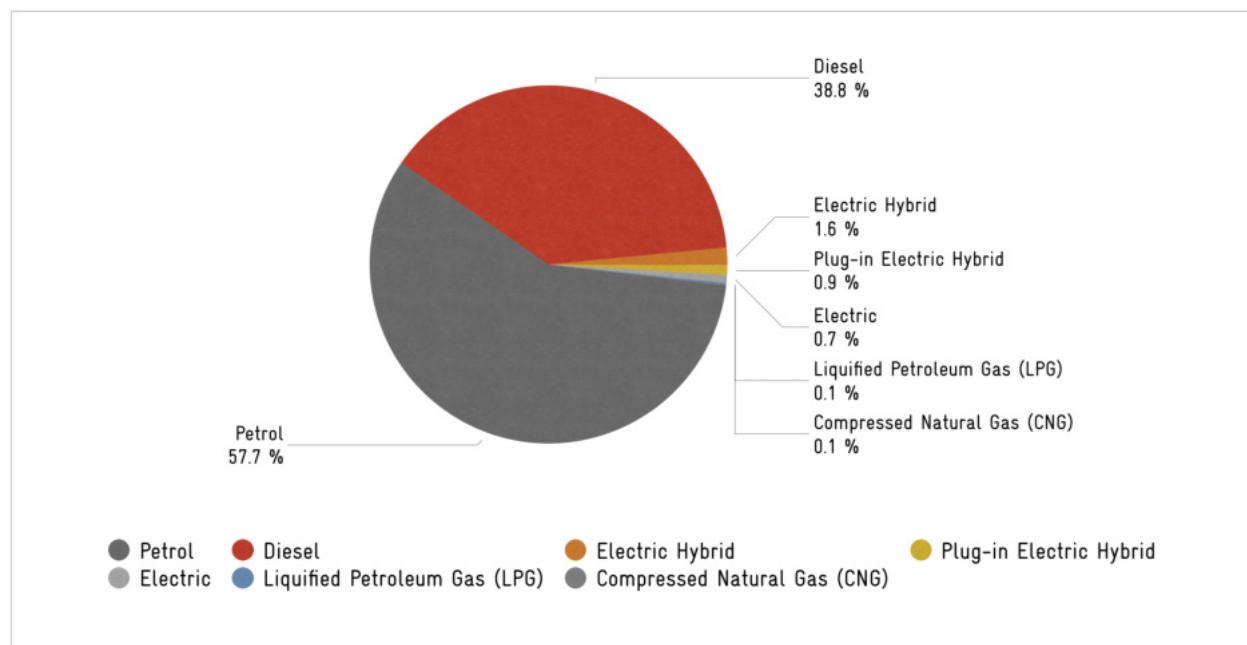
cars to get them to and from their workplace.

As shown in **Figure 5**, the internal combustion engine continues to be the dominant form of engine in German vehicles, with petrol and diesel-powered vehicles accounting for 57.7 %, and 38.8 % of all vehicles registered in 2017. Meanwhile, only 1.6 % of all private vehicles registered in 2017 were Hybrid Electric Vehicles (HEVs) and 0.7 % were Battery Electric Vehicles (BEVs).

**Figure 4:** Daily commute by mode of transport in Germany, 2016, (Statistisches Bundesamt, 2019a)



<sup>3</sup> Deaths attributable to fine particulate matter (PM2.5), ozone ( $O_3$ ), and nitrogen dioxide ( $NO_2$ )

**Figure 5: Vehicle registration by engine type, passenger vehicles, 2017, (KBA, 2019)**

Nevertheless, as shown in **Table 2**, the amount of annually registered BEVs and HEVs has grown substantially over the last decade and growth rates remain high. In 2017, 25,056 BEVs and 84,675 HEVs were registered in Germany. This compares to the registration of 11,410 BEVs and 47,996 HEVs in 2017, a year-on-year growth of approximately 120 % and 76 %, respectively.

In contrast to Germany, where car ownership rates have remained relatively stable over the past two decades, car

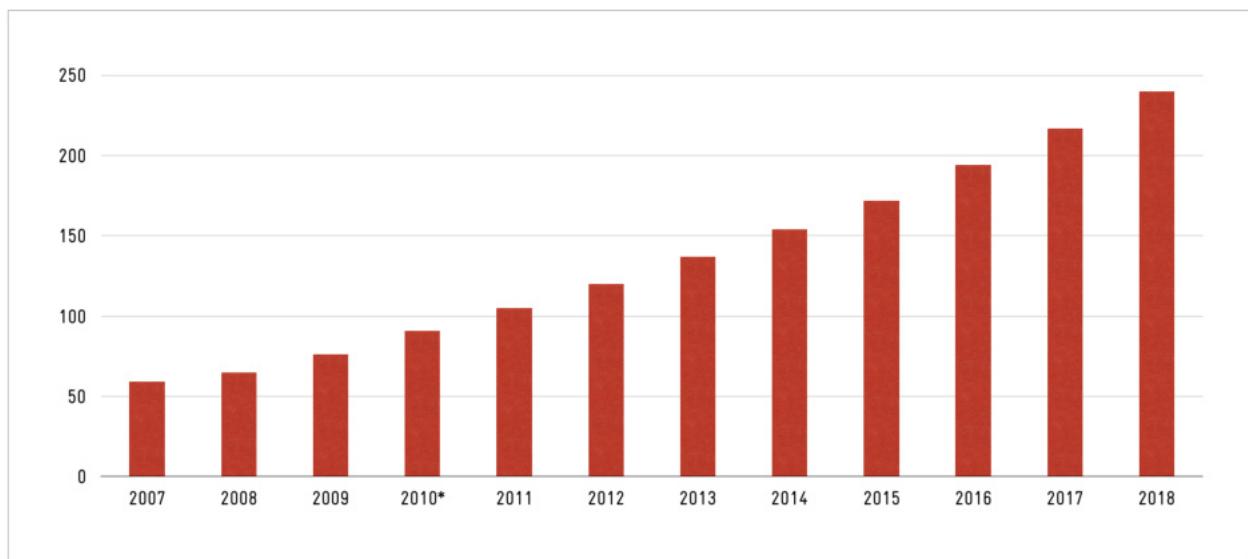
ownership has skyrocketed in China. By 2018, China had a car ownership rate of about 155 cars per thousand inhabitants, a figure that stood at just 80 in 2012 (Perkowski, 2018; Le Vine, Wu, & Polak, 2018).

Growth has been particularly rapid over the past decade. As illustrated in **Figure 6**, the total stock of private vehicles reached 217 million in 2017 and by 2018 rose to 240 million. While China became the world's largest car market in 2010, by 2017 over a quarter of all cars sold

**Table 2: Vehicle registration by engine type, passenger vehicles, 2017, (KBA, 2019)**

Engine Type	Sum of Vehicles Registered
Petrol	1,986,488
Diesel	1,336,776
Electric Hybrid	55,239
Plug-in Electric Hybrid	29,436
Electric	25,056
Liquified Petroleum Gas (LPG)	4,400
Compressed Natural Gas (CNG)	3,723

**Figure 6: Total stock of private vehicles in China 2007–2018 (in millions), (Statista, 2019a)**



in China. By the end of 2017, China had a total of 61 cities with over one million registered vehicles (Gasgoo, 2019).

Moreover, with over 50 % of the world's NEVs sold in China since 2017, the country also boasts the world's largest market for NEVs. By 2018, China had 2.6 million NEVs on its roads, 1.1 million more than the previous year (Ministry of Public Security, 2019). Pure battery electric vehicles (BEVs) accounted for 2.1 million, or 81.1 % of the total NEV stock (Ministry of Public Security, 2019). Nevertheless, as in Germany, the internal combustion engine remains the dominant form of vehicle engine with only about 2.7 % of cars sold in 2017 being NEVs (Manthey, 2018). In 2017, 89 % of all registered

non-NEV, were powered by petrol, 9.4 % by diesel and 1.6 % by natural gas<sup>4</sup> (VECC, 2019). The same year, approximately 85 % of diesel vehicles were trucks, making the share of diesel-powered private cars significantly lower than in Germany (VECC, 2019).

Today, with cars being integral elements of their respective transport sectors, road networks in both countries are highly developed. In 2018 German roads extended over a distance of 230,000 kilometres, of which 13,000 kilometres were highways (Statistisches Bundesamt, 2019b). These figures are dwarfed by China which in 2017 had a road network covering 4.8 million kilometres and a highway network of 1.4 million kilometres (Statista, 2019b).

### 2.3.2 Passenger Railway

Railway systems also play an integral role in both the Chinese and the German transportation sectors. By 2014, Germany's railway tracks covered a total of 67,400

kilometres, a network density of 93.4 kilometre of track per square kilometres of land, the fifth highest railroad density in the world (WEF, 2018a). In 2016, German

<sup>4</sup> Compressed natural gas, liquid nitrogen gas

railways clocked up over 95 billion passenger kilometres. With 7.2 % of railway tracks designated as High-Speed Rail (HSR) tracks, Germany currently has the fifth largest HSR network in the world, only behind, China, Spain, France and Japan. The World Economic Forum's Global Competitiveness Report 2018, ranks the efficiency of Germany's railway system as ninth in the world, as based on frequency, punctuality, pricing and speed (WEF, 2018a). In comparison, the efficiency of China's railway system is ranked as 25<sup>th</sup> in the world (WEF, 2018a).

In 2017, China's railway system carried a total of almost 1.4 trillion passenger-kilometres, making it the largest railway system in the world as measured by ridership (Statista, 2019c). By 2018, China had a railway density of seven kilometres of track per square kilometre (WEF, 2018a). Over the past decade, China has built a HSR network of

unparalleled dimensions. As of mid-2018, the country operated 64 % of all global HSR lines (Barrow, 2018a). China opened its first HSR line, a 113-kilometre track from Beijing to Tianjin, in 2008. While its first line took three years to build, in the decade that followed, China built almost 27,000 kilometres of HSR lines (Barrow, 2018a). While China is on course to open an additional 3,200 kilometres of track in 2019 alone (Tang, 2019), the country aims to have constructed a 35,000-kilometre-long HSR network by 2025 (see **Section 3.1**). By mid-2018, China Railway, the state-run railway operator, claimed to be carrying over four million passengers on its HSR network each day (Barrow, 2018a). During the weeklong 2019 Chinese New Year holiday, China's railway system made an epic 60.3 million passenger trips, a year-on-year growth of 4.4 % (Xinhua, 2019).

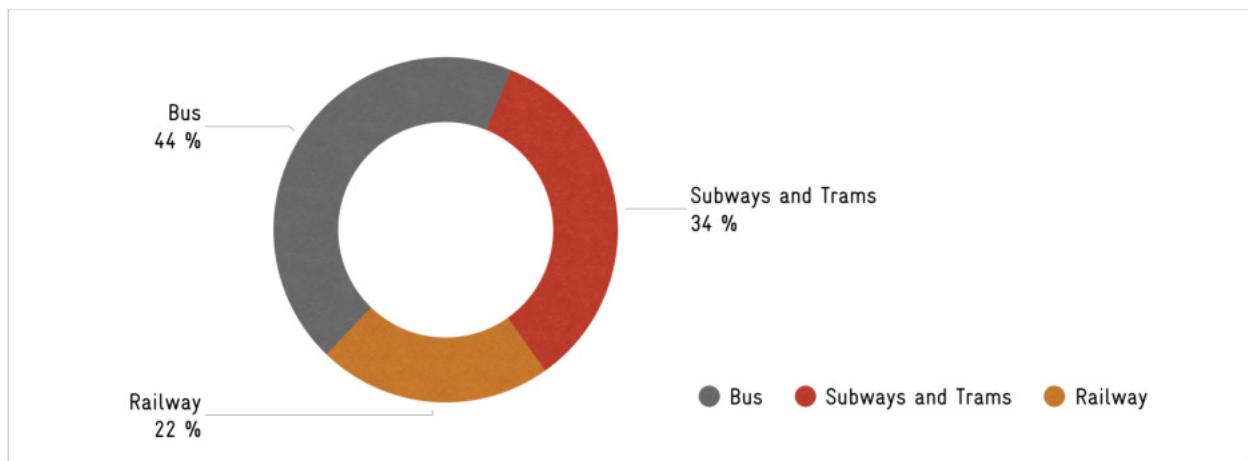
### 2.3.3 Local Public Transport

Public transport systems are major alternatives to individual motorised transport in both Germany and China. In 2017, over 11.5 billion public transport journeys were made in Germany (Statista, 2019d). As shown earlier in **Figure 4**, a total of 14.5 % of Germans rely on public transport or railway systems to get them to and from their workplace, making public transport a key pillar of Germany's transportation system. Indeed, with 177 annual journeys per capita in 2015, Germany has the highest public transport ridership rate in Europe and the third largest in the world, trailing only, albeit significantly, behind Japan's 246 and South Korea's 238 journeys per capita (UITP, 2017). In 2015, the most recent year with available data, China's urban public transportation users made 108 journeys per capita, significantly lower than in Germany (UITP, 2017). Buses, railways, trams and

metro lines are also supporting pillars of Germany's public transport system. While 44 % of all local public transport journeys are made by bus, 22 % are made by railway and 34 % by subways and trams (as shown in **Figure 7**).

