



China is racing towards
zero
emission
road transport
urban mobility beyond cars

China is racing towards zero emission transport: urban mobility beyond cars

China is racing towards
zero emission
road transport
urban mobility beyond cars



PREFACE

Climate change has posed significant threats to our planet, which is evident from the observed global warming, the melting polar ice shields, the rising sea level, and more frequent and severe extreme weather events. These alarming changes have caused extensive damage to cities, rural areas, and the rest parts of ecosystems worldwide. Intergovernmental Panel on Climate Change (IPCC) has concluded that human influence on the climate system is clear. To address climate change and ramp up the actions and investments needed, the global community adopted “Paris Agreement” in December 2015. Its primary objective is to **limit the global temperature rise this century well below 2°C above pre-industrial levels and strive to keep even lower at 1.5°C. To have the goal within reach, global greenhouse gases (GHGs) emissions need to peak before 2025, decrease by 45% by 2030, and achieve net zero by 2050.**

However, **the current actions are neither broad, nor bold, nor fast enough.** In 2020, the Arctic and the Antarctic continent witnessed record-breaking temperatures of 38.0°C and 18.3°C, respectively (WMO, 2021a, 2021b). As this warming trend continues, 2023 is set to be the hottest year on record at many places. Notably, Beijing experienced a scorching temperature of over 41.1°C, significantly higher than the previous records for the same period (Shi, 2023). The Middle East also endured an extreme heat index of 66.7°C, reaching the upper thresholds for human tolerance. Meanwhile, the Southern U.S. grappled with an exceptionally intense and extended heat wave from California to Florida. Phoenix City hit 43.3°C for 31 consecutive days (Patel, 2023). Furthermore, the return of El Niño has set the stage for soaring global temperatures and intensifying damaging weather patterns. It underscores the urgency to accelerate reductions in emissions.

China is the world’s second largest transport carbon emitter only after the U.S. Although currently, China’s transport emissions account for about 9% of the national total (IEA, 2021, 2023a, 2023c), they are comparable with many countries’ economy-wide emissions—three times that of the UK, twice as much as Canada’s, and almost equal Japan’s. China’s transport sector could come into the sixth place if it were a country. In China’s quest for zero emission transport, electric vehicles (EVs¹) is always the first one that people give credit to. Globally, China has ranked first in both EV production and sales for eight consecutive years since 2015. By the end of 2022, the country has seized 58% of global EV sales and 56% of total EV stock (IEA, 2023b). However, China's large population, growingly concentrated people in cities, and diverse economy mean that **China's passenger transport cannot rely solely on cars.** To ensure safe, equitable, convenient, economical, and clean travel for 1.4 billion people, China must seek sustainable ways beyond cars. Therefore, China prioritizes the development of public transport and active mobility² and keeps improving the service. There are also detours, some of which may serve as references for future development in China and other countries.

This report aims to present China’s initiatives, progress, insights, and lessons learnt in the pursuit of zero emission urban mobility beyond cars. It will be elaborated from the aspects including **buses, urban rails, shared bicycles, and electric two and three wheelers (E2/3Ws)³**. The information and discussions in this report could be valuable to countries at different stages of transition who seek to accelerate the advancement of zero emission urban mobility.

ABOUT THE AUTHORS

This report is a knowledge product of Energy Foundation China. Authors are:

Yin Le, Senior Program Officer of the Transportation Program, Energy Foundation China
Zheng Biqi, Program Officer of the Transportation Program, Energy Foundation China
Wang Man, Consultant of the Transportation Program, Energy Foundation China
Gong Huiming, Senior Program Director of the Transportation Program, Energy Foundation China
Sun Xuefei, Senior Program Associate of the Transportation Program, Energy Foundation China

ACKNOWLEDGEMENT

The team would like to thank the following experts for their contribution to this report:

Li Shanshan, Vice Country Director, Institute for Transportation & Development Policy
Liang Jindong, Executive Director, Beijing Smart & Green Transport Research Center
Peng Yuhui, Professor, Fuzhou University

The team also appreciates Ms. Li Li for her excellent editing, and appreciate the selfless help from Ms. Lin Weiwei, Ms. Xin Yan, Ms. Yang Peipei, Ms. Zhao Rui, and Ms. Zhuo Yuewen from Energy Foundation China.

DISCLAIMER

This document was prepared based on information and data acquired from public sources, neither Energy Foundation China nor any of its employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy and completeness. The views and opinions of authors expressed herein do not necessarily state or reflect those of Energy Foundation China. This document is for reference only. Readers are to exercise independent judgment on the contents, and Energy Foundation China does not assume any legal responsibility for the consequences caused by the use of this document by any individual or institution. Reference herein to any specific entity, product or service, does not necessarily constitute or imply its endorsement, recommendation, or favoring by Energy Foundation China.

CITATION

To reference this report, please use following citation as:

Yin, L., Zheng, B., Wang, M., Gong, H.,& Sun, X. (2023). China is racing towards zero emission transport: urban mobility beyond cars. Energy Foundation China (EF China).

¹ Its Chinese name is new energy vehicles (NEVs), including battery electric vehicles (BEVs), plug-in hybrid vehicles (PHEVs), and fuel cell vehicles (FCVs).

² Active mobility is the Chinese term of “slow transportation (慢行交通)” which includes both walking and non-motorized vehicles such as bicycles and e-bikes. It is similar to the term of “micro mobility” that includes bicycles, two wheelers, and three wheelers, either privately owned or publicly shared. The major difference between the two terms is whether walking is included or not.

³ This report will mainly look at the widely deployed electric two and three wheelers, because the fossil-fuel two and three wheelers, which are commonly used in rural areas and small cities, are often defined as motorcycles in China for their typical high speed of over 50km per hour.

TABLE OF CONTENTS

China is racing towards
zero emission transport:
urban mobility beyond cars

Executive Summary	01
LIST OF ACRONYMS AND ABBREVIATIONS	06
I A GLIMPSE OF CHINA'S URBAN MOBILITY DEVELOPMENT	
● KEY FACTORS determining China's urban mobility demand and international comparison	08
● KEY DRIVERS for China to move towards zero emission urban mobility	16
● Progress of zero emission urban mobility beyond cars in China	20
II TRANSIT BUS	
● WHAT'S the scale and emission of transit bus system in China?	31
● WHY does China prioritize the zero emission transformation of buses?	36
● HOW does the policy motivate the changes?	40
III URBAN RAIL	
● WHAT makes urban rail favored over road transport?	46
● HOW BIG and FAST does urban rail develop?	50
● HOW does urban rail contribute to ease the traffic and reduce emissions?	52
● WHAT kind of policies enable such development?	55
IV SHARED BICYCLES AND ELECTRIC TWO AND THREE WHEELERS	
● WHY are shared bicycles and E2/3Ws so popular?	61
● WHAT impacts do shared bicycles and E2/3Ws bring to urban mobility?	68
● WHAT are the key findings?	73
V KEY ELEMENTS FOR SUCCESS	
● Vision, mission and actions	80
● Proactive government and consistent and sustainable policies	80
● Consensus and alignment across stakeholders	80
● High-efficiency and low-cost manufacturing along the supply chain	81
● Overseeing, evaluating, and improving the policy goals	81
VI WHAT'S MORE FOR LOOKING AHEAD?	
● Strengthen overarching planning	83
● Improve the financial sustainability of public transport	83
● Avoid "one size fits all" policy for E2/3Ws management	83
● Seize the opportunity of future technology to provide more inclusive, safe and environmental transport services.	85
● ACCESS FOR ALL: improve the barrier-free mobility	85
Milestones of China's Urban Mobility Development beyond Cars (2007-2022)	86
Major Policies of China's Urban Mobility Beyond Cars (2003-2023)	87
References	89

Executive Summary

China's transport sector emitted 9.46 million tons of CO₂ in 2022, accounting for 9% of national total carbon emissions (IEA, 2023c). This makes China the world's second largest transport carbon emitter only after the U.S. Urban mobility represents a major emission source of China's road transport, which contributes about 80% of China's transport carbon emission and about 7% of China's national total carbon emission. Therefore, zero emission transformation of urban mobility is critical for China to achieve its carbon goals.

China has been making efforts to reduce urban mobility emissions, especially through its unprecedented and world-leading development of EVs. By the end of 2022, China accounted for 58% of global EV sales and 56% of EV stock (IEA, 2023b). However, China's transition to zero emission transport requires more than just EVs, due to its large population, vast territory, complex terrain, diversified and imbalanced economy, as well as growing travel demand coming along with fast urbanization. China must develop a high-capacity and comprehensive urban mobility system beyond cars to provide safe, equitable, convenient, economical and clean travel for its 1.4 billion people.

China operates one of the world's largest and cleanest urban mobility system

Bus and urban rail accounted for 72% of nationwide revenue urban passenger volume in 2019. Same year, 93 billion passenger trips were carried by bus and urban rail in China (MOT, 2014-2023), over nine times of the volume in the U.S. (APTA, 2023).

In 2022, China led the global bus market with its fleet taking a quarter of the world's buses. In terms of new bus sales worldwide, 83% of BEV and 96% of PHEV were in China (IEA, 2023b). As of 2022, China's bus stock was 703,200 (MOT, 2014-2023), which was 9.8 times of the U.S. (APTA, 2023). Among these buses, 77% had already been electrified and the remaining 23% fossil fuel buses are expected to be fully electrified in the coming few years (MOT, 2014-2023). This shift is facilitated by the fact that over 99% of the newly purchased or replaced buses in China by the end of 2022 are new energy vehicles (NEVs).

Globally, China has the largest urban rail network, in terms of length and the number of cities with urban rails. By 2022, 41 cities in China have had metros with a collective length of 8,448 kilometers. The daily ridership of China's urban rails hit 53 million passenger trips in 2022 (CAMET, 2014-2023).

In addition to its strides in bus electrification and urban rails, China has also been at the forefront of Bus Rapid Transit (BRT). By 2022, China had over seven thousand kilometers of BRT in operation. In 2019, BRT lines and vehicles per million inhabitants in China reached 4.4km and 6.7 buses (MOT, 2014-2020), surpassing the U.S. by fourfold and fivefold, respectively (APTA, 2023).

China also owns the world's largest bike, 2/3Ws and E2/3Ws system. Sixty percent of bike ridership comes from shared bicycles. By 2022, the nationwide fleet of shared bicycles was 14.9 million, with the services covering 400 cities (Wei, 2022). Meanwhile, 81% of 2Ws and 20% of 3Ws were electrified (CCCM, 2023, and iResearch, 2023). China's electric two and three wheelers (E2/3Ws) stock had exceeded 420 million by 2022, 1.3 times of China's national car stock and about 1.5 times of car stock in the U.S. and EU.

The push for zero emission transport: tackling climate, air, and health

Despite carbon emissions, reducing criteria air pollutants for air quality and public health also motivates China's transition to zero emission transport. Passenger transport, including urban mobility, contributes about 12% of national total Nitrogen Oxide (NOx) emissions (MEE, 2022, 2023). High concentrations of PM_{2.5} and ozone correlate with high vehicle stock. Fifty-six cities with large vehicle stock fail to meet both PM_{2.5} and ozone national standards, posing harm to the health of over 330 million people (about 24% of China's population [IPE, 2023c and Fuzhou University]).

China is decoupling the travel demand growth with emissions

In the past 50 years, urban built-up areas in China’s major cities expanded 7.5 times, increasing people’s commute distances (Liu et al., 2021). In 2022, the average single trip commute distance in Beijing, Shanghai, Shenzhen, and Guangzhou was 11.7km, 9.8km, 8.5km, and 9.1km respectively, increased by about 5%, 10%, 12%, and 5% from their 2020 levels (Zhao et al., 2020 and Wang et al., 2021, 2022, 2023). With a targeted 70% urbanization rate in 2030, 980 million people may live in cities, which will bring growing travel demands (NBS, 2023d). The demand could go even higher if China’s urbanization rate reaches 80%, the same as that of the UK and the U.S. Over the past two decades, China has been making efforts to decouple ridership growth from emissions by developing EVs, adopting cleaner internal combustion engine (ICE) vehicles, optimizing transport mode structure, and managing transit demands.

• Both fuel efficiency and criteria air pollutants emissions of ICE vehicles are continuously significantly tightened

China strengthens the emissions reduction of ICE vehicles by phasing out the yellow sticker and old cars and raising standards for fuel economy, fuel quality and vehicle emissions. China Phase III fuel economy standards tighten urban bus fuel consumption limits by 15.9%, compared to Phase I standard (Jin and Wang, 2011, Wen et al., 2014, & Wang et al., 2018). According to China V fuel quality standards, the most stringent globally by far, over 99% sulfur content in diesel and gasoline need to be reduced (TransportPolicy.net, 2018). Nitrogen Oxides (NOx) and particulate matter (PM) from buses dropped as much as 94% and 97% by China VI vehicle emission standards, compared to China I. And China has also moved to lead-free gasoline since early 2000s nationally (Science and Technology Standards Department, 2001, Environmental Standards Institute and Jinan Automobile Test Center, 2005, and Chinese Research Academy of Environmental Sciences et al., 2018).

• Public transit is the most prioritized urban transport mode for development

China has legally prioritized public transit over all the other modes since 2005. Consequently, China’s bus ridership and vehicle mileage reached 69 billion passenger trips and 35 billion kilometers in 2019 (MOT, 2020), about 15 times and 9 times the U.S. levels respectively (APAT, 2023). Public transit development, especially urban rails, brings down the use of cars. Annual private car vehicle kilometers traveled (VKT) is reduced by 2.5% per year in the past decades in Beijing, Shanghai, and Chengdu, despite their growing population, urban built-up areas, and vehicle stock (EF China analysis, Xiamen Environment Protection Vehicle Emission Control Technology Center, BTI, Shanghai Urban Rural Construction and Transportation Development Research Institute, Chengdu VECC).

• Shared bicycles and E2/3Ws play a unique and critical role for short-distance private trips and connection to public modes

Eight out of ten Chinese people choose bikes and two and three wheelers (2/3Ws) as one of their primary choices of urban mobility because they are affordable, convenient, flexible, congestion-free and can serve as a very pleasant “last-mile” solution. E2/3Ws replace 23% travel of trips previously by cars (ITDP, 2022). Fifty-five percent of shared e-bike trips connect to urban rail transit. The “bikes and E2Ws + urban rail transit” model has become popular among the citizens, expanding urban rail access.

• TOD is highlighted as a new development model to encourage public transport

Transit-Oriented Development (TOD) was first introduced to China around 2005. A number of localized TOD models have been created and practiced since then, including “rail plus property” (R+P), “integrated hub station development”, and “metro station-centered complex development”. All the models emphasize integrating transit and land use planning, thus reducing the travel demand and travel distances.

China takes systematic approaches to integrate policies and technologies together with stakeholders' alignment building, implementation and evaluation

Policies play a vital role, but there are also implicit drivers, including vision or long-term goals, proactive government, strong implementation, alignment across stakeholders, and to continuously improving technologies and products on the market.

• Vision guides long-term actions and strengthens market confidence

An ambitious vision guides the different stakeholders toward a shared goal. This will build market confidence, create economies of scale, and enhance the competitiveness of advanced technology and products.

• Alignment across stakeholders to build consensus

A wide range of government departments, including MOT, MOHURD, NDRC, MIIT, MEE, MPS, SAMR, MOF and etc, oversee urban mobility management. Other stakeholders along the industry chain include urban planners, investors and operators of bus lines and urban rails, vehicle manufacturers, consumers, drivers, and charging service providers. It is crucial for all these stakeholders to build consensus and enhance collaboration.

• Proactive policies to ensure implementation

China has been steadily expanding its bus and urban rail networks as well as electrifying its vehicle fleets to reduce emissions. Ministries and local governments enacted supporting policies on subsidies and Dedicated Bus Lanes (DBL). China rolled out national pilot programs on full-scale electrification of public vehicles, including buses, taxis, sanitation vehicles, postal and urban logistics vehicles with the targets to achieve an 80% market penetration rate for NEVs by 2025. All these efforts not only speed up China’s pursuit of zero emission transport, but also strengthen China’s R&D capability, manufacturing efficiency, and supply chain resilience.

Embracing innovation and new business models: advancing planning, financial sustainability, localized policy, future technology, and accessibility

• Overarching planning

China needs to integrate multifunctional land use into urban planning, in order to improve job-housing balance and reduce commuting distances.

• Financial sustainability

Currently, both buses and urban rails heavily rely on subsidies. China should conduct a detailed analysis of cost structure to refine subsidy policies, which will ensure necessary financial support while also boost operational revenues.

• Localized policies

It is important to avoid “one size fits all” approach, particularly concerning E2/3Ws, which have experienced rapid and unregulated growth over the past two decades. Coordination is essential among authorities, industry associations, companies, and users to govern the 420 million E2/3Ws. This approach enables their orderly development and emission reduction potentials.

• Future technology

The future of transport technology is experiencing rapid growth. Autonomous vehicles, for instance, are poised to bring about significant changes in the mobility services market, impacting the environment, economy, and social welfare in the coming decades. China should capitalize on the opportunities presented by future technology to reshape urban mobility, making it more inclusive, safe, and environmentally friendly.

• Transport accessibility

Considering China has about 85 million individuals with disabilities and 210 million people aged 65 or above, barrier-free mobility is gaining importance. Accessible facilities and services can provide equitable access to transport, employment, social activities, and personal fulfillment for different vulnerable groups. Developing barrier-free mobility will promote public transit use while building a more inclusive society.

In summary, by refining policies related to overarching planning, financial sustainability, contextualized policies, and inclusive accessibility, China can advance its progress toward zero-emission mobility. Leveraging demographic trends can also reinforce public transit priorities. China's comprehensive approach and updated policies can offer valuable experiences for sustainable mobility transitions worldwide.

LIST OF ACRONYMS AND ABBREVIATIONS

$\mu\text{g}/\text{m}^3$	Micrograms Per Cubic Meter	LDV	Light-Duty Vehicle
ACEA	European Automobile Manufacturers' Association	LNG	Liquefied Natural Gas
APM	Automated People Mover System	MaaS	Mobility as a Service
APTA	American Public Transportation Association	MARA	Ministry of Agriculture and Rural Affairs, PRC
BEV	Battery Electric Vehicle	MEE	Ministry of Ecology and Environment, PRC
BMCT	Beijing Municipal Commission of Transport	MEM	Ministry of Emergency Management, PRC
BMSTC	Beijing Municipal Science and Technology Commission	MIT	Ministry of Industry and Information Technology, PRC
BRT	Bus Rapid Transit	MNR	Ministry of Natural Resources, PRC
BTI	Beijing Transport Institute	MOC	Ministry of Construction, PRC (restructured as MOHURD in 2008)
CAMET	China Association of Metros	MOF	Ministry of Finance, PRC
CATARC	China Automotive Technology and Research Center Co., Ltd.	MOHRSS	Ministry of Human Resources and Social Security, PRC
CAUPD	China Academy of Urban Planning and Design	MOHURD	Ministry of Housing and Urban-Rural Development, PRC
CCCM	China Chamber of Commerce for Motorcycle	MOST	Ministry of Science and Technology, PRC
CFR	National Fire and Rescue Administration , PRC	MOT	Ministry of Transport, PRC
CNG	Compressed Natural Gas	MPS	Ministry of Public Security, PRC
CO ₂	Carbon Dioxide	Mt	Million Tonnes
CRAES	Chinese Research Academy of Environmental Sciences	NAAQS	National Ambient Air Quality Standards
DBL	Dedicated Bus Lane	NBS	National Bureau of Statistics, PRC
DG MOVE	Directorate-General for Mobility and Transport	NDRC	National Development and Reform Commission, PRC
DTI	Departing Time Interval	NEA	National Energy Administration, PRC
E-Bike	Electric Bicycle	NEV	New Energy Vehicle
EC	European Commission	NOx	Nitrogen Oxides
E-Moped	Electric Moped	OECD	Organization for Economic Co-operation and Development
E-Motorcycle	Electric Motorcycle	O ₃	Ozone/Trioxxygen
E2Ws	Electric Two Wheelers	PATH	Port Authority Trans-Hudson Corporation
E3Ws	Electric Three Wheelers	PHEV	Plug-In Hybrid Electric Vehicle
EU	European Union	PM	Particulate Matter
EV	Electric Vehicle	PM _{2.5}	Fine Particulate Matter
FCV	Fuel Cell Vehicle	PPM/ppm	Parts Per Million
FYP	Five-Year Plan	R+P	Rail Plus Property
GDP	Gross Domestic Product	RPK	Revenue Passenger Kilometers
GHGs	Greenhouse Gases	RMB	Renminbi (Chinese Currency Official Name)
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH	SAMR	State Administration for Market Regulation, PRC
GWWR	Gross Vehicle Weight Rating	SMP	Shenzhen Metro Group
ICCT	International Council on Clean Transportation	Sq Km/ km ²	Square Kilometer
ICE	Internal Combustion Engine	UITP	Union Internationale des Transports Publics
ICE2Ws	Internal Combustion Engine Two Wheelers	USD	United States Dollar
ICE3Ws	Internal Combustion Engine Three Wheelers	VGI	Vehicle Grid Integration
Km/h	Kilometer Per Hour	VKT	Vehicle Kilometers Travelled
KWh	Kilowatt Hour	WB	World Bank
IEA	International Energy Agency	WDI	World Development Indicators
IMF	International Monetary Fund	WMO	World Meteorological Organization
IPCC	Intergovernmental Panel on Climate Change	WPR	World Population Review
IPE	Institute of Public and Environmental Affairs		
ITDP	Institute for Transportation and Development Policy		

PART

A GLIMPSE OF CHINA'S URBAN MOBILITY DEVELOPMENT



KEY FACTORS determining China's urban mobility demand and international comparison

China has the third largest land area and the second biggest human population in the world, making its transport system ranking the top by many indicators. The first keyword about China's passenger transport and urban mobility is huge. But it is equally important to underscore other attributes of this system, including but not limited to diversified, strong growth complicated, substantial emissions, and racing towards zero.

Unlike other major economies, which has relatively stabilized mobility demands, China's urban passenger transport keeps growing steadily and rapidly, which makes its pursuit of zero emission urban mobility one of the most challenging.

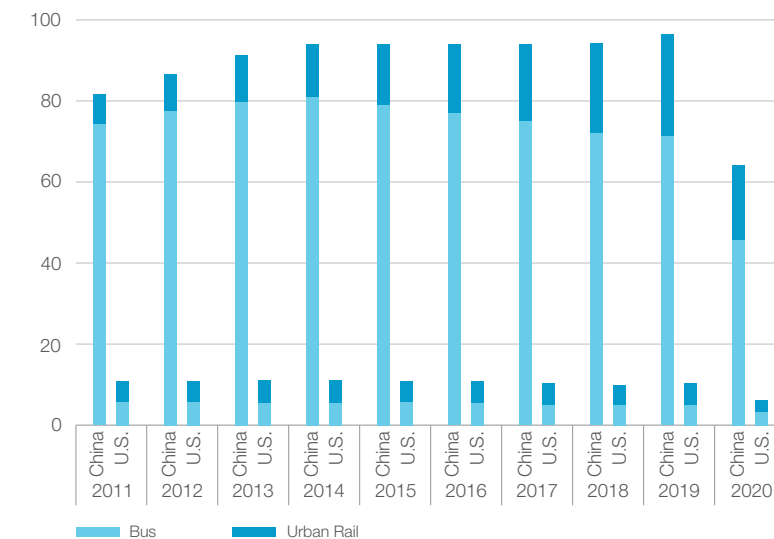


China operates one of the world's largest public urban mobility systems

Figure 1

Bus and Urban Rail Passenger Volume of China and U.S. (2011-2020)

• Passenger Volume (Billion Trips)



Ministry of Transport of China (MOT, 2014–2023), American Public Transportation Association (APTA, 2023, Table 1 & 3)

In 2019

93B

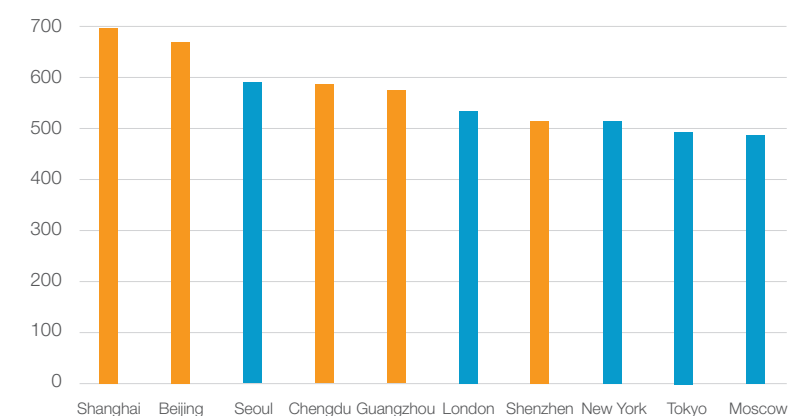
passenger trips were delivered by bus and urban rail⁴ in China in 2019.

>9×U.S.⁵

Figure 2

World's Top 10 Longest Municipal Metro/Subway Networks in 2020

• Total rail transit (Km)



UITP Secretariat (2022a)

Half

of the Top 10 longest municipal metro/subway networks are in China.

By 2022, subway systems in 41 cities of China had a collective length of 8,448km (CAMET, 2023).

⁴ "Urban rail" in China refers to the public transport system that uses rail structure for load-carrying and guidance. This system installs fully or partially enclosed dedicated rail lines to transport large numbers of passengers using train sets or single rail cars. The main urban rail types in China include subway, light rail, monorail, tram, maglev, automated people mover system (APM), and commuter rail. The "Urban Public Transport Classification Standards" (CJJ/T 114-2007) provides definitions for each urban rail type based on factors like the right-of-way, capacity, speed, track position, etc.

⁵ The urban rail number in the U.S. includes all fixed-guideway rail modes of urban transit, such as heavy rail, commuter rail, hybrid rail, light rail, and streetcar.

200B

Revenue passenger kilometers (RPK) by urban rail occurred in China in 2019.

≈4×U.S.⁶

96%

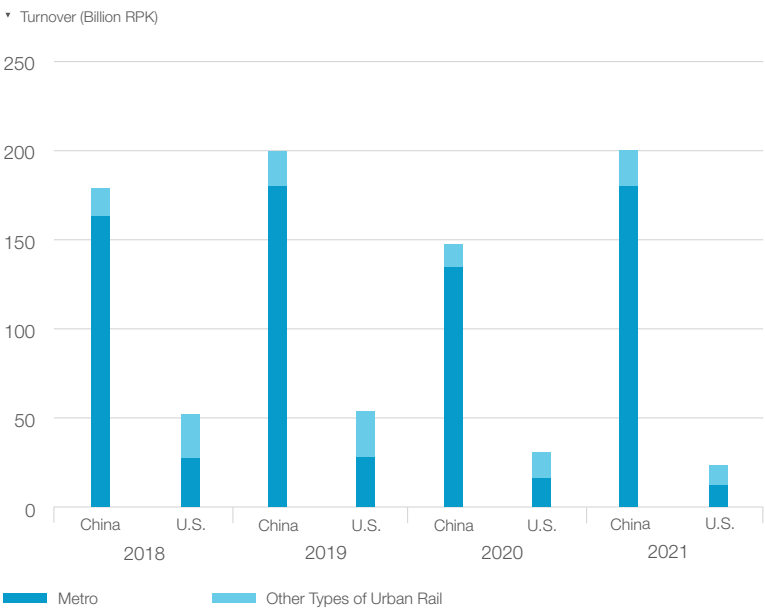
came from subway (metro), which reached

191B_{RPK}

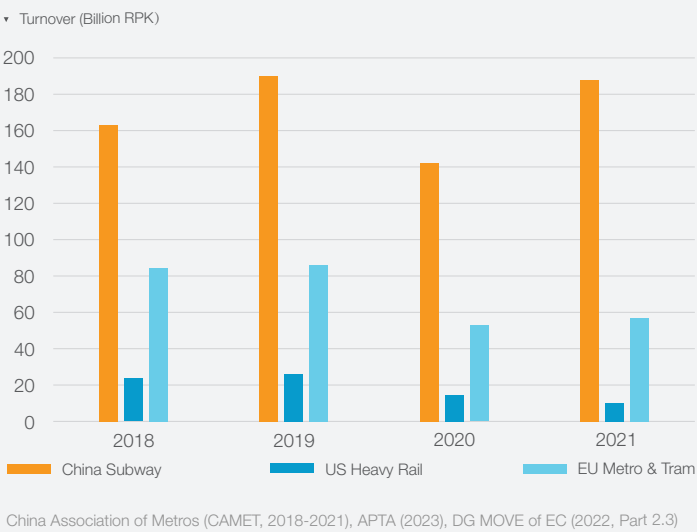
≈1.7
× (U.S. + EU)⁷

⁶ The U.S. metro statistics uses the definition of "heavy rail", a term similar with "subway" and "metro", which refers to electric railways on dedicated rights-of-way that transport large volumes of passengers. It mainly includes three types: (1) tracks in subway tunnels; (2) tracks on elevated structures; and (3) fenced ground-level tracks without road-crossings.
⁷ Numbers of EU metro include both metro and tram; other types of EU urban rail statistics is unavailable.

Figure 3
Urban Rail Passenger Turnover of China and U.S. (2018-2021)



Metro System Passenger Turnover of China, EU and U.S. (2018-2020)



China's vast land and diverse topography require a comprehensive transport system

The vast land areas, extensive north-south and east-west distances, varying altitude, and intricate landscapes pose challenges for transport in China. Meanwhile, each transport mode has its economic operation range. Cars, subways, buses, electric two-wheelers, bikes, and walking are suitable for different distances, ranging from tens of kilometers to hundreds of meters. For flights and railways, they serve even longer distances from hundreds to thousands of kilometers. Therefore, a comprehensive transport system is a must.



Imbalances of economy and population intensify demands for highly diversified transport choices

Individuals select their preferred modes of transport based on factors such as affordability, travel efficiency, comfort, and convenience. The imbalances in economic development and population distribution drive the need for a wide range of transport options.

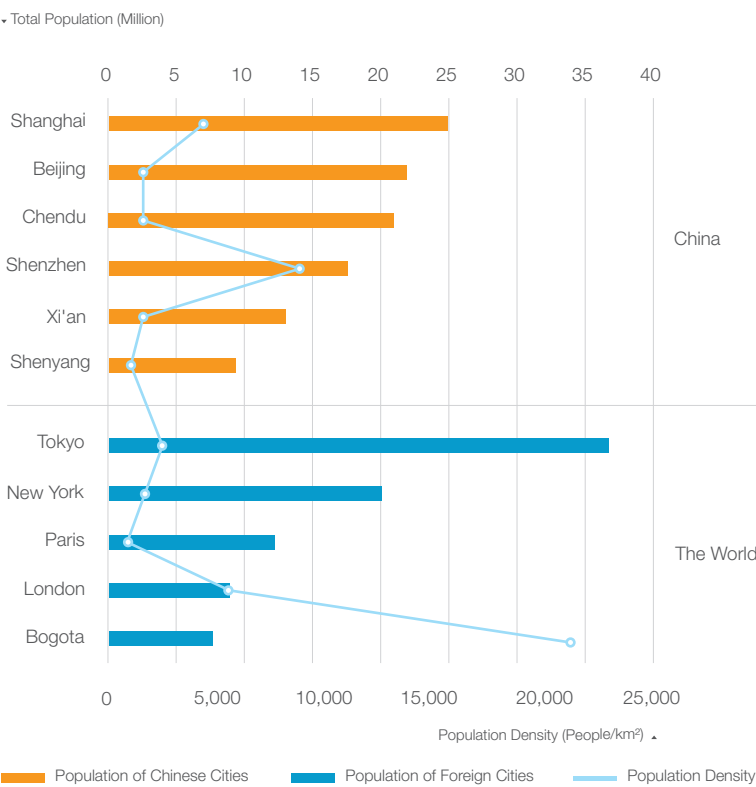


Fast urbanization pushes an increasing travel demand

The rapid expansion of cities and urbanization have extended people's travel radius in cities, leading to increasingly high demands on travel time/efficiency, punctuality, high-capacity urban mobility, etc.

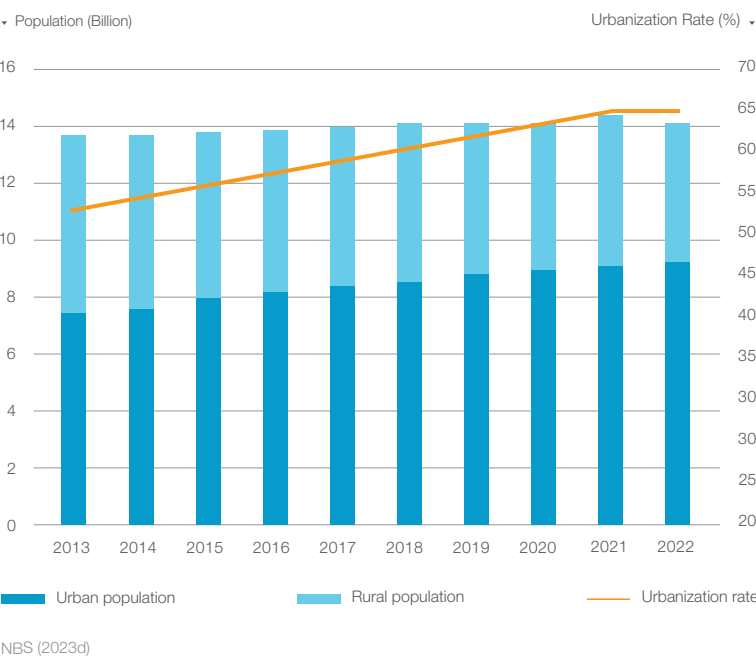
The passenger turnover grew rapidly, with China's urban rail passenger kilometers increasing by 77% between 2015 and 2019, representing a year-on-year growth rate of 19% (CAMET, 2020). While the demand went down during the Covid-19 pandemic, it made a robust recovery in 2023. This reveals the increasing need for longer distance commuting as urbanization develops and cities expand.

