Promoting China's Transition Towards Sustainable Transport Integration

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Executive Summary

The advancements in information and communication technologies (ICT) have unlocked new opportunities for innovative urban mobility services. Smartphone-based Mobility-on-Demand (MoD) services such as ride-hailing, dockless bike-sharing or car-sharing have exploded in China on a scale that is incomparable to any other country. For example, in 2019, the number of average ride-hailing orders in China was over 21 million per day and there were about 400 million registered shared bike users.

With the aim to systematically analyze the status of MoD development in China and layout the institutional foundations for the creation of a sustainable and climate-friendly MaaS ecosystem, the Sino-German Cooperation on Low Carbon Transport (CLCT) project of the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH and the China Academy of Transportation Sciences (CATS) of the Ministry of Transport of the People's Republic of China (MoT) conducted the study "From 'Mobility-on-demand' to 'Mobility-as-a Service': Promoting China's Transition Towards Sustainable Transport Integration" from 2020 to 2022.

The study collected first-hand data through interviews and surveys with local transport authorities, public transport service providers, MoD Service provider in the Greater Bay Area (GBA) of China (including the urban agglomeration as well as the city of Guangzhou, Shenzhen, and Foshan) and the city of Beijing.

While "MaaS" has appeared in central and local policies and regulations in China, it has not yet been clearly defined. In this study, MaaS is regarded as a mobility distribution service that integrates multiple modes of transport into a unified service system and platform based on the understanding of customer's travel needs. To provide benchmarking to China's MoD and MaaS development, the study refers to the six level of MaaS travel service integration (Jack Opiola, 2018), summarises 25 MaaS programs worldwide, and analyses some of their main features in Chapter 2.

In the last decade, the MoD services including ride hailing and dockless bike sharing went through start-up period, high-speed development period, shuffling stage, and entered into a stage of consolidated development with several established players including Didi Chuxing, Meituan Dianing, Amap, and HelloBike. By the end of 2020, there are 365.28 million of registered ride-hailing users in China and over 400 million registered shared bike users. With fragmented management responsibilities at the central level and largely decentralized local decision-making, systematic integration between private MoD service provider and public transport operators with shared data is especially challenging. Chapter 3 analyses the market development of MoD, current policies and stakeholders for MoD and MaaS development in China.

Based on field investigation, Chapter 4 analysed five cases of MaaS exploration in Chinese cities:

- The GBA government encouraged third-party to develop "one-order" intermodal passenger transport services that covers the entire area of 11 cities, includes urban transport, intercity transport, and cross-border transport.
- Shenzhen actively led the sharing of government transport data to the MoD services to encourage fair competition and improve their service level. At the same time, it initiated an On-demand Bus Pilot project called Maishi Chuxing, a phonic translation of MaaS Mobility in Chinese.
- Foshan is unique due to its developed transit alliance which integrates the services of different bus operators.
- Guangzhou provides an example of a region with an app that offers the option for users to create joint booking and integrated payment for buses and shared bikes.
- Beijing launched an official MaaS platform in collaboration with Amap and Baidu Map, aiming to provide residents with a one-stop travel service that includes smart routing and full navigation services, and green incentives. The Beijing MaaS grants post-trip incentives for choosing low carbon travel including using public transport, walking, and biking.

Based on Opiola's six level of MaaS integration, although with highly development MoD services, the investigated Chinese cities are still at the early phase of MaaS development where integration on travel booking, payment and collaboration between public and private operators are not well-developed.

In supporting China's development of a sustainable MaaS in the near future, the study provides the following recommendation:

- Enable effective data sharing
  a. Establish data sharing standards.
  b. Promote a data classification and hierarchical protection system.
  c. Establish a comprehensive data security supervision and management system.
  d. Form a data sharing mechanism for MaaS systems.