This stands in contrast to China where the development of subway networks in the past two decades has been extraordinarily rapid. While the first metro lines in China opened in Beijing in 1969 and Tianjin in 1984, by 2009 China still only had ten cities with metro lines. By early 2018 however, China had 33 cities with metro lines covering a total distance of 3,884 kilometres. In 2017 alone, four Chinese cities, namely Xiamen, Shijiazhuang, Zhuhai and Guiyang, opened their first metro lines while the country itself opened a total of 33 new lines covering 868.9 kilometres (Barrow, 2018b).

**Figure 7: Modal distribution of all local public transport journeys in Germany in 2015 (UITP, 2017)**

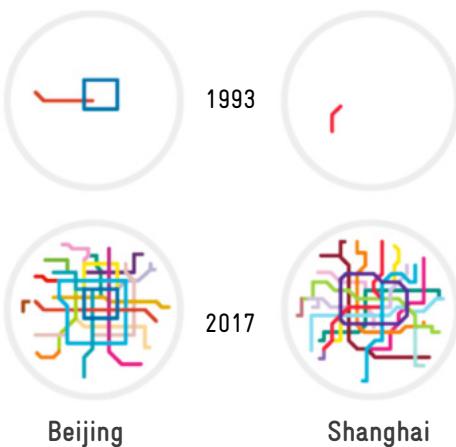


With subway lines covering 673 kilometres by March 2018, Shanghai's subway system is the world's longest, an incredible achievement considering the city only opened its first line in 1993 (China Daily, 2018a). Moreover, with 3.8 billion passengers carried in 2017, Beijing's subway system is the largest subway system in the world as measured by ridership volume (China.org, 2018). In comparison, Berlin's metro system, Germany's largest, carried 563 million passengers in 2017 (Internationales Verkehrswesen, 2018).

Chinese cities have also significantly expanded their Bus Rapid Transit (BRT) systems in recent years. By 2015

Chinese cities had over 2,900 kilometres of BRT lines and the country aims to construct another 5,500 kilometres of BRT lines by 2020 (World Resources Institute, 2017). While BRT developments were initially concentrated in first-tier cities such as Guangzhou and Beijing, over the past couple of years they have expanded rapidly throughout second, third and fourth tier cities such as Xiamen, Lanzhou, Urumqi, Yinchuan and Yichang. The fast-paced expansion of BRT is, in contrast to heavy-rail subway, partly the result of local municipal governments not requiring the approval of the central government to build BRT systems, providing a lower cost alternative form of public transportation.

**Figure 8: Development of metro system in Beijing and Shanghai, (Routley, 2017)**



China has also made significant progress electrifying public transportation bus fleets. Bus electrification is most visible in Shenzhen, whose more than 16,000-strong bus fleet is fully electric (Poon, 2018). According to estimates by Bloomberg, China currently adds about 9,500 electric buses, roughly the amount of buses in London's fleet, to the national fleet every five weeks (Poon, 2018).

Importantly, China's great strides in electrifying its bus fleets will lead to significant reductions in diesel demand. A report published by Bloomberg NEF states that, by the end of 2019, a cumulative 270,000 barrels of diesel will have been displaced globally by electric buses, with most displacement coming from China (Nightingale, 2019).

### 2.3.4 Bicycle

The bicycle also continues to be a popular form of transport in Germany. A Pew Research Centre survey revealed that Germany currently has the highest bicycle ownership rate in the world, with nearly eight out of every ten Germans claiming they own a bike (Poushter, 2015). As shown earlier in **Figure 4**, 9.2 % of Germans rely on their bicycles to get to and from their work place, the third largest share of commuting transportation choice after the car and public transportation. In 2013, 39 % of federal roads, 25 % of provincial roads and 16 % of municipal roads were equipped with cycling pathways (BMVI, 2014). In Berlin, 78 % of federal roads were equipped with cycling paths (BMVI, 2014). Moreover, Germany has over 19,000 kilometres of cycling tracks along federal highways and since 2015 the federal government has made 98 million EUR available per year to extend and maintain these tracks (BMVI, 2017). However, a Greenpeace study points out that German cities do not see high levels of cycling infrastructure investment, especially in comparison to cities in the Netherlands, Denmark or Norway. While German cities such as Berlin and Munich spend 4.70 EUR and 2.30 EUR per capita respectively on cycling infrastructure per year, Amsterdam, Copenhagen, Oslo and Utrecht invest 11 EUR, 36.50 EUR, 70 EUR, and 132 EUR, respectively per citizen each year (Greenpeace, 2018).

In Germany, bike sharing has had a rather bumpy ride. Bike sharing with docking systems began popping up in German cities in the early 2000s, and the two largest operators, DB Rent and nextbike, have built bike-sharing networks in most major German cities. Over the past few years, Asian free-floating bike-sharing firms have also entered the German market and have rapidly placed a large number of bicycles on German streets. In Berlin for example, the number of shared bikes grew from just over 10,000 in December 2017 to over 18,000 in April 2018 (Dobush, 2018). They have, however, failed to make a successful market entry. In July 2018, Chinese firm Ofo, one of the two largest bike-sharing companies, announced that it will entirely pull out of the German market. Similarly, Singaporean firm oBike recently took back around 6,000 out of its total of 6,800 bicycles in Munich (Dobush, 2018).

It is estimated that between 1978 and 1996, 45 % of urban commutes in China were made by bicycle, a figure that fell to 35 % for the period between 1995 and 2002 and later dropped to under 10 % (Thomas, 2018). With the rise of bike sharing however, the bicycle has experienced somewhat of a grand revival in China. Between 2015 and 2018, more than 20 million bike-sharing bicycles arrived on China's streets. In 2017 alone, the number of bike-sharing users in the country grew by 600 % (Thomas, 2018).

At its peak, China had more than 130 million registered bike-sharing users according to a study by Deloitte (Hecker, Quan, & Wu, 2018). While bike-sharing growth has slowed down substantially in 2018, it has already significantly shaped the nature of China's urban mobility sector.

While cycling infrastructure in China is relatively underdeveloped in comparison to Germany, Chinese cities are currently planning to dramatically expand their cycling infrastructure. Recent developments include Xiamen opening the world's first cycling highway in mid-2018 and Beijing's plans to construct a 3,200-kilometre-long cycling network within its fifth ring road (Schwankert, 2016).

### 2.3.5 E-Hailing and Car-Sharing

In recent years, the car-sharing, e-hailing and bike-sharing industries have seen explosive growth in both countries. While shared mobility is playing an increasingly important role in Germany, shared mobility has already had profound impacts on the movement of people in China. A major driver of shared mobility in China has been the large amount of funds that have flowed towards the development of the sector. Between 2013 and 2017, the Chinese shared mobility market has attracted more than 160 billion RMB (around 21 billion EUR) in investments, with 81.7 % of funds being directed into the ride-hailing market and 11.2 % into the bike-sharing segment (Hecker, Quan, & Wu, 2018).

Growth in the e-hailing market has been especially strong. By 2018, Germany had roughly 5.9 million e-hailing users while the total market generated approximately 822 million USD in revenue, a figure that stood at just 518 million USD in 2016 (Statista, 2019e). These figures, however, pale in comparison to China where the e-hailing segment has taken the country's mobility system by storm. In 2018, Didi Chuxing, China's largest e-hailing platform had 550 million users who covered a total of 48.8

billion kilometres, 31 million drivers, and with 2.5 billion unfulfilled ride requests, it seems that growth potential is still in abundance (Zhang, 2019). The same year, China's total e-hailing industry generated almost 200 billion RMB (around 25 billion EUR) in revenue, in the process substantially transforming the nature of China's urban mobility system (Statista, 2019f). Nevertheless, since its inception Didi Chuxing has yet to turn a profit and has made substantial operating losses every year.

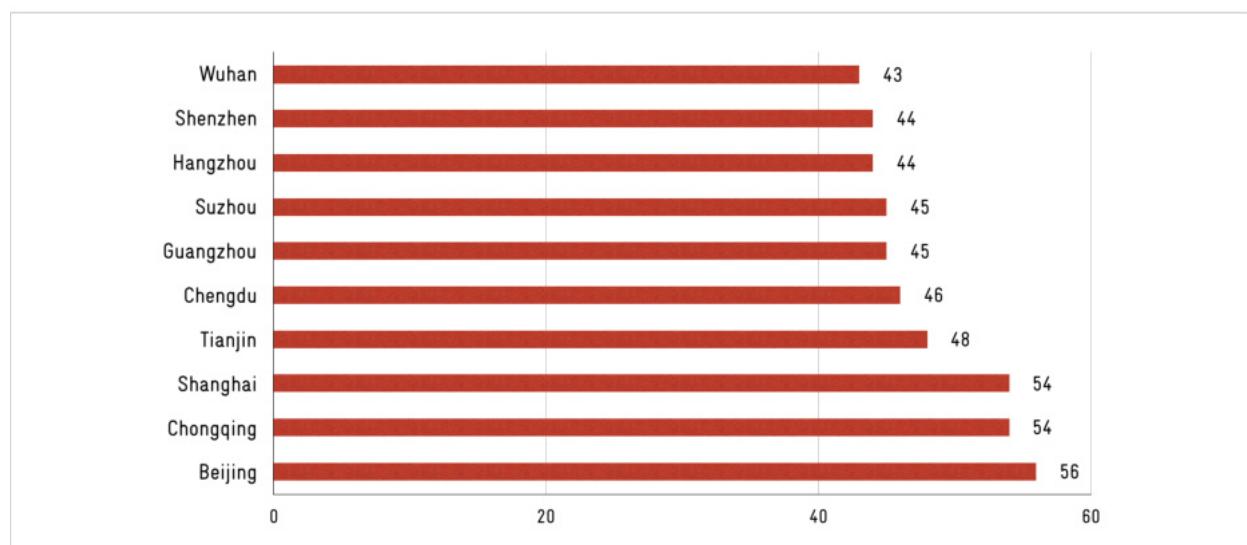
Car sharing has also grown in both countries. In 2017, there were over 1.7 million car-sharing users in Germany, a figure that stood at just 116,000 in 2008 and 757,000 in 2014 (Statista, 2019g). Similarly, the number of car-sharing vehicles on German roads has grown substantially, from 3,200 vehicles in 2009 to 17,200 vehicles in 2017 (Statista, 2019g). In 2017, a multitude of Chinese cities called for the expansion of car-sharing platforms, often to promote the NEV market. Today, the number of car-sharing companies in China has grown to more than a hundred, with a total fleet size of approximately 50,000 vehicles (Hecker, Quan, & Wu, 2018).

### 2.3.6 Commuting

Average commuting times and distances are an important metric for assessing the efficiency of a transportation system. Importantly, commuting journeys continue to be considerably longer in China than in Germany. In 2016, 69.7 % of Germans took under 30 minutes to get to and from their workplace each day, of which 22.2 % took under ten minutes (Statistisches Bundesamt, 2019a). A further 22.1 % took between 30 and 60 minutes while only 4.8 % took over an hour (Statistisches Bundesamt, 2019a). Similarly, 27.9 % of Germans have only had to travel under five kilometres to their workplace each day, while 75.3 % had to travel under 25 kilometres (Statistisches Bundesamt, 2019a).

Due to the varying coverage and efficiency of public transport infrastructure, lower car ownership levels, higher traffic congestion, as well as the sheer size of Chinese cities, commuting distances and times also vary heavily between Chinese cities. Within China's ten richest cities as measured by GDP, commuters in Beijing had to travel an average distance of 13.2 kilometres to their workplace each morning, the longest in China (Jiguang, 2019). In Wuhan, this figure stood at 8.2 kilometres (Jiguang, 2019). As shown in **Figure 9**, in Beijing the average commuting time was 56 minutes while commuters in Wuhan took an average of 43 minutes in 2018. Nevertheless, 97.7 % of commuters in Wuhan and 84.3 % of commuters in Beijing made it to work within an hour (Jiguang, 2019).

**Figure 9: Average commuting times in China's ten richest cities<sup>5</sup> (minutes), (Jiguang, 2019)**



<sup>5</sup> As measured by 2018 GDP

### 2.3.7 Civil Aviation

Aviation is a key pillar of the German and the Chinese transportation system, with the aviation market in both countries experiencing remarkable growth over the last decade. In 2017, Germany's civil aviation system carried a total of 212.4 million passengers, up from 164.1 million a decade earlier (Statista, 2019h). Meanwhile, China's aviation industry grew from having carried 183.6 million passengers in 2007 to carrying 551.2 million in 2017 (World Bank, 2019f). Moreover, China is currently the second largest aviation market in the world after the US, and according to the International Air Transportation Association, is destined to become the largest by 2022 (IATA, 2017). In contrast to China, a country more than 26 times the geographic size of Germany, most German flights are along international routes. In fact, in 2016 only 10.5 % of flights originating or arriving at German airports were domestic flights while in China over 88 % of all passengers were domestic flight passengers in 2017 (DFS, 2017; Jing Travel, 2018).