Figure 4
Total Population and Density of Selected Major Cities in China and World⁹



Zhou (2022), Alfonso (2016), Shenyang Municipal Statistics Bureau and Shenyang Municipal Ethnic and Religious Affairs Bureau (2023), Party History Research Office of Shenyang Municipal Party Committee (2023), Liu (2023)

Figure 5
Population and Urbanization Rate of China (2013-2022)



The most crowded city in China is Shenzhen, with a population density that is

1.5 times

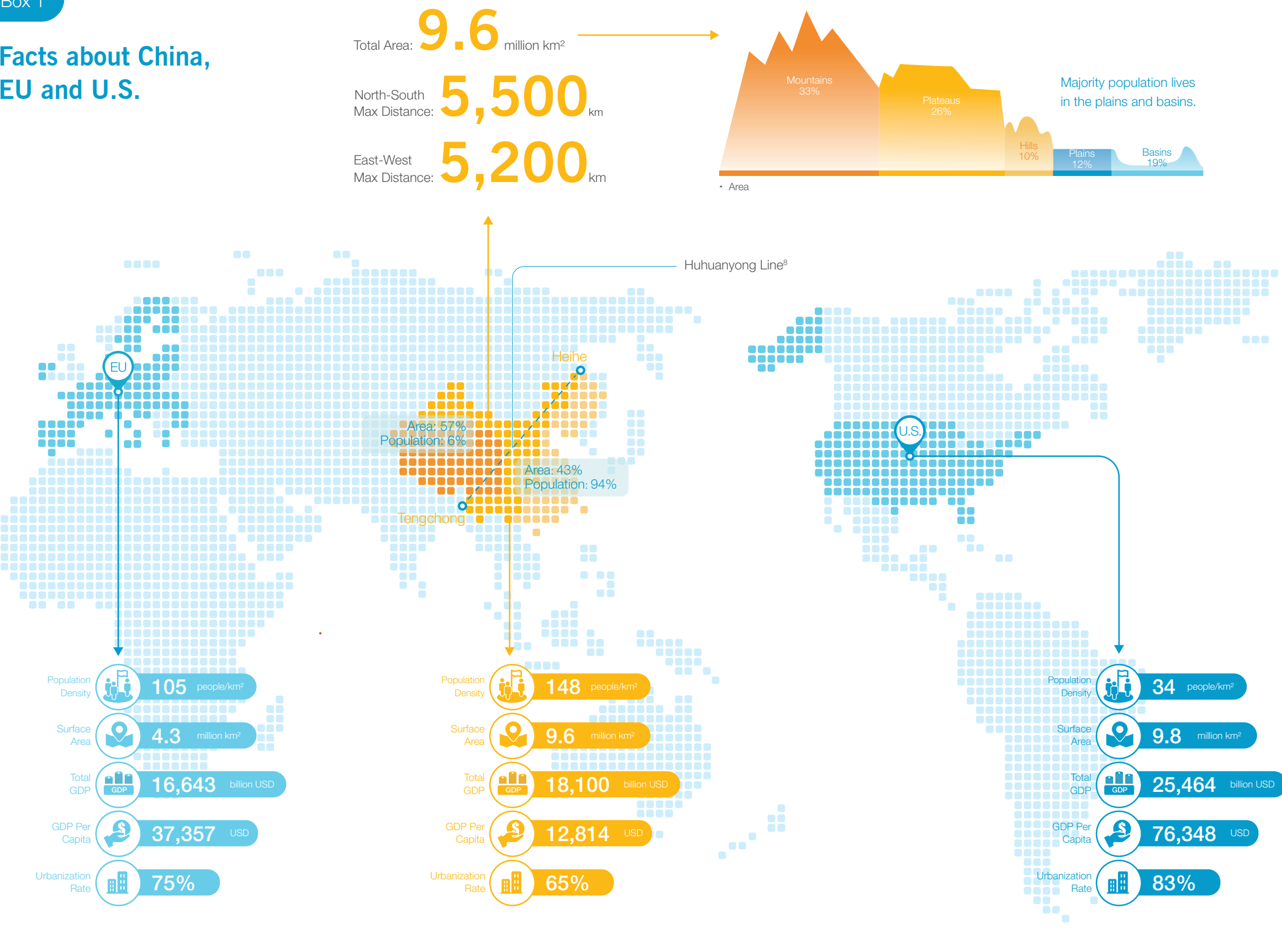
of London.

980M

people may live in cities when urbanization goal is achieved, which will result in growing travel demands.

The urbanization rate has increased from 55% in 2013 to 65% in 2022. The national aim is to reach 70% by 2030, meaning more urban transit and more long-distance intercity travel. If compared with the urbanization rates of 80% in the UK and the U.S., the demand could go even higher.

Facts about China, EU and U.S.



⁸ Known as Hu huanyong line or Heihe-Tengchong line, divides the area of China roughly into two parts with contrasting population densities. This line was drawn by a Chinese population geographer Mr. HU Huanrong in 1935.

⁹ Year of city data: Bogota, 2016; Tokyo, Paris and London, 2019; New York, 2020; Shanghai, Beijing, Chendu and Xi'an, 2022; and Shenzhen, 2023.

Figure 6
The Proportion of Population Aged 65 or Above (2013-2022)

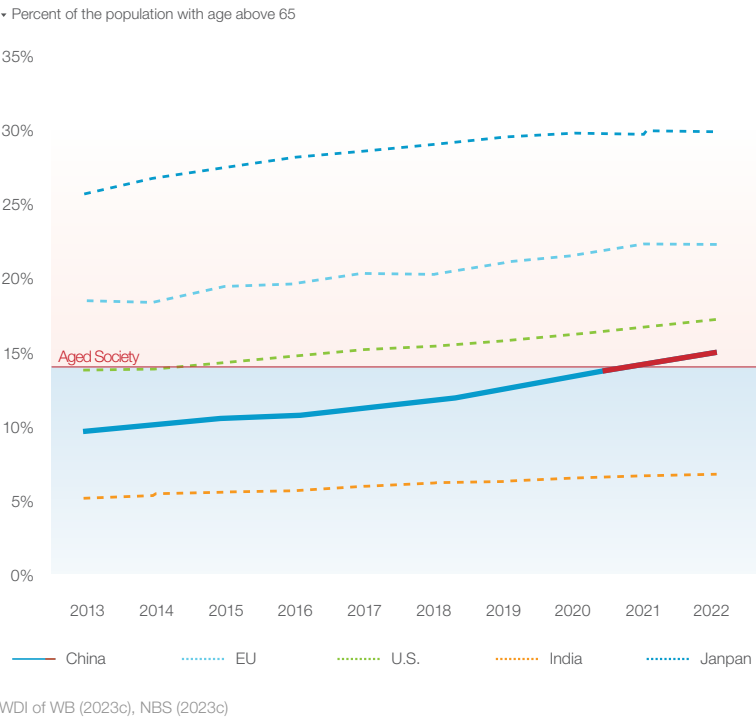
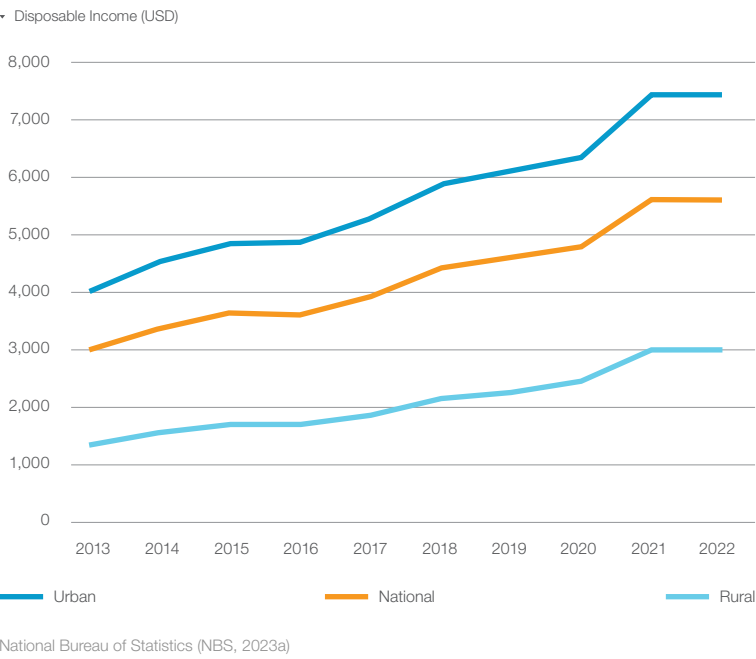


Figure 7
China Average Annual Per Capita Disposable Income (2013-2022)



15%

of the population in China is over 65 years old.

China has become an aged society since 2021 and is on the path to join the super-aged in 2030s. The aging rate climbs very quickly, which places high requirements on transport system accessibility.

China's urban area income

= 1.3 ×

national average

= 2.4 ×

rural area in 2022

Per capita disposable income in China is geographically imbalanced: Zhejiang's statistic in 2022 was 2.6 times higher than that of Gansu, representing the highest and lowest among provinces (NBS, 2023b).

China has

105

cities with population more than

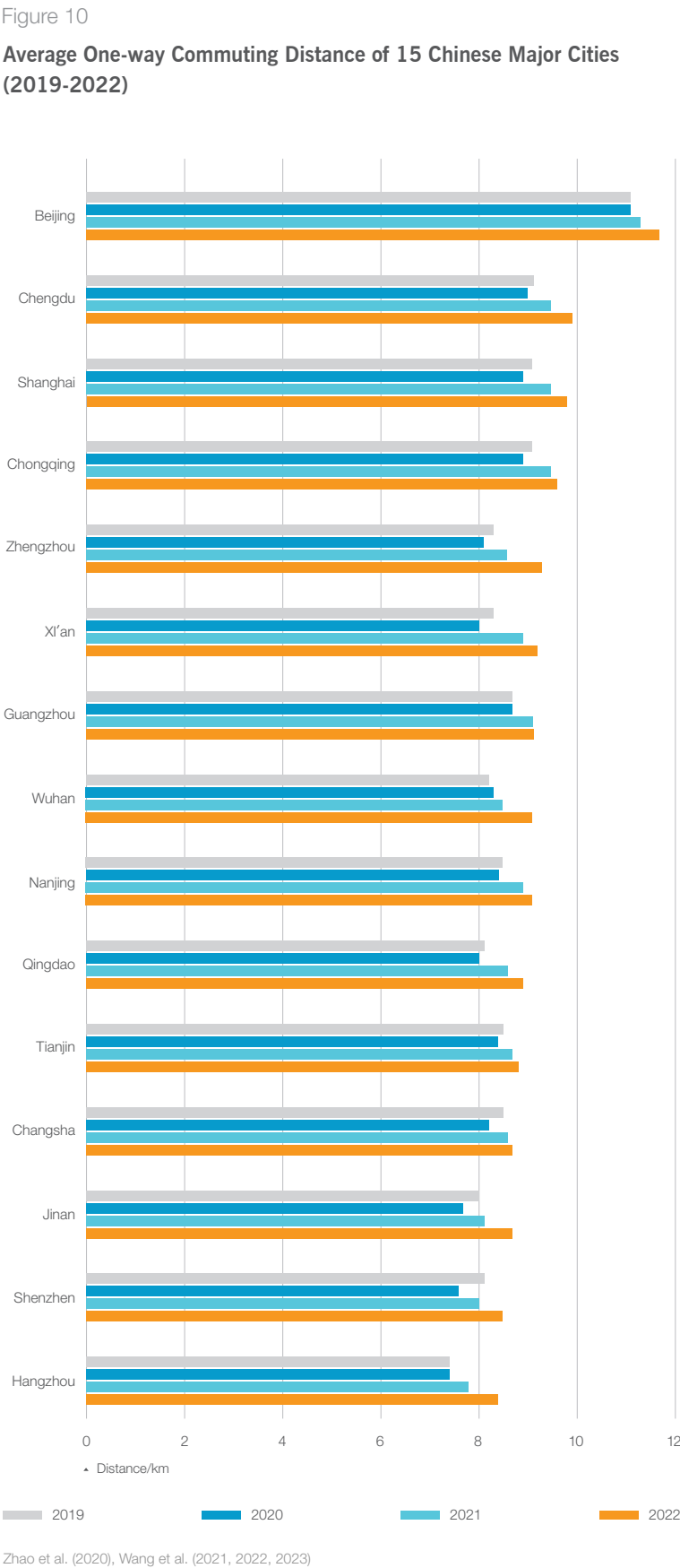
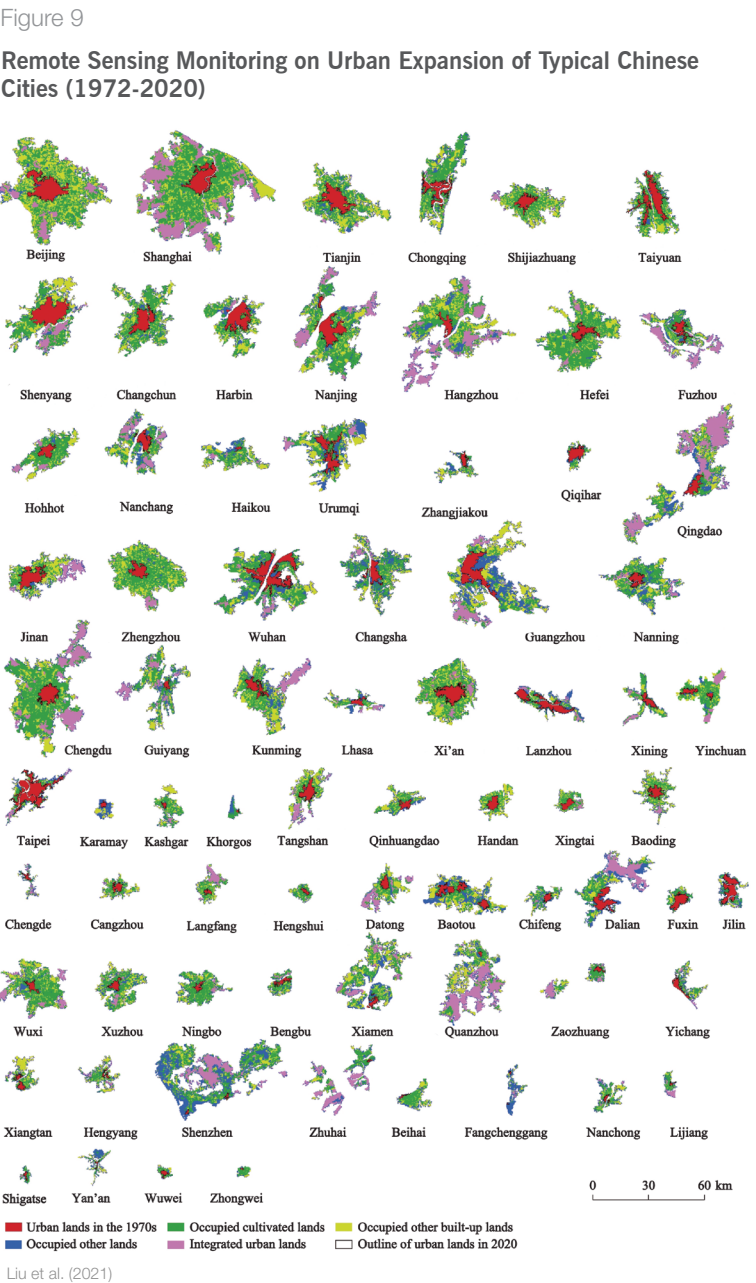
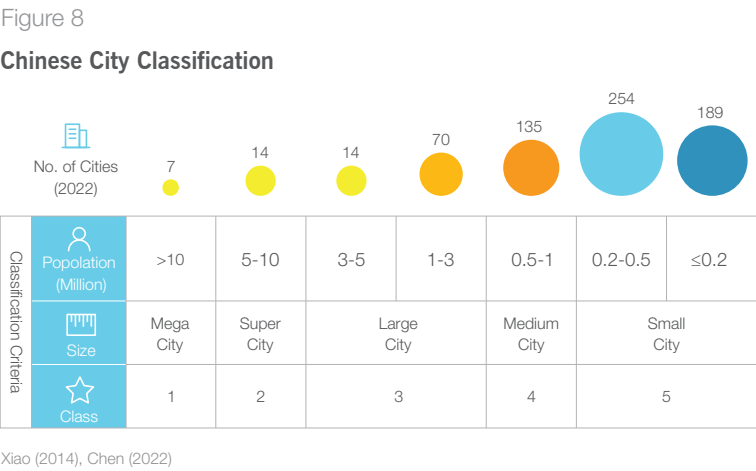
1M

Urban built-up areas expanded

7.5

times in 50 years

The ever-expanding urban area has increased residents in cities and commuting distances, which collectively place higher demands on the urban transit system.



ALL

monitored major cities have increasing commuting distances.

In 2022, the average single trip commute distance and time in four major cities were:

Beijing:
11.7km, 47 minutes;

Shanghai:
9.8km, 40 minutes;

Shenzhen:
8.5km, 36 minutes;

Guangzhou:
9.1km, 38 minutes.

KEY DRIVERS for China to move towards zero emission urban mobility

The primary drivers behind China's shift towards zero emission transport are carbon emission reduction for addressing climate change, pollutants reduction for improving air quality and public health and leapfrogging its auto industry for sustainability and competitiveness. Urban mobility plays a critical role in achieving these goals. As transport demand stays high, the key challenge lies in decoupling economic growth from carbon and air pollutants emissions.

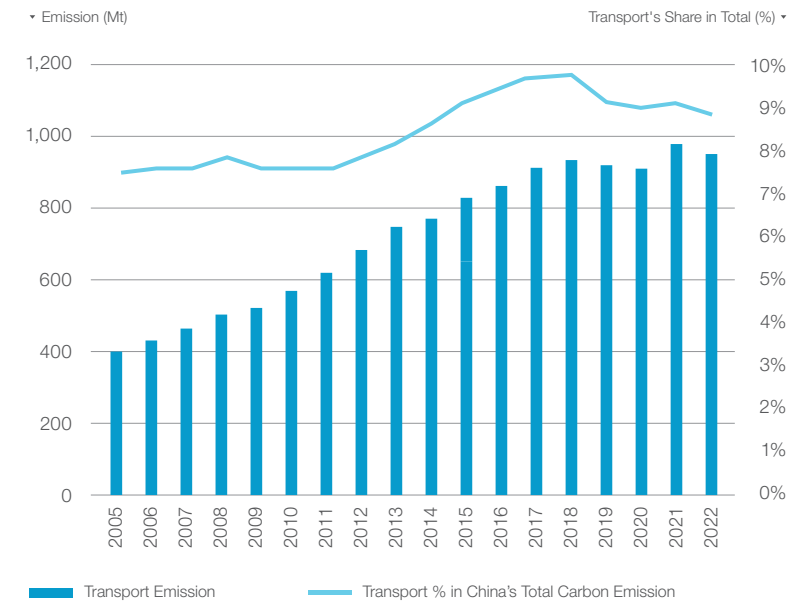
Transport is a major source of carbon emissions in cities. For instance, transport sector contributed 34% of Beijing's carbon emissions in 2019 (Beijing Transport Institute [BTI], 2022), making it the second-largest contributor only after the buildings sector and surpassing the industrial sector. To reduce transport emissions of carbon and air pollutants in cities, China has strived to electrify vehicles since 2009. Between 2015 and 2022, China has held the top position worldwide for EV production and sales for eight consecutive years.

Traffic congestion is another pressing issue in densely populated Chinese big cities and is widely regarded as a serious "big city disease". In 2022, the average travel speed in the 36 selected major cities¹⁰ across China was only 22.7km/h during weekday peak hours. Eighty-nine percent of these cities suffered with moderate congestion with road vehicles moving at 18-25km/h (Wang et al., 2023). The development of public transit and active mobility not only provides an alternative to driving but also effectively reduces congestion and emissions.

¹⁰ The thirty-six selected major cities include Beijing, Shanghai, Guangzhou, Shenzhen, Tianjin, Chongqing, Dalian, Qingdao, Ningbo, Xiamen, and 26 provincial capital cities (Harbin, Changchun, Shenyang, Shijiazhuang, Hohhot, Lanzhou, Yinchuan, Xi'an, Urumqi, Xining, Lhasa, Taiyuan, Jinan, Zhengzhou, Nanjing, Hangzhou, Fuzhou, Hefei, Wuhan, Changsha, Nanchang, Kunming, Guiyang, Chengdu, Nanning, and Haikou).

Figure 11

Carbon Emissions from China's Transport Sector (2005-2022)



International Energy Agency (IEA, 2021, 2023c)

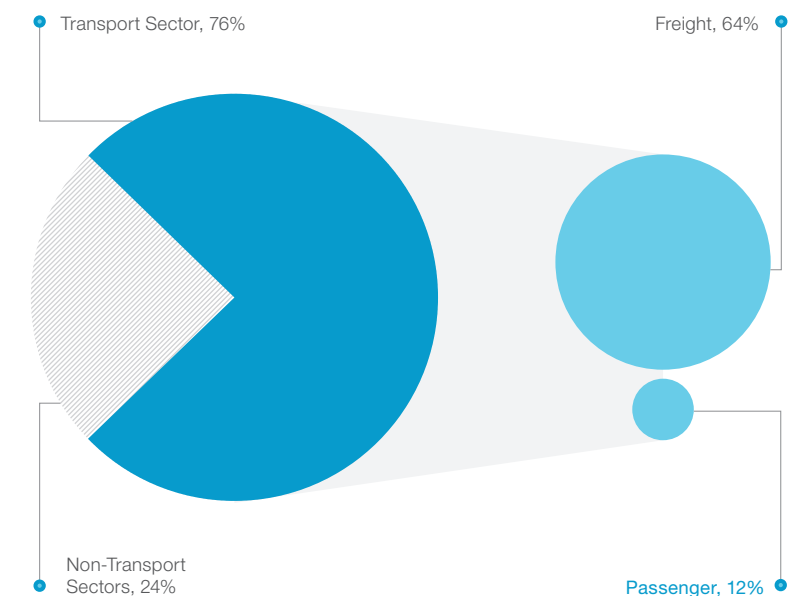
9%

national carbon emissions come from the transport sector.

In 2022, carbon emissions of China's transport sector was 946 million tons, accounting for about 9% of China's national total, in which, about 3% comes from passenger transport.

Figure 12

NOx Emissions by Sectors in China (2021)



Ministry of Ecology and Environment of China (MEE, 2022, 2023)

76%

of national NOx emissions come from the transport sector.

Passenger transport is not the major contributor to PM_{2.5} nationally, but it contributes 12% of the NOx emissions and concentrated in cities with a combined population of 910 million habitants.



More than one third of China's population lives in non-attainment areas, with either PM_{2.5} or O₃ exceeding NAAQS in 2022

Approximately

33%

national population, totaling

464M

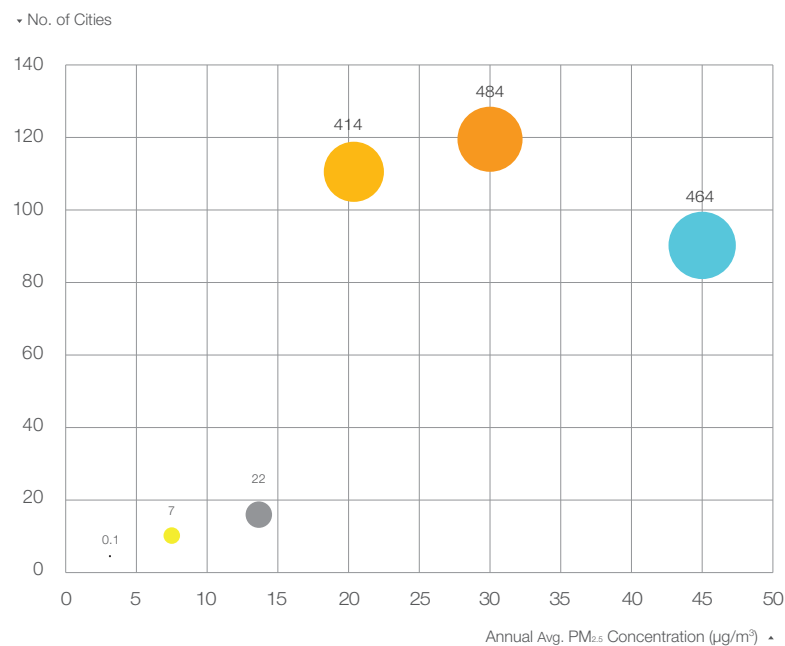
people, live in

89

cities where PM_{2.5} levels do not meet the current national standard of 35 µg/m³.

Figure 13¹¹

Population in China Exposed to PM_{2.5} in 2022 (Million)



Institute of Public and Environmental Affairs (IPE, 2023)

Approximately

41%

national population, totaling

571M

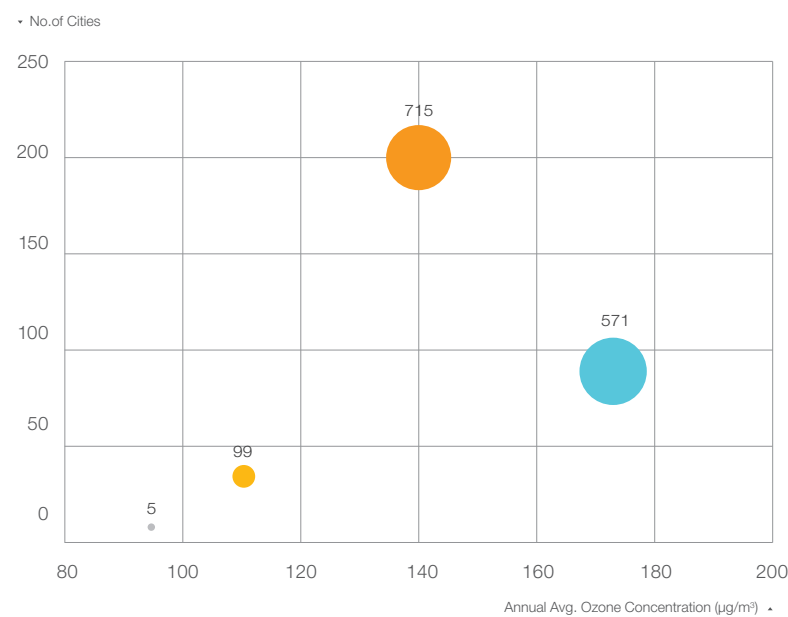
people, live in

88

cities where O₃ levels do not meet the current national standard of 160 µg/m³.

Figure 14¹¹

Population in China Exposed to Ozone in 2022 (Million)



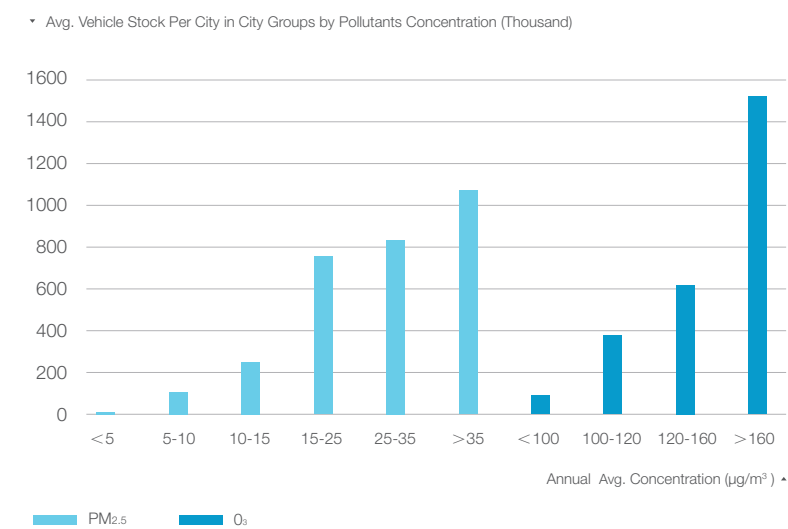
IPE (2023)



Cities with high vehicle stock tend to have high concentration levels of PM_{2.5} and O₃

Figure 15

Vehicle Stock, PM_{2.5} and O₃ Annual Avg. Concentrations in Cities of China (2022)



IPE (2023c) & Fuzhou University

56

cities do not to meet both PM_{2.5} and O₃ national standards.

24%

of national population and large vehicle stock.

It is critical to electrify these vehicles and encourage more passengers to take buses, urban rails, and active mobility options.

¹¹ In Figure 13 and Figure 14, cities are grouped according to their annual average concentration (in µg/m³) of PM_{2.5} (ranging from <5, 5–10, 10–15, 15–25, 25–35, to >35) and O₃ (ranging from <100, 100–120, 120–160, to >160). The center point of each bubble in both figures represents the average PM_{2.5} or O₃ concentration of the particular city group.

Progress of zero emission urban mobility beyond cars in China

For over two decades, China has been making efforts to decouple the emissions from ridership. In addition to all efforts to clean up the car fleet, the country has also progressively raised the fuel economy standards for commercial heavy-duty vehicles (HDVs) from Phase I to Phase IV, and the emission standards from China I to VI. In terms of structural development, public transit is the most prioritized, and active mobility² is highly encouraged. Moreover, the electrification of buses, 2/3 wheelers, and rail systems is propelling the transition towards zero emission transport.

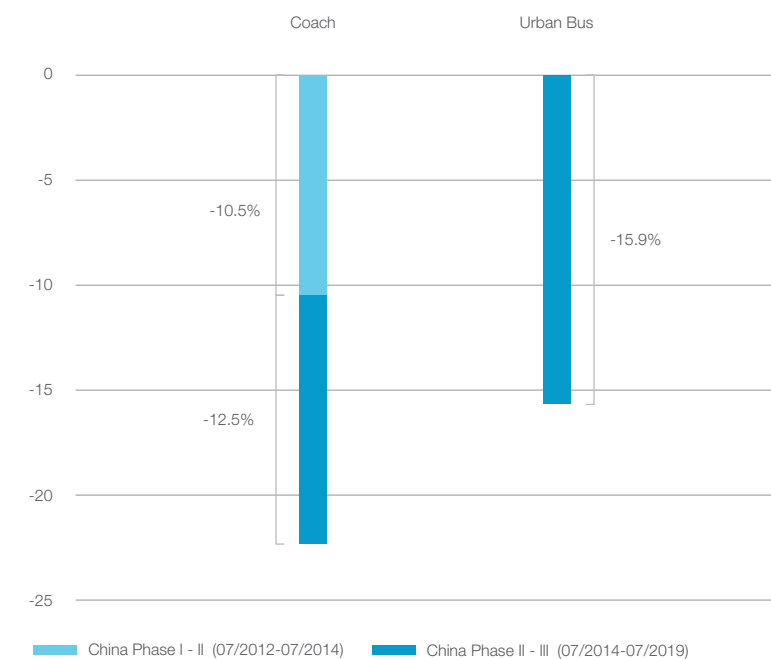


Keep upgrading standards for fuel consumption limits, vehicle criteria air pollutants emissions, and fuel quality

Figure 16

Fuel Consumption Limits for HDVs Tightened under Phase I-III Standards

• Reduction Rate (%)



Jin and Wang (2011), Wen et al. (2014), Wang et al. (2018)

China Phase III standard tightened the fuel consumption limits respectively by

23%

for coaches

and

15.9%

for urban buses

compared to Phase I.¹²

China Phase IV standard for HDVs fuel consumption limits is waiting for official adoption. Phase IV standard for light duty commercial vehicles (LDVs) has finished the public commenting of the first draft.

¹² These reductions represent the arithmetical averages of 12 defined grades in standards, which are based on the Gross Vehicle Weight Rating (GVWR) of commercial vehicles. The estimation does not take into account the market share of each GVWR category.

China VI standard requires a

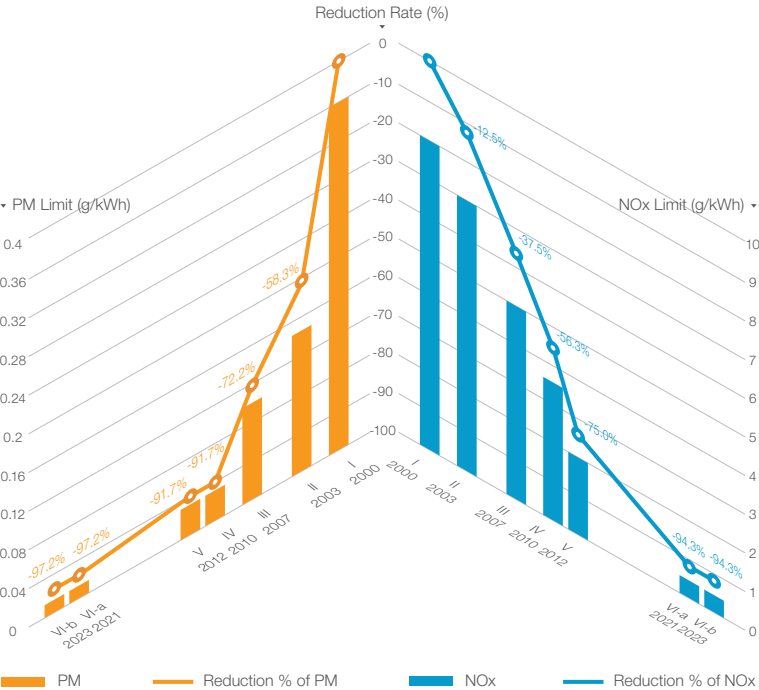
97%

reduction in NOx emissions and a

94%

drop in PM from HDVs, as compared to the earlier China I standard.