- Use MaaS as a Tool to Promote Sustainable Transportation
  a. Advocate for municipal governments to follow the principle of sustainable development and establish MaaS in accordance with their city's target visions for carbon dioxide peaking and carbon neutrality.
  b. The allocation and use of public resources such as roads and parking spaces should be reconsidered.
  c. Carry out comprehensive impact assessment work on the development of MaaS.
  d. Provide equity for users with special needs, such as elderly, children, and disabled people.
  e. Using MaaS as a platform for urban-rural mobility connection.

- Establish a Sustainable Business Model
  a. Encourage market innovation.
  b. Encourage flexible and diverse cooperation between public transportation companies and MaaS-related service providers.
  c. Encourage the application of blockchain technology to build a trust system.

1 INTRODUCTION

1.1 Background and Objective

In recent years, global climate change and environmental pollution caused by energy consumption have put tremendous pressure on worldwide transport sectors to foster a transition to low carbon technologies. With the global trend of urbanization, a further rapid increase in the number of motor vehicles is expected, which again drives the need for a sustainable transport transition. Technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), big data, cloud computing, and other innovations provide potential for sustainable development by creating innovative transportation resources. The promotion of intelligent and shared urban travel methods has become a major trend in urban transportation in many countries around the world. Various new app-based Mobility-on-Demand (MoD) services have emerged in the last decade, and attempts to develop them towards Mobility-as-a-Service (MaaS) models are on the way. MoD services refer to customized, end to end travel services based on the needs of users, such as ride-hailing, bike-sharing or car-sharing, powered by the convenience and widespread availability of smartphones. MaaS is a mobile distribution model that integrates different forms of transportation services into an online platform in which travellers can book travel services and obtain customized, point-to-point travel options.

These new and thriving mobility solutions also come with challenges. Due to a lack of integration with public systems, MoD services could actually compete with public transport and thus increase the number trips users make by car, further increasing congestion and leading to a further rise in emissions of carbon and other pollutants (Wang, et al, 2022). The competition between MoD services and traditional transport modes such as taxis, buses, docked bike sharing, etc. has increasingly become an issue. For example, taxi drivers in many countries protested the perceived unfair competition they face with online car-hailing services and demanded that governments implement stricter regulations for online ride-hailing in the early phase of the emergence of this industry[1]. Dealing with these conflicts and the resulting problems between MoD services and traditional public transport systems has become a major challenge for governments at all levels.

In China, the MoD services market is booming, with the scale of the industry being far ahead of that in other countries, and the services still have huge potential for further growth. As one example, looking at the dockless bike-sharing industry, China's MoD operators have provided a total of 19.5 million shared bicycles to approximately 400 million users, who have taken an average number of over 47 million daily trips by 2020[1]. Over the same timeline, China hosted 240 car-hailing companies, with a daily order volume of about 21 million trips[2]. As MoD services have further developed in China over recent years, their conflicts with traditional transportation methods have become more prominent. Therefore, the effective regulation of MoD services and their integration with existing public transport systems is a key priority for policy makers in China. Furthermore, to mitigate urban traffic congestion, noise and air pollution, and to make transport more seamless, inclusive, and eventually climate-friendly, transport integration between different mobility services is also key. One potential solution to achieve a higher degree of integration between services is MaaS. As MaaS offers a new paradigm by placing the user's needs at the centre of the transport system, it is considered a potential solution to urban transportation development problems (Barreto, et al. 2018). The Chinese government is actively promoting the development of MaaS in national policies and guidelines. For example, in the Outline for Building China's Strength in Transport, a top-level policy for the long-term development of China's transport sector released in September 2019, the integrated development of MaaS was emphasised.[3]

This study aims at laying out the institutional foundations for the creation of a MaaS ecosystem, integrating MoD and traditional transport modes with the goal

[1] China Smart Transport Association: China has over 400 million registered share-bike user, XinjingBao, 8th September, 2020, https://finance.sina.com.cn/chanjing/cyxw/2020-09-18/doc-iivhvpwy7461930.shtml