To accommodate for such a rapid increase in air travel, China has built an incredible number of airports. Between 2000 and 2017, the number of airports in China grew

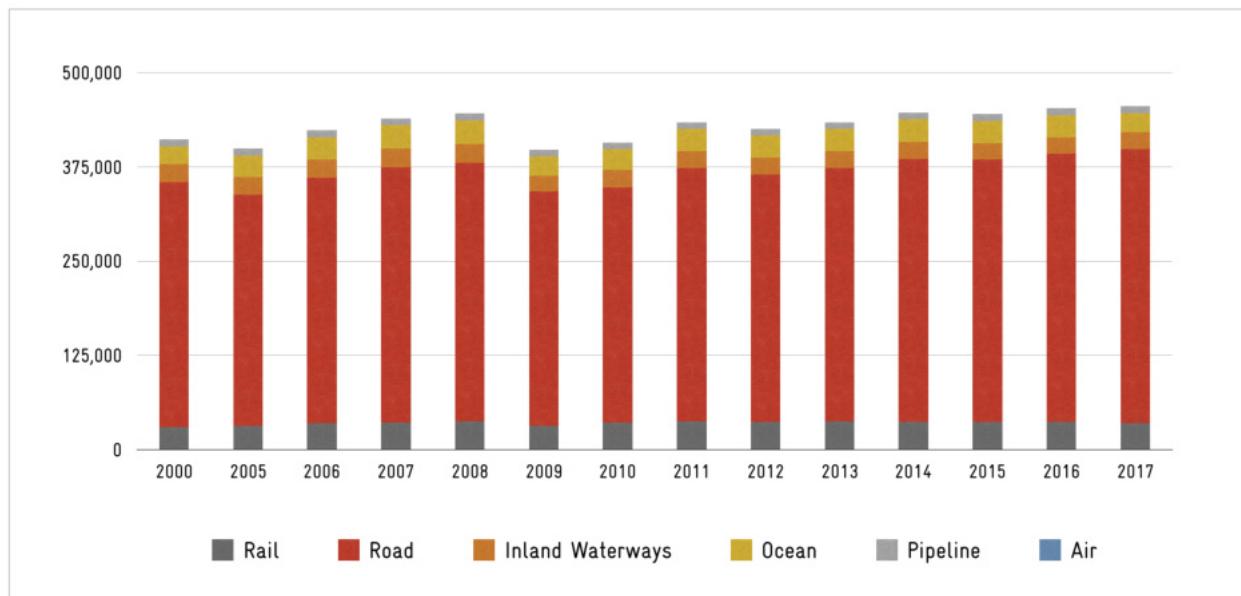
from 139 to 229 (WEF, 2018b). Moreover, the China Aviation Authority, China's aviation regulator, has laid out plans to double the number of airports in the country to 450 by 2035, with air travel to smaller cities expected to take off (Kirton, 2018). By late 2019, Beijing is set to open the world's largest airport by passenger volume, Beijing Daxing International Airport, which is expected to handle over 100 million passengers annually (Lowe, 2018).

The Chinese aviation industry is plagued by chronic flight delay issues. At the 13 Chinese airports that rank among the world's hundred busiest, the average flight was delayed by 43 minutes in 2017 (The Economist, 2017). This compares to a global average (excluding China) of 27 minutes (The Economist, 2017). Moreover, of the world's 100 busiest airports, the seven airports that suffer most from flight delays are all in China and include China's major aviation hubs, Beijing, Shanghai and Shenzhen. A key reason for China's poor record in this domain is the fact that the Chinese military controls around 75 % of Chinese airspace. When the air force takes flight, civilian aircrafts are barred from taking off, often for hours (The Economist, 2017).

## 2.4 Freight Transport and Logistics

Both Germany and China are at the forefront of the global logistics and freight transport industry. In 2017, a total of 4.6 billion tonnes of goods, or 666 million tonne-kilometres, were carried by the German freight sector (Statistisches Bundesamt, 2019c). As shown in **Figure 10**,

most freight in Germany is transported by road, with the share transported by roads slightly increasing over the past few years. In 2017, 79.1 % of freight was transported by roads, 18.1 % by rail and 8.4 % via inland waterways.

**Figure 10: Volume of freight transport by carrier in Germany, 10,000 tonnes, 2000–2017, (Statistisches Bundesamt, 2019c)**

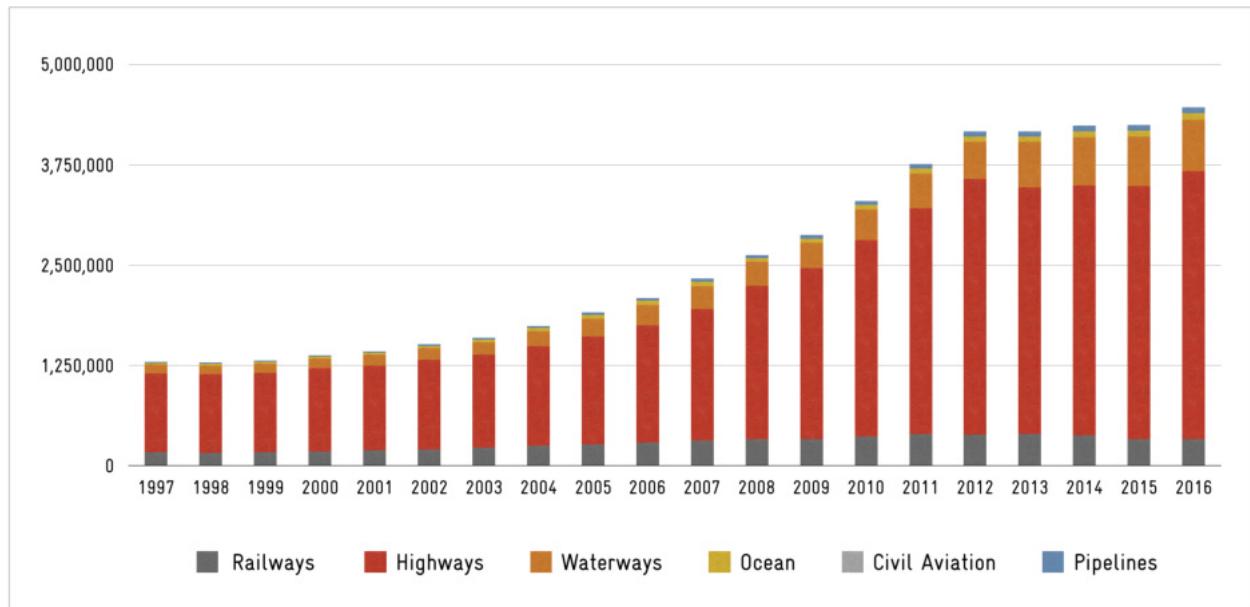
As with virtually every other transportation sector, China's economic transformation has dramatically propelled the growth of freight transport in China. As shown in **Figure 11**, in contrast to Germany, where freight volume has grown only marginally since the early 2000s, the volume of freight transported in China grew fourfold between 1997 and 2016. While the share of freight transported by road has remained at about 75 %, the share of freight carried by waterways has grown substantially, growing from 9 % in 1997 to 14 % in 2016. Meanwhile, the share of goods transported by rail has decreased from roughly 13 % to 7 % of total freight volume.

This shift has been largely driven by China's changing economic geography. While the majority of production had previously been located in close proximity to coastal export zones and ports, economic development has moved significant amounts of production into inland areas, requiring export-oriented products to be brought to the coastal ports for shipping. Meanwhile, the expansion of freight railway track has not been able to keep pace with the expansion of highway and road networks as well as

HSR track, which cannot carry freight.

The transportation of freight by ocean is also a key component of an economy's wider transportation system, and this is especially true for China and Germany, the world's largest and third largest exporting nations. In 2017, German ports processed a total of 19.5 million Twenty-foot Equivalent Units (TEUs), of which Germany's two largest ports, Hamburg and Bremerhaven, processed a total of 8.9 million and 5.5 million TEUs in 2017, respectively (Lloyd's List, 2019). This figure is dwarfed by Chinese ports which, in 2017, processed a grand total of 213 million TEUs (Lloyd's List, 2019). In 2017, the Port of Shanghai, the largest port in the world, processed a total of 40.2 million TEUs, more than double the total port volume of Germany that same year. The ports of Shenzhen and Ningbo-Zhoushan processed 25.2 and 24.6 million TEUs, making them the third and fourth largest ports in the world (Lloyd's List, 2019). Indeed, China has eight ports that are larger than Germany's largest port, the Port of Hamburg, and out of the world's ten largest ports, six are in mainland China.

**Figure 11: Volume of freight transport by carrier in China, 10,000 tonnes, 1997–2016, (NBS, 2019b)**



## 2.5 Economic Landscape

While several European states such as Austria and the United Kingdom (UK) currently invest a large majority of their state transportation expenditure in the railway sector<sup>6</sup>, Germany continues to invest largely in its extensive road network. In 2015, 68.4 % of total inland infrastructure investment went into road infrastructure, with railway infrastructure accounting for 26.7 % (ITF, 2019a). These investment proportions are similar for China, which in 2015 invested 78.5 % of total domestic transport expenditure in its road network, with 21.3 % flowing towards the railway sector (ITF, 2019a).

Over the past two decades, German state expenditure on transportation as a share of GDP has slowly been

decreasing, coming in at 1.8 % in 2000, 1.7 % in 2009 and 1.5 % in 2016. In absolute terms, state expenditure on transportation has been relatively variable, with the state spending about 20.2 billion EUR on transportation infrastructure and maintenance in 2000, 15.2 billion EUR in 2005 and 16.1 billion EUR in 2016 (ITF, 2019b)<sup>7</sup>. Nevertheless, Germany's per capita transportation infrastructure investments are the eighth highest in the OECD, valued at 243 USD per capita in 2016.

China's state expenditure on transportation infrastructure and maintenance has grown at a staggering pace over the past two decades. While transportation expenditure was lower than in Germany in 1995, valued at 14.8 billion EUR,

<sup>6</sup> In 2016, Austria and the UK invested 77.3 % and 6.2 % of their total inland infrastructure investment in the railway sector

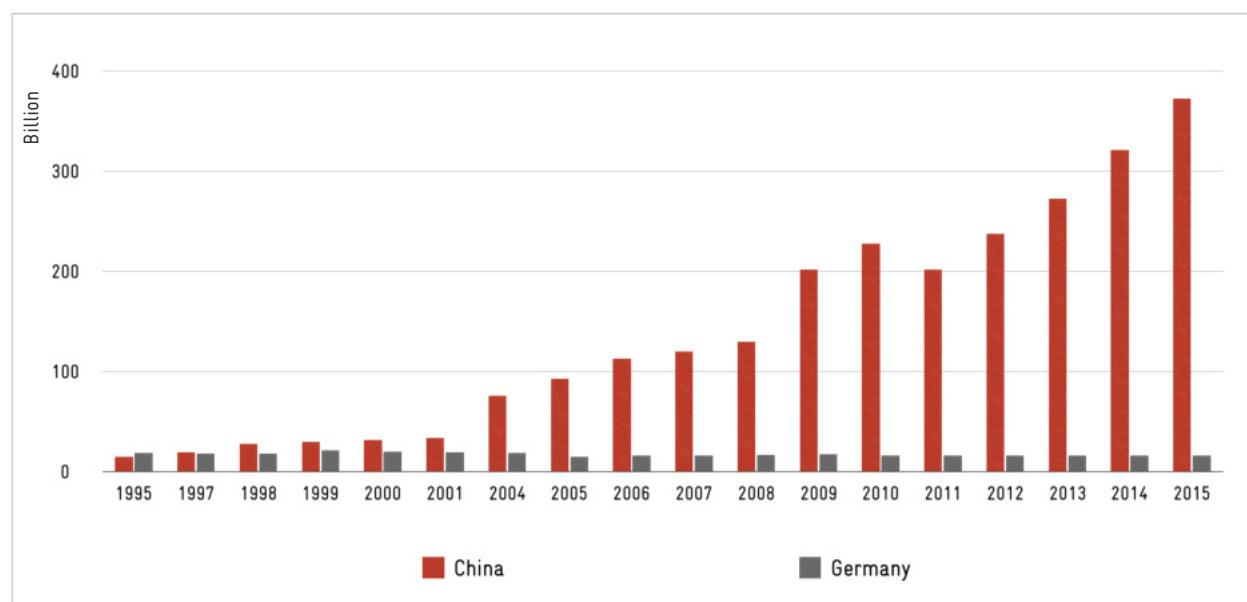
<sup>7</sup> All figures in constant 2005 EUR

by 2005 China had spent more than 129 billion EUR and by 2015 more than 372 billion EUR on transport infrastructure, more than 23 times the transportation expenditure of Germany (ITF, 2019b).