Figure 17
Reductions of HDV Emission Limits on NOx and PM under China I-VI Standards



Science and Technology Standards Department (2001), Environmental Standards Institute and Jinan Automobile Test Center (2005), Chinese Research Academy of Environmental Sciences et al. (2018).

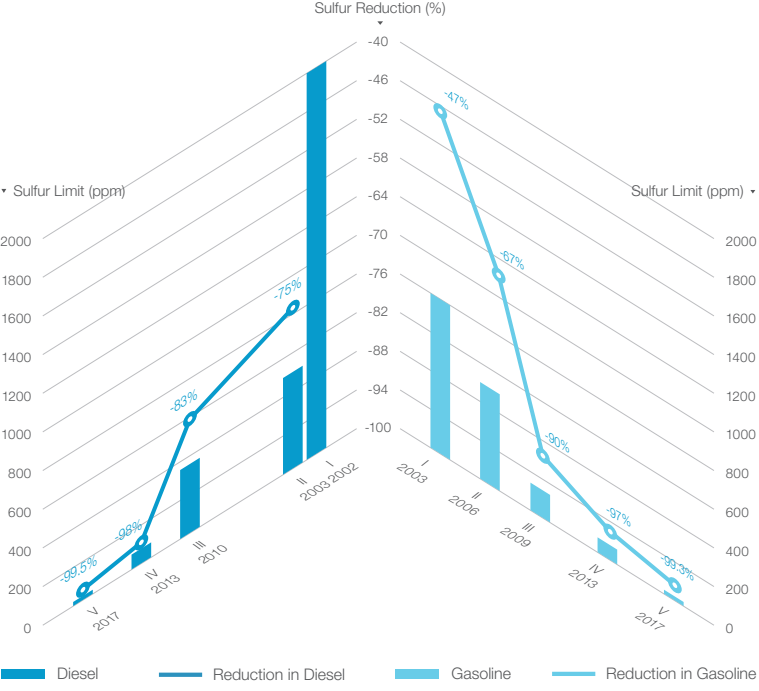
Sulfur content is reduced by over

99%

in diesel and gasoline.

China has adopted lead-free gasoline nationwide since early 2000s. The sulfur content in diesel and gasoline have both significantly dropped from 2000 ppm and 1500 ppm to 10 ppm, complying with China I-V fuel quality standards, which is by far the most stringent globally.

Figure 18
Reductions of Sulfur Limits on Diesel and Gasoline under China I-V Fuel Quality Standards



TransportPolicy.net (2018)



The public transit plays an increasingly bigger role

Public transit has gained growing importance in China. In 2004, the Ministry of Housing and Urban-Rural Development (MOHURD) issued the "Opinions on Giving Priority to the Development of Urban Public Transportation". Moreover, bus electrification has been a priority since the 2009 "Ten Cities x One Thousand Electric Vehicles" Pilot Program, with cumulative purchase subsidies around 200 billion RMB (\$3.36 billion) .¹³ The government provides substantial support for public transit, as the result, the public transit becomes cleaner despite the growing scale, although since 2023 China has stopped the NEV purchase subsidy.

Table 1

Major National Fiscal Incentives for Public Transit

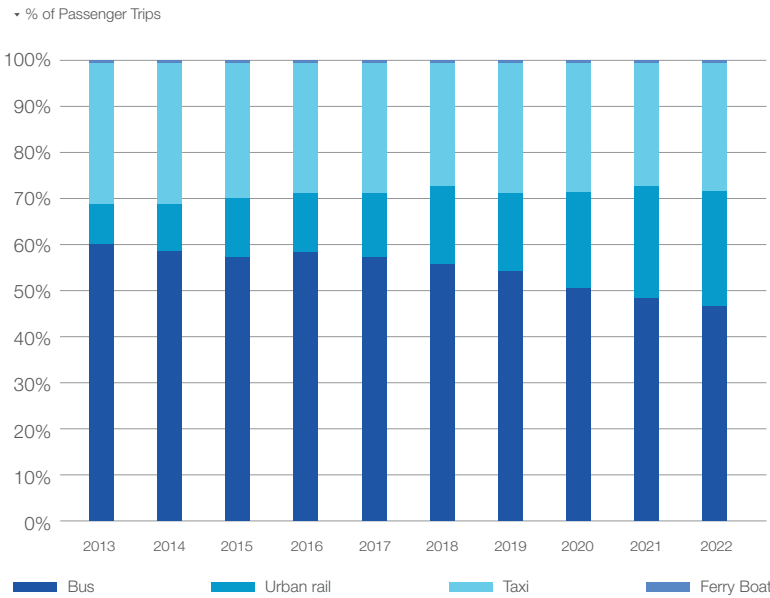
Major Incentives	Annual Average (Billion RMB)	Cumulative Amount (Billion RMB)	Provider	Period
Vehicle purchase tax exemption for all NEVs	22	200 ^a	Central Government	2014-2022
Purchase subsidy for all NEVs	15	200 ^b	Central Government	2010-2022
Bus operation subsidy	100 ^c	/	Local Government	in 2019
Subway operation subsidy ^d	110 ^d	/	Local Government	in 2020

a: Zhou (2023), b: Shang and Yu (2023), c: Jia (2023), d: ThePaper (2023).

About 77.2% of the buses on the road have already been electrified. By the end of 2022, over 98.7% of newly purchased or replaced buses are NEVs¹. It is evident that the transit bus fleet on the road will achieve full zero emissions in the coming few years.

Figure 19

China's Urban Transit Structure by Revenue Ridership (2013-2022)



MOT (2014-2023, Part 3.6)

¹³ The average exchange rate of 2010-2022 was used here, which was 6.55 RMB to \$1.

¹⁴ Both bus operation subsidy and subway operation subsidy are the sum of local subsidies nationwide.

Bus and urban rail collectively account for

73%

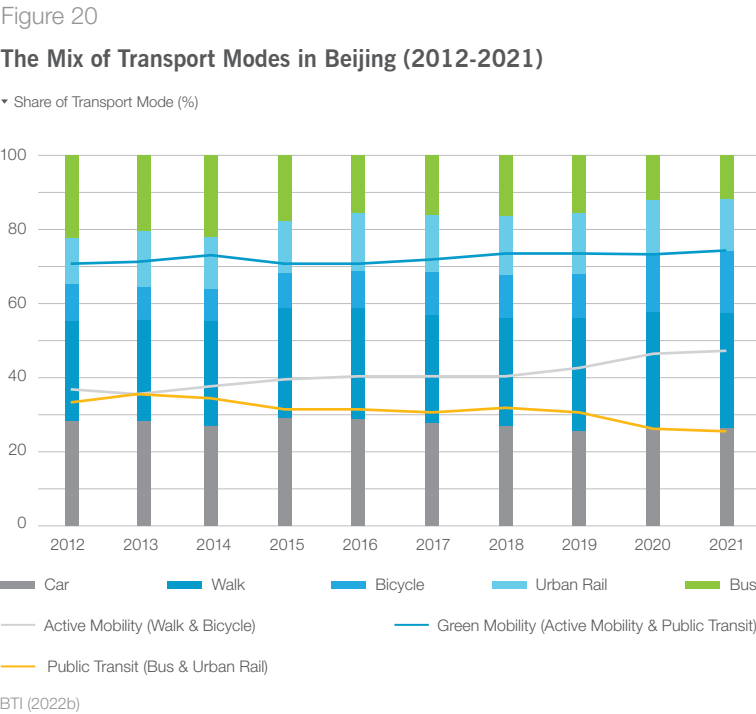
of revenue urban passenger volume in cities with the service in China.

The share of urban rail rose by 17% while bus dropped by 13% from 2012 to 2022.

Green mobility¹⁵ accounts for

74%

of Beijing urban passenger transport in 2019.



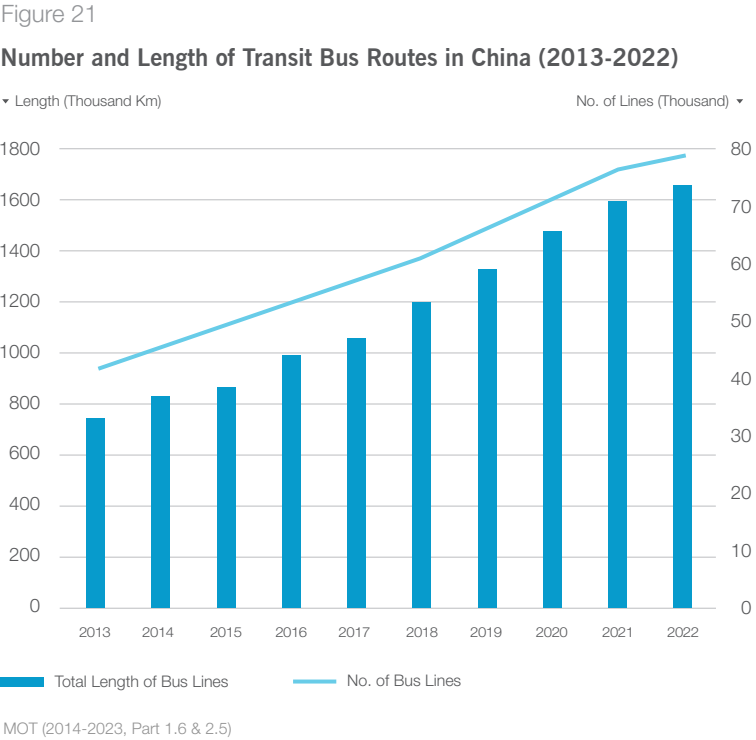
1.7M_{km}

bus routes across China equals

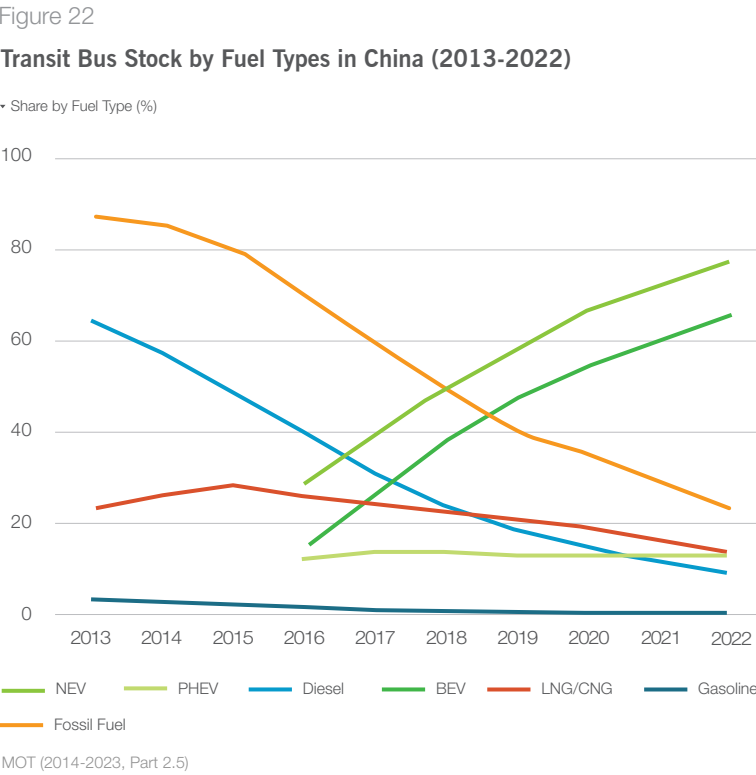
41 rounds

of the Earth's Equator

By the end of 2022, there were 703,200 transit buses running on a network of 78,000 routes, covering almost all the cities in China.



¹⁵ Green mobility consists of walking, bicycles, buses and urban rails.

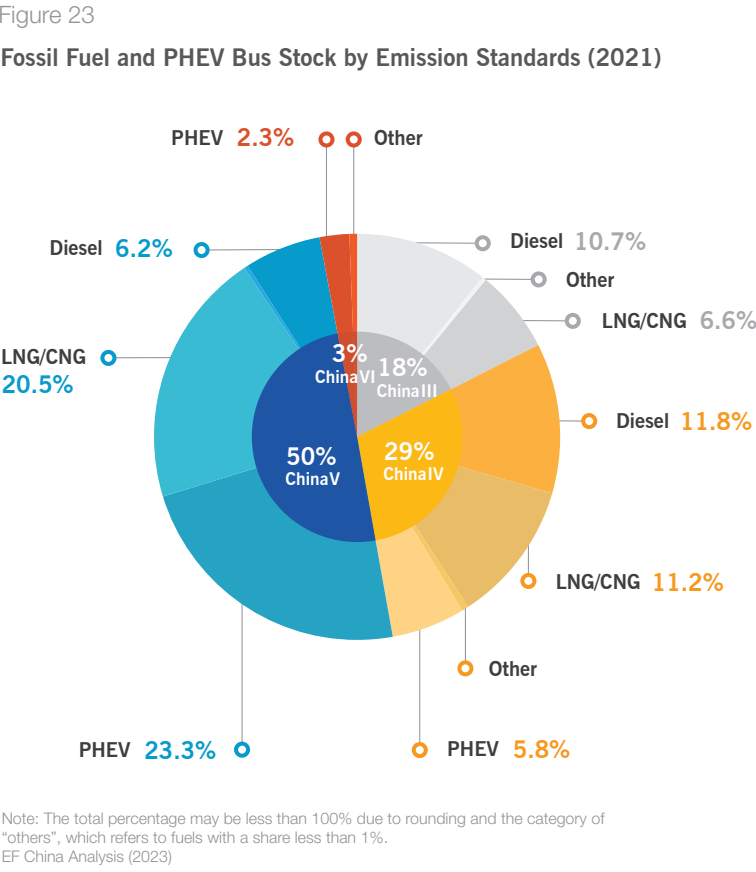


The share of fossil fuel buses in the bus fleet decreased by

64%

in only one decade.

In 2013, diesel, gasoline and LNG/CNG buses made up 87% of the bus fleet, but by 2022, their total share had plummeted to 23 % while NEVs' surged to 77%, making a strong contrast.



53%

fossil fuel and PHEV buses comply with China V and VI vehicle emission standards.

China retired almost all the old buses compliant with China I and II emission standards. Among the remaining fossil fuel and PHEV buses, 50% and 3% meet China V and VI standards, while 18% and 29% meet China III and IV standards.

In 2022, China accounted for

83%

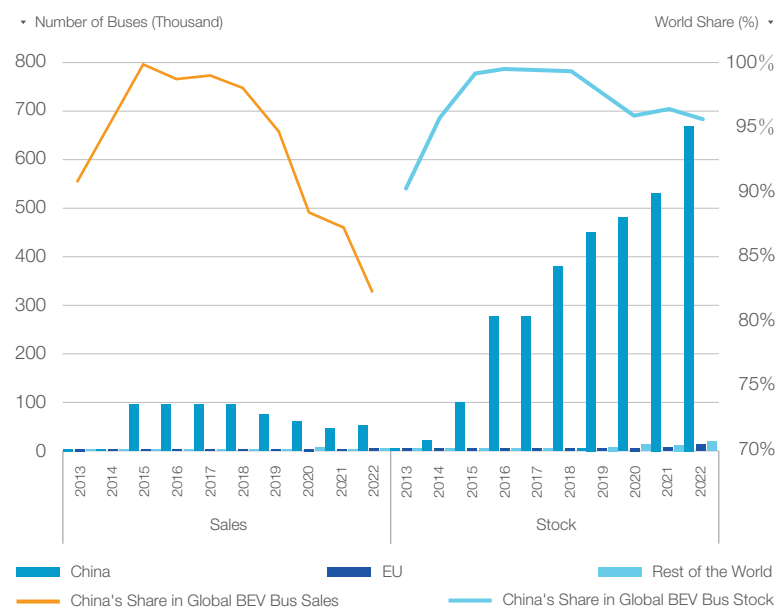
of global BEV bus sales. With the world's 1/4 bus fleet, China runs

96%

of global BEV buses.

Figure 24

Sales and Stock of BEV Buses in China, EU and the Rest of the World (2013-2022)



IEA (2023b), Bloomberg (2018)



Develop the urban rail for passenger transport

The rapid expansion of urban rail, which is 100% electrified, has replaced a considerable amount of road transport.

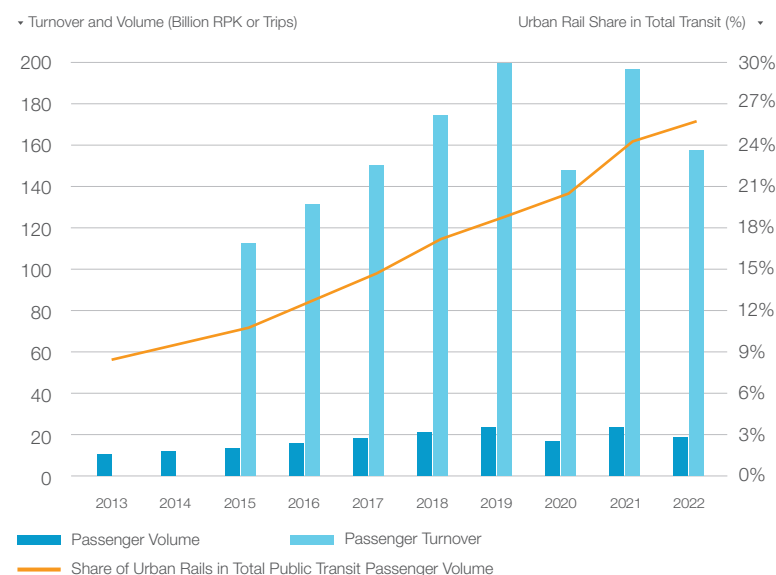
26%

urban transit¹⁶ trips in cities with the service are made by urban rail.

The share of urban rail passenger volume increased from 11% in 2015 to 26% in 2022.

Figure 25

Urban Rail Ridership of China (2013-2022)



MOT (2014-2023, Part 3.6), CAMET (2013-2023)

¹⁶ Urban public transit includes transit bus, ferry boat, and urban rail.



Micro mobility's zero emission transition has entered a new stage of optimization.

Micro mobility refers to short-distance transport provided by low-speed and light-weight vehicles such as human-powered and motorized 2/3Ws. In China, micro mobility transport is mainly composed of bicycles and 2/3Ws (E2/3Ws and ICE2/3Ws). Eighty percent of Chinese favor micro mobility as their primary choices of urban mobility, revealing its significance in the transition toward zero emission urban mobility.

- The focus of shared bicycle market is shifting from scaling up the bicycle numbers to higher turnover rates per bicycle

Bicycles are an eco-friendly mode of transport, making it crucial for steering urban mobility towards a greener future. China has been actively promoting bicycle sharing program by improving bicycle lanes and adding dedicated parking spaces. With the introduction of dockless shared bicycles¹⁷ (hereafter referred as "shared bicycles") in China around 2015, the travel rate of bicycle travel doubled from its lowest point, resulting in the deployment scale of 23 million shared bicycles and a greater presence of bicycles on the streets.

China's efforts to promote cycling go beyond merely expanding the scale of bicycle fleets. Since 2017, local governments have been urging shared bicycle operators to strategically deploy and schedule bicycles based on travel demands, while also placing limits on the size of the fleets. This aims to enhance the turnover rate of individual shared bicycles, serving a larger urban mobility demand with fewer bicycles. Taking Beijing as an example, the daily turnover rate increased from 1.1 times per day in the first half of 2019 to 3.3 times per day by the end of 2022.

- Two and three wheelers have successfully embraced electrification and are now committed to delivering high-quality products and sustainable development

Following China's urban motorcycle restrictions, E2/3Ws experienced rapid growth as substitutes for ICE2/3Ws, with over 84% of 2/3Ws now being electric. However, due to the lack of technical standards and regulations at the early stages of E2/3Ws development, a majority of E2/3Ws on the road are non-compliant with safety risks. For example, E2Ws became heavier and faster, resembling motorcycles. Occasional collisions may result from their quiet operations combined with unpredictable driving in vehicle lanes.

Since 2019, China has introduced new national mandatory technical standards for E2/3Ws products with clear product definitions and categories, enabling authorities to manage E2/3Ws under existing regulations to reduce accidents. Non-compliant products will be required to quit the market within a specified period.

These standards not only address the issues with product classification and definitions, but also encourage product improvements from the perspectives of safety and environment protection. For instance, the new standards for e-bicycles now mandate a maximum weight of 55kg, encouraging manufacturers to adopt lithium batteries, which have higher energy density, lighter weight, and more importantly, pose no risk of leaking harmful substances like lead sulfate and sulfur dioxide. In 2022, the penetration rate of lithium batteries in the E2Ws sales market reached 25%, nearly doubled since 2018. Undoubtedly, this rate is expected to continue rising and the current widely used lead-acid batteries will be phased out.

¹⁷ Since 2015, dockless shared bicycles have replaced docked bicycles as the predominant part of China's shared bicycle program.

80%

of the Chinese respondents prefer 2/3Ws for urban mobility, ranking the highest willingness in the world.

In 2022, Beijing's shared bicycles fleet was

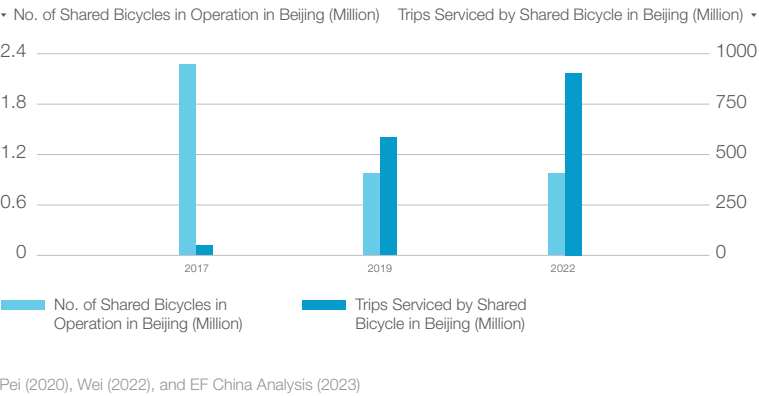
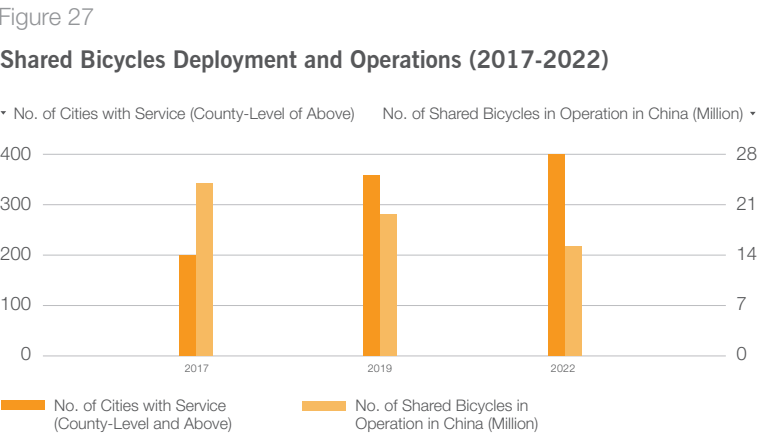
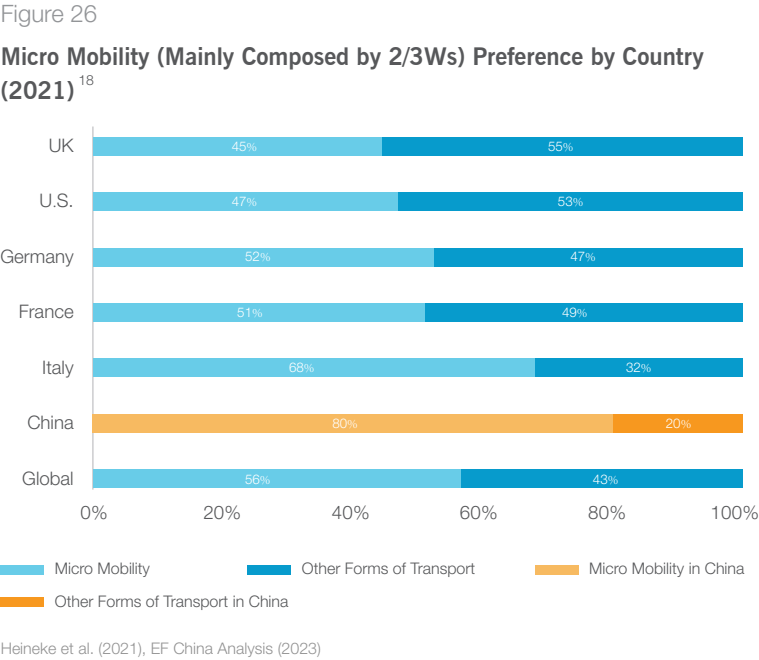
39%

of the size in 2017, yet served

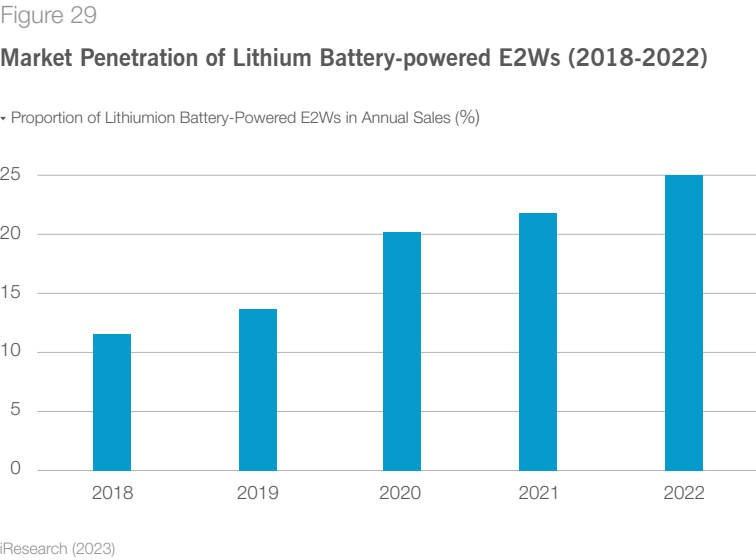
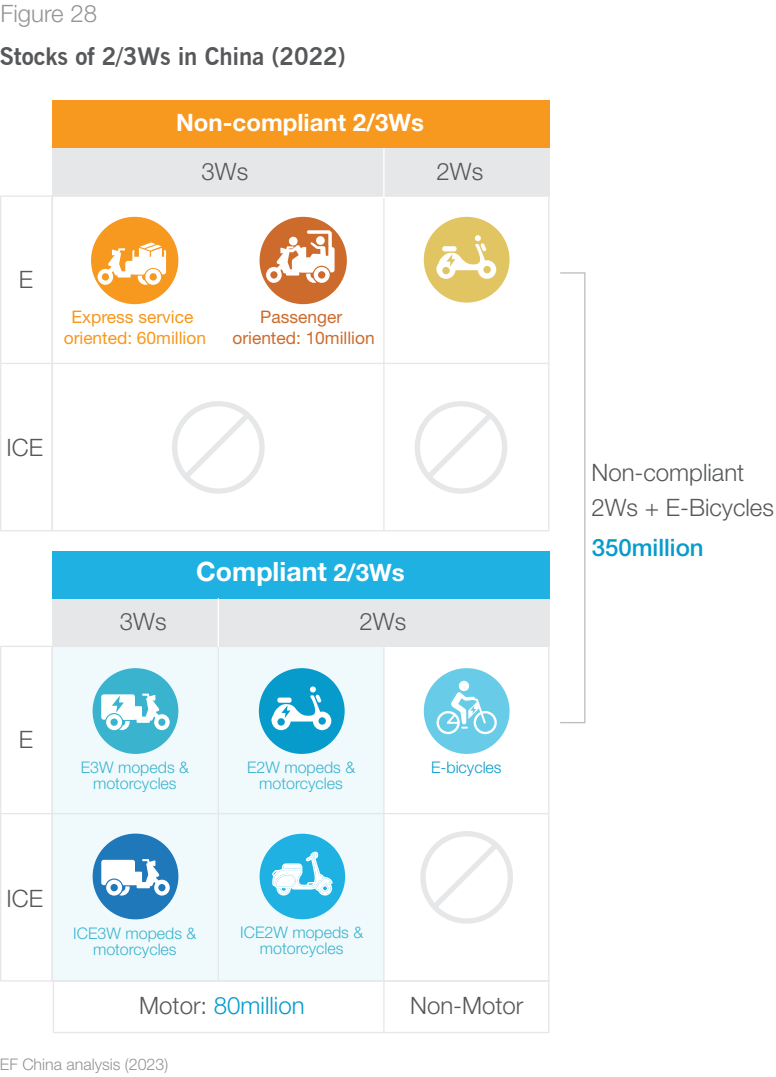
19

times more trips.

The government has optimized shared bicycle deployment. From 2017 to 2022, cities with shared bicycle doubled, but number of deployed bicycles decreased by 35%.



¹⁸ Figures may not sum to 100% because of rounding.



China has around

500M

2/3Ws, with over

84%

being E2/3Ws.

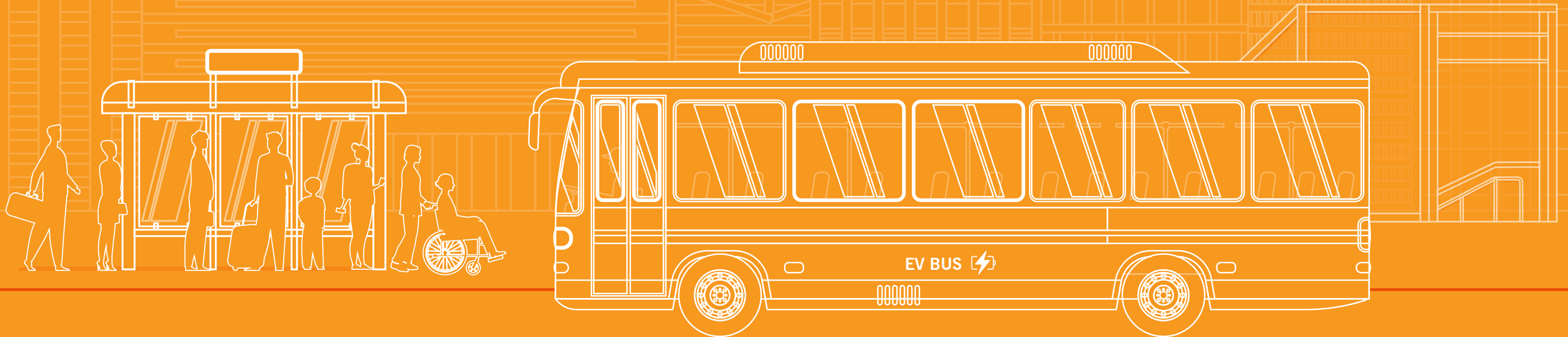
Most local governments have established transition deadline for non-compliant E2/3Ws by the end of 2023. However, in areas with weak supervision, non-compliant E2/3Ws may still exist.

The penetration rate of lithium batteries in new E2Ws sales has reached

25%

PART II

TRANSIT BUS



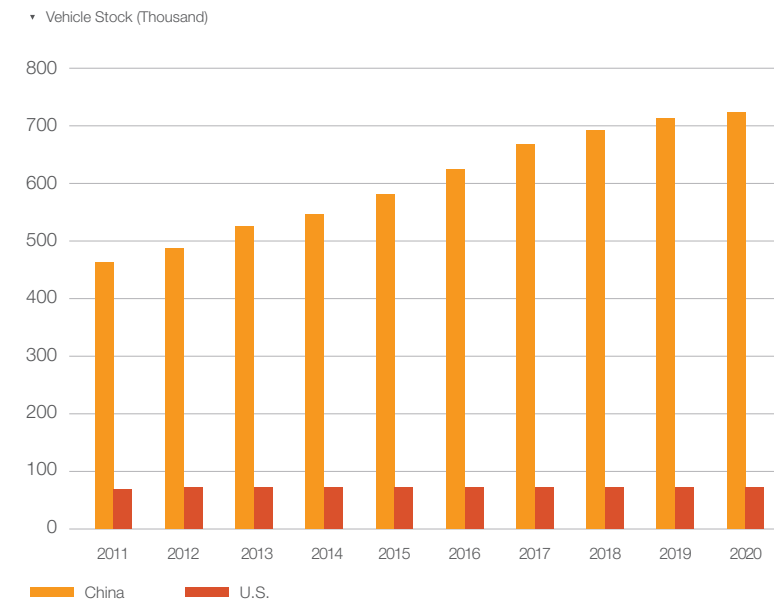
WHAT'S the scale and emission of transit bus system in China?