[2] Ride Hailing Operation Statistics, Ministry of Transport of the People's Republic of China, 18th September, 2021. https://www.mot.gov.cn/jiaotongyaowen/202109/t20210918_3619174.html

[3] For a summary and further discussion of the policy outline, see Sebastian Ibold and Jingzhu Li, "Outline for Building China's Strength in Transport – How China Wants to Become a Global Transport Superpower," Sustainable Transport in China, 11th October, 2019, https://transition-china.org/mobilityposts/outline-for-building-chinas-strength-in-transport/

of contributing to more effective, seamless, inclusive, and climate-friendly transport systems in China. Policy recommendations at the institutional level are therefore provided, aimed at ensuring the sustainable promotion and regulation of MoD within an integrated framework. This study will serve to equip Chinese policy makers and relevant governmental authorities with effective and efficient implementation strategies to further develop a low carbon transport sector in China. With similar transitions required worldwide, this research also provides valuable examples and experiences beyond the study region. The overall objectives of the study are as follows:

a. Identify the status of the integration of MoD and traditional transport services in China, and summarise their key aspects and the potentials of MoD and/or of the integration of MoD and traditional transport services;
b. Identify and analyse the key elements and stakeholders required for establishing the basis for a MaaS ecosystem integrating MoD and traditional transport services in China;
c. Identify the key drivers and barriers for the establishment of a MaaS ecosystem in China;
d. Provide specific policy recommendations to facilitate the establishment of a MaaS ecosystem integrating MoD and traditional transport services in China, and;
e. Facilitate experience and knowledge exchanges with regards to the integration of MoD and traditional transport services into a MaaS ecosystem in China through Sino-German cooperation.

1.2 Methodology

The scope of this study is urban transportation, excluding intercity travel. It focuses on existing MoD services (namely ride-hailing, dockless bike-sharing, and car-sharing services, as these are the three most prominent forms of MoD in China). The research methods are:

a. Literature review. Review and assess existing research, case studies, and other sources of information regarding MoD services and the integration of different transport services towards MaaS.
b. Qualitative interviews. Select three cities at different levels of development as case studies, and interview local transport authorities, traditional public transport service providers, and MoD service providers to investigate local development policies and determine what kind of policy support is needed for promoting MaaS.
c. Quantitative survey. Invite relevant experts to workshops to assess the results from the study and discuss the key elements that are promoting or hindering the realisation of MaaS in China. Following the workshops, design a Delphi survey for selected stakeholders to verify the key elements identified and defined, and then summarise the key findings, opportunities and challenges towards achieving MaaS in China.
d. Policy recommendations. Based on the findings of the literature review, interviews and survey, provide concrete policy recommendations and a roadmap for the system setup of MaaS for national and city level policy makers relevant to pursuing the realisation of MaaS in China.

GLOBAL DEVELOPMENT OF MAAS 2

This chapter will clarify the key elements of a successful MaaS system, introduce international best practices, and identify effective policies and regulations aiming at developing MaaS in different regional environments and diverse contexts.

2.1 The MaaS Concept and Its Emergence into Transport Discourse

The first vision of a MaaS-like system was introduced in 1996 at the ENTER Conference in Innsbruck by Nico Tschanz and Hans-Dieter Zimmermann from Austria, who envisioned an "intelligent information assistant" to be used as a platform for transportation providers and customers.[3] In their vision, one could search, combine and book tickets on the platform, and use many other travel related services, such as booking hotels and buying insurance. This kind of concept was ahead of its time considering that services, such as online booking engines, were far from sufficiently developed.

In 2014, the concept of MaaS was first explicitly proposed and defined by Sampo Hietanen, chairman of the Finnish Intelligent Transportation Association. In his 2014 article entitled "'Mobility as a Service' – the new transport model?",[4] Hietanen defined MaaS as "a mobility distribution model in which a customer's major transportation needs are met over one interface and are offered by a service provider." The concept of MaaS rapidly became an integral part of transportation discourse.