Both German and Chinese households spend significant amounts of their income on transportation. In 2016, the average German household spent 14.4 % of total household expenditure on transportation, the third highest expenditure group after housing and food (ITF, 2019c). This compares to an EU average of 12.8 % (Eurostat, 2019). In absolute terms, no other EU households spend

more than Germany on transportation-related activities (Eurostat, 2019). While Chinese households spend a similar proportion of their expenditure on transportation, absolute expenditure differs heavily between urban and rural households. In 2016, urban households spent 3,173 RMB (around 420 EUR) on transportation while rural households only spent 1,359 RMB (around 175 EUR) (NBS, 2019c). Nevertheless, due to persistent urban-rural income differentials, both urban and rural households spent approximately 13.5 % of their household expenditure on transportation (NBS, 2019c).

**Figure 12: State expenditure on transport infrastructure and maintenance, constant 2005 EUR, (ITF, 2019b)**



## 2.6 Industrial Perspective

German firms have long played an important role in the global transportation industry, with a multitude of German corporations being household names across the globe. Of Germany's ten largest corporations, as measured by 2017

revenue, six firms, namely, Volkswagen, Daimler, BMW, Siemens, Bosch and DHL operate in the transport and mobility industry with Volkswagen and Daimler holding the top two spots, respectively. While Chinese firms in the

transportation sector might not be household names outside of China just yet, Chinese firms have experienced remarkable growth and a wide array of Chinese firms are amongst the largest in their industries. China's wider transport industry is also relatively bifurcated; while State-Owned Enterprises (SOEs) such as China Railway or

the China Ocean Shipping Company dominate or even monopolise certain traditional transport sectors such as railway travel or freight, young and highly liquid firms such as Didi Chuxing or Meituan Dianping dominate many nascent transport sectors such as e-hailing or bike sharing.

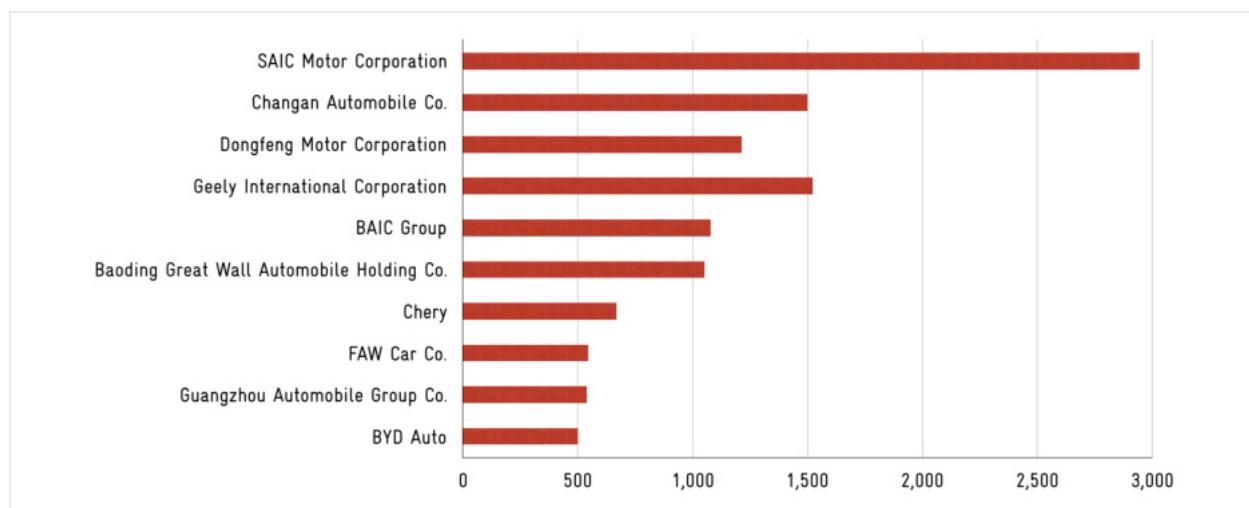
### 2.6.1 Automotive Industry

Well into the 21<sup>st</sup> century, the automotive industry remains a key pillar of Germany's economic structure. In 2017, the industry generated a turnover of 423 billion EUR while 20 % of total German domestic industry revenue was generated by the automotive industry (GTAI, 2018). One out of every five cars rolling out of the global automotive production line is produced by a German Original Equipment Manufacturer (OEM) (GTAI, 2018). In 2017, the German automotive industry generated 73.5 billion EUR in tax revenue (ACEA, 2018). Importantly, according to GTA, one third of global automotive Research and Development (R&D) spending was made by German OEMs in 2017. The German automotive industry is also heavily export-orientated, with around 75 % of the 5.7 million passenger vehicles the country produced in 2017 being shipped abroad (Ullrich, 2017). Indeed, automobiles and vehicle parts accounted for 16.6 % of Germany's export mix in 2016, making the automotive industry the country's largest export industry (Ullrich, 2017).

The magnitude of the German automotive industry makes it one of the country's largest employers. In 2017 the German automotive industry directly employed almost 820,000 people domestically whereby OEMs, suppliers, as

well as body and trailer manufacturers employed 479,800, 305,200 and 35,200 people, respectively (VDA, 2018). It is estimated that a staggering 1.8 million jobs in Germany are indirectly dependent on the automotive sector (Selwert & Recclus, 2017).

In contrast to Germany's long-established automotive industry, China's automotive industry, while being large, is still relatively young. In 2017, 30 % of the world's cars were produced in China, a figure that stood at just 2 % in 2002 (ACEA, 2018). In 2017, China's automotive industry generated approximately 8.5 trillion RMB (around 1.1 trillion EUR) in revenue, an increase of 6.4 % over 2016, while retaining profits of around 683 billion RMB (around 90 billion EUR). While in 2017 China's automotive R&D expenditure was the fourth highest in the world, China still only accounted for one tenth of the total automotive R&D expenditure of the European Union (ACEA, 2018). Moreover, the Chinese car industry is largely geared towards domestic consumption and is characterized by a low export orientation, with the industry accounting for less than 1.5 % of global car exports in 2018 (Workman, 2019). In 2017, the Chinese automotive industry directly employed around 1.6 million workers (Wickham, 2017).

**Figure 13: Leading automobile manufacturers in China in 2017 (in 1,000 units), by number of cars sold (CAAM, 2018)**

While Chinese automakers might not be household names across the globe just yet, their incredible growth record has also played a pivotal role for the German car industry. Through joint ventures with Chinese automakers, the German car industry has indirectly been able to generate substantial revenues, making the Chinese market incredibly valuable for German automakers. In 2018 for example, Volkswagen sold more than 3.1 million cars in China, of which around 1.7 million and 1.4 million were produced in joint venture partnerships with SAIC Motor Corporation and FAW Car Co., respectively (db.auto.soho, 2019). That year, the German giant only imported around 37,000 cars from its production facilities abroad (db.auto.soho, 2019). This explains why the Chinese market has become the most important market for German automotive OEMs with Volkswagen AG<sup>8</sup>, Daimler and BMW selling 40 %, 24 % and 21 % of all their cars in China in 2018.

In contrast to the German car industry, which is highly consolidated into a few large privately-owned corporations, China has 184 car manufacturers<sup>9</sup> of which the largest are state-owned. Nevertheless, the ten largest Chinese carmakers

currently account for 90 % of total car production with SAIC Motor Corporation and Changan Automobile Co. being the two largest producers of vehicles in China. Notably, Build Your Dreams (BYD), perhaps China's most ambitious NEV manufacturer, only broke through into the group of the ten largest car manufacturers in 2018.

Importantly, the Chinese automotive industry has also become increasingly geared towards the production of NEVS, with most Chinese automakers counting a multitude of electric models in their vehicle line-ups. In addition to China's large automakers, the past few years have seen the birth of multiple highly ambitious Chinese NEV start-ups, with NIO, Byton, Weltmeister and XPENG being perhaps the most prominent. Many of these start-ups are equipped with unique business models and mobility concepts and integrate shared mobility concepts or innovations such as battery swapping technology into their products. Moreover, many of these start-ups have former high-profile German OEM executives in their teams. China's NEV ambitions and challenges will be discussed in detail in **Chapters 3 and 4**.

<sup>8</sup> Including Audi and Porsche. 32 % of Audi cars are sold in China (Viehmann, 2018)

<sup>9</sup> Includes all state-owned, private and foreign-Chinese joint ventures engaged in vehicle manufacturing

## 2.6.2 Logistics and Freight Industry

The logistics industry remains one of Germany's leading industries. In 2017, Germany's wider logistics industry generated a total of 267 billion EUR in revenue, more than those of France and the UK, Europe's second and third largest logistics industries, combined (GTAI, 2019a). Germany's logistics industry thus accounted for over 25 % of total European logistics revenue (BVL, 2018). In 2017, German logistics giants DHL and DB Schenker were the world's largest and third largest Third-Party Logistics Providers (3PLs), respectively, as measured by gross revenue. Moreover, the World Banks' Logistics Performance Index<sup>10</sup> (LPI), a metric used to assess how efficiently individual countries move goods across and within borders, ranks Germany as the world's best performer (World Bank, 2018). With a market share of 21.5 %, German companies are the largest owners of container ships in the world, followed by Chinese firms who owned around 9.4 % of the world's container ships in 2017 (UNCTAD, 2017). Research by the Fraunhofer Institute revealed that the logistics industry is Germany's third largest employer and provided a staggering 2.5 million jobs<sup>11</sup> in about 60,000 individual companies in 2014 (GTAI, 2019a; Kübler, Distel, & Veres-Komm, 2015).

China's logistics industry has also been radically transformed in conjunction with the country's economic transformation. Today, the Chinese logistics industry is worth more than 280 trillion RMB (around 36 trillion EUR), with revenue estimated to reach 9 trillion RMB (around 1.2 trillion EUR) by the end of 2018 (China Daily, 2018b). The Chinese logistics industry is also the 26<sup>th</sup> most efficient logistics industry in the world, as ranked by the LPI (World Bank, 2018). In 2017, the state-owned shipping giant, China Ocean Shipping Company, known as COSCO, generated 140.8 billion RMB (around 18.4 billion EUR) in revenue and was the fourth largest shipping company in the world as measured by shipping capacity (UNCTAD, 2017). With revenues of 76.4 and 72.9 billion RMB (around 10 billion and 9.6 billion EUR, respectively) in 2017, Sinotrans & CSC Holdings and Jinzhong Energy International Logistics were the second and third largest logistics companies in China, respectively (Statista, 2019i). In part due to the rapid growth of Chinese e-commerce (see **Section 3.3**), Shun Feng Express, China's largest express logistics firm, is now China's fifth largest logistics firm, generating 57.5 billion RMB (around 7.5 billion EUR) of revenue in 2017 (Statista, 2019i).

## 2.6.3 Railways

Germany's railway sector also plays an important economic and industrial role. In 2016, the sector generated 20.1 billion EUR in revenue, with 10.5 billion EUR, 4.0 billion EUR and 5.6 billion EUR generated by short-distance passenger transport, long-distance passenger transport and freight transport, respectively (Bundesnetzagentur, 2016). The sector also remains a significant employer, employing

around 147,000 people in 2015. In 2017, German firm Siemens was the fifth largest rolling stock manufacturer in the world, as measured by segment revenue (SCI, 2018).

In contrast to Germany, where private railway operators also play a major role in the industry, in China virtually all rail operations are carried out by China Railway

<sup>10</sup> Index includes quality of customs, infrastructure, tracking and tracing, ease of international shipments, timeliness and service quality

<sup>11</sup> Includes warehousing, packaging, transportation, delivery and administrative employment

Corporation, commonly referred to as CR, a state-owned firm created in 2013 from the dissolution of the Ministry of Railways. In 2017, CR recorded around 1 trillion RMB (around 134 billion EUR) in revenue (CGTN, 2018). With the expansion of China's HSR system however, CR has become heavily indebted, with debt levels reaching five trillion RMB (around 660 billion EUR) by March 2018 (Financial Times, 2018). The railway sector is also a large employer in China, with CR providing 280,000 jobs, while China Railway Construction Corporation (CRCC), the state's railway infrastructure building arm,

provided 260,000 jobs and CRRC, the world's largest rolling stock manufacturer provided more than 180,000 jobs in 2016 (CRCC, 2017). Many Chinese HSR lines however, especially those connecting cities in Western China, are unprofitable. Nevertheless, certain lines are highly profitable with the Beijing to Shanghai line being the most profitable HSR line in the world, generating a profit of 12.7 billion RMB (around 870 million EUR) in 2016 alone (Tabeta, 2019). No wonder, one can travel the 1,318 kilometres long journey in less than four and a half hours.

## 2.6.4 Aviation and Aerospace

Carrying 84.9 million and 80.9 million passengers in 2016, China Southern and China Eastern, China's two largest airlines measured in terms of passengers carried, are the sixth and seventh largest airlines in the world respectively, and both are larger than Lufthansa that carried 62.4 million passengers that year (World Atlas, 2018). Nevertheless, with over 39.8 billion EUR of revenue in 2017, Lufthansa's revenue is the largest of any European airline, generating almost double the revenue of China Southern and China Eastern (Forbes, 2019). Moreover, with over 122,000 employees, Lufthansa provides more jobs than any other airline in the world (Forbes, 2019).

The aerospace industry is also sizeable in Germany. In 2017, the industry generated 40 billion EUR in revenue and provided more than 109,000 jobs in 220 companies and related institutions in Germany (GTAI, 2019b). In 2016, over 1,700 passenger aircrafts were produced worldwide with German technology and companies involved in the production of each aircraft (GTAI, 2017).