As the most cost-efficient and flexible form of public transport, transit buses are highly popular and widely used throughout China. The country, which initiated its first bus route in 1906, has successfully established and operated the world's largest and cleanest bus system.

- Over just one decade, China has significantly reduced the use of fossil fuel buses. The total share of diesel, gasoline, and LNG/CNG buses in the fleet had plummeted to 23% by 2022, from 87% in 2013 (Figure 22). Moreover, China owns the world's largest NEV bus market and fleet, no matter BEV, PHEV or FCV.
- Continuous efforts have been made to enhance fuel economy, lower vehicle emissions, and improve fuel quality to world-class standards. Limits on fuel consumption per 100km of new coaches and buses decreased by 23% and 16% between 2012 and 2019; NOx and PM emissions of new HDVs decreased by 94% and 97% between 2000 and 2021; and the sulfur content in diesel and gasoline both reduced by over 99% to 10ppm by 2017 (Figure 16,17 & 18).
- China is one of the pioneers who practice Bus Rapid Transit (BRT). By 2020, over seven thousand kilometers BRT networks were in operation across China (Figure 34).

Figure 30

Transit Bus Stock of China and U.S. (2011-2020)



MOT (2014-2023, Part 2.5), APTA (2023, Table 21).

In China,

703,200

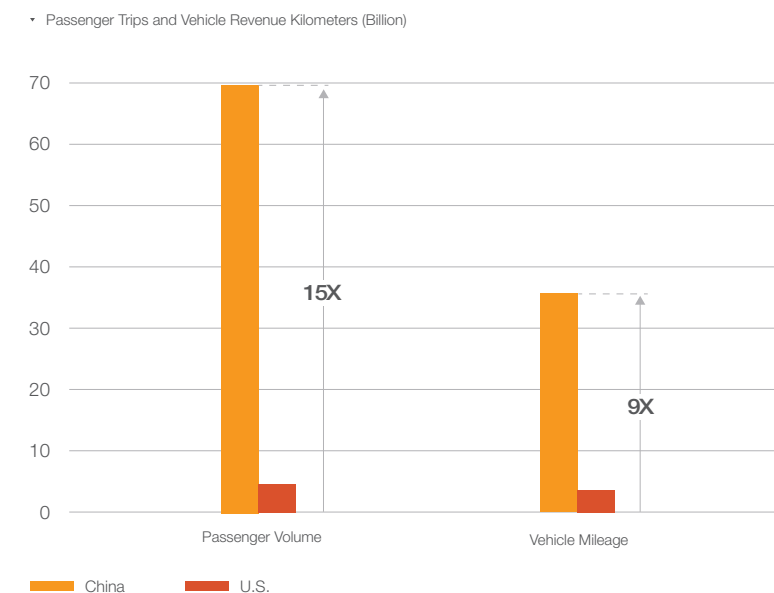
transit buses are in service by 2022

= 9.7 × U.S.

China's transit bus fleet grew by 55% during the decade.

Figure 31

Bus Ridership and Vehicle Mileage of China and U.S. (2019)



MOT (2020, Part 3.6), APTA (2023, Table 1 & 8).

China's bus ridership reached

69B

passenger trips

= 15 × U.S.

China's bus mileage reached

35B_{km}

= 9 × U.S.

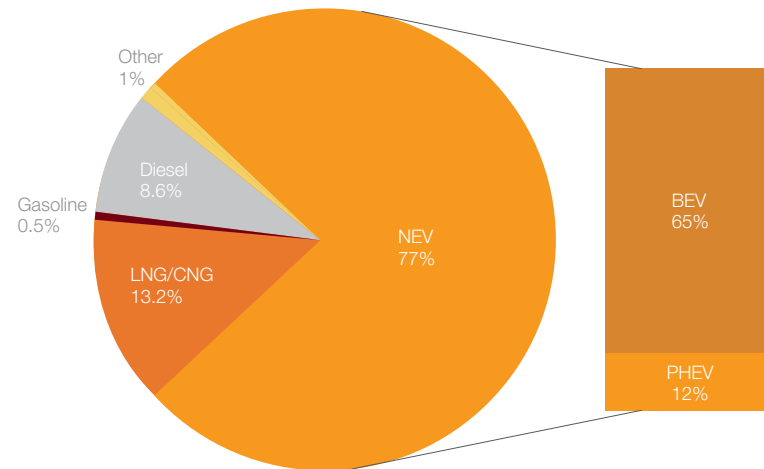
77%

of the transit bus fleet are electrified.

By 2022, the shares of BEV and PHEV in total transit bus stock were 65% and 12%, respectively.

The EV share of EU bus fleet is about 1% (European Automobile Manufacturer's Association [ACEA], 2022).

Figure 32
Transit Bus of China by Fuel Type¹⁹ (2022)



MOT (2014-2023, Part 2.5)

China's share in the world's NEV bus stock:

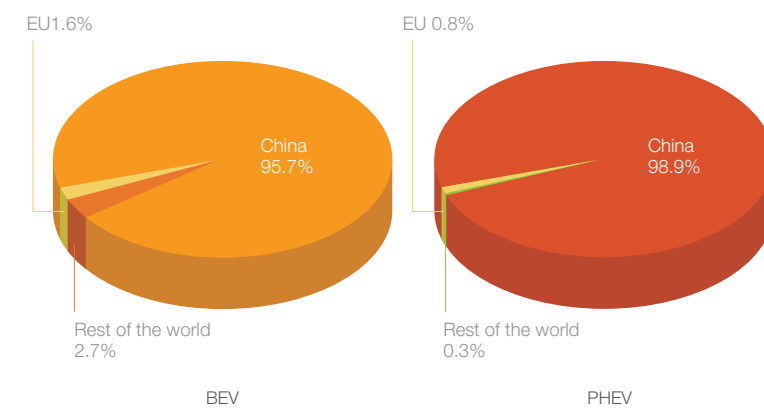
BEVs:

95.7%

PHEVs:

98.9%

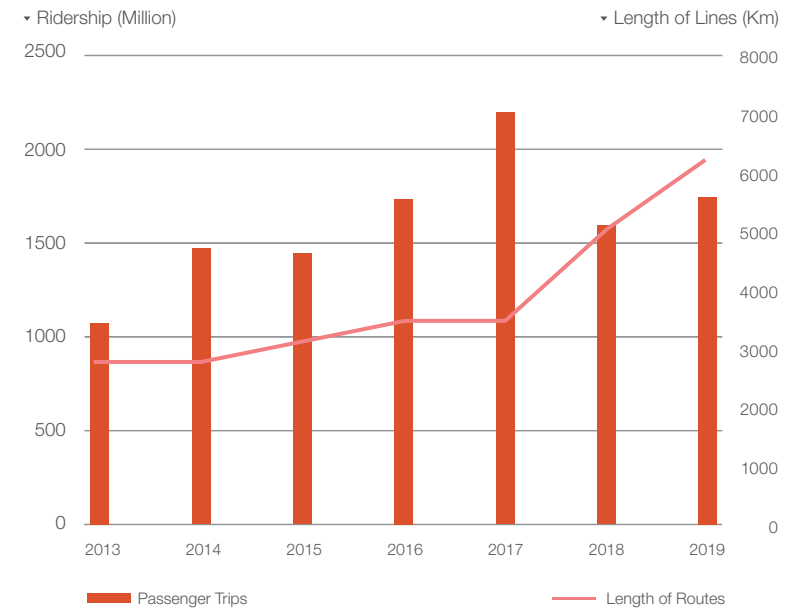
Figure 33
Global BEV and PHEV Bus Stock (2022)



IEA (2023b)

¹⁹ Other fuel types include hydrogen, dual fuel, and trolley.

Figure 34
BRT Development in China (2013-2019)



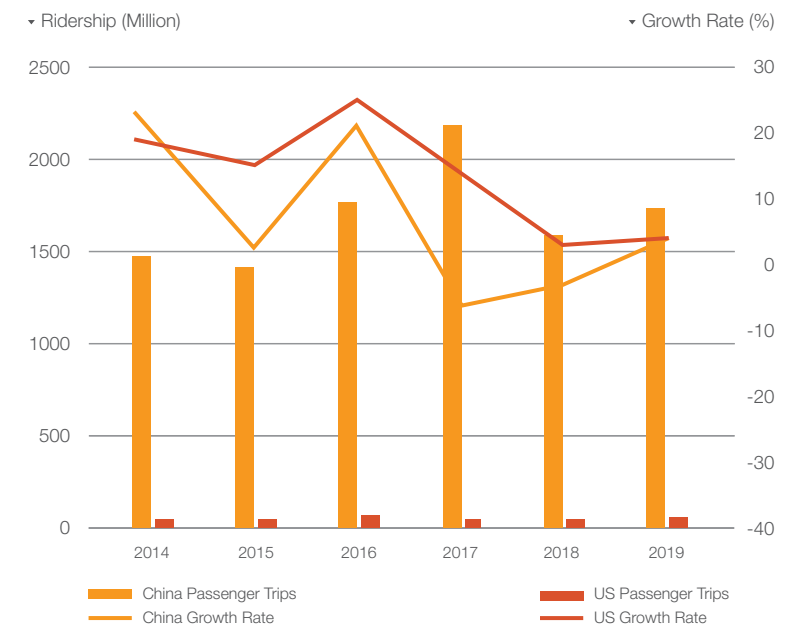
MOT (2014-2023, Part 1.6 & 3.6)

6,150km

BRT lines in China is in service by 2019

BRT system length increased 123% from 2,753km to 6,150km in six years.

Figure 35
BRT Ridership and Growth in China and U.S. (2014-2019)



MOT (2015-2021, Part 3.6), APTA (2023, Table 1)

BRT of China carried

1.7B

passenger trips in 2019.

=27 × U.S.

In 2019
Length of BRT lines:

4.4km
per million people

=4 × U.S.

No. of BRT vehicles:

6.7 buses
per million people

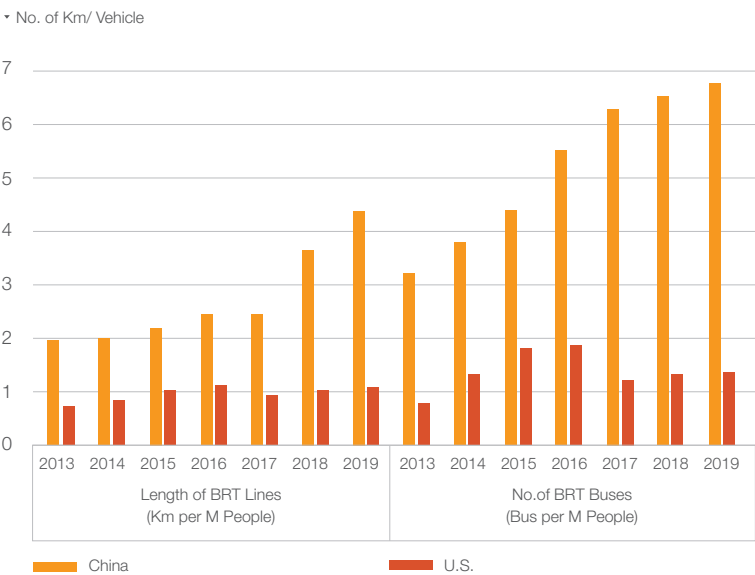
=5 × U.S.

Significant potentials of
BRT systems exist.

Champion Cities of China
fall behind **Bogoda**
by BRT indicators:

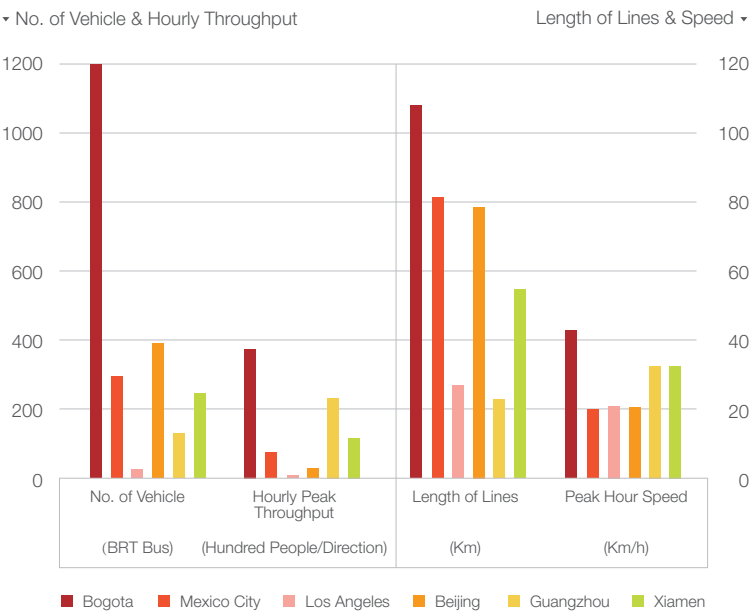
- Guangzhou:
38% by throughput
- Xiamen:
32% by speed
- Beijing:
27% by lines &
68% by stock

Figure 36
BRT Lines and Vehicles Per Million Inhabitants of China and U.S.
(2013-2019)



MOT (2014-2020, Part 1.6 & 2.5), APTA (2023, Table 21 & 50)

Figure 37
BRT Scale and Operation in Select Cities



Far East Mobility (2023)

II-2

WHY does China prioritize the zero emission transformation of buses?

Bus is one of the best choices for mass urban transit when taking into considerations on air pollution control, congestion mitigation, financial capacity, social fairness, and operational flexibility.

Besides, buses could be the pilot vehicles for new technology demonstrations, which can help scale up the zero emission transition of other vehicle categories. Like other countries, China prioritizes bus development mainly because it is naturally greener as a mode of public transport. On average, one bus is capable of replacing at least 30 cars on the road (ACEA, 2022). Due to this low occupancy of roads per passenger, developing buses can free up road space and help ease traffic congestion. It will also reduce fuel consumption, carbon footprint, and air pollution per passenger.



Transit bus is a green transport mode by nature

Theoretical carrying capacity:

1 bus

≈ 30 cars



ACEA (2022)



Buses play an important role in new technology demonstrations

As a public mobility service provider, the transit bus operation company maintains close ties with the government. Government subsidies are crucial for supporting bus purchases and operations. Therefore, bus operation companies often stick to the government's guidance. In light of these, buses have always been at the forefront, leading the way in implementing mandatory end-of-life vehicle rules and emission standards, as well as piloting demonstrations of cutting-edge technologies.



“Ten Cities × One Thousand Electric Vehicles” Pilot Program

China launched this program in 2009 and deployed over 27,400 NEVs in 25 pilot cities within three years, 84% of which are public service NEVs, particularly buses (China Automotive News, 2013). Three types of new technologies, including BEV, PHEV and FCV were encouraged. China's EV market took off afterwards.



Orderly Charging and Vehicle-Grid Integration (VGI)

VGI and orderly charging allow EVs as responsive mobile energy sources to either take energy from and/or supply energy to the power grid when needed. China has set up policies and pilot projects to support VGI, especially in regions with rapidly deployed EVs, like Shanghai, Beijing, and Guangdong province. For instance, Beijing has a VGI pilot program for BEV transit buses, fully shifting bus charging to off-peak hours. It demonstrates the value of VGI operations for peak shaving (Li et al., 2022).



Mobility as a Service (MaaS)

MaaS aims to provide an alternative for private cars that may be as convenient, more sustainable, less congested, cheaper, and with larger transport capacity. MaaS integrates different forms of transport and related services into one comprehensive and on-demand mobility service. MaaS offers end-users the added value by letting them access mobility through a single application and payment. To meet a customer's request, a MaaS operator provides different transport options, including public transit, active modes such as walking and cycling, car/bike sharing, taxis, car rentals, or a mix. Beijing launches China's first MaaS platform, which includes buses, subways, shared bicycles, ride-hailing, walking, and driving (MaaS Alliance, 2023).



Customized Bus

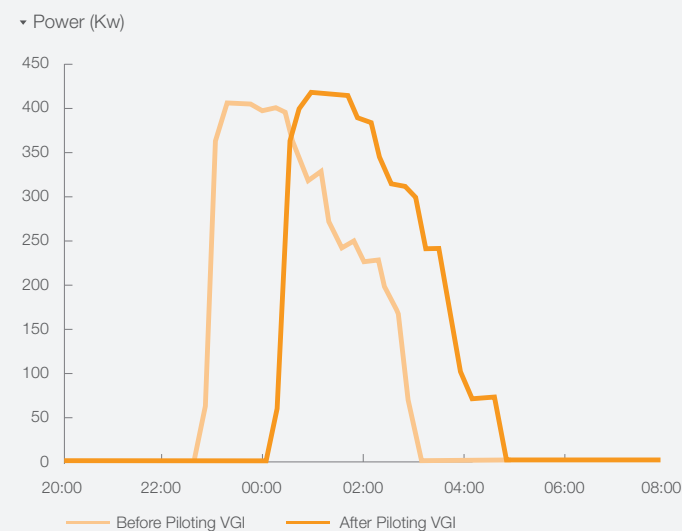
In order to meet different transit demands, China introduced a new model of customized buses, which is between the traditional buses and taxis. People who work and live in the same area with similar commute needs can group together to order a customized bus. The route, frequency, and schedule are tailored to meet this group's specific needs. Besides routes designed for daily commute, new products are emerging. For example, Shanghai launched medical-themed customized buses in August 2022 to take people to their desired hospitals and help make doctor appointments on the bus. A new “bus pooling” model was also launched in Shenzhen in July 2022. By 2021, 94% of provinces, autonomous regions, and municipalities-including Beijing, Hebei, and Shanxi-had customized bus routes, totaling over 5,400 routes that generated 180 million passenger trips annually (Sun & Deng, 2021).

Beijing: the pioneer city for zero emission buses

- Beijing was the first batch of pilot cities in China's "Ten Cities × One Thousand Electric Vehicles" Pilot Program, starting with 50 BEV buses in 2010 (Zhang, 2010). By 2022, over 90% of Beijing's bus fleet has been electrified.
- By 2022, Beijing had 1,524 bus charging point distributed at 225 bus terminals (Li, 2023).
- Beijing launched the MaaS platform in 2019. By May 2023, more than 30 million people had registered for the platform. It serves no less than six million passenger trips daily, saving at least 400,000 tons of carbon emissions and facilitating the trade of 120,000 tons of voluntary carbon credits (Fang & Ran, 2023).
- Beijing launched China's first customized bus route in 2013. By 2022, it had 396 customized routes, providing personalized transport service for 20,000 citizens daily and helping them save 30% commute time (Beijing Municipal Commission of Transport, 2023). Beijing also arranges customized school buses (BTI, 2023).
- Beijing piloted one of China's first bus VGI projects at a transit bus charging station in 2021 (Li et al., 2022).
- Beijing developed 1005km DBLs by the end of 2022 (BTI, 2023).

Figure 38

Power Curve of A Bus Charging Station in Beijing Before and After Piloting VGI



Li et al. (2022)



Screenshot of Beijing MaaS App

HOW does the policy motivate the changes?

Policy plays a vital role for the zero emission transit buses, both strategically and tactically.



Elevate public transport as a national priority

China has established public transport as a national priority through institutionalized policies and specific regulations.

- The first national level initiative on proposing public transport as a social welfare measure tied to national economic progress and livelihood improvement was the **“Opinions on Giving Priority to the Development of Urban Public Transport”**, issued by the former Ministry of Construction (now MOHURD) in 2004 (MOC, 2004). In 2005, General Office of the State Council circulated this opinion and enhanced it with 22 recommendations focused on public transport planning, infrastructure, operations, rights of way, incentives, and supervision (MOHURD, 2005).
- **Guiding Opinions on Giving Priority to the Public Transport in Urban Development by the State Council officially elevated public transit priority as a national strategy** (State Council, 2013a). MOHURD and MOT issued opinions on economic policies (MOHURD, 2006) and other implementation measures (MOT, 2013).
- In 2007, Legislative Affairs Office of State Council started to solicit suggestions on Urban Public Transport Regulations/Directives. This marked the first legislative effort to formally clarify the public interest nature of China’s public transport system. MOT is actively pushing for the official release of these regulations in 2023.



Establish transit buses as pioneers and leaders with quantified goals in reducing carbon and air pollutants emissions

Air quality improvement has been a major driving force to scale up NEV buses in cities since 2013. This impetus has been further strengthened by carbon peaking and neutrality goals.

- In 2013, China implemented the **Action Plan for Prevention and Control of the Air Pollution** (State Council, 2013b), which mandated that at least 60% of new and replaced buses in Beijing, Shanghai, and Guangzhou must be NEVs or clean fuel vehicles.
- In 2018, China released **Three-year Action Plan for Fighting to Win the Battle Against Air Pollution** (State Council, 2013a), which mandated at least 80% of new and replaced buses, sanitary trucks, post office trucks, taxis, light logistic trucks to be NEVs in key air pollution areas. It further required 100% new and replaced buses in municipalities and provincial capitals in these key areas to be NEVs.
- In 2021, State Council released the **Action Plan for Carbon Dioxide Peaking Before 2030** (State Council, 2021), which re-emphasized developing green and low-carbon public transport and electrifying vehicles used for urban public services.
- In 2022, China reduced the share of diesel buses in the transit bus fleet to only 9%, while ramping up the share of BEV buses to 65% (Figure 32).



Provide fiscal incentives to support electric transit buses

The public transport priority strategy establishes financing mechanisms for transit service providers, including a set of subsidies and preferential taxation policies. Accumulatively, around 200 billion RMB in purchase subsidies were provided through the “Ten Cities × One Thousand Electric Vehicles” Pilot Program and afterward (Zhou, 2023). In 2019, the government provided subsidies totaling 100 billion RMB to support nationwide transit bus operations (Jia, 2023). For all public transport operators, the value-added tax is exempted. NEV transit buses receive exemptions from vehicle and vessel registration tax and vehicle purchase tax as well.

Preferential taxation policies save spending for NEV owners

- Since 2012, NEV buses have been exempted from vehicle and vessel registration tax. This policy was updated three times in 2015, 2018, and 2022 to increasingly tighten criteria on fuel efficiency, mileage range, and emission reduction so as to further encourage technology development.
- Since 2014, NEV buses received a vehicle purchase tax exemption. Tax exemptions for all NEVs (buses, passenger cars, trucks, etc.) totaled 200 billion RMB from 2014 to 2022, and are estimated to reach 115 billion RMB in 2023 alone and 520 billion RMB between 2024 and 2027 (Zhou, 2023).

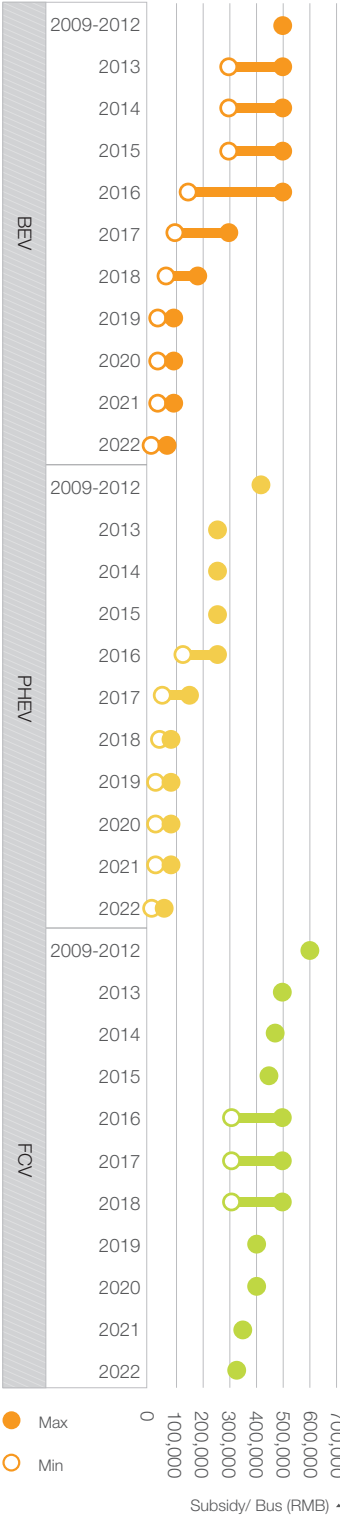
National and local subsidies helped electric buses kick off

Favorable subsidies for procurement and operations of NEV buses are provided to partially offset the high cost of NEV buses.

- Subsidies for procurement from central and local governments: From 2010 to 2022, national NEV purchase subsidies are estimated to reach 200 billion RMB in total (Shang & Yu, 2023). Municipal governments of many large cities also provided additional local subsidies. For example, since 2015 Beijing has provided the local purchase subsidy at the same level as the national (Beijing Municipal Science and Technology Commission [BMSTC], 2015), and since 2018 half the ratio (Li & Yao, 2020).
- Subsidy for operations: A key policy is transitioning bus operation **subsidy from oil to electricity**. In 2015, the central government began phasing out its “oil subsidy” and shifting to an “electricity subsidy”. This incentivized the initial market for BEV and PHEV buses in China. By 2019, the fuel subsidy fund for fossil fuel buses had been reduced by 60%, compared to 2013 level. Besides, operating subsidies for NEV buses are provided on a yearly per vehicle basis (Ministry of Finance [MOF] et al., 2015). Many large cities have also provided local subsidies for the operations of NEV buses. For example, Beijing provides an annual operating subsidy of 80,000 RMB for each qualified BEV bus (Zhev, 2015).

Figure 39

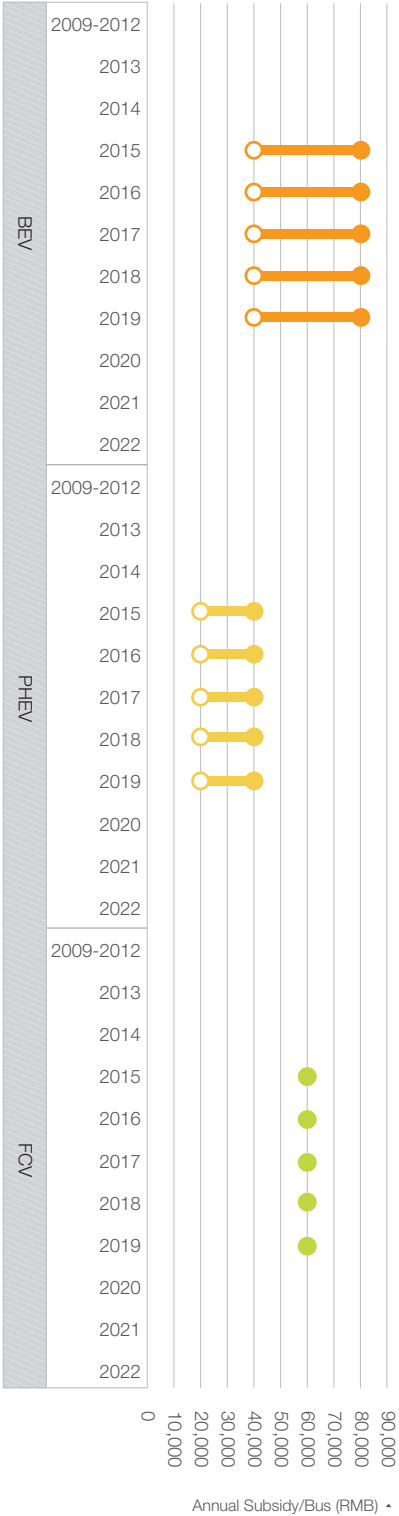
National Subsidy Criteria for NEV Bus Purchase (2009-2022)



MOF (2013, 2014, 2016, 2019a, 2019b, 2020), MOF, Ministry of Science and Technology (MOST), et al. (2015), MOF and MOT (2009), MOF et al. (2018), MOF,MIIT,et al. (2015).

²⁰ It was provided in the form of electricity subsidy, which was shifted from the oil subsidy provided since 2010.

Criteria of Major National NEV Bus Operation Subsidy²⁰ (2015-2019)



200B_{RMB}

NEV purchase subsidies are provided for passenger cars, buses, trucks, and other qualified vehicles by technical criteria to encourage technology advancement.

Operating subsidies are also provided for NEV buses with an annual mileage of 30,000 km or above between 2015 and 2019.

Table 2

Subsidies in Beijing, Shanghai, and Shenzhen

	Purchases (RMB/vehicle)	Operations (RMB/vehicle/year)
Beijing	Since 2015: Same of national subsidy (BMSTC, 2015) Since 2018: Half of national subsidy (Li et al., 2020)	BEV buses: 80,000
Shanghai (2021-2023)	BEV and PHEV buses: 350,000 to 500,000 FCV: 800,000	BEV: 90,000-140,000 PHEV: 10,000 FCV: 70,000
Shenzhen	BEV: 90,000 * Shenzhen only subsidize BEV buses	Based on annual operating mileage

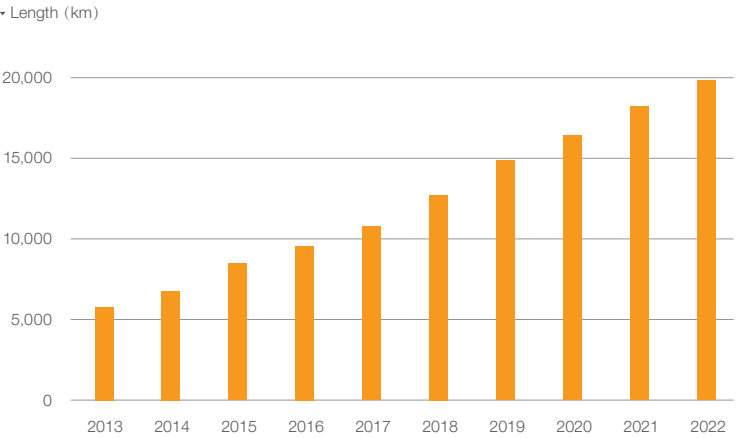
a: Zhev (2015), b: BMSTC (2015), c: Li & Yao (2020), d: Shanghai Municipal Transportation Commission (2021).

Dedicated Bus Lanes (DBLs) provide important non-fiscal incentives

Non-fiscal incentives are used to achieve optimal results with minimal effort. DBLs were designed to give transit buses priority on the road. They are exclusively for bus use during specific hours, such as the morning rush hours from 7-9 am. Non-bus vehicles are discouraged from using the lanes, with penalties for violations. In June 2023, Ministry of Public Security (MPS) made amendments to optimize the efficiency of DBL while maintaining the right-of-way of transit buses. The adjustments include modifying time slots for exclusive bus lane use, allowing non-public vehicles access during non-exclusive hours, and potentially permitting other public vehicles such as shuttle buses and school buses to share DBLs during exclusive hours (Ren, 2023).

Figure 40

Length of Dedicated Bus Lanes in China (2013-2022)



MOT (2014-2020, Part 1.6)

Cities offer local subsidies to support preferred technologies.

The length of DBLs grows

5 times to 19,900 km from 2013 to 2022.

Beijing alone has 1005km DBLs by the end of 2020 (BTI, 2023).

PART III

URBAN RAIL²¹



²¹ Based on the definitions in Footnote 4 and 6, "urban rail" in China, excluding the commuter rail and tram which account for 12% and 5% of the system length in 2022, is similar to "metro" globally and "heavy rail" in the U.S. China's light rail is not same as its U.S. counterpart. It is more similar to the international "metro" or "subway" based on standards in China. This principle also applies to China's monorail, maglev and APM.

WHAT makes urban rail favored over road transport?

Initially, bus development took off before urban rails in China due to the country's less developed economy. But with rapid economic growth and urban expansion, travel distances increased and higher speed and better efficiency were needed. Also, the exploding urban population required higher-capacity mobility to handle massive passengers. Buses could not meet the demand for speed, reliability and capacity anymore.

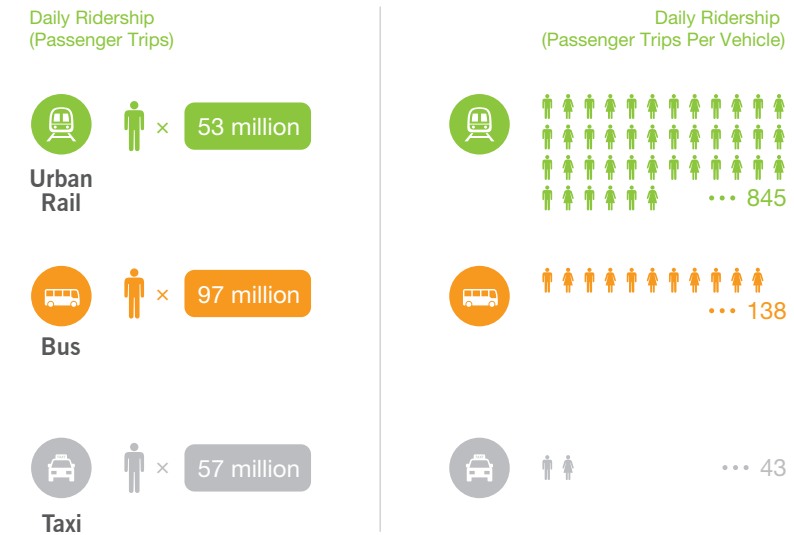
With over 900 million urban residents, traffic congestion has become a huge problem. In 2022, road vehicles in 89% of 36 major cities across China move at 18-25km/h due to congestion (Wang & Cao, 2023). Urban rails pull ahead as the first choice over struggling road transport.