Following this initial definition of MaaS, the Intelligent Transport System (ITS) World Congress in Bordeaux in October 2015 proposed the objective of creating "a common approach to MaaS, unlocking the economies of scale needed for successful implementation and take-up of MaaS in Europe and beyond."[2] Its more than 100 participants also reflected the interdisciplinary nature of MaaS; they included transport service providers and public transport operators, private MaaS operators and integrators, IT system providers, educational institutions, ministries, as well as municipal and regional governments. In a 2017 white paper, MaaS Alliance defined MaaS as "the integration of various forms of transportation services into a single mobility service accessible on demand."[3] It effectively linked the conceptualisation of MaaS with a single integrated mobility service and stressed the role of mobile devices as "command centers for personalized mobility." Maria Kamargianni and Melinda Matyas (2017) of MaaSLab at the UCL Energy Institute expanded this definition with an emphasis on the centrality of users and technology: "A user-centric, intelligent mobility distribution model in which all mobility service providers' offerings are aggregated by a sole mobility provider, the MaaS provider, and supplied to users through a single digital platform."[4]

Despite the relatively recent emergence of MaaS as a concept, the nascent body of research on the subject has grown rapidly in recent years. Pangbourne et al., reflecting on the risks inherent in an overreliance on technology,[5] emphasized that, to ensure the economic and environmental potential of MaaS, relevant stakeholders needed to monitor planning, pricing, and consumer protection as critical elements of MaaS.

At the 2018 MaaS Market conference in Atlanta, USA, Jack Opiola provided a categorisation of MaaS into six different levels of travel service integration (Table 1). This categorisation framed the levels of integration as different stages in a gradual development towards a fully integrated MaaS ecosystem:[6]

Table 1: Levels of Integration of Mobility Services Leading to MaaS

Level	Description	Explanation
0	This is the base level, relatable with today.	There are account base systems in place, individual modes of transportation already have a digitised interface and thetraveller has information available online for each.
1	There is one-to-one integration between some private services.	Duets of services start to develop joint offering (e.g.tolling+carpark; private car+ferry; and, car park+ride bus services)
2	Integrated payment and ticketing across modes of limited public and private modes of transportation services.	In this level, greater integration occurs but this time between aprivate operator and a public transport mode of operation. Integration shows promise but other PT modes skeptical and continue to stay aloof.
3	Unified interface for single account used in multiple modes of transport services.	Instead of having muitiple channels, interface is unified across modes, providers and services that the traveller finds necessary for joumeys are provided by a single meta-operator through a traveller account.
4	All modes are integrated, private and public, including routing, ticketing, and payment.	Open data and standards are defined and commonly used by all transportation providers and MaaS meta-operators to provide services for Travellers.
5	Active artificial intellgent choices are taken based on travels preferences and near real time data for *ad-hoc* changes to a joumey.	Based on traveller specific behavior and profiling, minimal(to none) intervention is needed by the traveller for an end-to-end joumey based on the traveller's preferences, past travel history, and filters.
6	MaaS connects beyond mobility, interfacing with loT's, smart building, and smart cities.	As MaaS evolves, so do other systems involved in the traveller's day, such as smart work spaces, smart-homes, smart-cities, and general services (e.g. food, groceries, entertainment, sport, culture) to provide convenient and seamless interface with the Traveller's eco-system.

Source: Opiola, Jack. "Levels of MaaS: a US-European comparison." Presented at MaaSMarket: Optimising Multi-Modal Mobility. Atlanta, United States (2018). https://www.maas-market.com/sites/default/files/JACK%20OPIOLA.pdf