Moreover, Airbus, the world's largest commercial aircraft producer next to Boeing, has many of its largest and most important operations based in Germany.

China's aerospace industry has also come a long way, from failed experiments with reverse-engineered Boeing and McDonnell Douglas aircrafts in the 1970s and 1980s, to the development of narrow- and wide-body commercial jet aircrafts geared to launch by 2021. The Commercial Aircraft Corporation of China (COMAC), established in 2008, wants its jetliners to account for 20 % of the global commercial aircraft market by 2025 and, as most of China's airlines are state owned, is expected to reach substantial market shares relatively quickly (Lee, 2018). Currently however, only 50 % of components used by COMAC are produced domestically and most aircraft systems are still developed and manufactured by Foreign-Chinese joint ventures or supplied by foreign firms altogether (Lee, 2018).



### 3. Chinese Transportation and Mobility Trends

As illustrated in **Chapter 2**, the Chinese transport sector has been fundamentally reconfigured in conjunction with China's economic transformation and has proven to be inherently dynamic. China's wider mobility sector

continues to be in a state of constant evolution and is heavily influenced by political, economic, social, technical and legal developments.

#### 3.1 Political Trends

China's wider transport and mobility developments are massively driven by state ambitions, which continue to provide China's industry with directional thrust, thereby playing a significant role in shaping the sectors throbbing dynamism. Among the most important political ambitions

are the 'Made in China 2025' plan, the 'Belt and Road Initiative', various action plans and strategies such as the 'Blue Sky Action Plan' and the global Paris accords on climate protection.

In 2015, the State Council announced the ‘Made in China 2025’ plan, a ten-year plan set in motion by the Ministry of Industry and Information Technology (MIIT) which calls for the promotion of technological “breakthroughs” in ten key sectors. Aimed at closing the technological gap between China and the West, as well as lessening China’s dependency on imports, the ‘Made in China 2025’ plan seeks to rapidly increase the global competitiveness of Chinese companies by strategically targeting industries and technologies of the future. The plan is often claimed to be directly inspired by the German Industry 4.0 plan.

Of the ten strategic sectors targeted in the ‘Made in China 2025’ plan<sup>12</sup>, several are directly linked to transport and mobility. Importantly, the plan aims to increase the global recognition of Chinese car companies and calls for the rapid development of NEVs. By 2025, China wants NEVs to account for 80 % of total Chinese car sales and make up 20 % of the total vehicle stock. The export share of NEVs is also scheduled to increase to 10 % by 2025. The ‘Made in China 2025’ plan also ambitiously seeks to make China a key player in the aviation industry and to break the Airbus-Boeing duopoly that has defined the aviation industry over the past two decades. By 2025, China wants its domestically produced commercial jet aircrafts and regional turboprop airplanes to supply 10 % and 20 % of the Chinese aviation market, respectively, as well as to have developed large jet aircraft engine prototypes. Similarly, China aims to become a world leader in high-tech ships and maritime engineering equipment by capturing 80 % of the global high-tech ship market by 2025. The plan envisions Chinese railway firms, already dominant in the domestic market, to pursue high growth potentials overseas. Chinese train makers, the plan projects, should make 30 % of their sales in foreign markets by 2020 and 40 % by 2025. To

realize these targets by 2025, the Chinese state is investing heavily in R&D, standardization and certification as well as in technology transfer by means of international cooperation. As such, the central government has set aside loans, bonds and subsidies worth 1.5 billion USD, with local governments committing a further 1.6 billion USD.

The 13<sup>th</sup> FYP, published in 2015, also contains numerous transport and mobility targets that China aims to reach by 2020. These include the construction of one million kilometres of rural roads to facilitate rural development and to interlink all administrative villages via paved roads and shuttle bus services. Similarly, the plan calls for the construction of 50 new civil airports, 3,000 new kilometres of new urban rail transit lines, and the construction and upgrading of around 30,000 kilometres of expressways.

Chinese policymakers not only ambitiously seek to develop a world-class transportation industry, they also seek to harmonize China’s economic development strategy with environmental protection policies. In 2018, the State Council set in motion a second ‘Blue Sky Action Plan’, a three-year plan that aims to tackle the pollution- and smog-related issues that continue to plague Chinese cities. The first ‘Blue Sky Action Plan’, which ran between 2013 and 2017, set PM2.5 target levels for key regions, thereby requiring significant reductions such as 15 % in the Pearl River Delta and 33 % in Beijing (GOV.cn, 2013). Indeed, in Beijing average annual PM2.5 levels dropped from 89.5 µg/m<sup>3</sup> to 58 µg/m<sup>3</sup>, a drop of 35 % (Feng, 2018). The second ‘Blue Sky Action Plan’ stipulates a 15 % reduction of sulphur dioxide and nitrogen emissions by 2020, as compared to 2015 baseline levels and an 18 % reduction in PM2.5 levels (Wang, 2018). As transportation continues to be a major contributor to pollution in China, the plan

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<sup>12</sup> The ten industries include: Information technology, numerical control tools and robotics, aerospace equipment, ocean engineering equipment and high-tech ships, railway equipment, energy saving and new energy vehicles, power equipment, new materials, medicine and medical devices and agricultural machinery.

calls for a range of policies designed to reduce transport emissions. These include calls and policies for increasing the NEV ratio of public service and light logistics vehicles to 80 %, the premature implementation of China V emission standards<sup>13</sup>, restrictions on the supply of certain diesel and gasoline fuels and the phasing out of older truck types that fail to comply with China III emission standards. The action plan, published in October 2018, also calls for the encouragement of freight transport by rail as a means to reduce road freight transport, calling for an increase of the national railway freight volume by 20 % per year between 2018 and 2020.

A further political driver for change in the mobility space is the Belt and Road Initiative (BRI), a Chinese state-backed infrastructure investment campaign to construct

road, rail and sea transportation routes linking Asia to Europe and Africa. The BRI is highly emblematic of China's ambitions to become a global leader in transportation and mobility. Through BRI, the Chinese government claims to "connect regional connectivity and embrace a brighter future".<sup>14</sup> The campaign has already led to China investing in transport infrastructure in a series of Asian and African countries. As such, China has already invested in railway infrastructure in countries such as Kenya, Ethiopia and Indonesia as well as in port and logistics infrastructure in places such as Sri Lanka or Pakistan. Nevertheless, the BRI is still young and while China has already invested heavily in transport projects along the corridor, intentions are partly unclear, and outcomes remain to be seen.

## 3.2 Economic Trends

Chinese incomes have experienced incredible levels of growth over the reform era, with per capita GDP having grown more than tenfold over the past three decades, from 730 USD in 1990 to 7,329 USD<sup>15</sup> in 2018 (World Bank, 2019g). Naturally, high levels of income growth have fuelled the demand for private vehicles and well-developed mobility systems, which, as shown in **Chapter 2**, have experienced dramatic growth trajectories. As China moves further up the income ladder and Chinese consumers demand higher value goods and more efficient transportation services, economic growth continues to define the nature of transport and mobility in China.

Yet, while Chinese incomes have grown substantially over the past decades, persistent income inequalities, especially those between the urban and the rural population, make the affordability of certain modes of transportation a key issue. Tickets for Chinese HSR lines for example, are significantly more expensive than those for the traditional railway system, effectively denying a large proportion of the Chinese population access to HSR travel. In this sense, while China is developing modern transport systems, it simultaneously continues to provide necessary traditional and affordable transport options. Similarly, persistent income inequalities have also made many contemporary mobility trends possible. China's e-commerce and food

<sup>13</sup> See **Section 3.5**

<sup>14</sup> See <https://eng.yidaiyilu.gov.cn/zchj/zcjd/1180.htm>

<sup>15</sup> Constant 2010 USD

delivery industry for example, whose logistics segment is powered by a vast army of cheap migrant labour, has benefitted tremendously from cheap labour costs, thereby fuelling the expansion of the delivery industry.

Even outside the domain of the ‘Made in China 2025’ plan, strong industrial and economic policies, underpinned by state subsidies and a wide range of financial incentive policies, have played an integral role in shaping the Chinese mobility sector. Recently, this has been especially prominent in the domain of NEVs. Substantial purchase subsidies, purchase tax exemptions and state investments into charging infrastructure have all played a vital role in making China the world’s largest NEV market. Indeed, between 2009 and 2015, the Chinese state spent 4.5 billion EUR on NEV purchase subsidies alone (Retzer, Huber, & Wagner, 2018). Moreover, the nexus between the Chinese state, state banks and state enterprises also continues to influence the economic advancement of the Chinese mobility industry. China’s largest carmakers for example, are mostly state-owned and receive steady state funding to further advance their technological capabilities and competitiveness. In October 2018, for example, FAW, China’s oldest automaker, announced that the Chinese government, with the help of 16 state banks, would supply FAW with a credit line of over 1 trillion RMB (around 132 billion EUR), an unprecedented signal of support for the Chinese industry (Ren, 2018).

China also exhibits a relatively decentralized economic structure, with local governments enjoying significant fiscal and industrial policy freedoms. These structures allow different regions within the country to promote their own ‘local champions’. For example, Shenzhen, home to vehicle manufacturer BYD, has a 100 % electrified bus fleet with 80 % of buses delivered by BYD and is aggressively promoting the electrification of its taxi fleet (Climate

Action, 2017). These dynamics, financially beneficial for local companies, continue to play a large role in promoting the development and growth of Chinese mobility companies.

In recent years, Chinese transport and mobility companies have become increasingly active in global markets. In addition to BRI-related infrastructure projects such as in Ethiopia, Turkey or Pakistan, Chinese mobility companies have increasingly begun unleashing their products onto foreign markets. Perhaps the most visible examples were Ofo and Mobike, two Chinese companies who had taken the global bike-sharing market by storm before getting into serious financial problems. Similarly, BYD has opened production facilities in Europe and is a major supplier of new energy buses in the UK. Recently, Chinese companies have also been active in acquiring ownership stakes of foreign companies. In February 2018 for example, Geely, one of China’s largest carmakers and owner of Volvo Cars, acquired a 9 billion USD stake in Daimler AG, the biggest investment in a global automaker by a Chinese company (Bloomberg, 2018a).

Domestically, the Chinese car industry is also going through somewhat of a restructuring process. Subsidies for NEVs are set to be phased out from 2020 and a quota system will be introduced that will mandate production of certain amounts of NEVs. Moreover, the policy capping foreign ownership of car manufacturing ventures at 50 % is slowly being dismantled. Already, BMW has announced that it will increase its stake in the BMW-Brilliance joint venture to 75 % by 2022 (BMW Group, 2018). With an estimated 184 automakers in China, these developments could lead to a consolidation of the Chinese automotive industry.

Key drivers of innovation in the mobility space are China’s

three tech-giants, Baidu, Alibaba and Tencent. In 2016, these three companies alone were responsible for 42 % of all venture capital investment in China (Woetzel, et al., 2017). In comparison, in the US, Amazon, Facebook, Google and Netflix only accounted for 5 % of total US venture capital that year (Woetzel, et al., 2017). All three Chinese tech-giants are investing heavily in the development of ICV technology and autonomous driving. Similarly, the world's two largest bike-sharing companies, Ofo and Mobike were financially supported and kept afloat by Alibaba and Tencent, respectively. Now, Ofo as well as Meituan Bike (formerly Mobike), which was taken over by Meituan Dianping, halted international expansion due to immense financial burdens in 2018 (Liu, 2019).

Nevertheless, while economic and industrial dynamics aggressively shape the nature of mobility in China, the

Chinese economy is currently growing at its slowest pace in decades and is, to a certain extent, shrouded in economic uncertainty. While the Chinese economy grew at an average of more than 10 % for most of the past three decades, since 2010 growth rates have fallen to 10.6 % in 2010, 7.7 % in 2013 and 6.9 % in 2017 (World Bank, 2019h). Moreover, concerns about high levels of domestic commercial debt brought about by overinvestments in infrastructure construction, unsustainable financing mechanisms and industrial overcapacity all raise concerns that the Chinese economy cannot sustain the levels of economic growth necessary to realize the state's ambitious plans. Similarly, concerns that a US-Chinese trade war is actively targeting the strategic 'Made in China 2025' industries raises concerns that macroeconomic conditions could jeopardize the success of China's ambitious transportation and mobility plans.

### 3.3 Social Trends

China is currently experiencing a profound social transformation. The country is rapidly urbanising, going through major demographic changes, experiencing shifts in education; all dynamics that are reverberating into China's mobility space.

The rapid pace of China's urbanization continues to shape the nature of China's transportation and mobility sector. Between 1990 and 2017, the percentage of Chinese citizens living in urban centres grew from 26.4 % to 58 %. In 1978, at the beginning of the reform era, this figure stood at just 17.9 % (World Bank, 2019i). Rapid urbanization has dramatically increased the size of Chinese cities; between 1990 and 2017 the population of Beijing grew from 6.8 million to 21.7 million while the population

of Shanghai grew from 8.6 million to 24.2 million (Beijing Municipal Bureau of Statistics, 2018; Statista, 2019j; Statista, 2019k; Shanghai Gov, 2018). While cities such as Shanghai and Beijing have introduced a series of measures designed to cap their populations, urbanization in China, especially in lower tier cities, is expected to continue for the foreseeable future.