Urban rail has magnificent transport capacity

Figure 41

Daily Ridership of Urban Rail, Bus and Taxi in China (2022)



MOT (2022)

China's urban rail transported

53M

passenger trips daily in 2022.

Figure 42

Urban Rail Daily Ridership Nationwide and in Major Cities in China (2013-2022)



CAMET (2013-2023)

55

cities in China have urban rails, but

48%

ridership happened in

4

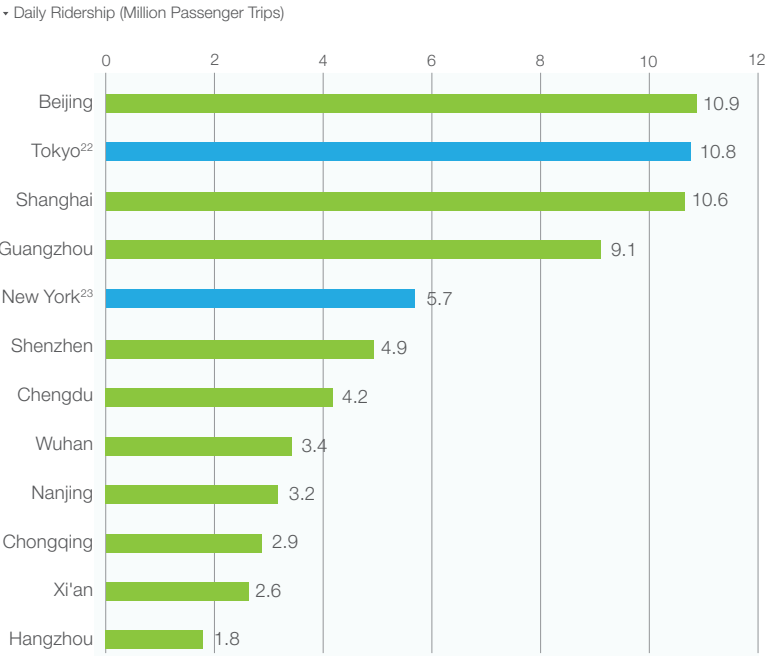
major cities: Beijing, Shanghai, Guangzhou, and Shenzhen.

Beijing and Shanghai

urban rails are among the global busiest, with daily ridership over

10M

Figure 43
The 10 Busiest Urban Rails in China and Comparison with Global Cities (2019)



CAMET (2020), Statista (2022), MTA New York City Transit (2020), Port Authority Trans-Hudson Corporation (PATH, 2020), APTA (2020).

²² The number covers both Tokyo Metro and Toei Subway
²³ The number covers MTA New York City Transit, Port Authority Trans-Hudson Corporation, and Staten Island Rapid Transit



Urban rails are faster and more reliable

Urban rail is preferred by city dwellers as it allows passengers to travel farther and faster with high punctuality.

1

Faster than road.

Urban rail in China averages 36km/h (CAMET, 2023), about 58.6% faster than the average travel speed in the 36 selected major cities and 44%-100% faster in medium congestion cities (Wang & Cao, 2023).



2

High frequency.

By 2022, the average departing time interval (DTI)²⁴ is shorter than 290 seconds. Approximately 25% of lines depart within 180 seconds. The interval is shortened to under 120 seconds during rush hours in megacities (CAMET, 2013–2023);



3

High punctuality.

The average punctuality remains above 99.9% in years (MOT, 2023a);



4

Long operation hours.

On average, China's urban rails operate 17 hours daily, up to 18.7 hours in Beijing (CAMET, 2013–2023);



5

Enhances habitability.

Urban rail has become an indicator of the quality of life, attraction, competitiveness, and prosperity in cities. A new model, known as “rail plus property” (R+P) or “integrated hub station development”, helps to recover costs and enable financial sustainability.



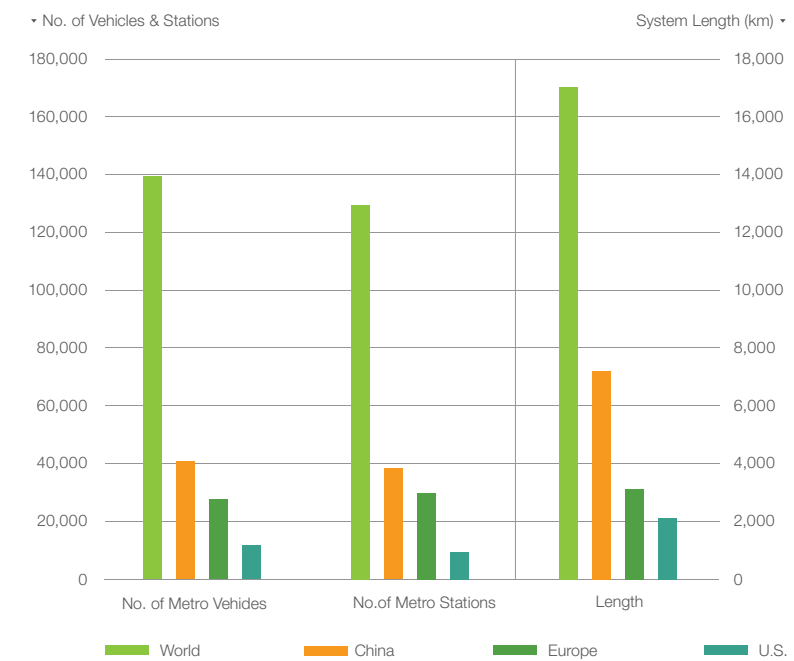
²⁴ DTI measures the time from one train fully leaves the platform until the next train starts moving in. The interval between trains can be even shorter than the DTI.

HOW BIG and FAST does urban rail develop?

China leads the world in urban rail infrastructure, especially the network length and number of cities with urban rail. Metro systems dominates China’s urban rail, comprising 88% of length and 95% of passenger turnover. From 2013 to 2022, the number of cities, lines, stations and vehicles with urban rail grew robustly at 190%, 261%, 280%, and 336%, respectively (CAMET, 2014–2023).

Figure 44

Number of Metro Vehicles, Stations and Length in China, Europe, U.S. and World (2020)



CAMET (2021), UITP Secretariat (2022), APTA (2023, Table 21, 49, 51)

Table 3

World Metro Regional Distribution

		 Number of Cities	 Population Served (million)
2020	World	193	N/A
	Europe	46	52
	U.S.	13	23
	China ²⁵	38	421
2022	China	41	450

CAMET (2021,2023), UITP Secretariat (2022), APTA (2023, Table 21, 49, 51), World Population Review (WPR, 2023a, 2023b), Office of the Leading Group of the State Council for the Seventh National Population Census (as cited in Chen, 2022), Liu (2023)

²⁵ Numbers of China include subway only, instead of all urban rail systems.

About

30%

world metro vehicles and stations are in China.

By the end of 2020, China had 44,000 metro vehicles running through over 3,800 metro stations, accounting for 32% and 30% of the world’s total, respectively.

HOW does urban rail contribute to ease the traffic and reduce emissions?

With all the advantages mentioned above, urban rails have been picking up more of the traffic load and easing the burden on the road. In 2022, urban rails took 26% of China's urban transit passenger volume, increasing from just 9% in 2013. The increase mainly comes from replacing the use of cars and transit buses.



Development of urban rails brings down the mileage of cars

Figure 45

Annual Driving Mileage for Private Cars in China's Mega Cities



EF China analysis, Xiamen Environment Protection Vehicle Emission Control Technology Center, BTI, Shanghai Urban Rural Construction and Transportation Development Research Institute, Chengdu VECC

Beijing, Shanghai, and Chengdu have seen over a

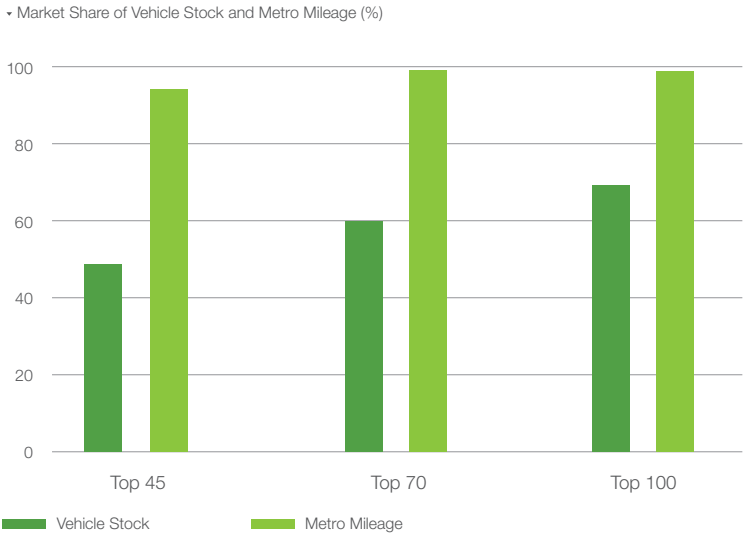
2.5%

annual drop in private car vehicle kilometers traveled (VKT).

Even as China's mega cities see their population, urban built-up areas and vehicle stock numbers go up, private car mileage is actually decreasing steadily.

Figure 46

Top Cities' Share in China's Vehicle Stock and Metro Mileage



EF China analysis, Xiamen Environment Protection Vehicle Emission Control Technology Center, BTI, Shanghai Urban Rural Construction and Transportation Development Research Institute, Chengdu VECC



Urban rails are zero emission because it is 100% electrified

Urban rails consume energy for traction and non-traction purposes like air conditioning, lighting and platform screen door system. The energy efficiency of urban rail stays stable between 0.1 to 0.2 kWh/person kilometer (MOT, 2023a).

WHAT kind of policies enable such development?

As an essential part of public transport, urban rail benefits from the national strategy to put public transport as the priority. Besides, the encouragement on Transit-Oriented Development (TOD) as well as multi-functional integrated transport hubs also create an enabling environment for urban rail development.



Governmental subsidies support the sustainable operation

The investment and operation cost²⁶ of urban rail systems are notably high. Although the cost varies across cities, on average, the construction of every kilometer subway means 700-800 million RMB investment and often exceeds 1 billion RMB in the megacities. Taking Shanghai and Beijing for example, the estimated investment per kilometer reaches 2 billion RMB for Shanghai Metro Line 20, and 1.5 billion RMB for Beijing Subway Line 25 Phase 3 (Rail-stdaily, 2023). Estimates show that subway investment payback in China requires at least 29 years (Wu, 2017), based on the average level of costs and revenues.

The fast expansion of urban rail networks and the affordable ticket prices are largely attributed to government support. Similar to buses, governments provide significant subsidies to the operations of urban rails. In 2022, the nationwide total subsidies for metros, a primary category of urban rails, surpassed 110 billion RMB. At the city level, Beijing allocated over 26 billion RMB in subsidies in 2022. Some other cities, including Hangzhou, Chongqing, Zhengzhou, Suzhou, Qingdao, Chengdu, Ningbo, and Nanjing also provided subsidies over 5 billion RMB (ThePaper, 2023).



Encourage TOD as a new development model

In 2018, General Office of the State Council issued **Opinions on Further Strengthening the Administration of Planning for Construction of Urban Rail Transportation**, emphasizing the importance of establishing viable financing models and internalizing land value to cover urban rail system costs (State Office, 2018).

To reduce reliance on subsidies, urban rail companies proactively explore to establish their own “self-restoration” mechanisms for financial self-sufficiency. TOD, provides a promising approach. By applying the TOD model, developers can engage in high-density property development around rail stations, generating revenue through real estate to support subway operations. Successful global examples include the new World Trade Center in New York, the Grand Front in Osaka, the Kowloon station in Hongkong. These TOD projects are financially self-sustaining while benefiting urban development and mobility improvement.

China actively promotes TOD to effectively manage its rapid urbanization with the development of public transit networks. Localized TOD models include “R+P”, “integrated hub station development”, and “metro station-centered complex development”, emphasizing multifunctional mixed-use of land and integrated urban planning around transit hubs. Shenzhen leads mainland R+P. In 2022, Shenzhen Metro reported a revenue of 16 billion RMB from station-city integration. In the same year, Beijing Investment, the operator of Beijing Metro, had a total revenue of nearly 6.3 billion RMB from its real estate development and primary land development. Chengdu Rail Transit Group received 6.2 billion RMB from station comprehensive development revenue. Rail transit in Hangzhou, Qingdao, Ningbo, Nanning, Guangzhou, and other cities also reported significant income from real estate-related activities (ThePaper, 2023).

²⁶ The investment cost includes land acquisition and resettlement, civil engineering, road occupation and diversion, pipeline relocation, vehicles (rail cars), mechanical and electrical equipment, etc.

Box 3

Shenzhen metro: best TOD development with least subsidies and highest revenue

In many cities, TOD is practiced as “Development Oriented Transit” or “Transit Adjacent Development”, where the transit systems and the surrounding development are independently planned with poor connectivity.

Shenzhen Metro Group (SMP) distinguished itself by introducing mainland China's first R+P TOD model with the development of Qianhai Depot Station in 2008. In this case, SMP maximized the utility of depot land for commercial property and social housing development alongside metro infrastructure. This enabled Shenzhen Metro to become financially self-sustained and reduce its reliance on government subsidies.

SMP has successfully applied the R+P TOD model to 34 metro projects, developing a comprehensive value chain consisting of metro infrastructure, operations, integration of urban development and transit, and property management. In 2022, SMP earned 16 billion RMB in revenue from integrated development of metro and property, the highest among all metro companies in China. Meanwhile, SMP received only 531 million RMB government subsidy, among the lowest subsidies for all urban rail systems in China (Song, 2023).





Promote multimodal transport hubs integrating urban rail, city bus, railway, and airports

Multimodal transport hubs can reduce transit distances and improve efficiency. The State Council issued the “Outline of the Plan for the Development of Road Transport Industry during the Period of the 12th Five-Year Plan” in June 2012, setting targets of developing 42 national-level transport hubs²⁷ characterized by zero-distance interchange and seamless connections (State Council, 2012). This kicked off the development of a multimodal transport hub in China.

In the following year 2013, “Guiding Opinions on Promoting the Development of Comprehensive Transport Hubs” detailed design principles, key tasks and safeguard measures to stimulate the planning and development of the 42 hubs. Social capitals investment and participation in the development and operation was encouraged. Multi-purpose and mixed use of land ensured the sustainability with diverse financing and well-designed business models (NDRC, 2013).

The Central Committee of the Communist Party of China (CPC) and State Council (2019, 2021) further emphasized the commitment to building robust, multi-level, integrated transportation hub systems in the “Outline for Building China’s National Strength in Transport” and “National Comprehensive Three-dimensional Transportation Network Planning Outline”. MOF revised the rules to allow the use of funds generated from vehicle purchase taxes for the construction of comprehensive transport hubs (Jin et al., 2023).

²⁷ Forty-two national-level transport hubs are in Beijing, Tianjin, Harbin, Changchun, Shenyang, Dalian, Shijiazhuang, Qinhuangdao, Tangshan, Qingdao, Jinan, Shanghai, Nanjing, Lianyungang, Xuzhou, Hefei, Hangzhou, Ningbo, Fuzhou, Xiamen, Guangzhou, Shenzhen, Zhanjiang, Haikou, Taiyuan, Datong, Zhengzhou, Wuhan, Changsha, Nanchang, Chongqing, Chengdu, Kunming, Guiyang, Nanning, Xi'an, Lanzhou, Urumqi, Hohhot, Yinchuan, Xining, and Lhasa.

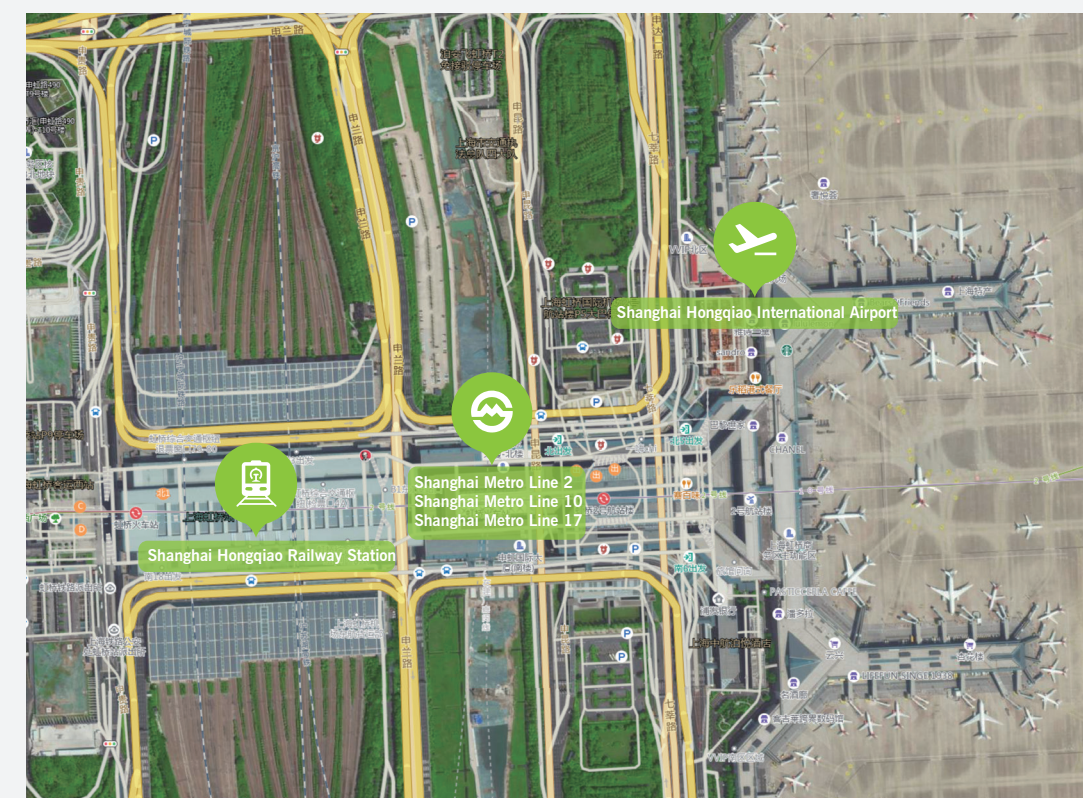
Box 4

Shanghai Hongqiao Transportation Hub: the pioneer of integrating multiple transport modes

Shanghai Hongqiao Transportation Hub consists of Shanghai Hongqiao International Airport, the intercity high-speed Shanghai Hongqiao railway station, three metro lines, buses, taxis, and a maglev station.

In 2019, the hub witnessed an average daily passenger throughput exceeding 1 million, reaching a peak daily flow of 1.5 million. By 2021, the annual total passenger volume had exceeded 300 million. Because of the convenience, 48% of inbound passengers arriving at Hongqiao Airport or railway station take metro lines to their destinations in the city. The hub encouraged more outbound passengers to choose railways, with the share increasing from 61% in 2011 to 74% in 2019. The overall passenger volume of Hongqiao railway station in 2019 was 253% of the level in 2011. The overall passenger volume of Hongqiao Airport in the same year was 135% of the level in 2011 (ThePaper, 2019). Hongqiao Hub has become the most important transport hub in East China, laying a solid foundation for the integration of urban functions and driving the economic prosperity of Shanghai. In addition, it serves as a vital facilitator for the economic activities of the entire Yangtze River Delta region by providing substantial support for regional transportation centered around Shanghai.

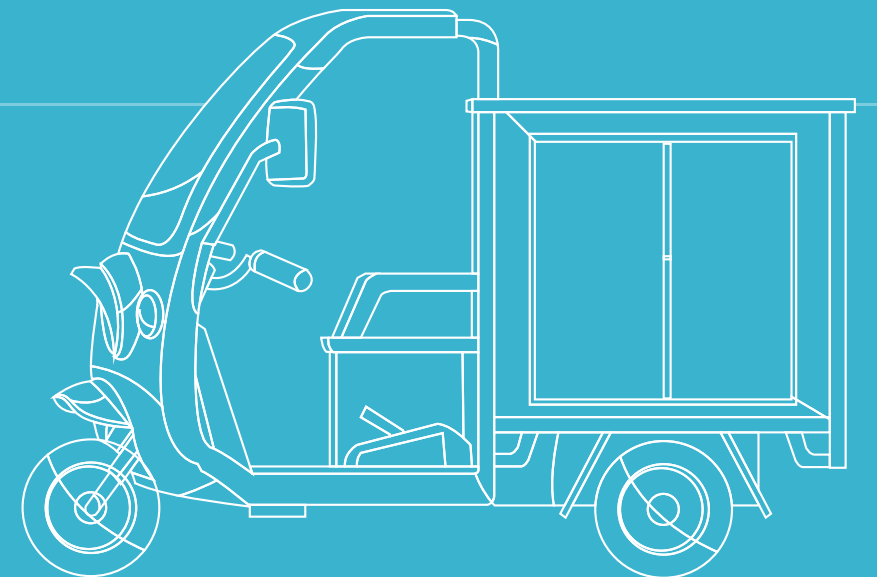
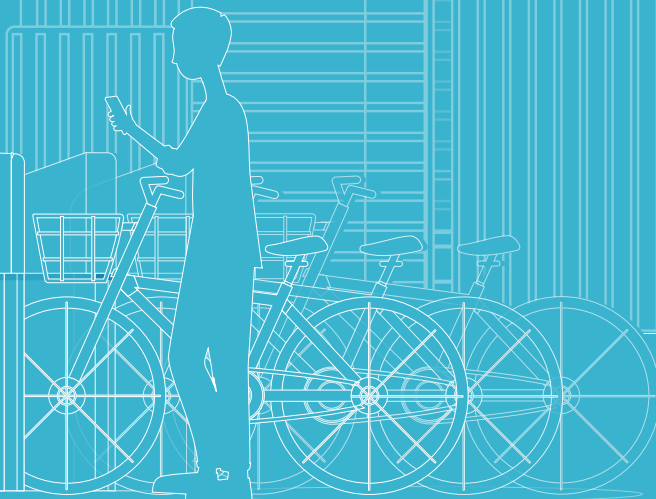
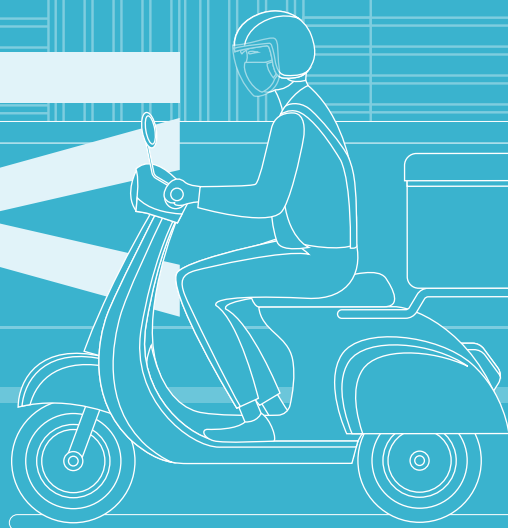
As the first of its kind in China, the Hongqiao Hub model has been followed by other cities, including Hangzhou, Guangzhou, and Shenzhen. Going forward, China should see more “Hongqiao Hubs” to improve the efficiency of passenger transport.



Screenshot of Amap

PART IV

SHARED BICYCLES AND ELECTRIC TWO AND THREE WHEELERS



WHY are shared bicycles and E2/3Ws so popular?

In the 1980s, China's cities were characterized by compact layouts, resulting in short-distance urban passenger trips and low demands for urban mobility. Meanwhile, the motorcycle and auto industry in China was still at an early development stage, and most people could not afford to buy vehicles. This made bicycles and buses the preferred choices for urban mobility.

When China's cities began expanding in the 1990s, there was a noticeable increase in the travel distance for urban mobility. Supported by increasing income and a more developed motorcycle industry, a growing population chooses motorcycles to meet this demand change.

Moving into the 2000s, public transport and motorcycles became the primary solutions for urban mobility, while private cars also made their entrance. Meanwhile, bicycles experienced a significant decline in market share due to insufficient parking infrastructure and dedicated bicycle lanes, easy theft risks, and limitations for long-distance trips.

Because public transport could not provide quality high door-to-door service and family income levels still prevented the majority from purchasing a car, ICE2/3Ws became prevalent in personal urban mobility. This was due to their superior maneuverability compared to bicycles, flexibility compared to public transport, and affordability compared to cars.

However, the widespread use of cheap motorcycles also resulted in some unexpected issues, including an increase in motorcycle-related robberies and traffic accidents in early-developing cities like Guangzhou. These issues had negative impacts on the city's image and public safety. After careful consideration, Guangzhou Municipal Government made a difficult decision to ban the use of motorcycles in downtown areas.

Since the 2000s, ICE2/3Ws faced extensive restrictions in urban areas across China, primarily due to environmental concerns and their association with illegal activities like robbery. Growing traffic accidents of management challenges were also part of the concerns. At the same time, China started to encourage private cars. However, private cars are still not the preferred choice due to their high purchase and maintenance cost. In 2022, the median disposable income per capita in China was 31,370 RMB, while only 3,195 RMB (NBS, 2023e) was spent on transport on average. People are eager to seek affordable, personalized, and efficient transport modes.



Shared bicycles and E2/3Ws seize a significant market share for urban mobility



Shared mode is leading bicycles back to cities

In the 1980s, private bicycles were widely used in China with a travel rate exceeding 50%, earning China the title "Bicycles Kingdom." However, under the dual forces of urbanization expansion and automobile industry development, the travel rate of bicycles had dropped to 5.5%. When shared bicycles emerged around 2015, the travel rate of bicycles doubled to 11.6%, with shared bicycles contributing to approximately 60% of this increase (Beijing Tsinghua Tongheng Planning and Design Institute & Mobike, 2017).




E2/3Ws have been the preferred choice for urban travel and delivery

E2Ws reign supreme in urban individual mobility. For example, e-bicycles accounted for 20% of urban transport in Shenzhen, and nearly 1/3 in Nanning in 2022 (Wang, Y., 2023). Regarding the delivery service, E2/3Ws also demonstrates dominance. Take Jiangsu Province, one of the top three regions for logistics services, as an example. In 2022, there were 86,500 delivery vehicles (Jiangsu Road Safety Association, 2022), of which 87% were E2/3Ws, including approximately 64,000 E3Ws and 11,400 E2Ws.

Table 4
Bicycles and E2/3Ws for Various Demand of Urban Mobility

Product		Product Technical Standards Comparison			
		Design Speed	Curb Weight	Attribute	Driver License
Bicycle	private bicycle	/	/	Non-motorized	Not required
	shared bicycle				
E-Bicycle	private e-bicycle	≤25km/h	≤55kg	Non-motorized	Not required
	shared e-bicycle				
E-Moped (2W)		20km/h - 50km/h	/	Motorized	Required
		≤50km/h	>40kg		
E-Moped (3W)		≤50km/h	≤400kg	Motorized	Required
E-Motorcycle (2W)		>50km/h	/	Motorized	Required
E-Motorcycle (3W)		>50km/h	≤400kg	Motorized	Required



Distinctive advantages drive the expansion of shared bicycles and E2/3Ws

Economically affordable

E2/3Ws demonstrate its cost advantages whether for intensive commercial utilization or daily personal travel. Their annual operating costs remain within 27% of ICE2/3Ws, and even more affordable compared to private cars.

- **Acquisition costs.** The acquisition cost of mainstream E2/3W models is 50%-60% of ICE2/3Ws with comparable performance. However, it is noteworthy that E2/3Ws have lower durability—with similar usage intensity, E2/3Ws have a lifetime of three to five years, whereas ICE2/3Ws commonly last around eight years.
- **Energy consumption.** E2/3Ws have only 4%–9% energy cost of ICE2/3Ws for the same mileage, due to electricity-gasoline price differential and energy consumption differences.
- **Maintenance costs.** E2/3Ws have a maintenance cost advantage because of their simpler structure and cheaper components. For instance, replacing the battery on a 3000 RMB E2W costs around 400 RMB, while replacing the engine in a similar performing ICE2W would cost approximately 1000 RMB. Moreover, in contrast to ICE2/3Ws, E2/3Ws do not require regular maintenance costs such as oil changes and filter replacements.

Congestion-free

- **Utilize non-motor lanes.** Despite their maneuverability, E2/3Ws are typically classified as non-motorized vehicles in road management. This classification enables them to access less congested non-motor lanes.
- **Compact size.** Compared to private cars, both bicycles and E2Ws occupy only a quarter of the road space, and E3Ws take up just half. The compact size of E2/3Ws allows them weave through congested roads more seamlessly, especially when traffic rules may not be strictly enforced.

Convenient and flexible

- **Easy to charge.** All E2/3s sold in the market are equipped with portable chargers, and the batteries can be easily detachable. With stable voltage and widespread access to electricity in China, people can take the batteries home or to workplaces for charging conveniently. Although indoor charging is prohibited due to potential fire risks, enforcing this restriction is challenging. Many people still take the risk for the sake of convenience.
- **Easy to park.** The compact size of E2/3Ws facilitates flexible parking. It will save time and parking costs, especially for instant delivery and express logistics scenarios which often require frequent stops for door-to-door service in residential communities and narrow alleyways.
- **Easy modification.** The simple structure of E2/3Ws allows for easy and cost-effective modifications to meet individual requirements, whether for passenger or freight transport, such as adding a canopy for protection against rain.
- **24/7 service.** Compared to scheduled public transport, bicycles and E2/3Ws not only offer door-to-door service, but also cater to mobility demands outside public transport service hours.

Low entry barriers

It addresses the flexible travel demands of vulnerable groups, notably the elderly over 60 years old, who normally have less income after retirement and prefers low speed mobility for short distance trips, especially in cities without good bus service. They accounted for 19.8% of the national population by 2022.











- **Easy to master driving skills.** Individuals with bike riding experience can quickly master driving E2/3Ws without extra training.
- **Low driving qualification requirement.** E-bicycles, classified as non-motorized vehicles due to their low speed and lightweight, do not require licenses. E-moped and e-motorcycle do require corresponding licenses. Nevertheless, lax enforcement, particularly in suburbs areas with limited supervision, has led to many unlicensed individuals on the road. It facilitates the accessibility and popularity of E2/3Ws among a diverse range of users.

Environmental and climate friendly

- **Zero emission.** Powered by electricity, E2/3Ws produce no gas, smell or other emissions during operation, contributing to cleaner air and safeguarding people's health.
- **Higher energy efficiency.** E2Ws, when fully loaded with passengers, demonstrate only one fourth of the per capita energy consumption of EVs, and E3Ws have less than half of the energy consumption of EVs.

Table 5

Annual cost comparison of E2/3Ws and ICE 2/3Ws ²⁸

Purpose	Freight-Express logistic		Passenger-Commute	
Vehicle type	E3Ws	ICE3Ws	E2Ws	ICE2Ws
Vehicle cost (RMB)	 4500	 8500	 3000	 5000
License price and tax (RMB)	 585	 926	/	 627
Lifetime (Year)	 3	 8	 5	 8
Annual Mileage ²⁹ (km)	29120	29120	5824	5824
Energy consumption per 100km	5.6kWh	4L (gasoline)	1.6kW.h	2.5L (gasoline)
Energy Price (RMB)	0.5/kWh	8.12/L	0.5/kW.h	8.12/L
Annual Insurance (RMB)	 400	 400	/	 120
Annual Cost (RMB)	 2910	 11036	 647	 2006

EF China analysis (2023)

For business use, E3Ws annual cost

< 27%

of ICE3Ws

For daily personal travel, E2Ws annual cost

< 33%

of ICE2Ws

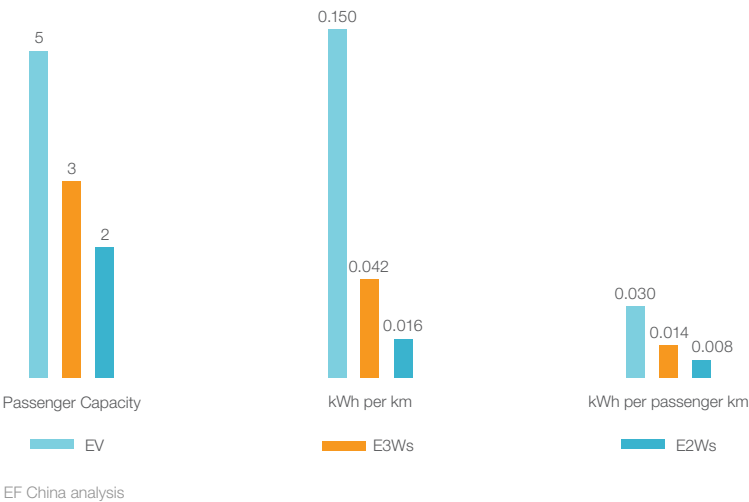
The cost advantage of E2/3Ws is even more evident if comparing to private cars.

²⁸ Based on market prices and operating costs of mainstream E2/3Ws models.

²⁹ Assuming the daily average mileage for 3Ws used in freight express is 80km, and for 2Ws used in passenger commute is 16km, considering a year as 364 days.

> 3 × EVs

Figure 47
Energy Efficiency of Different Transport Modes



60%

bicycles ridership comes from shared bicycles



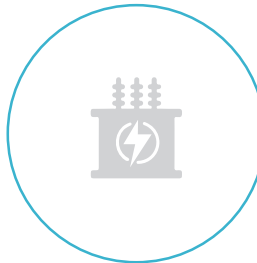
55%

shared e-bicycle ridership serves connection to rail transit



280

cities had established battery swapping stations



99.9%

national average power supply reliability provide accountable infrastructure

WHAT impacts do shared bicycles and E2/3Ws bring to urban mobility?