The different levels of MaaS integration outlined in Table 1 are a helpful tool for understanding the gradual path towards a fully integrated MaaS ecosystem, with Level 6 even implying that MaaS would itself be ultimately integrated into a wider ecosystem of urban life. This categorisation also retains certain limitations, however. Firstly, findings outlined in the table are the result of Opiola's examination of MaaS at different levels of integration in US and Europe. Would the same levels be applicable to contexts outside of these regions? For example, could technological innovation with AI (Level 5), as is increasingly prominent in China, occur before sufficient modal integration is achieved? Similarly, the bulk of MaaS-related research is focused on a European context

or politically and administratively comparable examples, such as Australia or, again, the US. There remains a gap in literature on MaaS ecosystems as they are being developed in East Asia, and most notably, a lack of research on China's experience. The distinct characteristics of China's mobility market, technological innovation, and related political administration warrant a closer examination of the country's experience with MaaS development. This experience rests on a gaining momentum for achieving China's ambitious 2030 carbon dioxide emission peaking and 2060 carbon neutrality climate targets through innovative solutions from the transport sector. In recent years, China has seen the emergence of such solutions in the form of MoD services and a flurry of transport-related policy incentives.

To address the gap identified in the literature review of a lack of information on MaaS systems development in East Asia, this study aims to provide a comprehensive analysis of China's experience, from its development of MoD services to the existing and potential integration of MoD and public transport services into MaaS ecosystems. This study will cover multiple aspects of MaaS systems, including technology, public policy and governance, business models, and public-private cooperation. Through field investigations, the study examines Beijing's MaaS trial and its efforts on carbon emission reductions, and the regional transport integration of the MaaS system in the Greater Bay Area of Guangdong Province.

In this study, MaaS is regarded as a mobility distribution service. Based on a deep understanding of customers' travel needs, it integrates multiple modes of transport into a unified service system and platform. Operators draw on big data to schedule and allocate an optimal selection of transport resources, ultimately meeting the travel demands of customers by providing the most convenient mobility services to serve their needs.

2.2 MaaS Development Worldwide

2.2.1 International Cases

This section will introduce some most well-known MaaS initiatives around the world, such as Optymod (Lyon, France), Whim (Helsinki, Finland), UbiGo (Gothenburg, Sweden), and Moovel (Germany), whose interfaces integrate different travel modes, providers, and services, and are comprised of booking, execution, and payment services.[7] Looking at the levels of MaaS outlined earlier in Table 1, these MaaS systems would fit into integration levels 2 and 3.

In 2013, a Swedish government research project set up a virtual company to develop an innovative transport broker service in Gothenburg, Sweden, named UbiGo. It offered its users "one-stop" access to a range of travel services through a web-interface adapted to smartphones (subsequently referred to as an app) by combining access to public transport, car-sharing, car-rental, taxi, and bike-sharing services. The service was quickly discontinued after a lack of support from the government for third-party-selling of transport tickets.[8],[9] In 2015, Aisin, a global supplier of automotive components, announced its cooperation with UbiGo and provided MaaS business services via the company in 2016. After several years of operation, UbiGo could be classified as having level 3 integration with its attainment of preference amongst users.

Unlike UbiGo, which was born out of a government project, some MaaS platforms emerged through business expansions. The Transit App, launched in 2013, was initially a public transport query tool registered in Montreal, Canada. It could display real-time information on public transport services in the user's area. Transit began its development by partnering with multiple transit agencies to aggregate their schedules, publishing frequency and service information so that the user could use Transit to secure transport options in any participating city across different forms of travel. In 2016, Transit first introduced payments for bike-sharing providers. In 2018, it also integrated public transport ticketing into the app and steadily added more payment options in partnership with mobile ticketing platforms including Token Transit[4] and Masabi[5]. Today, the app also includes ride hailing services like Uber, and Lyft, as well as rail services through VIA. It can be classified as having level 3 integration, in accordance with the standards of Table 1.

Another way toward MaaS implementation is Public Private Cooperation (PPP). One such example of a service developed through PPP is Mobility, operated in Parma, Italy. Mobility is the result of cooperation between Parma's mobility sector and the urban bus operators EMT and SMAP[6]. Mobility provides real-time information and travel plans for buses and public bicycles, as well as on current

and predicted traffic conditions and available parking spaces, effectively acting as a multimodal transport route planner. The platform aims to increase the attractiveness of sustainable mobility options through the provision of real-time information and the adoption of new technologies. Since Mobility combines most public modes of transport, as well as car-sharing, taxis, and even regional train transit options, it can be classified as having level 3 integration status.