As Chinese cities have grown in conjunction with rising incomes, cities have been confronted with massive mobility challenges. To cope with enormous population growth, as shown in **Section 2.2.2**, Chinese cities have rapidly developed their public transportation and subway systems as well as their road infrastructure. Furthermore, to reduce traffic congestion, Chinese cities limit the number of cars

that can be registered every year. In Beijing for example, future car owners go through a monthly lottery process to register their vehicles while in Shanghai license plates are auctioned off at an average price of 88,000 RMB (around 10,500 EUR) (The Economist, 2018a). In Beijing, the average chance of successfully obtaining a license plate for a conventional vehicle was just 0.2 % in 2017 (The Economist, 2018a). However, Chinese cities have also begun decreasing the amount of licence plates available for NEV buyers. Beijing, for example, will only issue a total of 60,000 licence plates for NEVs in 2019<sup>16</sup> (Jing, 2019). As of December 2018, 400,000 people have applied for a NEV license plate in 2019, meaning that applicants will have to wait for up to eight years to receive their much-desired NEV plates (Jing, 2019).

Largely a legacy of the infamous ‘One-Child Policy’, China is also currently undergoing considerable demographic change. By 2025, the share of China’s population of 65 and over is estimated to exceed 14 %, meaning China will officially have become an ‘aged society’ (Sheehan, 2017). Not only will China’s ageing population affect China’s labour markets and the industrial dimensions of China’s transport industry, but demographic change will also require Chinese policymakers to carefully consider how the nature of mobility needs to adapt to the realities of an ageing population, a fact that seems not to be on the agenda of the government just yet.

A major social trend within the Chinese mobility sector has been the proliferation of Chinese e-commerce and express delivery services. Today, with just a few taps on a smartphone, Chinese consumers can have virtually any type of good delivered to their doorstep. With over 533 million online shoppers, more than 100 million parcels were delivered in China each day in 2017, making the

parcel delivery market worth an estimated 976 billion RMB (around 128.5 billion EUR) (Reuters, 2018; Statista, 2019l; Wenyu, 2018). On the 11<sup>th</sup> of November 2018, Single’s Day, a Chinese shopping holiday comparable to Black Friday in the US, Alibaba, China’s largest e-commerce retailer recorded 27 billion EUR in revenue on a single day, more than half of Germany’s total e-commerce revenue in 2018 (China Internet Watch, 2018). Similarly, in recent years, food delivery has skyrocketed in China. In 2017, China’s largest food delivery company, Meituan Dianping, processed over 57 billion USD in transactions between 320 million active customers and 4 million restaurants (Bloomberg, 2018b). The expansion of Chinese home delivery services has required a massive upheaval in the underpinning logistics industry, with seven Chinese express delivery companies going public in 2017 alone. The industry has become increasingly competitive with e-commerce retailers progressively getting into the delivery business themselves. In fact, large online retailers have been investing in drones to bring online shopping to China’s 600 million-strong rural population (The Economist, 2018b).

Chinese citizens are also becoming increasingly aware and more conscious of the disconcerting environmental issues facing China today. In a national survey conducted by the China Centre for Climate Communication (CCCC, 2017) in 2017, 79.8 % of respondents claimed that they worry about the implications of climate change, with a majority of respondents contending that air pollution is the most pressing issue that the Chinese government should address today. With transport being a major polluter in China, 98.3 % of respondents said that they strongly support governmental policies designed to encourage the purchase of energy efficient and clean energy vehicles (CCCC, 2017). Similarly, 98.7 % of respondents claimed that schools should teach students about climate change.

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<sup>16</sup> 40,000 plates available for conventional vehicles in 2019

With Chinese president Xi Jinping recently proclaiming that education is the driving force for the future of China's development, the Chinese education system has become increasingly geared towards producing the talented and capable individuals the country requires to become a 'science and technology superpower'. Over the past ten years, China has built an incredible number of universities, opening 1,800 universities between 2011 and 2014 alone (Frolovskiy, 2017). Notably, the higher education system has focussed on training science, technology, engineering and mathematics (STEM) graduates, who in 2016

numbered a staggering 4.7 million, more than in any other country in the world. While the quality of Chinese education remains below the standard of most Western European and North American nations, the incredible number of STEM graduates can be seen as concerted intention to supply the Chinese industry in general, and the Chinese mobility industry in particular, with the necessary engineers, mathematicians and brainpower it needs to achieve the ambitious targets set by Chinese policymakers.

### 3.4 Technical Trends

The Chinese mobility landscape is also heavily shaped by digitalisation and the development of innovative digital technologies. Indeed, with digitalisation progressing at an impressive pace, China has rapidly emerged to become a powerhouse of digital innovation. A key driver in this domain has been the proliferation of internet connectivity and mobile phones. In 2018, the country had 802 million internet users, more than the US and Europe combined, with 98 % of people being mobile users (McCarthy, 2018). In conjunction with the expansion of internet connectivity, online payment services have grown massively over the past few years. In 2016, the volume of digital payments in China was eleven times greater than in the US (Zorzetto, 2018). By 2018, the country had 460 million mobile payment users, a year-on-year growth of around 40 million users (Statista, 2019m). Today, around 68 % of Chinese internet users make use of mobile payment services, a market that is dominated by tech giants Alibaba and Tencent (Rosa-Bohrer, 2019). In addition to online payment services, the startlingly rapid growth of Chinese e-commerce, as illustrated in **Section 3.5**, has been a hallmark of Chinese digitalisation.

China's great digitalisation strides have had a particularly profound impact on mobility, with a multitude of innovations in the mobility space originating from within the digital economy. Today, around 31 % of Chinese citizens use bike-sharing apps, 37 % purchase bus or train tickets online and 43 % use online e-hailing services (McCarthy, 2018). Digitalisation has also brought about an incredible availability of data that along with the development of Artificial Intelligence (AI), has made China an emerging ICV and autonomous vehicle powerhouse.

As such, China's tech-giants, along with traditional automotive OEMs and young innovative start-ups, have been dedicating large amounts of resources towards the development of ICVs and autonomous vehicles. As of 2018, Baidu, Alibaba, Tencent, JD.com and DiDi Chuxing have all announced their own autonomous vehicle projects. Baidu is currently China's leader in the development of ICV technology and by late 2020 aims to have developed fully automated (level 5) driving capabilities on highways and certain city roads (Schlobach & Retzer, 2018). In April 2017, the company launched its Apollo platform, an

open-source platform for ICV technology that seeks to build an ecosystem allowing firms to integrate resources and share data (Schlobach & Retzer, 2018). More than 116 partner firms have since joined the platform. Moreover, Baidu already has level 4 minibuses, produced by Xiamen King Long, operating in over ten locations throughout China (Gasgoo, 2018a). Similarly, DiDi Chuxing has also shown itself to be incredibly ambitious in developing ICV technology and has been issued test licenses in China, the US and Canada. The company has also built a research centre in Silicon Valley that houses more than a hundred researchers and AI specialists. Additionally, the company was the first to receive autonomous vehicle testing licenses in China's tech hub, Shenzhen. Alibaba has recently entered the ICV game and in the summer of 2018 received Hangzhou's first licence for autonomous vehicle road testing where it is now testing a level 4 self-driving logistics vehicle (Gasgoo, 2018b). Moreover, by late 2019 Alibaba plans on launching its first in-house developed AI inference chips to support its ICV ambitions (England, 2018). SenseTime, the world's most valuable AI start-up, backed by Alibaba, has recently opened a self-driving vehicle research facility in Japan (Liao, 2019). Similarly, Tencent recently received licenses to test self-driving vehicles in Shenzhen and Beijing where it has begun testing level 3 self-driving vehicles. The company has begun recruiting senior autonomous vehicle engineers in Silicon Valley. Finally, JD.com, one of China's largest e-commerce platforms, is currently developing and testing autonomous vehicles for parcel deliveries. Out of China's traditional automotive OEMs, SAIC and Changan are currently the most ambitious in developing autonomous driving technology, having received testing permits in both China and the US (Schlobach & Retzer, 2018).

Autonomous driving as a mobility trend is underpinned by China's aggressive AI ambitions. By 2030 China wants

to become a global leader in Artificial Intelligence (AI) technology and has been dedicating vast resources towards attaining this goal. In 2017, 48 % of total global equity funding for AI came from China, with the US accounting for 38 % (Chun, 2018). Already today, five of the seven largest AI start-ups in the area of computer vision are Chinese.

China has also been aggressively developing traction battery producers that are already playing a vital role in supplying domestic and international automakers with traction batteries, an integral (and high-value) component for the production of NEVs. Indeed, over the past few years, Chinese companies Contemporary Amperex Technology Co Ltd. (CATL) and BYD have overtaken South Korean and Japanese battery producers to become the two largest producers of traction battery cells. While BYD's cell production is largely geared towards use in its own NEV products, CATL has already disclosed supply deals with German OEMs such as BMW and Volkswagen. A number of smaller Chinese battery manufacturers such as Lishen Battery or Guoxuan High-Tech have also experienced remarkable growth and have become sizeable and important producers of traction battery cells.

In addition to the rapid growth of NEVs and ICVs, China is experiencing growth in the fuel cell and hydrogen vehicle department, particularly in the domain of cargo transportation, delivery vehicles and buses. Over the past few years the amount of scientific publications and declared patents related to the technology has grown substantially. Similarly, several fuel cell pilot projects are running throughout the country. Currently, a multitude of Chinese enterprises are working with foreign enterprises to catalyse the development of the technology. Most notably, Canadian fuel cell pioneer Ballard has signed agreements with various Chinese enterprises to deploy

fuel cell technology. For example, in February 2018, the deployment of 500 delivery vehicles for the city of Shanghai, made by Dongfeng motors and all using Ballard fuel cell technology, was announced (Ballard, 2018). Similarly, Chinese start-up Shanghai Sinotran New Energy

Automobile Operation Co., announced an investment of 10 million EUR by French company Air Liquide, with the goal of operating a fleet of up to 7,500 fuel cell trucks and establishing a network of around 25 hydrogen fuel stations in China by 2020 (Green Car Congress, 2018).

### 3.5 Legal Trends

Legal developments in China, particularly the establishment and enforcement of emission standards and a brand-new cybersecurity law, are also shaping the contours of the country's mobility landscape.

China has made profound progress regarding the setting and enforcement of emission standards. China's modern nationwide emission control program has its origins in the late 1990s, beginning with the elimination of leaded gasoline and the implementation of progressively stringent tailpipe emission standards for light-duty vehicles. Chinese emission standards followed the model of European regulations. The current national emission standard, China V, was applied nationwide to all gasoline vehicles sold after January 2017 and for all diesel vehicles sold after January 2018.

Today, Chinese emission standards are amongst the world's most stringent. China VI emission standards for gasoline and diesel vehicles, announced in June 2018 and set to be implemented in 2020 and 2023, are between 40 % to 50 % more stringent than China V standards. Importantly, these standards include standards for heavy-duty vehicles (HDVs) which are set to force diesel particulate filters on all new diesel HDVs introduced to the market after mid-2021 (Cui & Minjares, 2018). China is the world's largest

HDV market and as vehicles affected by China VI account for over 90 % of particulate matter emissions and nearly 70 % of NOx emissions from China's on-road transportation fleet, China VI can be seen as a significant milestone in China's quest to reduce road emissions (CCAC, 2018). The International Council on Clean Transportion (ICCT) estimates that China VI emission standards are set to lead to a reduction in China's annual average PM2.5 and ozone concentrations by 5 % and 2 % respectively in 2030 and an accumulated black carbon (soot) reduction of 993,000 metric tonnes over the period 2020 to 2050 (Cui & Minjares, 2018).

China's cybersecurity law, one of the most comprehensive legislations in PRC history, came into effect in June 2017. The law, officially designed to '*protect the rights and interests of citizens, safeguard national security, and promote economic development through heightened network*' via audits, surveillance and localisation of data, is a milestone in the standardization of personal data<sup>17</sup>. In essence, the cybersecurity law puts a check on how companies handle user data, particularly with whom and how it is shared. However and perhaps most importantly, the law requires Chinese network and server operators to cooperate with Chinese authorities and allow full data access upon request, thereby granting the Chinese state the legal right to access

<sup>17</sup> Full explanation of the law can be found under: <https://www.dezhira.com/library/legal/cyber-security-law-china-8013.html>

any disconcerting data of any company and associated personal information within its jurisdictions.

This has particularly far-reaching ramifications for foreign enterprises operating in China. As the law requires network operators in critical sectors, including the transport sector, to store all data that is collected or produced in China within the country, foreign enterprises are having to comprehensively restructure their data management systems. As such, foreign firms must either invest in new data servers or hire local server providers such as Huawei, Tencent or Alibaba and entrust them with their data.