The emergence of shared bicycles and E2/3Ws not only encourages people to shift away from high-emission transport modes such ICE2/3Ws, but also serves as a substitute for short-distance public transport or walking. In addition to solving “last mile” urban mobility demand challenges, their combination with emerging industries like instant delivery creates new mobility demands.

Therefore, shared bicycles and E2/3Ws have complex effects on the zero-emission transition in urban mobility.



Replace higher-emission modes of travel

• E2/3Ws have a noticeable impact as an alternative to car

Following motorcycle restrictions, taxis and private cars have gradually become one of the predominant forms of personalized urban mobility. As direct alternatives to conventional options, E2/3Ws exhibit a remarkable substitution rate of 23% for car travel (Institute for Transportation and Development Policy [ITDP], 2022).

• The electrification penetration rate of 2/3Ws continues to increase

China possessed the world's largest ICE2/3Ws fleet with the stock reaching 100 million in 2005. By the end of 2022, E2Ws accounted for 81% of new 2Ws sales, securing absolute dominance. However, the fact of 3Ws is complete opposite. The rise of last-mile freight delivery is increasing the demand of 3Ws, but the penetration rate of E3Ws in new 3Ws sales witnessed a noticeable decline to 20% from 29% in 2020. The main reason is that around 2020, local governments started imposing restrictions on non-compliant E3Ws in urban areas, but the regulations for compliant E3Ws have remained unclear. Consumers are worried that the new E3Ws they purchased might be affected by new restrictive regulations. They tend to prefer ICE3Ws with more clearly defined regulatory requirements. In the contrast to consumers, manufacturers have positive expectations for compliant E3Ws and are translating these positive expectations into action. 84% of the newly approved 3Ws models in 2022 were electric, with 94% being high-powered models rated at 800W or above, aligned with freight ICE3Ws products. Therefore, the electrification transition of 3Ws is expected to grow in future, once regulations for compliant E3Ws are defined.

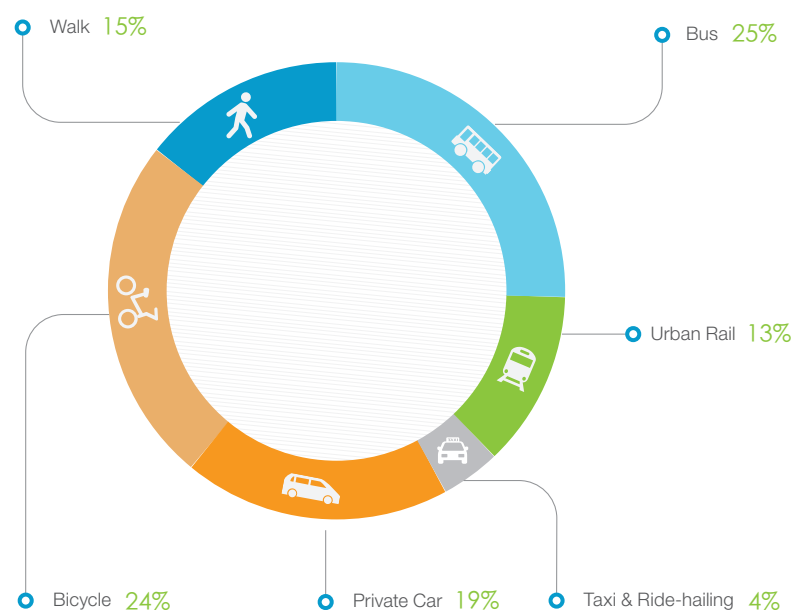
E-bicycles replaces

23%

travel used to be conducted by passenger cars.

Figure 48

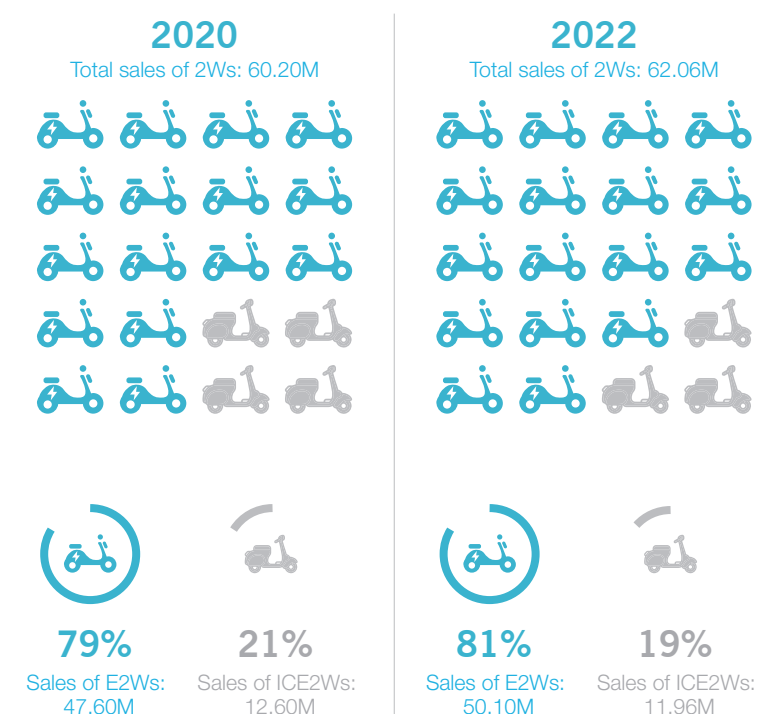
Transport Modes Replaced by E-Bicycles (2022)



ITDP (2022)

Figure 49

Penetration Rate of E2/3Ws in New 2/3Ws Sales (2020 and 2022)



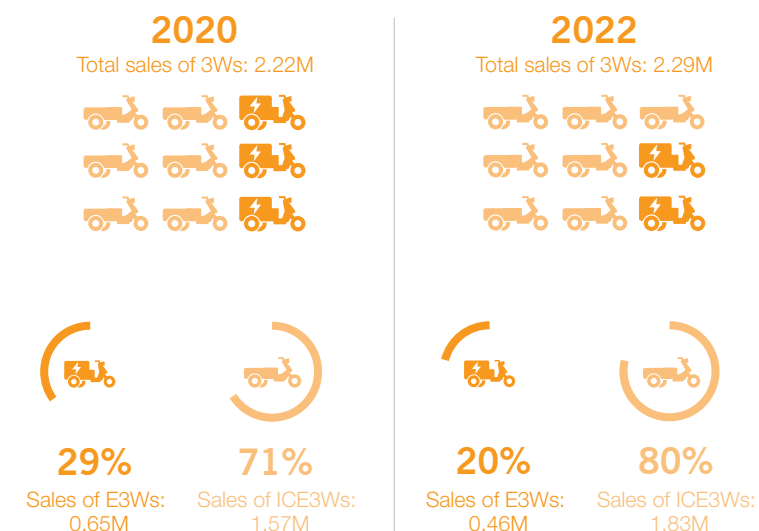
In 2022,

81%

of new 2Ws sales are electric.

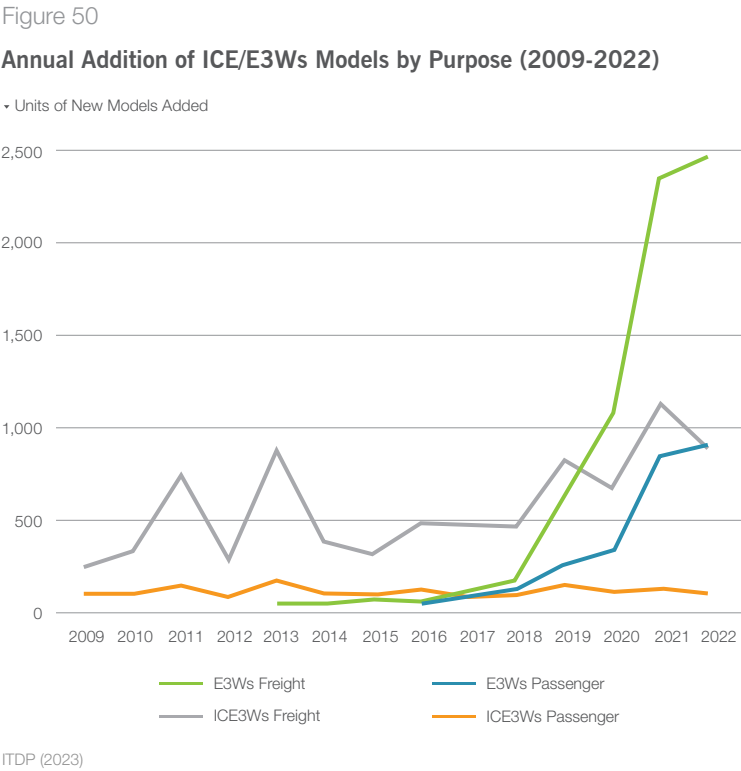
20%

of new 3Ws sales are electric.

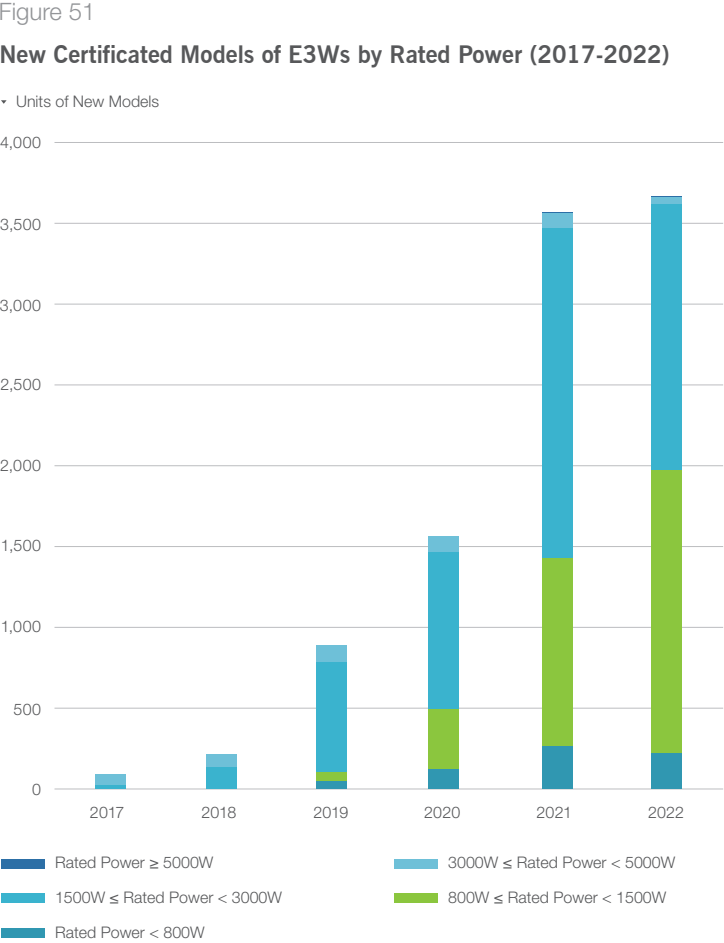


CCCM (2021, 2023), iResearch (2023)

In 2022,
84%
of certificated 3Ws models
applied for production are
E3Ws.

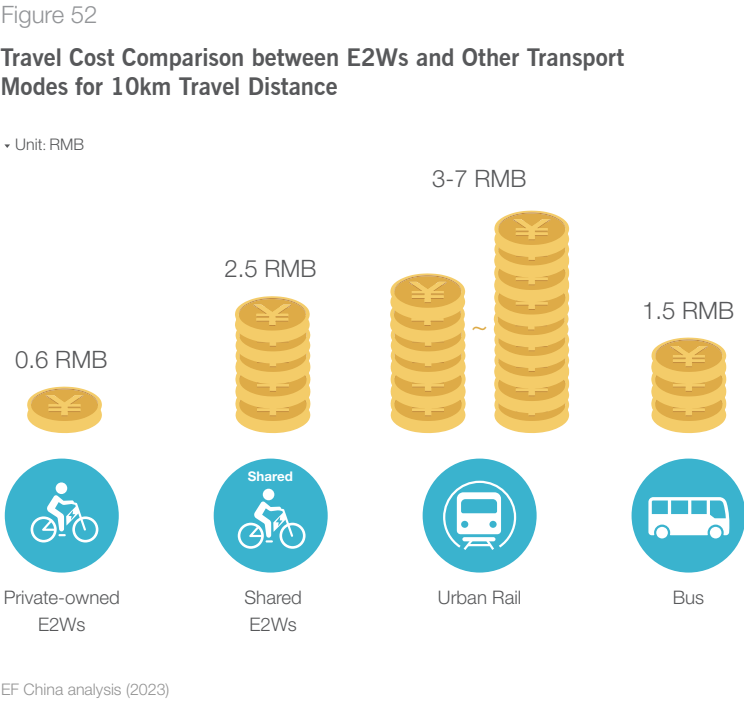


94%
of certificated new E3Ws
models have a rated power
exceeding 800W.



Complex impacts on public transport service

- **Increasing urban rail attractiveness by bridging the “last mile”**
2Ws travel is particularly active around urban rail stations, indicating most 2Ws trips are connected to transit. Nationwide, bicycles and E2Ws accounted for over 20% (Tsinghua Tongheng & Mobike, 2017) of mobility around urban rail stations. In cities with extensive rail networks exceeding 300km, this share was over 30%. In Beijing, with the country's longest rail system, it reached an impressive 40%. In 2022, 55% of shared e-bicycle rides were used to connect to rail transit. "Shared bicycles/E2Ws + urban rail transit" model could be further promoted by providing non-motor facilities around urban rail stations, such as dedicated parking area and non-motor lanes.
- **Diverting passengers from public transport**
For average distance of urban mobility of 10km, shared bicycles and E2/3Ws have much lower costs than public transport. They also provide flexibility in routes, time saving, and opportunities for physical exercise. The benefits have led to an increasing preference for shared bicycles and E2/3Ws over traditional public transport.



Travel expense of E2Ws
could be as low as
9%
of urban public transit.

WHAT are the key findings?

Two and three wheelers have emerged as solutions due to their advantages of low cost, convenience, flexibility, and congestion-free. They have become the most widely adopted and fastest-growing mode of urban mobility in China, a trend could also be observed in many developing countries.

What distinguishes China's approach is the significant progress made in the electrification of 2/3Ws. This development had a profound impact on the transport system, positioning 2/3Ws as an active driver in the shift towards zero emission urban mobility.



The restriction on fossil fuel motorcycles created market opportunities for E2/3Ws

In the early 2000s, the fossil fuel motorcycles (including 2Ws and 3Ws) was one of the major transport modes in China, accounting for 33% of global demand at around 16 million units per year (Marklines, 2017). However, many cities initiated motorcycle restrictions due to concerns on safety, congestion, and pollution. Measures included halting new motorcycle licenses in provincial capitals and establishing area-specific restrictions. By 2020, more than 30% of China's cities had implemented varying degrees of "motorcycle restriction", gradually pushing motorcycles out of urban areas (Wang, S., 2023).

However, urban mobility demand still needs to be satisfied. Technological advancements in key E2/3Ws components like motors, batteries, chargers and controllers significantly improve their load capacity, climbing ability, and range. Consequently, E2/3Ws emerged as replacements, filling the gap left by motorcycle restrictions.

Traditional motorcycle production hubs like Jiangsu and Zhejiang rapidly transitioned to E2/3Ws production. From 2001 to 2010, E2/3Ws business grew rapidly, adding over 240,000 new companies (including manufacturers and supporting companies). The average annual growth rate in this period was 33%, 17 times that of 1991 to 2000.

While the E2/3Ws industry underwent rapid growth, the entry barriers for manufacturers and products failed to keep pace. Without effective quality supervision, low quality products flood the market. Consumers are unable to assess the quality of E2/3Ws on their own. They tend to buy E2/3Ws based on affordability, high speed and long range. Yet, these products often suffer from poor quality and pose potential safety risks, such as the risk of frame breakage or spontaneous combustion.



Standards and regulations drive the E2/3Ws industry towards sustainable growth

The imposition of the "motorcycle restriction" resulted in a surge in demand for E2/3Ws. However, this increased demand was met with a flood of substandard "motorcycle-like" products, leading to pressing safety concerns, such as spontaneous combustion, over speeding, brake failure, and chassis fractures. Outdated product technical standards failed to keep up with the market, leaving E2/3Ws on the road without clear classification and legal basis. E2/3Ws experienced uncontrolled growth due to these regulatory gaps.

To address these challenges and steer the sustainable development of E2/3Ws industry, China introduced two national mandatory technical standards in 2018 and 2020—the "Safety Technical Specification for Electric Bicycle (GB17761-2018)" and the "Safety Specifications for Electric Motorcycles and Electric Mopeds (GB 24155-2020)". The primary significance of the new standards is to clearly define product types for different E2/3Ws, allowing local governments to manage E2/3Ws based on existing regulations and eliminating regulatory gaps. Another purpose of the new standards is to enhance critical elements such as fire safety and speed limits, guiding manufactures to produce high-quality and environmentally friendly E2/3Ws. The mandatory requirements of the new standards are transitioning from partial to full enforcement. It demonstrates the regulatory authorities' ambition to guide the sustainable transformation of E2/3Ws industry. For products that do not comply with the new technical standards, different regions set transition periods ranging from three to five years.

By 2022, as the transition period for non-compliant E2/2Ws came to an end in most regions, these vehicles were phased out from the sales market. With quality control improved, regulations now aim to expand oversight across the entire E2/3Ws lifecycle, addressing issues of sales, traffic regulations, parking and charging, and recycling.

- **Sales and traffic regulations**

Compliant E2/3Ws must be licensed for road use, while non-compliant ones require temporary licenses and after the transition period they are not allowed for use or storage in public areas. Enterprise information is also captured during business-oriented E2/3Ws registration to ensure corporate responsibilities for traffic safety, especially for instant delivery and logistics vehicles.

- **Parking and charging**

Regulations now restrict E2/3Ws parking and charging in building corridors, stairwells, safety exits, and even homes to prevent fire accidents. The development of centralized public charging infrastructures is underway to address the charging demands.

- **Recycling**

Retailers are encouraged to implement trade-in programs and collect non-compliant E2/3Ws. Local automobile industry associations can facilitate the compensated removal of non-compliant E2/3Ws.



Enabling infrastructure of road and power grid provides a solid foundation

- **Paved roads ensure smooth ridership**

After decades of construction and updates of road, more than 99.98% of China's road network (ENNweekly, 2019) in both urban and rural areas is paved with asphalt or cement, which enable smooth ridership of E2/3Ws.

- **Stable and massive power grid ensures the accountable charging**

China's power system holds a world record for over 30 years without major widespread outages (Zhao, 2023). By the end of 2022, China's national power generation capacity exceeded 2,560 GW, equivalent to total G7 capacity, with the national average power supply reliability of 99.9% (China Electric Power News, 2023). In addition to reliability, the accessibility of the power grid is also a crucial factor, China had already achieved 100% electricity coverage in 2013 (WDI of WB, 2023d). Even remote regions like Tibet, Gansu, and Qinghai, now have solar photovoltaic systems to ensure accessible electricity. In terms of affordability, with prices significantly lower than OECD countries (40%), the U.S. (60%), and emerging economies (71%) (State Grid Corporation of China, 2021). China's affordable electricity also makes E2/3Ws highly cost-effectiveness compared to ICE2/3Ws.



Accelerating the construction of safe and convenient charging facility

Fire incident is one of the primary concerns with E2/3Ws. Approximately 80% of E2/3Ws fires occur during charging (Shi & Sun, 2021), stemming from subpar batteries and electrical components, the absence of short-circuit protection in early models, and unsafe charging practices like using improvised wiring and overcharging.

As all E2/3Ws are equipped with portable chargers and limited dedicated parking and charging spaces in urban areas, people often charge their E2/3Ws in public areas like stairwells, hallways, and near emergency exits. It would obstruct escape routes in the event of a fire. Moreover, people often bring the entire E2/3Ws or detachable batteries home for charging due to anti-theft and convenience. However, these conveniences come at the cost of significant safety risks. If a fire occurs, it could lead to more severe casualties and property losses.

To improve the safety of E2/3Ws usage, authorities have introduced a series of regulations promoting centralized parking and charging facilities equipped with safety features. For example, Beijing residential areas had achieved full coverage of such facilities by the end of 2022.

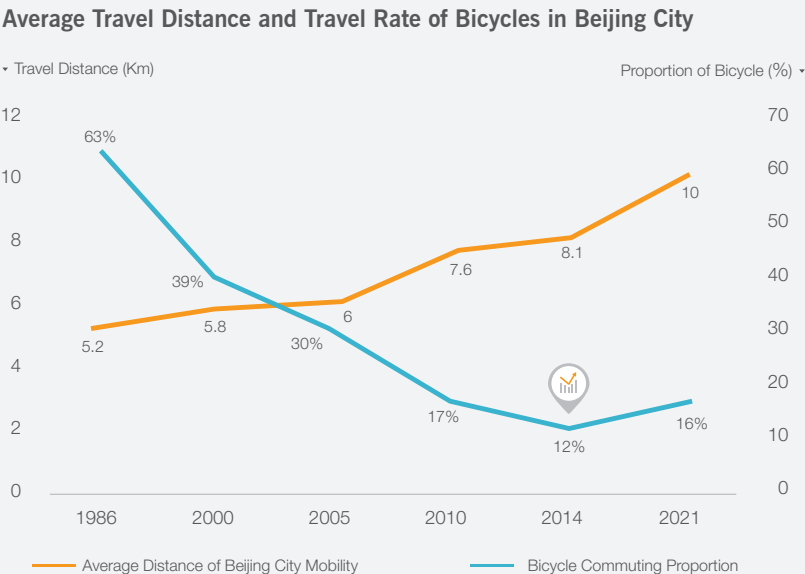
For high-frequency charging industries like instant delivery and express logistics, battery-swapping models are encouraged. By the end of 2022, over 280 cities had established battery swapping stations (Yuan, 2023).

Beijing: shared bicycles and E2/3Ws environmentally address developing mobility demands

Shared bicycles become the popular solution for “last mile” challenge of urban mobility

In Beijing, the average travel distance increased from 5km in the 1980s to 10km in 2021. The travel rate of bicycles plummeted to a 12% between 1984 and 2014. However, the trend reversed after 2014, primary due to the emergence of shared bicycles.

Figure 53



Liu (2016)

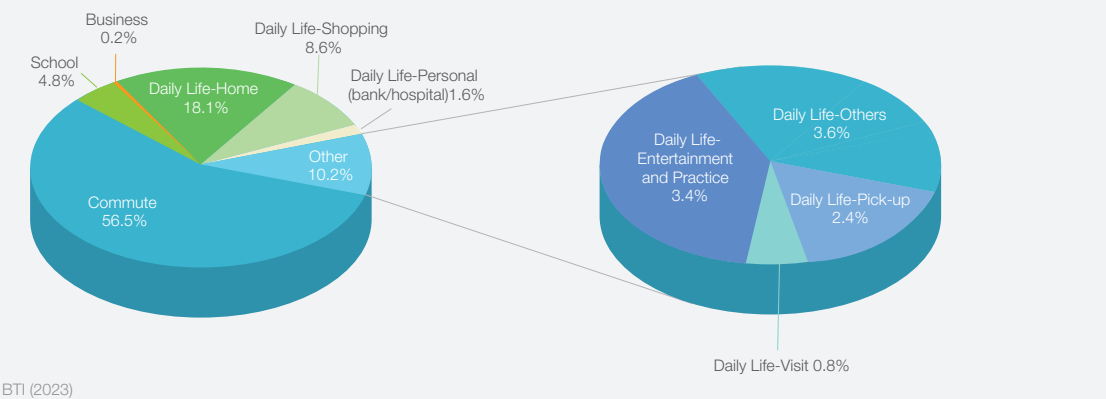
- **Growing urban rail travel has increased the demand for short-distance urban mobility connectivity**
As public transport networks expand to serve mid-to-long distance travel in cities, substantial connectivity demands are generated around transit stations. It is commonly referred to as the “last mile” challenge. In 2016, Didi, with 80% of the ride-hailing market share in China, reported that over 20% of the orders in Beijing had trip origins or destinations within 500 meters of subway stations (Sha, 2016). The statistic means 278,000 daily ride-hailing trips connecting to urban rail. This scenario presents a seeming paradox: Why would people choose more expensive and potentially congested taxi or ride-hailing services over bicycles for the last mile? The reason lies in the usage costs of private bicycles, including anti-theft measures, storage facilities, and maintenance, making them less favored.
- **Sharing mode helps cyclists get rid of the usage cost**
Shared modes effectively separate ownership from usage, making bicycles convenient for “pick up and go”. People can enjoy the flexibility of bicycles without the cost of private ownership, thereby renewing the appeal of bicycles for short-distance mobility.
- **Dedicated bicycle lanes safeguard the safety of cyclists.**
Beijing removed select roadside vehicle parking spots, and added ground markings to safeguard the rights of cyclists. These efforts established a 3,200km interconnected bicycle network (Sun et al, 2020), significantly improving cyclist safety and overall convenience in urban areas.

In 2022, Beijing recorded 950 million shared bicycle rides, representing approximately 42% of the city’s total rail transit ridership. During peak hours, 44.7% of the shared bicycle trips were connected to or from urban rail stations (Kang et al, 2023). It demonstrates more and more people choose shared bicycles to connect the rail transit “last mile”.

E2/3Ws satisfy the majority of door-to-door mobility demands from both personal travel and livelihood purposes

Figure 54

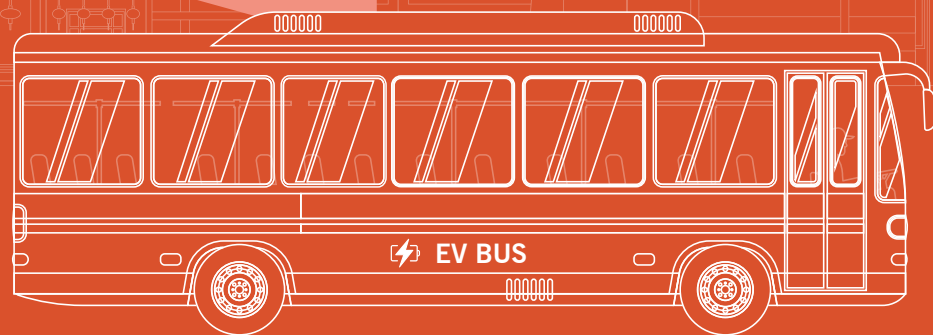
2022 Beijing City Residents’ Travel Purposes



BTI (2023)

- **E2Ws have a great potential to satisfy over half of personal travel demand**
In 2022, the average commute distance in Beijing was 11.7 km, a range that E2Ws can easily cover. Compared to public transport, E2Ws provide on-demand, door-to-door travel without the issue of overcrowded vehicles, satisfying the flexible and time-saving travel needs of commuters. The prevalence of E2Ws during peak commuting hours is the best evidence.
- **E3Ws address aging population’s travel demand**
In 2022, aged 60 and above made up 21% of Beijing’s population, many of whom engage in daily activities including transporting grandchildren to school, visiting hospitals, or going shopping. This aged population needs flexible, effortless, and people-carrying transport options. However, private cars were not their first choice due to cost considerations and the requirement for a driver’s license. In 2021, only 6.5% of the population aged 60 and above had a motor vehicle driver’s license nationwide. Non-compliant E3Ws, which remain unaffected by motorcycle restrictions, emerged as an ideal choice for the elderly seeking convenient and license-free urban mobility. As the transition period for non-compliant E2/3Ws comes to an end by 2023, the mobility demands of the aging population once again become an issue that needs to be addressed.
- **E2/3Ws became the first choice for instant delivery and logistic express**
In 2022, Beijing processed approximately two billion express orders. Last-mile delivery is typically carried out by couriers with their own transport. As a tool for couriers to manage their earnings, the delivery vehicle needs to be highly practical and cost-effective. Timeliness and door-to-door service are at the core of last-mile delivery’s value. Moreover, the delivery fee per order typically ranges from 4 to 6 RMB (Lian, 2023). The low usage cost makes E2/3Ws the preferred choice for last-mile delivery. In 2022, Beijing had 43,845 E3Ws dedicated to delivery services, and instant delivery services were predominantly carried out by E2Ws.

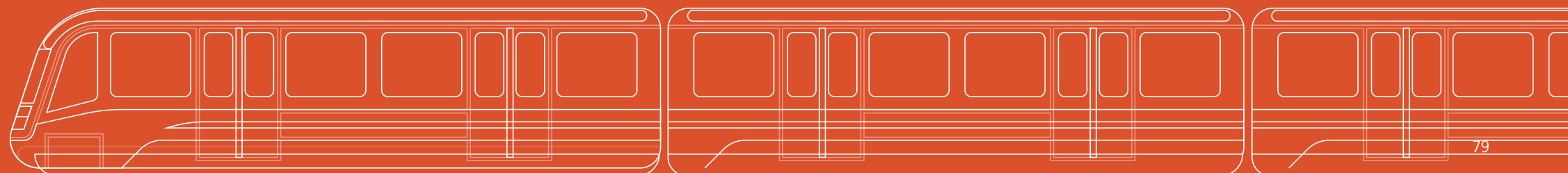
PART V



KEY ELEMENTS FOR SUCCESS



There is no single silver bullet for achievements in China. Instead, a combined systematic approach is the key.





Vision, mission, and actions

It is fundamentally important to guide development with a clear vision, strong mission, and swift actions. Different stakeholders can align their actions toward a shared goal. For example, the recent national pilots on full electrification of public vehicles aim to achieve an 80% market penetration rate by 2025 for NEV buses, taxis, sanitation vehicles, postal and urban logistics. In addition to the clear policy signals and targets, China's enormous domestic market of 1.4 billion people also plays a significant role by attracting industries to invest for technology and product innovation. This market size could create economies of scale, reducing costs and boosting the competitiveness of advanced technology and products.



Proactive government and consistent and sustainable policies

A proactive government is vital for driving development in the public sector. Endorsed by State Council and supported by different ministries and local governments, China takes steady steps to expand the network of bus and urban rails to attract passengers, and electrify the fleets to reduce emissions. Over the past two decades, China issued at least four medium- and long-term plans and dozens of fiscal and non-fiscal policies to encourage the development of comprehensive transport network, new energy vehicle industry and hydrogen energy. These policies integrate the infrastructure, vehicle, battery and alternative fuels as one system for achieving zero emission passenger transport. By August 2023, at least 23 provincial level governments have issued incentive policies to promote NEV bus development.



Consensus and alignment across stakeholders

The shift to zero emission passenger transport involves many stakeholders, including government departments like MOT, MOHURD, NDRC, MIIT, MEE, MPS, MOF, SAMR, urban planners, investors, bus and urban rail operators, vehicle manufacturers, consumers, drivers, and charging service providers. This list can extend further when considering local differences across China. These stakeholders may have different perspectives on the changes. For example, urban rails are thriving in major cities, while bus companies face tough challenges. In the case of E2/3Ws, the market is growing with concrete demand, but it also poses serious challenges to road safety. Therefore, it is crucial to establish the consensus, form collaborative efforts, align with potential partners to solve the challenges.



High-efficiency and low-cost manufacturing along the supply chain

China is the only country in the world that has industrial capabilities across all categories listed in the United Nations Industrial Classification. This has allowed China to develop the most complete and largest power battery industry globally, covering R&D, production, recycling, and equipment support. Key raw materials of negative electrode, electrolytes and diaphragms are largely import independent. The localization rate of lithium battery equipment and other key processes equipment has surpassed 90% and 80%, respectively. This complete industrial chain enables extremely efficient manufacturing at relatively low costs. But critical minerals, especially cobalt, could become a bottleneck for sustainable development. Despite this, the Yangtze River Delta has successfully implemented the coordinated development of industrial clusters. A NEV manufacturer can acquire the required supporting parts within a four-hour drive, creating a unique “four-hour industrial circle” that is currently unparalleled outside of China.