Another case of MaaS development through government-enterprise cooperation is Whim. MaaS Global started operating Whim in 2016, making Helsinki the first city in the world with a dedicated MaaS operator[7]. Through its open interface, MaaS Global's Whim platform has successively connected independent travel service platforms, such as taxi companies, public transport companies, bike-sharing and car-sharing service providers. It has developed from a single service access point to a comprehensive access platform for independent travel services. Whim is easy to use and has a wide range of transportation options. Users can pick a corresponding package with content and payment standards that are formulated according to their different needs. For example, users can pay for travel by binding their bank or credit cards, or instead choose to buy Whim credits to settle travel expenses on a monthly basis. With a unified interface, and ticketing and payment integration for a wide range of modes, the platform corresponds to level 3 integration.

The commercial application of MaaS is widely developing rapidly worldwide. In addition to the above-mentioned applications, there are also Optymod in France, Smile in Austria, Jelbi in Germany, and My Cicero in Italy. Jelbi, for example, offers access to all transport modes available in Berlin, and may therefore also be classified as having a level 3 of travel service integration. However, at present, most of these platforms[8] still only serve one city, or a few cities separately.

2.2.2 Impact

Even though MaaS platforms worldwide have not yet advanced into higher integration levels according to the aforementioned levels of integration outlined in Table 1, they have had positive impacts on urban transportation, increasing the modal share of public transport and reducing the use of private vehicles. According to the International Transport Forum (ITF), the introduction of MaaS systems has reduced congestion by 37% in the Helsinki Metropolitan Area.[10] According to a study of Juniper Research, commuters travelling via MaaS will save, on average, 37% of their baseline journey time, calculated at 67 minutes per day for drivers and 61 minutes per day across all modes. The reduction in the amounts was made through the improved route planning available with the use of MaaS platforms, and travel options provision across different mobility modes, including the accurate location and route planning of bike-sharing solutions. A person only using MaaS on weekends can already save up to an estimated 13 hours of travel time per year.[11] If 33% of the total recovered travel time was used for productive business purposes, the simple implementation of MaaS could generate $733 billion in additional income worldwide.[12]

[4] Token Transit is an app where users can buy tickets and passes for public transit and get digital tickets via mobile phone in United States and Canada.
[5] Masabi is a London based technology company that develops and markets fare collection services for public transport companies.
[6] EMT and SMAP are Madrid's public transport operators.
[7] Köllinger, C. 2018: How Helsinki became a 'Mobility as a Service' leader. Eltis. The Urban Mobility Observatory. https://www.eltis.org/discover/news/how-helsinki-became-mobility-service-leader
[8] For a summary table of various MaaS schemes in operation, please see Annex 1.

2.3 Policies, Regulations, and Standards Related to MaaS

2.3.1 International Policies, Regulations and Standards

In the EU, the European Commission ensures compatibility, interoperability, and continuity in the Intelligent Transport System (ITS) policies of its member countries. A delegated regulation concerning the provision of EU-wide multimodal travel information services was established in 2017. This regulation made it mandatory for every member state to participate in the National Access Point, a digital interface through which static and dynamic travel and traffic data with full compatibility and interoperability can be accessed. Member states are required to feed such data into the interface through entities such as transport providers.[13] Through these measures, policy-level support has been provided to boost the development of infrastructure for data sharing to enable the development of MaaS platforms in the EU.

One example of a non-regulated market is Sweden. Even though MaaS has been developed in Sweden since 2013 and the Swedish government has a positive attitude towards it, there are currently no special laws and regulations in place for its development. Sweden is currently drawing a roadmap for transport services for the next generation in the national infrastructure planning of 2018 -2029. Planning initiatives include the development of new technologies for transportation systems, the improvement of digital services, the development of door-to-door transportation chains under the use of multiple transport modes, and the combination of automated driving and electric vehicles to promote the development of MaaS.