These changes are also shaping the development of

China's mobility sector, with profound implications for the development of AI and Big Data heavy mobility innovations, particularly within the ICV and autonomous driving domain. First, the law is emblematic of a tug of war between those in China pushing for increased data privacy protection and those advocating greater freedoms for data usage as a means to provide innovative thrust for the development of fields such as AI and Big Data. Second, with foreign firms now having to store data domestically, the move bolsters domestic data management and telecommunication companies against global competitors, potentially putting Chinese ICV and autonomous driving enterprises at an advantage vis-à-vis their foreign competitors.



## 4. Assessment and Outlook: Future of Chinese Mobility

Over the past thirty years, China's economic transformation has catalyzed a monumental mobility transformation that continues to this very day; China has quite literally put the 'pedal to the metal'. The Chinese mobility sector is highly dynamic and is in a continuous state of flux and evolution. The Chinese transport sector is a complex construct and involves a vast array of stakeholders; from passengers and consumers, local and international automakers, logistics and shipping providers, mobility consultancies, innovative start-ups, research institutes, infrastructure construction companies, international financial institutions, to international organisations. With so many agents involved in shaping the transport landscape of the future, and

technological variables in abundance, mobility outcomes are unclear and robust predictions of the future are all ill-fated. Nevertheless, China has proven itself to be ambitious and contemporary technological developments and ambitions are likely to usher in a new era of mobility.

Thus, it is now time to explore the future of Chinese mobility. By drawing on interviews with experts and stakeholders within the Chinese transport industry, this chapter will assess and discuss possible future directions, outline challenges that China might face on its way to building sustainable transport systems, as well as capture general sentiments about the future of Chinese mobility.

While a wide variety of transportation domains will be explored, special attention will be given to electrification and NEVs. The chapter will also explore and highlight

important mobility lessons that can be drawn from the Chinese experience.

## 4.1 Structural Change

Fast growing urban populations with growing disposable incomes will continue to put pressure on national transportation systems. Indeed, by 2030, China expects to add another 300 million citizens to its already sprawling cities (Harvey, 2013). For Binyam Reja, Transport Practice Manager for Central Asia, China and Mongolia at the World Bank in Beijing, how Chinese policymakers respond to continued urbanization will be of critical importance in defining the sustainability of Chinese transportation systems. With cities urbanizing and suburbanizing, commuting distances and times are growing larger and longer, making it necessary to continue urban public infrastructure expansion to curb the growth of motorization and improve transport sustainability. These challenges, Binyam Reja claims, will be particularly stark in China's large city clusters<sup>18</sup>, as they are developing into large economic masses where people are going to live and trade over huge distances. Thus, while China has already built urban transportation infrastructure at an unprecedented rate, the country will need to continue expanding urban transportation networks to improve transport efficiency. Sun Shengyang, Senior Researcher at the China Academy of Transportation Sciences (CATS), a research division of the Chinese Ministry of Transportation (MOT), foresees commuter railway systems becoming increasingly important in China's large city clusters as a means to connecting suburban citizens with existing urban public transportation systems. Indeed, no Chinese city currently

has a commuter railway network. In addition to expanding urban rail systems, China will also need to improve the integration of the highways it has built with urban road systems to improve overall efficiency and connectivity.

Yet it is not only transport infrastructure that will need to be expanded. With urban land becoming increasingly rare and people still migrating to cities, space for road and rail infrastructure will become ever more scarce, requiring stakeholders to think of new and innovative ways to develop urban mobility. Liu Daizong, China Transport Program Director at the World Resources Institute (WRI) in Beijing, insists key development plans must include the full integration of public transport services with new mobility solutions such as ride-sharing or bike sharing, as well as developing urban sub-centres which can reduce the need for urban travel.

Indeed, the future of shared mobility in China looks bright. Hui He, Senior Researcher at the ICCT in Beijing, foresees that by replacing private vehicles with shared mobility solutions, shared mobility can play an instrumental role in meeting the daily transportation demands of the urban population. Shared mobility will likely be driven by China's younger generation, a generation which is increasingly accepting and embracing innovative mobility solutions. Moreover, for China's mobility platforms, such as those in the bike-sharing and e-hailing segment, to have

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<sup>18</sup> Jing-Jin-Ji Region, Pearl River Delta, Yangtze River Delta

a positive impact on transportation sustainability, they will also require improved and fine-tuned regulatory frameworks and supervision. For example, WRI's Liu Daizong believes better regulatory frameworks could push

forward the electrification of shared-mobility vehicles and move individualized e-hailing services more towards seat-sharing service vehicles such as microbuses, and in the process improve transport sustainability.

## 4.2 Infrastructure Investment

Expansive and costly transportation infrastructure investments are likely to continue over the next few years. While significant investments are needed to improve transport efficiency, with the pace of Chinese economic growth expected to continue slowing down, many experts anticipate that the state will ramp up infrastructure investments as an economic stimulation mechanism. What continued infrastructure investment means to the wider transportation sector remains unclear however. With highway and HSR networks in China now covering most economically major regions, the return on investments for infrastructure is slowing down substantially, raising questions of economic viability. As most infrastructure projects in China are financed by short maturity commercial loans, the continued expansion of infrastructure investment could amplify China's already disconcerting domestic debt<sup>19</sup> worries and if investment returns drop, could spark financial instability. These sentiments are widely reflected amongst transport stakeholders in China.

In line with this, Tang Wei, a Senior Researcher at the China Highway and Transportation Society (CHTS), a policy and technology research institute linked to the Chinese Ministry of Transport, argues that debt and

infrastructure investments in the context of an economic slow-down is one of the biggest problems the country faces in continuing to overhaul its transportation sector and industry. Similarly, Terry Zhao from Beijing LINC Technology, an electro-mobility consultancy, explains that investments in low return sectors such as HSR and highway infrastructure are also to a certain extent 'crowding out' investments in productive and innovative sectors. As such, he asserts that China should restructure its investment pool away from heavy infrastructure investments towards sectors with higher return potentials and, in his opinion, that the NEV and ICV industries would present such opportunities.

Nevertheless, it is clear that infrastructure investments are still needed to improve the quality and efficiency of transportation systems, especially in the domain of urban transport. To continue financing transport infrastructure projects in the long-term, World Bank expert Binyam Reja asserts that China needs to identify ways to diversify infrastructure financing from short-term commercial loans towards long-term bonds with institutional investors. Second, policymakers at the local level could diversify their revenues by developing user charges, property tax and infrastructure levy systems. Third, as the value of land

<sup>19</sup> Between 2008 and 2018, Chinese domestic debt grew from about 180 % to almost 300 % of GDP (Wolf, 2018). While overall debt levels should not be seen as dangerously high, the rapid rate in which debt is accumulating is what makes Chinese domestic debt a potentially dangerous macroeconomic issue.

appreciates when infrastructure is built, policymakers need to find innovative solutions to capture this appreciation of value. In other words, current Chinese financing structures

are unsustainable and policymakers need to find new and innovative financing solutions to continue improving the scope of Chinese transportation.

### 4.3 Wider Industrial Development – Key Obstacles

In its quest to reach the ambitious transport targets set in the ‘Made in China 2025’ plan, the 13<sup>th</sup> FYP, the ‘Blue Sky Action Plan’ and other industrial development plans, China has many obstacles to overcome.

First, and perhaps most importantly, economic uncertainty could force China’s industry to apply the brakes. Economic growth is slowing down, China’s heated property market and infrastructure investments have led to an accumulation of domestic debt, and trade tensions with the US are ongoing. As the economy slows down, demand for products could be stunted and economic uncertainty could provoke unease among investors.

Second, the future of the Chinese transport industry, especially from a technological position, is confronted with challenges of a political nature. For Robert Earley, of EQ Consulting, a sustainable transport consultancy, due to tight firm-state relations, Chinese technology can only be successful on a global scale if it is politically accepted by other countries and can win the trust of foreign consumers. Due to data privacy concerns, these challenges could prove especially onerous for data and connectivity-heavy mobility solutions such as shared mobility and ICVs.

Third, while Chinese policymakers have proven themselves to be skilled at guiding transport stakeholders

in developing transport systems, both a lack of coordination and conflicts of interests between state organs and ministries are posing challenges to the further development of the sector. In the view of Tang Wei from CHTS, policy overlaps and a clear lack of coordination of responsibilities, such as competition for industry and infrastructure development powers between the MOT and the National Development and Reform Commission<sup>20</sup> (NDRC), present major challenges for the sector. Related concerns are echoed by CATS expert Sun Shengyang who posits that while industrial development plans for the automotive industry target vehicle sale increases, transport-related policies are often designed to limit vehicle growth in an attempt to manage severe traffic congestion in cities. In Beijing for example, 2019 NEV license plate applicants are set to wait for up to eight years before receiving license plates. The limits on car registrations, which exist in all major Chinese cities, could stunt vehicle demand and provide difficulties for growth of the NEV industry. While coordination problems between state institutions are not unique to China, the paramount role that the Chinese state plays within the Chinese transportation sector could make such issues a significant pressure point.

Finally, short-term thinking amongst Chinese policymakers is also expected to remain a problem for the transport sector. One interviewed stakeholder explained

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<sup>20</sup> A macroeconomic agency under the Chinese State Council, which enjoys broad administrative and planning authorities over the Chinese economy

that with state officials usually having one to five year terms, officials who wish to demonstrate their performance to guarantee a move up in the government ranks, continue to borrow and invest, often in financially unviable projects, to boost their short-term standing; when the related problems arise, it is their successors who are left to deal with them. While China's meritocratic bureaucratic

system has been an important driver of China's economic development, a transition towards sustainable transport requires long-term strategic planning, and while industrial development plans such as 'Made in China 2025' have long-term orientations, vested interests and short-termism could jeopardize the country's ambitions.

## 4.4 Electrification and NEVs

The electrification of Chinese transport and the development of a competitive NEV industry is expected to continue for the foreseeable future and, by improving urban air quality, will prove instrumental in shaping the future of Chinese sustainable mobility. Importantly, state ambitions will continue to play a key role in this domain. For Wang Yunshi, Director of the China Center for Energy and Transportation at the Institute of Transportation Studies at University of California Davis, the Chinese state's electrification ambitions are driven by three key forces. First, with the country importing more than two thirds of the oil it consumes, the Chinese state has become increasingly worried about energy dependency and sees electrification as a potential means to an end. Second, environmental issues in urban areas, especially in China's three large city clusters, and related policies such as the 'Blue-Sky Action Plans' will continue to drive electrification as a means to reduce urban air pollution. Finally, with the Chinese Internal Combustion Engine (ICE) industry still underperforming, government policies will continue to fortify Chinese efforts in building a NEV industry that can be competitive in the international arena.

Indeed, China's ambitious drive in the development of a competitive NEV and ICV industry is already taking

center stage in China's future mobility plans. China, most experts claim, has come to realize that it cannot compete with established global automakers in the domain of ICE vehicles but is confident it can leapfrog the technology to become a global electro-mobility powerhouse.

There are many reasons for stakeholders to be confident and optimistic in China reaching the NEV targets stipulated in the 'Made in China 2025' plan. Rainer Becker, Senior Mobility Director at Byton, one of China's most ambitious NEV start-ups, believes there is a strong and positive political environment for NEVs in China. The highly supportive character of the state, he claims, and the large publicity that NEVs have received, are giving the vehicles a positive perception amongst Chinese consumers and will contribute to the growing demand for such products. Moreover, with motorization rates still significantly lower in lower tier cities, rising incomes and growing mobility demands present promising opportunities for the electro-mobility market where new car buyers, it is hoped, will skip ICE vehicles altogether and move straight to NEVs.

Indeed, Chinese NEV ambitions present challenges for the globally established automotive industry and for ICE vehicles. Zhang Lin, Senior Manager at the China office of

VDA, the German association of the automotive industry, believes that while differences in vehicle quality and technology levels will still be observable in a decade, the gap between Chinese and German producers will gradually close. A key notion in this domain is China's ability to take up, implement and optimize new technologies in their products at faster rates than their international competitors and this makes Chinese products increasingly attractive. Similarly, in the view of a strategy expert at one of Germany's leading OEMs, due to their flexibility and creativity, as well as their capacity to attract large sums of venture capital, Chinese NEV start-ups need to be taken seriously as potential competitors, not just for NEV products but for the wider automotive market.

Autonomous driving is also set to continue developing at an impressive pace in China. For Terry Zhao, from Beijing LINC Technology, the country will be at the forefront of ICV development as China holds informational

advantages over its global counterparts. Indeed, as shown in **Section 3.4**, China's information industry giants, Baidu, Alibaba and Tencent are all involved in autonomous driving projects and are heavily funding necessary AI development. These conclusions are echoed by Zhang Lin from the VDA who stresses that what will happen in the domain of digital infrastructure and connectivity technology will be instrumental for the development of the wider automotive sector. A widespread adoption of ICVs will also have profound impacts on existing mobility systems. In the view of Christian Hochfeld, Executive Director of the German Think Tank Agora Verkehrswende, the widespread adoption of autonomous driving vehicles could lead to more vehicles on Chinese roads, implying that autonomous driving would only be manageable if implemented within shared mobility concepts. Market regulation, likely through price incentives, he adds, will be needed to ensure that autonomous driving will have positive impacts on mobility.