Overseeing, evaluating, and improving the policy goals

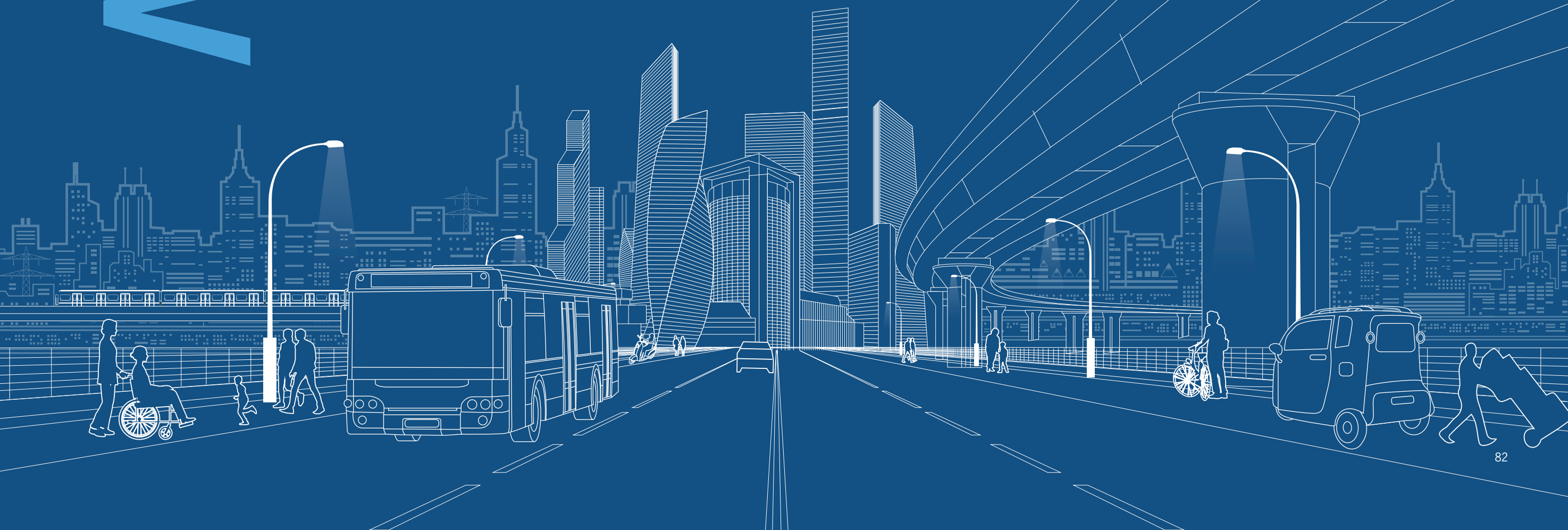
To stay current with the changing technology, passenger demand, and market dynamics, China regularly reviews, assesses, and updates its development goals and related policies. For example, the 2021 Action Plan for Carbon Dioxide Peaking Before 2030 set a goal for around 40% of vehicles to be powered by new and clean energy by 2030. Two years later, with NEV development exceeding forecasts, the government adopted a new policy in 2023 to pilot full electrification of public vehicles. It requires 80% of newly purchased and replaced buses, rental cars, sanitation trucks, postal office trucks, and urban logistics trucks to be NEVs in the pilot areas. This adaptive approach to policy development releases the potential for a zero emission transformation.

PART V

WHAT'S MORE FOR LOOKING AHEAD?



China's urban mobility beyond cars has not achieved zero emissions yet. More attention and improvements are still needed.





Strengthen overarching planning

Urban planning and transport planning have mutual impacts on each other. Strengthening their integrated planning is the key to creating positive synergies. During the urban planning stage, mixed-purpose and multifunctional use of urban lands should be applied to promote job-housing balance. The coordinated distribution of urban transit networks and land functions is crucial to improve commuting efficiency, ease congestion and reduce air pollution. Moreover, connecting and coordinating transport modes planning will maximize benefits during public transit operations. These planning principles were poorly practiced in China for years and require serious attention in the future.



Improve the financial sustainability of public transport

After three years of the epidemic, people began to prefer non-public transport like private cars and active mobility. The sharp drop in ridership and revenue made operations difficult. For years, most bus operations have to rely on government subsidies. Local governments subsidies for public transport average tens of millions annually per city, and billions in megacities. However, economic downturns amplify the pressure on local finances. Moreover, the NEV bus operation subsidy phased out in 2020.

To address this challenge, public transit subsidies should be used more wisely and policies should be refined to improve the financial sustainability. For example, differential fares could be applied to various social group —maintaining discounts for vulnerable groups but reasonably raising fares for others. The expenses of transit bus or urban rail operations should be analyzed and reasonably split between parts deserving subsidies and parts coverable through improved market operations.

Moreover, the rise of private companies providing public transport service with few subsidies requires the government to reconsider its role of subsidized transit in the face of competition from private entities and mobility services.



Avoid “one size fits all” policy for E2/3Ws management

- **While new national standards and local regulations for E2/3Ws are in place, this marks only the first step in the management of E2/3Ws. Numerous issues in the full lifecycle management of E2/3Ws are urgently needed to be addressed**

The new national standards have explicitly included E2/3Ws in the scope of the Product Quality Law of China, outlining manufacturer and seller responsibilities for product quality by clearly defining product categories. Through enhancing technical specifications and safety requirements, the new national standards aim to ensure the quality of E2/3Ws entering in the market. However, it can only guarantee compliance at the time of production and sale. The anti-tampering design of E2/3Ws can be easily circumvented, providing a foundation for illegal modifications.

The inherent flaws in the anti-tampering design have triggered chaos in the aftermarket of E2/3Ws. In order to satisfy consumer demands for enhanced speed, range, and comfort, various unqualified components flooded the market, such as illegally modified batteries, canopies, etc. People can easily obtain these unqualified components online or offline at a very low cost. Taking E2/3W batteries as an example, some small businesses and home workshops produce “new batteries” by illegally assembling used batteries. Although these batteries are at low-cost, they pose significant safety risks, such as spontaneous combustion. However, some cost-conscious consumers accept the risk to save money, considering the eager for range and charging efficiency. Beyond accessible unqualified components, there is also widespread availability of illegal modification services. The structure of E2/3Ws is simpler than that of ICE2/3Ws, with a low threshold for modification technology. Consumers can even find step-by-step modification tutorials online.

The management of E2/3Ws' usage behavior also faces significant challenges. Flexibility and convenience are key reasons for the popularity of E2/3Ws, as they can navigate streets and alleys freely and park and charge anywhere. However, these advantages enable intrusions into lanes and sidewalks, violating parking and charging regulations. Take charging behavior as an example. Although local governments have explicitly prohibited indoor charging for E2/3Ws and have supplemented it with community management agency and property management companies, and promote centralized public charging infrastructures to address charging demands, indoor charging persists. The main reason is that the violations can happen anytime, anywhere, making enforcement difficult. At the same time, centralized public charging infrastructures are still in the early stages of promotion without large coverage.

- **Corresponding to these E2/3Ws issues is management dilemma, which arises from three crucial contradictions**

The contradiction between the rapid growth of the aftermarket demand for E2/3Ws and the outdated product standards and regulatory systems. Regulators lack the basis and measures for effective supervision, allowing illegal modifications grow uncontrollably within regulatory blind spots.

The contradiction between the widespread E2/3Ws demand for road access and limited road resources. China currently has 330 million cars, while there are 500 million E2/3Ws. Though E2/3Ws have compact size, their demand for road resources cannot be ignored. The predominant road design in China centers around vehicles, leading to frequent violations by E2/3Ws entering motor lanes or sidewalks due to limited road resources.

The contradiction between the massive regulatory subjects and the limited oversight capacity. With 500 million E2/3Ws in China—a number still rising—their usage scenarios are pervasive in various aspects of life. The existing regulatory heavily relies on on-site supervision by law enforcement officers, which evidently cannot be adequate.

- **Precise management can both address mobility demand and promote sustainable development**

Precise regulations and measures can address existing management challenges of E2/3Ws, enabling them to play their rightful role in the transition to zero emission transport.

Adopt differentiated management for the aftermarket and usage phases of E2/3Ws. E2/3Ws are popular primarily because they satisfy various mobility demands, resulting in diverse usage characteristics. For example, E2/3Ws used for logistics express may seek modifications to increase cargo space. Such modification can be allowed on the basis of safety, but the corresponding requirements should be imposed on driver qualifications and vehicle insurance.

Optimize the scale of E2/3Ws fleets through the sharing mode. Introduce shared e-bicycles in areas with limited road resources and high E2/3Ws frequency, such as main city arteries, leveraging the advantages of the sharing mode to reduce the presence of E2Ws and ease congestion.

Apply digital technology for the "unmanned supervision" of shared bicycles and shared e-bicycles. Implement electronic fencing technology to define permissible parking areas and restricted areas. It is not only able to effectively regulate parking behavior but also significantly reduce the need for on-site supervision.

Seize the opportunity of future technology to provide more inclusive, safe and environmental transport services

With the rapid development of information technology, the future of transport is already entering into people's daily life. In 2022, penetration rate of new passenger vehicle equipped with advanced driver assistance functions has reached 34.5% in China.

Future technology will revolutionize the current transport supply and demand. For example, shared autonomous taxis can provide more precise and convenient transport services, allowing vulnerable groups to enjoy more comfortable, personalized, and door-to-door travel; autonomous deliveries can offer more efficient and cost-effective freight services to address the "last mile" delimma.

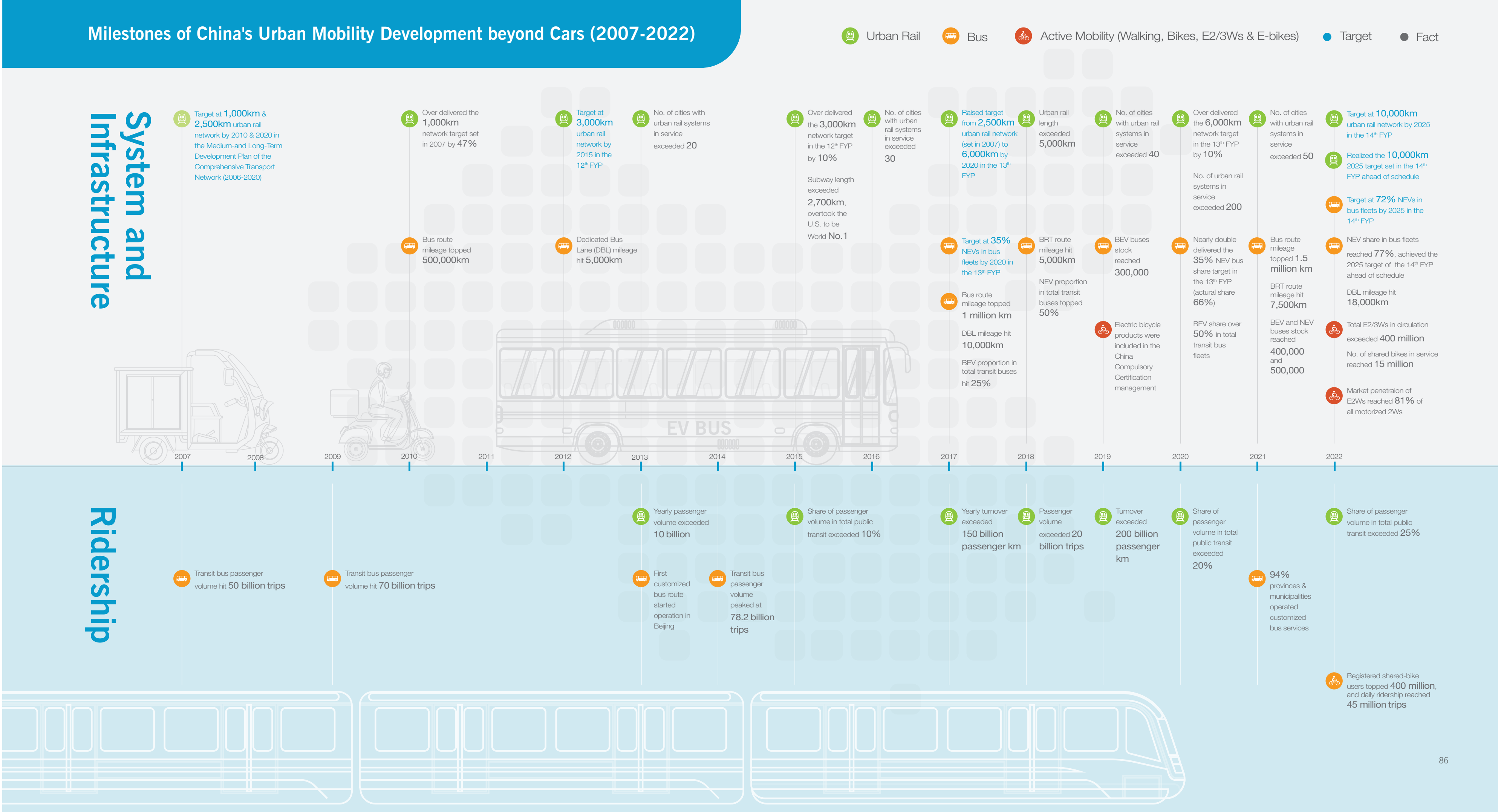
It is a great opportunity to reshape urban mobility to be more inclusive, safe, and environmental. However, new technology not only brings opportunities but also challenges. The introduction of new transport services requires a new management system and a clear division of responsibilities, such as determining the responsibilities for autonomous vehicles's behavior. Furthermore, pursuing improvements in automation performance without coordination with environmental protection efforts will result in a continuous increase in energy consumption.

Faced with the irreversible future trends in transport development, the government needs to proactively address challenges by guiding the development of new transport supply to meet the demands of urban mobility, seizing the opportunity to create a more inclusive, safe, and environmentally friendly urban mobility system.

ACCESS FOR ALL: improve barrier-free mobility


China has made great improvements since 1980s, but the barrier-free door-to-door trip remain challenging due to insufficient facilities, poor design, damages, blockages and so on. Efforts are needed to improve the facilities, but more importantly, increasing the employment of people with disabilities will directly enhance supply, testing, design, and usage of facilities.

Barrier-free mobility enables equitable access to opportunities. Incomes of persons with disabilities remain low, about 30% of the national average. Improved accessibility is estimated to benefit at least 500 million people yearly, almost 35% of national population in China. Moreover, growing demand for accessibility may push public transport improvements. Most cities are designed for people without disabilities and prioritize vehicles over the needs of pedestrians, cyclists, or transit users. There is a greater need to build more inclusive, walkable, cyclable neighborhoods around accessible transit hubs.



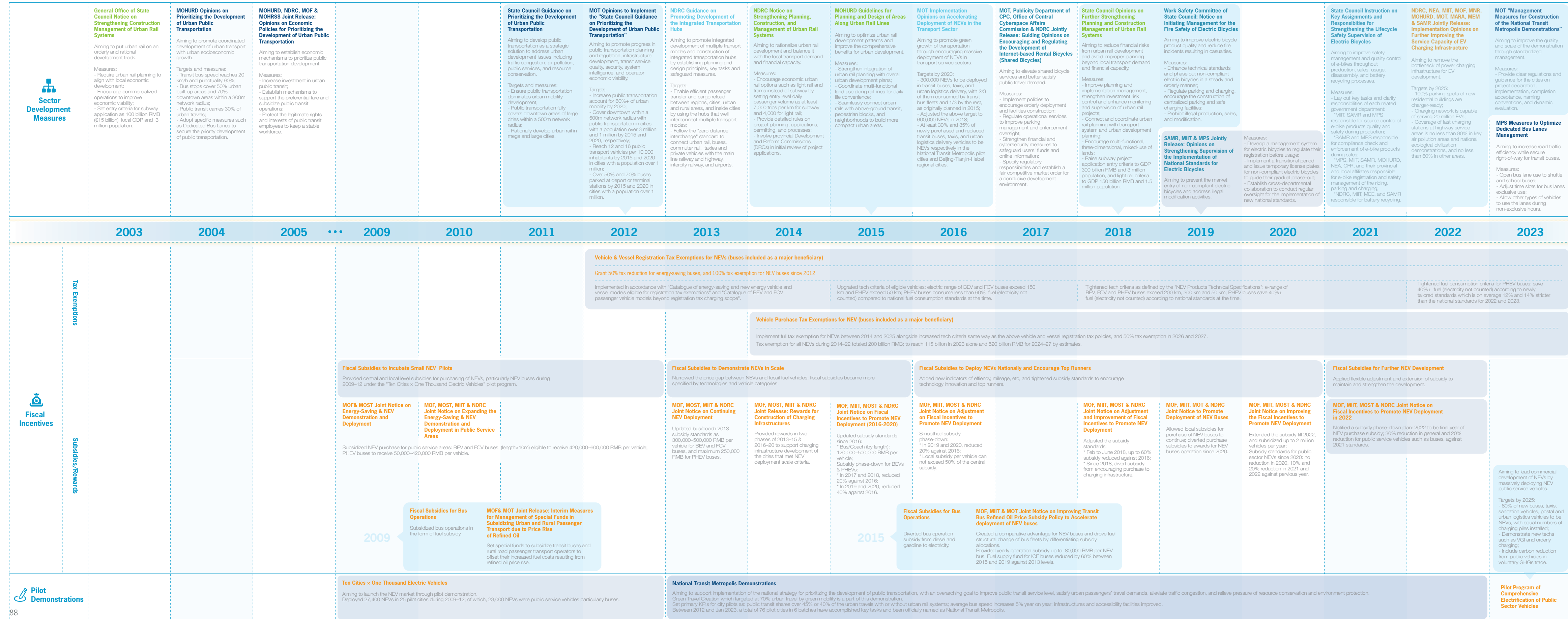
Major Policies of China's Urban Mobility Beyond Cars (2003-2023)

● Bus ● Urban Rail ● Active Mobility ● Urban Mobility ● Overall Transport

 Strategy	Medium- and Long-term Development Plan of the Comprehensive Transport Network (2006-2020) Aiming to build a modernized comprehensive transport network with reasonable layout and optimal modes structure to enable convenient, smooth, safe, and reliable transport by 2020. Targets by 2010 and 2020: - 1,000km & 2,500km urban rail by 2010 & 2020; - 42 national comprehensive hubs by 2020.			Medium- and Long-Term Development Plan for the Automotive Industry (2017-2026) Aiming to develop China as one of the world's top auto producers in ten years. Targets by 2020 and 2025: - Several Chinese NEV brands enter world's Top 10 in production and sales by 2025; - Annual production and sales of NEV reach 2 million by 2020; - Penetration of NEV sales exceeds 20% by 2025.		Outline for Building National Strength in Transportation (2019-2050) Aiming for a world-class transport system in China and emphasizing on green growth. Targets by 2035 and 2050: - By 2035, a strong transportation network is basically built, with environmental factors integrated into transport infrastructure planning, construction, operation, and maintenance; transport energy structure greenized by fully electrifying or using clean and new energy fuels in the urban transit and logistic delivery vehicles; and public awareness of low-carbon travels increased by implementing green travel initiatives; - By 2050, strong transportation network is fully built with world-class environmental performances.		National Comprehensive Three-dimensional Transportation Network Planning Outline (2021-2035) Aiming to build a modernized high quality national transport network to support economy development. Targets by 2035: - Greenize the lifecycle of transport infrastructure construction; - Continuously decrease transport energy intensity to realize significant reductions in carbon emission compared to 2020 levels; - Strengthen pollution source control based on technology progress; - Transform transport energy towards high efficiency and low carbon/pollution solutions; - Improve the transport infrastructures and services for diversified and personalized travel demands.	Medium- and Long-Term Development Plan for Hydrogen Industry (2021-2035) Aiming to promote high quality development of hydrogen for a clean, low carbon, safe, and efficient energy system. Targets by 2025: - Annual CO ₂ emission reduction reaches 1-2 million tons; - Annual production capacity of green hydrogen reaches 100,000–200,000 tons; - Stock of FCVs reaches 50,000 associated with a suitable number of hydrogen supply stations; Medium- and Long-term Targets: - Encourage a complementary development model for BEVs and FCVs.		
	2007	...	2012	2013	...	2017	2018	2019	2020	2021	2022
 Transport Sector Five- Year Plans	11th Five-Year Plan for National Comprehensive Transportation System (2006-2010) Aiming to initially formulate a comprehensive transport system with improved layout, structure, capabilities, and quality to alleviate transport stress and support socioeconomic development. Targets by 2010: - Energy intensity of rail and road transport to be reduced by 20% ; - Subway and light rail networks jointly reach 1,000km ; - Build key transport sections in "five vertical and five horizontal comprehensive" networks.	12th Five-Year Plan for National Comprehensive Transportation System (2011-2015) Aiming to initially form a "five vertical and five horizontal" comprehensive transport network, with focuses on highway and high speed rail networks. Targets by 2015: - Urban rail network of 3,000km; - 42 national transport hubs; - Air and noise pollution and carbon emission of transport continuously reduced.		13th Five-Year Plan for National Modern Comprehensive Transportation System (2016-2020) Aiming to basically build a safe, convenient, efficient, and green comprehensive transport system, and some areas lead in realizing transport modernization. Targets by 2020: - Transport carbon intensity to be reduced by 7% ; - Urban rail network of 6,000km; - 35% NEVs in transit bus fleet; - A network of Dedicated Bus Lanes covers all the cities with a population over 3 million.					14th Five-Year Plan for Green Transportation (2021-2025) Aiming to initially form a green and decarbonized development pattern for the transport sector, from infrastructure, equipment to operations, to support the national transport development strategies from environmental perspectives. Targets by 2025 : - Carbon intensity of road vehicles and ships to be reduced by 5% and 3.5% ; - NEV share in transit buses, taxis & ride-hailing cars and urban delivery vehicles to be increased to 72%, 35%, and 20% ; - 60 pilot cities in progress to enable 70% urban travels carried by green mobility (public transit, walking and bicycles).	14th Five-Year Plan for National Modern Comprehensive Transportation System (2021-2025) Aiming to realize the integrated development of transport system, make breakthrough in green and intelligent growth, and progress in overall transport capacity, including service quality, efficiency and economic performance. Targets by 2025: - Urban rail network reaches 10,000km; - 72% NEVs in transit bus fleet.	
			Air Pollution Prevention and Control Action Plan (2013-2017) Aiming to improve the national air quality and significantly reducing days of severe air pollution within five years; gradually eliminate days of severe air pollution within ten years. Identified NEVs as one of the key measures to build on the goals. Targets by 2017: - Require public and sanitation sectors as well as government departments to take lead in using NEVs, and incentivize NEV consumption by individuals with subsidies and issuance of license plates; - At least 60% newly purchased and replaced buses in Beijing, Shanghai, and Guangzhou to be NEV or clean fuel vehicles.		Three-year Action Plan for Fighting to Win the Battle Against Air Pollution (2018-2020) Aiming to largely reduce major air pollutants such as PM2.5 together with GHGs emissions, and improve ambient air quality as well as number of days with blue sky within three years. Targets by 2020: - Over 80% of newly purchased and replaced buses, sanitary trucks, taxis, etc. to be NEVs in key air pollution areas; - 100% NEV buses in municipalities and provincial capitals in key air pollution areas.	Green Travel Action Plan (2019-2022) Aiming to promote green travel and reinforce "prioritizing development of public transportation" by creating enabling environment for green mobilities. Targets by 2022: - Improve public transport service quality; - Optimize active mobility systems; - Implement differentiated management of travel demands; - Foster green travel cultures.	Action Plan for Green Travel Creation (2020-2022) Aiming to reinforce implementation of the Green Travel Action Plan. Targets by 2022: - Guided the public to prioritize green mobilities and reduce car use; - 70% of travel by green mobility in 60% of the pilot cities; - Over 80% satisfaction for green mobility services.	Action Plan for Carbon Dioxide Peaking Before 2030 Aiming to peak carbon emissions by 2030 through optimizing energy and industrial structure; with carbon intensity per unit of GDP reduced by 65%+ than 2005, and non-fossil energy share increased to 25%. Targets by 2030: - NEV and clean energy vehicle penetration reaches 40% ; - Green mobility carries 70%+ urban travels in cities with a population over 1 million; - Oil consumption of road transport peaks before 2030; - Reduce carbon intensity of revenue transport by 9.5% and energy intensity of rail transport by 10% compared to levels in 2020.	Implementation Plan for Synergizing Reductions of Criteria Pollutants and Carbon Emissions (2022-2030) Aiming to develop effective patterns and experiences in synergizing reduction of air pollution and carbon emissions by 2025, and substantially improve the synergized management capacity by 2030. Targets by 2030: - Accelerate deployment of NEVs in public sectors such as transit buses; - NEV penetration in key air pollution areas reaches 50%+ ; - Promote modal shifts of road-to-rail and road-to-water for environmental benefits.	Five-Year Action Plan for Building China's National Strength in Transportation (2023-2027) Aiming to make solid progress during the initial phase to implement the "Outline for Building National Strength in Transportation". Targets by 2027: - Over 75% trasit buses and over 35% taxis are NEVs; - Promote the use of NEV heavy-duty trucks; - Establish a long-term mechanism for the National Transit Metropolis Demonstrations to continuously promote green urban mobility, and develop at least 60 pilot cities with a population over 1 million and green mobility share over 70% ; - Institutionalize the transport carbon peaking and neutrality management system.	

87

Major Policies of China's Urban Mobility Beyond Cars (2003-2023)



REFERENCES

Rosendo, R. O. A. (2016). *Densidades divergentes y segregación socio-espaical en la Bogotá de hoy: un análisis a partir de un índice de calidad de vida* [Densities divergent and socio-spatial segregation in today's Bogotá: an analysis based on a density quality index]. Universitat Politècnica de Catalunya. <https://upcommons.upc.edu/handle/2117/110052>

American Public Transportation Association. (2020). *Public Transportation Ridership Report Fourth Quarter 2019*. <https://www.apta.com/wp-content/uploads/2019-Q4-Ridership-APTA.pdf>

American Public Transportation Association. (2023). *Fact book data in excel: Appendix A, 2022 public transportation fact book* [Data set]. <https://www.apta.com/research-technical-resources/transit-statistics/public-transportation-fact-book>

Beijing Municipal Commission of Transport. (2023). 2023年,北京交通致力让市民出行更美好 [Beijing endeavors to provide better transit service for citizens in 2023]. <http://ie.bjdt.com.cn/bjrbjbeijinghao/content/Share/5de090f5e4b03e4c1d7bdc837/AP64409763e4b0017157a4ec3f.html>

Beijing Municipal Science and Technology Commission. (2015, August 12). 北京市纯电动客车相关政策解读会在京召开 [Understanding Beijing's financial incentives for BEV bus purchases]. http://kw.beijing.gov.cn/nr/2015/8/12/art_6382_43286.html

Beijing Transport Institute. (2021). 提高公交专用道利用率研究 [Research on improving the utilization of dedicated bus lanes].

Beijing Transport Institute. (2022a). 北京交通碳达峰碳中和目标、路径及策略研究报告 [Research on carbon neutrality pathways and strategies in Beijing's transportation sector].

Beijing Transport Institute. (2022b). 2012-2021年北京市交通发展年报 [Beijing Transport Development Annual Reports 2012-21].

Beijing Transport Institute. (2023). 2023年北京市交通发展年度报告 [Beijing Transport Development Annual Report 2023].

Beijing Tsinghua Tongheng Planning and Design Institute. & Mobike. (2017). 2017年共享单车与城市发展白皮书 [China's shared bicycles and urban development] [White paper]. <http://www.191bt.com/archives/581592.html>

CAPOL. (2019). 以交通为设计导向,建造连接上方的城市生活 [Build urban living above subways with transit-oriented design]. <https://www.capol.cn/newsdetail.aspx?ids=100000115665958>

Central Committee of the CPC, & State Council of China. (2012). 交通强国建设纲要 [Outline for building China's strength in transportation]. https://www.gov.cn/zqzhcgc/2019-09/19/content_5431432.htm

Central Committee of the CPC, & State Council of China. (2021). 国家综合立体交通网规划纲要 [Outline development plan for national comprehensive three-dimensional transport network]. https://www.gov.cn/gongbao/content/2021/content_5593440.htm

CGMODEL.COM. (2023). 上海虹桥综合交通枢纽鸟瞰 [Overview of Shanghai Hongqiao Multimodal Comprehensive Transport Hub] [Photograph]. <https://www.cgmodel.com/model/591657.html> Chen, Q. (2022, October 8). 中国现在有多少大城市?第七次人口普查分县数据报告(一) [How many major cities are there in China now? Report on seventh national population census by county (Part1)]. Cainx. <https://opinion.cainx.com/2022-10-08/101498861.html>

Chen, X., Han, Y., & Wu, M. (2023, April 25). 一升一降!共享出行创造巨大经济价值[Rise and fall Shared travel creates huge economic value]. Pishu. <https://www.pishu.cn/zxcz/xwdt/592565.shtml>

China Association of Metros. (2013). 城市轨道交通2012年度统计和分析报告 [2018 Annual statistics and analysis report on urban rail transit]. <https://www.camel.org.cn/tjxc>

China Association of Metros. (2014). 城市轨道交通2013年度统计和分析报告 [2018 Annual statistics and analysis report on urban rail transit]. <https://www.camel.org.cn/tjxc>

China Association of Metros. (2015). 城市轨道交通2014年度统计和分析报告 [2018 Annual statistics and analysis report on urban rail transit]. <https://www.camel.org.cn/tjxc>

China Association of Metros. (2016). 城市轨道交通2015年度统计和分析报告 [2018 Annual statistics and analysis report on urban rail transit]. <https://www.camel.org.cn/tjxc>

China Association of Metros. (2017). 城市轨道交通2016年度统计和分析报告 [2018 Annual statistics and analysis report on urban rail transit]. <https://www.camel.org.cn/tjxc>

China Association of Metros. (2018). 城市轨道交通2017年度统计和分析报告 [2018 Annual statistics and analysis report on urban rail transit]. <https://www.camel.org.cn/tjxc>

China Association of Metros. (2019). 城市轨道交通2018年度统计和分析报告 [2018 Annual statistics and analysis report on urban rail transit]. <https://www.camel.org.cn/tjxc>

China Association of Metros. (2020). 城市轨道交通2019年度统计和分析报告 [2019 Annual statistics and analysis report on urban rail transit]. <https://www.camel.org.cn/tjxc>

China Association of Metros. (2021). 城市轨道交通2020年度统计和分析报告 [2020 Annual statistics and analysis report on urban rail transit]. <https://www.camel.org.cn/tjxc>

China Association of Metros. (2022). 城市轨道交通2021年度统计和分析报告 [2021 Annual statistics and analysis report on urban rail transit]. <https://www.camel.org.cn/tjxc>

China Association of Metros. (2023). 城市轨道交通2022年度统计和分析报告 [2022 Annual statistics and analysis report on urban rail transit]. <https://www.camel.org.cn/tjxc>

China Automotive News. (2013, December 12). “十城千辆”工程 初探新能源汽车市场化 [“Ten Cities, One Thousand Electric Vehicles” pilot program, the first exploration of the market of new energy vehicles in China]. China Association of Automobile Manufacturers. http://www.caam.org.cn/chn/8/cate_81/con_5109126.html

China Chamber of Commerce for Motorcycle. (2021, January 12). 2020年我国摩托车产销量超1700万辆 [Production and sales of motorcycles in China exceeded 17 million in 2020]. <http://ccmcp.com/yaowen.aspx?d=1203>

China Chamber of Commerce for Motorcycle. (2022, January 14). *完美收官, 2021我国摩托车产销超2000万辆* [A perfect closure of 2021, production and sales of motorcycles exceeded 20 million in China]. <http://cccmp.com/yaowen.aspx?id=1502>

China Chamber of Commerce for Motorcycle. (2023, January 16). *2022年我国摩托车产销量下滑16%, 大排量摩托车增长47%* [Production and sales of motorcycles declined 16% in China in 2022, those of large displacement motorcycles increased 47%]. <http://cccmp.com/yaowen.aspx?id=1658>China Electric Power News. (2023, September 14). *全国平均供电可靠率达99.896%* [National average power supply reliability rate reaches 99.896%]. <https://www.cec.org.cn/detail/index.html?3-325041>

Chinese Research Academy of Environmental Sciences, Jinan Automobile Test Center, Beijing Institute of Technology, China Automotive Technology Research Center, Xiamen Environment Protection Vehicle Emission Control Technology Center & Tsinghua University. (2018). GB 17691-2018*重型柴油车污染物排放限值及测量方法 (中国第六阶段)* [Limits and measurement methods for emissions from diesel fuelled heavy-duty vehicles, China VI (GB 17691-2018)]. Ministry of Ecology and Environment of China. <https://www.mee.gov.cn/ywgz/fgbz/bz/bzwb/dqjhbj/dqdywrrwfpbz/201807/W020180703397013304274.pdf>

Directorate-General for Mobility and Transport. (2022). *EU transport in figures: statistical pocketbook 2022*. Publications Office of the European Union. <https://data.europa.eu/doi/10.2832/216553>

ENNWeekly. (2019, Septemer 22). *让每个乡村通上公路, 中国为什么能?*[Why can China have roads paved for every village]. <https://mp.weixin.qq.com/s/R2PRi1U0O1Q5-iZWNajU7A>

Environmental Standards Institute & Jinan Automobile Test Center. (2005). GB 17691-2005*车用压燃式、气体燃料点燃式发动机与汽车排气污染物排放限值及测量方法 (中国第三、四、五阶段)* [Limits and measurement methods for exhaust pollutants from compression ignition and gas fuelled positive ignition engines of vehicles, China III, IV, V (GB 17691-2005)]. The State Environmental Protection Administration of China (now Ministry of Ecology and Environment). <https://www.mee.gov.cn/ywgz/fgbz/bz/bzwb/dqjhbj/dqdywrrwfpbz/200701/W020110127400649893698.pdf>

European Automobile Manufacturers' Association. (2022). *Fact sheet: Buses*. <https://www.acea.auto/fact/fact-sheet-buses>

Fang, B. & Ran, L. (2023, May 10). *北京MaaS“小步快跑”, 绿色出行一体化渐行渐近* [Beijing MaaS platform sets the pace for integrated green mobility]. Beijing Business Today. <https://www.bbtnews.com.cn/2023/0510/475315.shtml>

Far East Mobility. (2023). *City BRT data* [data set]. Far East Mobility: BRT & urban transport planning. <https://brt.fareast.mobi>

General Office of the State Council of China. (2018). *国务院办公厅关于进一步加强城市轨道交通规划建设管理的意见 (国办发〔2018〕52号)* [Opinions of the General Office of the State Council on further strengthening the administration of planning for construction of urban rail transportation (Guobanfa No. 52 of 2018)]. https://www.gov.cn/zhengce/content/2018-07/13/content_5306202.htm

Heineke, K., Kloss, B., Rupalla, F. & Scurtu, D. (2021, December 2). *Why micromobility is here to stay*. McKinsey & Company. <https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/why-micromobility-is-here-to-stay##/>

Institute for Transportation and Development Policy. (2022). *中国电动两轮车生产应用状况、挑战与对策* [Production and application status, challenges, and measures of electric two wheeler vehicles in China].