Finland, another early adopter of MaaS, opted for an approach that deregulates the market to allow access to new technologies. Finland took this approach through the establishment of the Act on Transport Services, which combined relevant transport market legislations and created the preconditions for the digitalization of transport and new business models.[14] Based on this policy, Finland realized a user-oriented mobility service by promoting the digitization of transport services and effective use of data. In January 2018, regulations related to providing open access to relevant data and the ITS Directive were issued. In July 2018, the various regulations related to MaaS-related transport were unified, ensuring the interoperability of data. In addition to road transport, the required qualifications for aviation, shipping, and railway services to participate in MaaS were relaxed, which was perceived as a step towards deregulation and increased market orientation to further support the integration of these modes of transport into MaaS platforms.

The core requirements of MaaS systems are digitalized transport management and data interconnection, and examples of how different countries in the EU have promoted these steps have been outlined here. In particular, the Swedish approach reflects the efforts required to provide a legislative foundation for the digitization of transport. On the other hand, as shown in the Finnish approach, deregulated markets have relatively low requirements that need to be met to access systems relating to the transport industry, which has been beneficial to their development of MaaS. This demonstrates that though countries may pursue different paths to MaaS development, they may still end up with similarly effective systems.

2.3.2 Chinese Policies, Regulations and Standards

China's transportation sector is strictly regulated, setting it apart from the deregulation of the industry that has occurred in other countries. The country is still taking efficient steps however, to develop MaaS systems, in its own specific context. In July 2015, the State Council issued the Guiding Opinion on Actively Promoting the "Internet Plus[9]" Action Plan. In regards to transportation, the Plan encouraged apps and internet platforms to provide real-time public traffic information to answer queries, support route planning, allow online ticket purchases, provide intelligent parking services for users, and promote the overall compatibility and interconnectivity of data from multiple sources and realize "one-stop" services based on an internet platform. The Plan includes a statement

[9] "Internet Plus" (Hulianwang Jia 互联网 +) mean the integration of the Internet of Things and traditional industry.

on promoting "the compatibility and interconnection of data from multiple data sources", which is similar to EU measures, requiring member states' entities to provide compatibility data. This Plan can be regarded as the first official step towards MaaS development in China, even though the term "MaaS" does not yet appear in the document.

In August 2019, the General Office of the State Council of the People's Republic of China issued the Guiding Opinions on Promoting the Healthy Development of Platform Economy, which provides policy support for regulating the influx of digital information technology, social capital and innovative ideas into the transport industry, and further supports the development of MaaS platforms. Five measures can be summarized from this policy: 1. Simplify administrative processes and provide clear policy guidance on establishing a platform economy; 2. Issue inclusive and prudent regulations on the platform economy; 3. Encourage platform development; 4. Optimize the development environment, and; 5. Enhance legal guarantees of stockholders. The first two measures intend to deregulate the transport sector, which is conducive to the development of MaaS.

On July 25, 2019, the Ministry of Transport of the People's Republic of China (MoT) issued the Outline of Digital Transport Development Planning, to define the next stage of MaaS. The policy envisages to take advantage of existing internet platforms as the starting point, deepen multi-source data collection, integrate online and offline resources, encourage open access to all passenger ticketing systems, and create digital travel assistance, to provide "end to end" customized travel services for passengers. MaaS is clearly advocated in this policy as the link between travel demand and transport services to provide instant and articulate solutions. Even though the elaborations on the development of MaaS platforms is only discussed in a small section of this policy, it is still a milestone document for MaaS in China as, for the first time, MaaS appears as an explicitly proposed system in an official policy of the MoT.