#### 4.4.1 Future Development of the Chinese NEV and Automotive Industry

Domestically, the Chinese automotive and NEV market is likely to undergo further upheaval, with many expecting the market to consolidate. In the long term, NEV expert and industry consultant Terry Zhao predicts that the expiration of NEV subsidies in 2020, and unleashed market dynamics, will weed out inefficient and less innovative firms, consolidating the Chinese market into a handful of large manufacturers, akin to current market structures in Germany or Japan. More particularly, Zhang Lin from VDA believes that within the next five years the industry could see a multitude of mergers, especially between China's large state-owned carmakers, as market pressures intensify and players try to increase their market share. Naturally, consolidatory

dynamics will pose existential threats for many firms in the industry, both for China's large OEMs and for the country's multitude of NEV start-ups.

Yet, many firms remain optimistic and confident about their future. Rainer Becker from Byton contends that while the dangers of market mechanisms are always present, the flexibility of young start-up firms in adopting and developing new technologies makes them well-suited to be competitive in the future. Similarly, Terry Zhao also believes that the phasing out of NEV subsidies is not a major worry for the Chinese industry as a whole. China's financial system, he argues, is becoming mature enough for companies to raise funds via market mechanisms, reducing

the industry's reliance on state support and subsidies, thereby fostering firms to become financially sustainable and competitive on domestic and global markets.

Nevertheless, how Chinese automakers attempt to position themselves on global markets remains open, with many plausible scenarios being put forward. Christian Hochfeld of Agora Verkehrswende suggests that Chinese

carmakers will not necessarily position themselves as classic manufacturers and sellers of vehicles. Instead, possible scenarios in which Chinese automakers could increase their global footprint include via global shared-mobility platforms, by dominating certain supplier markets such as traction battery production, or by increasing their equity stakes in established global automakers<sup>21</sup>.

#### 4.4.2 Electrification Challenges

China is nevertheless confronted with a multitude of domestic obstacles in its quest to leapfrog ICE vehicles and become a global NEV powerhouse. Importantly, China could run into many demand-side obstacles. UC Davis expert Wang Yunshi expects that with a rapidly ageing population, growth in the Chinese car market could slow down considerably as there exists a negative causal relationship between age and car demand. Similarly, the performance of the general economy could also dampen the demand for NEVs; as economic growth slows down, demand could dry up. These worries are echoed by a spokesperson at one of China's most ambitious NEV start-ups who stresses that the country's macroeconomic performance is a major, probably the most pressing, worry for the future of their company.

Safety concerns could also affect vehicle demand. As China has a large number of NEV manufacturers and suppliers, and the technology is developing at a rapid pace, the appropriate implementation of safety standards and testing procedures is proving a challenge for the industry and could explain a variety of recent NEV incidents and accidents. Indeed, as explained by Kim Hyoungmi, Senior Policy Specialist at the Natural Resources Defense Council

(NRDC) in Beijing, as NEV technology is developing so rapidly, it is difficult for standards and regulations to keep pace with technological developments, leading to a range of safety issues and inefficiencies that the industry still needs to tackle.

As the country attempts to shift automotive demand towards domestically produced NEVs, automakers could also suffer from brand-awareness related problems. UC Davis expert Wang Yunshi points out that Chinese consumers have long accepted Western brands and are not nationalistic when it comes to buying products such as cars. Similarly, a spokesperson at one of China's most successful NEV start-ups, affirms that Chinese consumers, especially those in non-tier one cities and in rural areas, aspire to buy Western brands that they perceive as having superior quality and prestige over their domestic counterparts. Nevertheless, these perceptions are slowly changing, she claims, as NEVs are receiving a lot of positive publicity through state support. In sum, these challenges imply that Chinese manufacturers will have to develop and market truly competitive products in order to capture demand from international competitors, at home and abroad, a heavy challenge indeed.

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<sup>21</sup> In February 2018, Geely acquired an 8 billion EUR, or 9.7 %, stake in Daimler AG, becoming the largest single shareholder in the corporation

### 4.4.3 Electrification and Energy

While electrification is set to substantially improve air quality in Chinese cities, its impact on cutting total GHG emissions will remain low as long as coal remains China's primary source of energy. This, as UC Davis transportation expert Wang Yunshi posits, is due to the notion that Chinese policies have actively targeted cuts in PM2.5 particulates but not in specifically reducing GHG emissions. While China has made substantial progress in clean coal technology and has closed many outdated coal power plants in recent years, thereby reducing harmful pollutant concentrations such as Sulphur and NOx, China is still building coal power plants to meet electricity demand.

Thus, with coal being China's primary source of energy, the impact of electrification on transport sustainability is inextricably linked with the integration of clean and renewable energies into the power grid. However, energy and transport expert Robert Earley points out there are mismatches between policies designed to promote renewable energies and those designed to improve transport sustainability. In fact, there are currently no quantitative policies and targets for renewable energy sourcing for EV charging for example. Moreover, in the view of Christian Hochfeld from Agora Verkehrswende, the construction of energy distribution networks and the alleviation of energy-transmission bottlenecks will continue to be a major challenge for China, especially

when it comes to the integration of renewable energies into national energy grids. China's power market reform is still underway and lacks the right incentives that would give the power sector the ability to use the right market forces to improve integration of EV charging and renewable energies.

In addition to renewable energy integration, tighter integration of electric grids with charging infrastructure will be important in optimizing energy consumption. For NRDC expert Kim Hyoungmi, demand response and other mechanisms where NEVs could provide more value to the power system will play a key role in enhancing efficiency for electro-mobility. For example, by using policy instruments, NEV users could be incentivized to charge their vehicles during low demand periods to lower peak-hour demand. Indeed, Zheng Yali, Head of the Automotive Industry Research Department at the Society of Automotive Engineers of China (SAE), believes vehicle-to-grid (V2G) and smart charging demonstration projects in China could prove feasible for nationwide adoption. Another key challenge to providing an extensive and efficient charging infrastructure is the belief that most urban citizens reside in apartment buildings where home charging is not necessarily feasible for most NEV owners, requiring the country to invest heavily in public charging infrastructure.

### 4.4.4 Fuel Cell Technology

While China is set to deepen its loyalty to electrification, fuel cell technology could also play an important role in improving the sustainability of Chinese transportation. Indeed, recent developments suggest that subsidies for fuel

cell vehicles might not be phased out in conjunction with the phasing out of NEV subsidies. Moreover, Zheng Yali from SAE believes that fuel cell technology should not be seen as a zero-sum game competitor to electrification.

Instead, the two technologies could successfully complement each other. While NEVs are highly suited for short-distance and private urban travel, fuel cell vehicles could play an important role for buses and logistics

vehicles. Nevertheless, currently China's focus for future mobility rests heavily on electrification and the broader adoption of fuel cell technology remains to be seen.

## 4.5 Logistics, Freight and Shipping

The Chinese freight and logistics sectors are also expected to adapt to changing realities. As the majority of freight in China is currently transported by road, shifting freight transport to more sustainable transport modes such as railway or waterways will play a key role in reducing Chinese transport emissions. While Chinese railway networks, it is often claimed, are largely underutilized for freight transportation, trucks often emit more than expected due to overloading issues, making the road to rail shift of paramount importance for transport sustainability. However, as explained by one interviewed expert, CR, which operates most rail routes in China, does not currently have the logistics and business orientation that would be necessary to efficiently and quickly shift freight transportation from road to rail. Nevertheless, China has already introduced a number of policies designed to catalyse this shift, especially in the domain of mineral ore and coke transport, and is expanding freight railway lines in regions where these commodities are mined and produced.

Of course, not all freight can be moved away from roads, meaning that efficiency improvement in road vehicles is required. However, in contrast to passenger vehicles, where a large number of electric vehicle models are already available, model availability for electric freight vehicles remains low. Indeed, in which technological direction Chinese HDVs will develop remains unclear; while some

posit that electrification will be the preferred way, others posit that fuel cell technology or synthetic fuels will dominate. Nevertheless, as articulated by ICCT expert Hui He, moving HDVs towards electrification or fuel cell power will be one of the core challenges in China's mission to cut transport emissions.

There is also sizeable emission reduction potential in non-road sectors such as aviation and shipping, where efficiency and sustainability improvements could have global reverberations. For example, with seven out of ten of the world's busiest ports sprinkled across China's coastline, WRI expert Liu Daizong points out that improving the efficiency of Chinese ports will have profound impacts for the sustainability of the global shipping industry. In this domain, China has already begun to implement policies designed to more efficiently link ports with road and railway systems, an attempt at optimizing intermodal transport operations, as well as to build shore-to-ship power solutions to reduce emissions in coastal areas.

In sum, for the Chinese freight and cargo transport sector to cut down on emissions, a significant overhaul of the system will be necessary. Intermodal operations need to be improved, e-commerce distribution channels optimized, the bulk of freight transport shifted from road to rail and the sustainability performance of road transport vehicles and HDVs significantly improved.

## 4.6 Conclusion and Lessons

Regardless of the direction that China's transport and mobility sector will take in the future, China's mobility transformation has been nothing short of staggering. Over a short period, China has built a transport sector that no other can rival in scale, underpinned by an industry that has become increasingly innovative, and one that has the power to shape future global mobility trends; and all of this from low levels of economic development. As such, it is useful to ask ourselves what lessons countries from both the developed world, particularly well-established mobility giants such as Germany, and those from the developing world can draw from the Chinese experience.

A key take-away for countries in the developed world is the speed at which China is able to plan and execute its industrial development ambitions. This view is supported by Christian Hochfeld from Agora Verkehrswende who posits that for countries like Germany, the incredibly dynamic nature of change within the Chinese transport sector can provide a valuable, albeit potentially bitter lesson in how quickly change can come about. It is important to realize, he adds, that Germany's position as a mobility giant could be in jeopardy if the country does not adapt, innovate and reconfigure itself in tandem with global dynamics and realities. On a related note, Rainer Becker from Byton claims that Chinese mobility companies show more of a 'go-for-it' attitude than their German counterparts who often tend to focus more on weighing and balancing risks. This could potentially give them a competitive edge in the long run. Countries such as Germany, it is often argued, will need to learn from China's ability to embrace innovation if they wish to stay at the forefront of the global transportation industry.

Indeed, China has been embracing and welcoming disruptive technological developments with open arms. A key take-away in this domain is the large availability of risk and venture capital in China. With both the state and the private sector essentially 'betting on innovation', the Chinese industry is flush with capital intended to develop and adopt new and disruptive technologies, to develop innovative mobility systems and concepts, as well as to fund mobility start-ups. As history has often shown, risk often pays off. In contrast, as many interview partners agreed, Germany has a comparatively risk-averse attitude towards financing innovation and could draw valuable lessons from China in this domain.

Notwithstanding China's achievements in the mobility sector, China's experience needs to be taken with a healthy dose of scepticism. It remains unclear whether China is developing mobility firms that can compete on a global basis or whether state subsidies and venture capital are merely keeping unviable business models afloat. Indeed, many 'innovative' Chinese companies such as Didi Chuxing, China's bike-sharing operators, or BYD's NEV arm are yet to turn a profit. Similarly, many interview partners are highly sceptical of Chinese NEV start-ups, stating that when established automakers start flexing their muscles, advantages in scale and experience could prove insurmountable challenges for the Chinese industry. Only the future can tell.

The Chinese mobility sector can also provide valuable lessons for countries in the developing world who are confronted with their own mobility challenges. Robert Earley from EQ Consulting points out that China's capacity to develop and manage public transportation

systems, even in times of low economic development, has been an impressive success and could provide lessons for the developing world. Indeed, when China built its second metro line in Tianjin in 1984, China had a per capita GDP of just 481 USD<sup>22</sup>, less than countries such as Malawi, Uganda, or Afghanistan have today (World Bank, 2019j). Similarly, for World Bank transportation expert Binyam Reja, China's innovative financing approach and the mechanisms it has used to raise funds can provide useful lessons for countries around the world. Financing transportation is expensive and raising the capital necessary to undertake investments is a major challenge for countries across the world; a challenge that China has managed to overcome with remarkable ease. Indeed, the Chinese financing approach, while having raised worries about high levels of debt, has successfully been able to support the expansion of Chinese transportation expenditure and has allowed China to build the largest HSR and road networks on our planet.

China's success in building transportation systems has, to a large degree, been underpinned by the country's institutional capacity. In brief, the nature in which China has organized and pulled together relevant stakeholders and built the capacity necessary to plan and execute projects on time and at an acceptable quality, are achievements that need to be further studied and shared with other countries who are in the process of building their own transport systems. These capacities also inspire optimism for China to be able to successfully restructure and develop its transportation system to improve urban air quality, cut carbon emissions and increase sustainability. Of course, with China boasting a population of 1.4 billion people and a highly centralized bureaucratic political structure, the country has always had a unique political-economic environment. Thus, while China's experience with transport cannot simply be transferred to other countries, studying the structures that have allowed Chinese dynamism to flourish can provide valuable lessons for countries across the globe.

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<sup>22</sup> Constant 2010 USD

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