Institute for Transportation and Development Policy (ed.). (2023). *Public Notice on Road Motor Vehicle Production Enterprises and Products*. Ministry of Industry and Information Technology.

Institute of Public and Environmental Affairs. (2023). *2022年度城市空气质量简报* [2022 Brief report on urban air quality in China]. <https://www.woa.ipe.org.cn/Upload/2023092010465744084b60c1e208b6459889cdaf4cdd466f84.pdf>

International Energy Agency. (2021). *Energy and carbon tracker 2021*. <https://www.iea.org/data-and-statistics/data-product/iea-energy-and-carbon-tracker-2021>

International Energy Agency. (2023a). *CO2 emissions in 2022*. <https://www.iea.org/reports/co2-emissions-in-2022>

International Energy Agency. (2023b). *EV data by country, Global EV outlook 2023* [Data set]. <https://www.iea.org/data-and-statistics/data-product/global-ev-outlook-2023>

International Energy Agency. (2023c). *Greenhouse gas emissions from energy highlights*. <https://www.iea.org/data-and-statistics/data-product/greenhouse-gas-emissions-from-energy-highlights>

International Monetary Fund. (2023). *World Economic Outlook Database 2023, IMF* [Database]. <https://www.imf.org/en/Publications/WEO/weo-database/2023/April>

iResearch. (2023). *2023年中国两轮电动车行业白皮书*[China electric two wheelers industry] [White paper]. https://report.iresearch.cn/report_pdf.aspx?id=4149

Jia, Y. (2023, July 31). *每年补贴1000亿仍停运, 财政补贴为何解决不了多地公交难题?* [Annual subsidies of 100 billion failed to solve public transit challengs in China] IFENG Perspective. http://h5.ifeng.com/c/vivoArticle/v002qjZdi1-_aWOMU4IUzF210RWD496--RCTe7s25cGSEh7Zo_?isNews=1&showComments=0

Jiangsu Road Safety Association. (2022, October 3). *江苏省快递电动三轮车管理现状分析及对策研究*[Analysis of the current management of delivery E3Ws in Jiangsu province and research on related solutions]. Road Traffic Mangement (9), 48-51. https://www.sohu.com/a/589821668_468661

Jin, L., He, H., Cui, H., Lutsey, N., Wu, C., Chu, Y., Zhu, J., Xiong, Y. & Liu, Q. (2021). *驱动绿色未来: 中国电动汽车发展回顾及未来展望* [Driving A Green Future—A Retrospective Review of China's Electric Vehicle Development and Outlook for The Future]. International Council on Clean Transportation; China EV100. <https://theicct.org/wp-content/uploads/2021/06/China-green-future-ev-ch-jan2021.pdf>

Jin, J., Sun, G., Song, Y., Bao, J., Qi, J., Huang, H., Xu, H., Fang, T. & Yan, H. (2023). *强化综合交通枢纽专项规划引领作用* [Strengthen the leading role of special planning for comprehensive transportation hubs]. China Transportation News. https://www.zgtb.com/2023-06/06/content_358995.html

Jin. Y. & Wang Z. (2011). QC/T 924-2011*重型商用车辆燃料消耗量取值 (第一阶段)* [Fuel consumption limits for heavy-duty commercial vehicles, Phase I (QC/T 924-2011)]. National Technical Committee of Auto Standardization.

Kang, H., Zhang, L. & Wang, S. (2023). *热点研究 | 《2023年度中国主要城市共享单车/电单车骑行报告》: “轨道+共享骑行”成为超(特)大城市通勤刚需* [Research on hot issues | "Ridership of shared bicycles/e-bikes in China's major cities": "rail + shared bikes" has become a rigid demand for commuting in mega(super) cities]. China Academy of Urban Planning and Design; Didi Bike. <https://mp.weixin.qq.com/s/mnNS2j70NYM1UoMT3d3TkA>

Li, B. (2023, July 3). *北京清洁能源和新能源公交车占比超94%* [Clean energy and NEV buses account for over 94% of Beijing's bus fleets].People's Daily. <http://bj.people.com.cn/n2/2023/0703/c14540-40479551.html>

Li, L., Li S., Wu J., Guo W., Zhao L. & Hu J. (2022). *双碳目标下中国新能源汽车与能源融合的发展目标与推进路径研究*[Research on the targets and approaches of vehicle and grid integration (VGI) development in China under the dual carbon targets]. Tsinghua Sichuan Energy Internet Research Institute & China Society of Automotive Engineers.

Li L. & Yao Z. (2020). *New energy buses in China: overview on policies and impacts*. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. https://transition-china.org/wp-content/uploads/2021/01/2020_GIZ_New-Energy-Buses-in-China.pdf

Lian, Z. (2023, March 29). *新零售中局: “30分钟”如何重塑电商格局?*[Games of new retail: how does “30 minutes” reshape the e-commerce landscape?]. Bosandao. <https://mp.weixin.qq.com/s/koSxXal6KTBFWpGfcy3eag>

Liu, F., Zhang, Z., Zhao, X., Liu, B., Wang, X., Yi L., Zuo, L., Xu, J., Hu, S., Sun, F. & Wang, Y. (2021). *Urban Expansion of China from the 1970s to 2020 Based on Remote Sensing Technology*. Chinese Geographical Science, 31(5), 765–781. <http://egeoscien.neigae.ac.cn/en/article/doi/10.1007/s11769-021-1225-5>

Liu, M. (2016, July 7). *北京市第五次综合交通调查结果出炉 小汽车出行比例首次下降* [Beijing's fifth comprehensive traffic survey released, share of car travel decreased for the first time]. Beijing Municipal Government Website. https://www.gov.cn/xinwen/2016-07/07/content_5089031.htm

Liu, X. (2023, May 11). *深圳人口微降, 不必过度解读* [Shenzhen population slightly decreased, but no need for overinterpretation]. Liu Xiaobo Financial Commenrary. https://mp.weixin.qq.com/s/WeTtDJE4Tgg_rB9i8AkGQ

MaaS Alliance. (2023). *What is MaaS* [Introduction]. <https://maas-alliance.eu/homepage/what-is-maas/>

Marklines. (2017). *全球摩托车产量与销量 (上) :印度市场占全球市场的3分之1* [Global motorcycle production and sales (Part 1): 1/3 of the global market is in India]. <https://www.marklines.com/cn/report/rep1590201704>

Ministry of Construction of China (now Ministry of Housing and Urban-Rural Development). (2004). *关于优先发展城市公共交通的意见(建城〔2004〕38号)* [Opinions on giving priority to the development of urban public transportation (Jiancheng No. 38 of 2004)].

National Development and Reform Commission. (2013). *促进综合交通枢纽发展的指导意见(发改基础〔2013〕475号)* [Guiding Opinions on Promoting the Development of Comprehensive Transport Hubs (Fagai Jichu No. 475 of 2013)].

Ministry of Ecology and Environment of China. (2022). *2022年中国移动源环境管理年报* [China mobile source environmental management annual report 2022]. <https://www.mee.gov.cn/hjzl/sthjzk/zydhjgl/202212/W020221207387013521948.pdf>

Ministry of Ecology and Environment of China. (2023). *2021年中国生态环境统计年报* [Report on the state of the ecology environment in China 2021]. <https://www.mee.gov.cn/hjzl/sthjzk/sthjtnb/202301/W020230118392178258531.pdf>

Ministry of Finance of China. (2013). *关于继续开展新能源汽车推广应用工作的通知(财建〔2013〕551号)* [Notice on continuing the promotion the applicaiton of new energy vehicles (Caijian No.551 of 2013)].

Ministry of Finance of China. (2014). *关于进一步做好新能源汽车推广应用工作的通知(财建〔2014〕11号)*. [Notice on further improving the promotion and application of new energy vehicles (Caijian No.11 of 2014)].

Ministry of Finance of China. (2016). *关于调整新能源汽车推广应用财政补贴政策的通知(财建〔2016〕958号)* [Notice on adjusting and imporing the financial subsidy policies for the promotion and application of new energy vehicles (Caijian No.958 of 2016)].

Ministry of Finance of China. (2019a). *关于进一步完善新能源汽车推广应用财政补贴政策的通知(财建〔2019〕138号)* [Notice on further improving financial subsidy policies for the promotion and application of new energy vehicles (Caijian No.138 of 2019)]. https://www.gov.cn/zhengce/zhengceku/2019-10/14/content_5439544.htm

Ministry of Finance of China. (2019b). *关于支持新能源公交车推广应用的通知(财建〔2019〕213号)* [Notice on supporting the promotion and application of new energy buses (Caijian No.213 of 2019)].

Ministry of Finance of China. (2020). *关于完善新能源汽车推广应用财政补贴政策的通知(财建〔2020〕86号)* [Notice on improving the financial subsidy policies for the promotion and application of new energy vehicles (Caijian No.86 of 2020)].

Ministry of Finance of China, Ministry of Industry and Information Technology of China & Ministry of Transport of China. (2015). *关于完善城市公交车成品油价格补助政策加快新能源汽车推广应用的通知(财建〔2015〕159号)* [Notice on improving refined oil price subsidy policies for urban buses to accelerate the promotion and application of new energy vehicles (Caijian No.159 of 2015)]. https://www.gov.cn/gongbao/content/2015/content_2909278.htm

Ministry of Finance of China, Ministry of Science and Technology of China, Ministry of Industry and Information Technology of China & National Development and Reform Commission. (2015). *四部门关于2016-2020年新能源汽车推广应用财政支持政策的通知(财建〔2015〕134号)* [Notice from four departments on the financial support policies for promotion and application of new energy vehicles during 2016–2020 (Caijian No.134 of 2015)]. https://www.gov.cn/xinwen/2015-04/29/content_2855040.htm

Ministry of Finance of China, Ministry of Science and Technology of China, Ministry of Industry and Information Technology of China & National Development and Reform Commission. (2018). *关于调整完善新能源汽车推广应用财政补贴政策的通知(财建〔2018〕18号)* [Notice on adjusting and imporing the financial subsidy policies for the promotion and application of new energy vehicles (Caijian No.18 of 2018)].

Ministry of Finance of China & Ministry of Transport of China. (2009). *关于开展节能与新能源汽车示范推广试点工作的通知(财建〔2009〕6号)* [Notice on implementing energy-saving and new energy vehicle pilot programs (Caijian No.6 of 2009)].

Ministry of Housing and Urban-Rural Development of China. (2005). *国务院办公厅转发建设部等部门关于优先发展城市公共交通意见的通知(国办发〔2005〕46号)*. [Circular of the General Office of the State of Council on transmitting and issuing the opinions of the Ministry of Construction and other Departments on giving priority to the development of urban public transport (Guobanfa No. 46 of 2005)]. General Office of the State Council of China. https://www.gov.cn/govweb/gongbao/content/2005/content_92902.htm

Ministry of Housing and Urban-Rural Development of China. (2006). *关于优先发展城市公共交通若干经济政策的意见(建城〔2006〕288号)* [Opinions on economic policies and other measures for implementating public transportation as priority in urban development (Chengjian No.288 of 2006)]. https://www.gov.cn/zwqk/2006-12/04/content_461023.htm

Ministry of Transport of China. (2013). *交通运输部关于贯彻落实《国务院关于城市优先发展公共交通的指导意见》的实施意见*[Opinions on implementing guiding opinions of the State Council on giving priority to the public transportation in urban development]. https://xxgk.mot.gov.cn/2020/jigou/ysfw/202006/t20200623_3315616.html

Ministry of Transport of China. (2014). *2013年交通运输行业发展统计公报* [China's Transportation Statistics Annual Report 2013]. <https://www.mot.gov.cn/fenxigongbao/hangyegongbao>

Ministry of Transport of China. (2015). *2014年交通运输行业发展统计公报* [China's Transportation Statistics Annual Report 2014]. <https://www.mot.gov.cn/fenxigongbao/hangyegongbao>

Ministry of Transport of China. (2016). *2015年交通运输行业发展统计公报* [China's Transportation Statistics Annual Report 2015]. <https://www.mot.gov.cn/fenxigongbao/hangyegongbao>

Ministry of Transport of China. (2017). *2016年交通运输行业发展统计公报* [China's Transportation Statistics Annual Report 2016]. <https://www.mot.gov.cn/fenxigongbao/hangyegongbao>

Ministry of Transport of China. (2018). *2017年交通运输行业发展统计公报* [China's Transportation Statistics Annual Report 2017]. <https://www.mot.gov.cn/fenxigongbao/hangyegongbao>

Ministry of Transport of China. (2019). *2018年交通运输行业发展统计公报* [China's Transportation Statistics Annual Report 2018]. <https://www.mot.gov.cn/fenxigongbao/hangyegongbao>

Ministry of Transport of China. (2020). *2019年交通运输行业发展统计公报* [China's Transportation Statistics Annual Report 2019]. <https://www.mot.gov.cn/fenxigongbao/hangyegongbao>

Ministry of Transport of China. (2021). *2020年交通运输行业发展统计公报* [China's Transportation Statistics Annual Report 2020]. <https://www.mot.gov.cn/fenxigongbao/hangyegongbao>

Ministry of Transport of China. (2022). *2021年交通运输行业发展统计公报* [China's Transportation Statistics Annual Report 2021]. <https://www.mot.gov.cn/fenxigongbao/hangyegongbao>

Ministry of Transport of China. (2023). *2022年交通运输行业发展统计公报* [China's Transportation Statistics Annual Report 2022]. <https://www.mot.gov.cn/fenxigongbao/hangyegongbao>

Ministry of Transport of China. (2023a, *January 10*). *2022年城市轨道交通运营数据速报* [2022 urban rail operationdata briefing]. https://mp.weixin.qq.com/s/nbbPHtm-YUzYqbd9_o6vfw

Ministry of Transport of China, Publicity Department of the CPC, Office of the Central Cyberspace Affairs Commission, National Development and Reform Commission, Ministry of Industry and Information Technology of China, Ministry of Public Security of China, Ministry of Housing and Urban-Rural Development of China, People's Bank of China, General Administration of Quality Supervision, Inspection and Quarantine of China, & China National Tourism Administration. (2017). *交通运输部等10部门关于鼓励和规范互联网租赁自行车发展的指导意见* [Guiding opinions on encouraging and regulating the development of internet-based rental bicycles (shared bicycles)]. https://www.gov.cn/xinwen/2017-08/03/content_5215640.htm

MTA New York City Transit.(2020). *Subway and bus ridership for 2019*. <https://new.mta.info/agency/new-york-city-transit/subway-bus-ridership-2019>

National Bureau of Statistics of China. (2023a). *China annual per capita disposable income of residents—urban, rural and national average (2013–22)* [Data set]. <https://data.stats.gov.cn/easyquery.htm?cn=C01>

National Bureau of Statistics of China. (2023b). *Provincial annual per capita disposable income of residents—urban and national average (2013–22)* [Data set]. <https://data.stats.gov.cn/easyquery.htm?cn=E0103>

National Bureau of Statistics of China. (2023c). *Chinese population by age 2013–22, national annual data* [Data set]. <https://data.stats.gov.cn/easyquery.htm?cn=C01>

National Bureau of Statistics of China. (2023d). *Total, urban and rural population of China 2013–22, national annual data* [Data set]. <https://data.stats.gov.cn/easyquery.htm?cn=C01>

National Bureau of Statistics of China. (2023e, January 18). *China's households' income and consumption expenditure in 2022* [Press release]. http://www.stats.gov.cn/english/PressRelease/202301/t20230118_1892303.html

Party History Research Office of Shenyang Municipal Party Committee. (2023).*City Overview. Shenyang Municipal Government*. <https://www.shenyang.gov.cn/wssy/scfm/csgk/#111>

Patel, K. (2023, August 8). 2023 is on track to be the hottest year on record. *The Washington Post*. <https://www.washingtonpost.com/climate-environment/2023/08/08/2023-is-track-be-hottest-year-record>

Pei, J. (2020, Feburary 25). *截至2019年年底北京市共有90万辆共享单车*[Beijing deployed 900,000 shared bicycles by the end of 2019]. The Beijing News. <https://tech.sina.cn/i/gn/2020-02-25/detail-iimxstf4165971.d.html>

Port Authority Trans-Hudson Corporation. (2020). *PATH Ridership Report (by month) 2019*.<https://www.panynj.gov/path/en/about/stats.html>

Rail-stdaily. (2023, July 21). *每公里造价超20亿! 地铁建设成本为何越来越高?*[Two billion RMB per kilometer! Why are subway construction costs soaring?]. Sohu.com. https://www.sohu.com/a/704903728_120599226

Ren, Q. (2023, April 7). *城市公交专用道将优化管理* [Management of dedicated bus lanes will be optimized]. Xinhua News Agency. http://www.news.cn/politics/2023-04/07/c_1129502279.htm

Science and Technology Standards Department. (2001). GB 17691-2001*车用压燃式发动机排气污染物排放限值及测量方法 (中国第一、二阶段)* [Limits and measurement methods for exhaust pollutants from compression ignition (C.I.) engines of vehicles, China I-II (GB 17691-2001)]. State Environmental Protection Administration of China (now Ministry of Ecology and Environment). <https://www.transportpolicy.net/wp-content/uploads/2021/08/1923.pdf>

Sha, S. (2016, August 29). *观点:关注城市交通“最后一公里”* [Opinion: Pay attention to the “last mile” of urban mobility]. China Science Daily. <https://news.sciencenet.cn/htmlnews/2016/8/354753.shtm>

Shanghai Municipal Transportation Commission. (2021). *上海市关于印发《关于2021-2023年本市新能源 公交车发展扶持政策的实施意见》的通知* [Circular of Shanghai Municipality on printing and issuing the implementation opinions on supporting policies for new energy buses development in Shanghai during 2021–2023]. <https://jtw.sh.gov.cn/jgfl-jhcwc/20221111/76f78469cdf4f5fbb60ad1408796f32a.html>

Shang, Q. & Yu, X. (2023, Feburary 6). *新能源汽车进入后补贴时代* [New energy vehicles enter the post-subsidy era]. Xinhua Outlook Weekly. http://lw.news.cn/2023-02/06/c_1310695367.htm

Shenyang Municipal Statistics Bureau & Shenyang Municipal Ethnic and Religious Affairs Bureau. (2023). *Population and ethnicity*. Shenyang Municipal Government. <https://www.shenyang.gov.cn/wssy/scfm/rkmz/#111>

Shi, Y. & Sun L. (2021, July 5). *解决电动自行车停放和充电问题需综合施策 (来信与访谈)* [Addressing the challenges of e-bike parking and charging demands with comprehensive measures (letters and interviews)]. People's Daily,7. <http://society.people.com.cn/n1/2021/0705/c1008-32148231.html>

Song, W. (2023, August 4). “自我造血”机制领跑全国,解码“轨道+物业”模式的“深圳样本” [Leading the nation with a “self restoration” mechanism: Decoding the Shenzhen case of “Rail+Property” model]. Yangcheng Evening News. https://www.sohu.com/a/710710659_121687414

Splendid Cultural Geography. (2021). *中国天命线,86年来无人能破* [China's line of destiny has stayed valid for 86 years]. https://mp.weixin.qq.com/s/uXRwHPsHyQAta_vDjN5AoQ

State Administration for Market Regulation of China, & National Certification and Accreditation Administration. (2018). *市场监管总局 认监委关于发布电动自行车产品由许可转为实施强制性产品认证管理安排的公告* [Notice on implementing the mandatory China Compulsory Certification for electric bicycles]. https://www.cnca.gov.cn/zwxx/gg/2018/art/2023/art_b7029cc00f0543d9b54a0ffddba6801f.html

State Administration for Market Regulation of China, Ministry of Industry and Information Technology of China, & Ministry of Public Security of China. (2019). *三门门关于加强电动自行车国家标准实施监督的意见 (国市监标创〔2019〕53号)* [Opinions on Strengthening Supervision of the Implementation of National Standards for Electric Bicycles (Guoshijianbiaochuang No. 53 of 2019)]. https://www.gov.cn/xinwen/2019-03/20/content_5375351.htm

State Council of China. (2012). *国务院关于印发“十二五”综合交通运输体系规划的通知 (国发〔2012〕18号)* [Circular of the Ministry of Transport on printing and issuing the outline of the plan for the development of road transport industry during the period of the Twelfth Five-year Plan (Guofa No.18 of 2012)].

State Council of China. (2013a). *关于城市优先发展公共交通的指导意见 (国发〔2012〕64号)* [Guiding Opinions of the State Council on giving priority to the public transportation in urban development (Guofa No. 64 of 2012)]. https://www.gov.cn/zhengce/zhengceku/2013-01/05/content_3346.htm

State Council of China. (2013b). *国务院关于印发大气污染防治行动计划的通知 (国发〔2013〕37号)* [Circular on State Council on printing and issuing the action plan for prevention and control of the atmospheric pollution (Guofa No.37 of 2013)]. https://www.gov.cn/zhengce/content/2013-09/13/content_4561.htm

State Council. (2018). *国务院关于印发打赢蓝天保卫战三年行动计划的通知 (国发〔2018〕22号)* . [Circular of the State Council on Printing and Issuing the Three-year Action Plan for Fighting to Win the Battle Against Air Pollution (Guofa No.22 of 2018)]. https://www.gov.cn/zhengce/content/2018-07/03/content_5303158.htm

State Council of China. (2021). *国务院关于印发2030年前碳达峰行动方案的通知 (国发〔2021〕23号)* [Circular of the State Council on printing and issuing the action plan for carbon dioxide peaking before 2030 (Guofa No.23 of 2021)]. https://www.gov.cn/gongbao/content/2021/content_5649731.htm?eqid=c98f853400010301000000036488dfcf

State Grid Corporation of China. (2021). *我国电价的国际比较分析* [International comparative analysis of China's power tariff]. <http://www.sasac.gov.cn/n16582853/>

Statista. (2022). *World's busiest metro networks in 2019 and 2020, ranked by number of trips (in millions)*. <https://www.statista.com/statistics/555773/largest-metro-networks-worldwide-by-ridership>

Sun, H. & Deng, W. (2021, November 12). *大城市公交如何吸引客流?定制公交已在京冀等29个省份开通* [How do pubic transport in major cities attract ridership? Customized buses operating in 29 provinces]. Beijing Daily. <https://bj.bjd.com.cn/5b165687a010550e5ddc0e6a/contentShare/5b16573ae4b02a9fe2d558fa/AP618e5d40e4b023337f1a4c00.html>

Sun, H., Zhang, C. & Bai, G. (2020). *5年治理3200公里自行车道 北京慢行系统加速跑* [Beijing straightened out 3,200 kilometers of bicycle lanes in five years, the active mobility system accelerated]. Beijing Daily. <https://news.sina.cn/gn/2020-10-26/detail-iznctkc7734431.d.html>

ThePaper. (2019, November 2). *高铁、飞机、地铁……上海虹桥枢纽十年运行大数据来啦* [Shanghai Hongqiao Hub reveals operation data for the past decade]. https://www.thepaper.cn/newsDetail_forward_4847047

ThePaper. (2023, May 22). *透视30城地铁财报:6家公司营收破百亿,补贴总额超千亿* [Insight from financial reports of 30 city metro systems: Six companies exceed 10 billion yuan in revenue, subsidies over 100 billion]. https://m.thepaper.cn/newsDetail_forward_23177011

TransportPolicy.net. (2018). *China: fuels: diesel and gasoline*. <https://www.transportpolicy.net/standard/china-fuels-diesel-and-gasoline>

UITP Secretariat. (2022). *Metro world figures 2021. Union Internationale des Transports Publics*. <https://www.uitp.org/publications/metro-world-figures-2021/>

Wang, K., Zhao, Y, Ma, L., Wu, S., Fu L., Ran J., Wu, K., Tian, X., Wang, S., Liao, J., Zhang, S., Liu, Y., Tian, S., Kang, H., Wang, R., Wang, N., Geng, X., Wang, Q., Guo, Y,... Liu, R. (2021). *2021年度中国主要城市通勤监测报告* [Annual report on commuting of major cities in China 2021]. MOHURD; China Academy of Urban Planning and Design.

Wang, K., Zhao, Y., Ma, L., Wu, S., Fu L., Dai, Y., Jiao, Y., Kang, H., Zhang, L., Ran, J., Wu, K., Tian, X., Wang, N., Liao, J., Ling, B., Chen, Y., Zhou, B., Wang, S., Zhang, S., ... Yan, A. (2022). *2022年度中国主要城市通勤监测报告* [Annual report on commuting of major cities in China 2022]. MOHURD; China Academy of Urban Planning and Design.

Wang, K., Zhao, Y, Ma, L., Wu, S., Fu L., Tian, X., Zhang, S., Kang, H., Zhang, Y., Dai, Y, Liao, J., Ling, B., Ye, M., Ran, J., Wu, K., Chen, Y., Zhou, B., Wang, S., Liu, Y., ...Yu, Y. (2023). *2023年度中国主要城市通监监测报告* [Annual report on commuting of major cities in China 2023]. MOHURD; China Academy of Urban Planning and Design. <http://transport.chinautc.com/2023%E5%B9%B4%E5%BA%A6%E4%B8%AD%E5%9B%BD%E4%B8%BB%E8%A6%81%E5%9F%8E%E5%B8%82%E9%80%9A%E5%8B%A4%E7%9B%91%E6%B5%8B%E6%8A%A5%E5%91%8A.pdf>

Wang, R. & Cao, X. (2023). *2023年度《中国主要城市道路网密度与运行状态监测报告》发布* [Release of annual report on road network density and traffic operation in major Chinese cities 2023]. MOHURD; China Academy of Urban Planning and Design. <https://mp.weixin.qq.com/s/HBdmR8NR9kp2WMCLAHZw9A>

Wang, S. (2023, March 16). *摩托车复兴:只有速度,没有激情?* [Motorcycle renaissance: only speed, no passion?]. TideSight. https://mp.weixin.qq.com/s/___biz=Mzg4NTQ1MTY0Mw==&mid=2247501974&idx=1&sn=a16cb5eacbc060aa663b373cbc249821&chksm=cfaa3682f8dbf94a1178b3ee1ec676c0125f7dc993e81ed7ef9faec65fb11545b1550cfe10a#rd

Wang, Y. (2023, May 9). *交通设施 | 城市应该善待支撑民生的电动自行车* [Transportation Facilities | Cities should take good care of electric bicycles that serve people's livelihood]. ThePaper. https://www.thepaper.cn/newsDetail_forward_23012237

Wang, Z., Zheng T., Jin Y., Wang C., Zhou X., Ren S., Wang S., Zhang C., Lu H., Ge S., Jiang D., Zhang B., Xu W., Meng G., Rao H., Bao W., Zhang J., Zhang M., Chen Z., ... Fu Y. (2018). *GB30510-2018重型商用车辆燃料消耗量取值 (第三阶段)* [Fuel consumption limits for heavy-duty commercial vehicles, Phase III (GB30510-2018)]. National Technical Committee of Auto Standardization.

Wei, W. (2022, January 27). 多次违停将被限用 北京共享单车推“新规” [Beijing released new rules on use of shared bikes, users that repeat disorderly return and parking will be limited]. Beijing Business Today. <https://m.gxfin.com/article/finance/cj/default/2022-01-27/5736907.html>

Wen, B., Jin, Y., Wang, Z., Zheng, T., Li, H., Zhang, L., Zhang, C., Gao, H., Qin, K., Lu, H., Wang, Z., Du, G., Han, Y., Tian, Y., Huang, X., Zhang, Z., Yan, B., Duan, Y., Zhang, B., ...Fu, Y. (2014). GB30510-2014重型商用车燃料消耗量限值 (第二阶段) [Fuel consumption limits for heavy-duty commercial vehicles, Phase II (GB30510-2014)]. National Technical Committee of Auto Standardization.

Work Safety Committee of China's State Council. (2018). 国务院安委会办公室关于开展电动自行车消防安全综合治理工作的通知 (安委办〔2018〕13号) [Notice on Initiating Management for the Fire Safety of Electric Bicycles (Anweiban No. 13 of 2018)]. https://mem.gov.cn/gk/tzgg/tz/201805/t20180516_230525.shtml

World Bank, World Development Indicators. (2023a). *Surface area (sq. km)—China, United States, European Union* [Data set]. <https://data.worldbank.org/indicator/AG.SRF.TOTL.K2?end=2021&locations=CN-US-EU&start=2021>

World Bank, World Development Indicators. (2023b). *Population, total—China, United States, European Union* [Data set]. <https://data.worldbank.org/indicator/SP.POP.TOTL?locations=CN-US-EU>

World Bank, World Development Indicators. (2023c). *Population ages 65 and above (% of total population)—United States, European Union, United Kingdom, Germany, Japan, India, World* [Data set]. <https://data.worldbank.org/indicator/SP.POP.65UP.TO.ZS?locations=US-EU-GB-DE-JP-IN-1W&start=2013>

World Bank, World Development Indicators. (2023d). *Access to electricity (% of population)—China* [Data set]. <https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=CN>

World Meteorological Organization. (2021a, December 14). *WMO recognizes new Arctic temperature record of 38 C* [Press release]. <https://public.wmo.int/en/media/press-release/wmo-recognizes-new-arctic-temperature-record-of-38%E2%81%B0c>

World Meteorological Organization. (2021b, July 1). *WMO verifies one temperature record for Antarctic continent and rejects another* [Press release]. <https://public.wmo.int/en/media/press-release/wmo-verifies-one-temperature-record-antarctic-continent-and-rejects-another>

World Population Review. (2023a). *The 300 largest cities in the United States by population 2023*. <https://worldpopulationreview.com/us-cities>

World Population Review. (2023b). *Europe cities by population 2023*. <https://worldpopulationreview.com/continents/europe/cities>

Wu, H. (2017). 整个中国只有三条地铁线盈利:拿什么来拯救中国地铁? [Three profitable lines only: how to save Chinese subway systems?]. Sohu.com. https://www.sohu.com/a/205574767_656927

Xiao, X. (2014). 国务院印发《关于调整城市规模划分标准的通知》[Circular of the State Council on adjusting the criteria for classification of the scale of cities] [Graph]. Xinhua News Agency. https://www.gov.cn/xinwen/2014-11/20/content_2781534.htm

Yuan, J. (2023, April 11). 电动自行车“换电”亟待进一步规范 [E-bicycles “battery swapping” needs further regulations]. China Youth Daily, 5. http://zqb.cyol.com/html/2023-04/11/nw.D110000zgqnb_20230411_2-05.htm

Zhao, L. (2020, November 24). 郑德高:揭开这个世界级交通枢纽的设计谜底 [Zheng Degao: Unveiling the design enigma of the world-class Hongqiao transportation hub]. Changning district government in Shanghai. https://mp.weixin.qq.com/s?__biz=MjM5ODAzNzgyNQ==&mid=2652605014&idx=3&sn=1864095dddc4f25fc71d1f5f294ca7e1&chksm=bd3f41488a48c85e0fc33b4c6e7c1abc7811ae97c9767683989cd89c6c955dea8c3969ff1548#rd

Zhang Z. (2010). 盘点十城千辆示范行动进展 [Reviewing the progress of “Ten Cities, One Thousand Electric Vehicles” pilot program]. China Automotive News. <https://www.d1ev.com/news/shichang/404>

Zhao, Y., Ma, L., Wu, S., Fu, L., Ran, J., Wu, K., Wang, N., Tian, Si., Kang, H., Liu, Y., Liao J., Liu, R. & Tian, X. (2020). 2020年度中国主要城市通勤监测报告 [Annual report on commuting of major cities in China 2020]. MOHURD; China Academy of Urban Planning and Design.

Zhao, Z. (2023, January 16). 中国工程院院士舒印彪:电力系统面临安全新挑战 [CAE Academician Shu Yinbiao: China's power system faces new security challenges]. Official wechat account of China Electricity Council. <https://bit.ly/3MLEyWR>

Zhev. (2015). 北京纯电动客车最高补贴50万元 每年补贴8万元运营费 [Beijing provides up to 500,000 RMB subsidy for eligible BEV bus purchase with an additional annual operating subsidy of 80,000 RMB]. Sohu.com. https://www.sohu.com/a/26771643_114771

Zhou, C. (ed.) (2023, June 21). 财政部:2024-2027年减免车辆购置税规模总额将达到5200亿元 [Total vehicle purchase tax reduction and exemption will reach 520 billion yuan during 2024-2027]. Chinanews.com. <https://www.chinanews.com.cn/cj/2023/06-21/10028881.shtml>

Zhou, M. (2022, August 15). *Strength and weaknesses: A comparison of Beijing with four major metropolises*. PRC State Council Information Office of China. http://english.scio.gov.cn/in-depth/2022-08/15/content_78372923.htm



Energy Foundation China is a professional grantmaking charitable organization registered in California, U.S. Our vision is to achieve prosperity and a safe climate through sustainable energy. Our mission is to achieve green-house gas emissions neutrality, world-class air quality, energy access, and green growth through transforming energy and optimizing economic structure. We deliver the mission by serving as a regrantor, facilitator, and strategic advisor.