Building on this milestone inclusion, the Outline of Digital Transport Development Planning aims to create an "intelligent mobile space" in which passengers' travel, business, shopping, and entertainment plans are mutually integrated to create a new travel experience. The document also promotes digitalization and encourages and standardizes the development of customized city buses, intelligent parking and public transport systems, car maintenance solutions, online ride hailing, bicycle sharing, and car-sharing and other new urban travel services.

Also in 2019, a high-level strategy, the Outline for Building China's Strength in Transportation was published by the Central Committee of the Communist Party of China and the State Council. In this strategy, MaaS is again clearly mentioned as a measure to "accelerate the development of new business forms and new models."

In conclusion, existing Chinese policies demonstrate positive attitudes towards the development of MaaS systems in China. However, to further develop MaaS systems effectively, systematic regulation and guidelines are needed to clearly define how these systems would function, what would legitimately make them MaaS systems, and what their strategic potential is to the overall transport industry. Furthermore. more details on the rights and responsibilities of various stakeholders and specific regulations on the establishment of necessary integrated payment systems, information and data sharing options, and the actual operation of digitalized interfaces are needed. Such policies should not only touch upon technological needs, but also on consumer rights and benefits, as well as safety issues. To achieve this, cross cutting policies in relation to social-economic planning, urban and transport planning, and climate change and carbon neutrality planning are needed.

Table 2: Transit App, Optymod, Mobility 2.9 Services. SHIFT-Project 100, UbiGo, Mobility Shop

Scheme (Area)	TransitApp (USA, UK, Canada, Europe, Australia)	Optymod (Lyon, France)	Mobility 2.0 Services (Palma, Spain)	SHIFT—Project 100 (Las Vegas, USA)	UbiGo (Gothenburg, Sweden)	Mobility Shop (Hannover, Germany)
Status & Starting Time	Operational (2012–)	Operational (2012–)	Pilot (2013–)	Operational (2013–2015)	Pilot (2013–2014)	Operational (2014–)
Transport Modes |& Services	Public Transport (PT) (Inc. local ferry) Bike sharing Car sharing Taxi Ride-hailing	PT Bike sharing Regional train Parking	PT Bike sharing Taxi	Bike sharing Car sharing Taxi Shared shuttle	PT Bike sharing Car sharing Car rental Taxi	PT Car sharing Taxi Regional trains
Tariff Option	Pay-per-use	None	Pay-per-use	Monthly tariff	Monthly tariff	Fixed monthly membership to access discounted tariff
Interface	App/Web	App	App/Web	App	App	App
Functions	Real time info. Trip planning Booking (shared modes/ Taxi) Payment (bike sharing) Service alerts Departure alarms Stop notifications	Real time info. congestion Prediction Trip planning Booking (bike sharing) Service alerts Plane's arrival-departure time info	Real time info. Trip planning Service alerts Real time congestion monitor	Trip planning Booking Payment Invoicing	Trip planning Booking Ticketing Payment Invoicing 24hr customer service phoneline	Real time info. Booking Ticketing Payment Invoicing Service alerts
Stakeholders & Service Aggregator	Public and private actors 3rd party	Public actors Local authority	Public and private actors Local authority	Private actor 3rd party	Public and private actors 3rd party	Public and private actors PT provider
Technologies	GPS / ePay (bike sharing only)	GPS	GPS	GPS / ePay	GPS / Smart card	GPS / ePay / Smart card
Demand orientation	Yes	Yes	Yes	Yes	Yes	Yes
Registration requirement	Yes, for booking and customisation	Yes, for customisation	Yes, for booking and customisation	NA	Yes, for usage and customisation	Yes, for usage and customisation
Personalization	Store regular and preferred Routes Saved location	Input personal address, Preferable modes, and ownership of bicycle	Store favourite trips	Automatically optimised trip planner	NA	Store favourite trips and recall previous trip
Customization	Minimised walking option Disabled certain service/modes Link with calendar and personal contact	Select service subscription for news	Enable certain map sections and accessibility map people with special needs	Mobility budget with Top-up	Mobility budget with Top-up and roll over	Possibility to create individual mix of transportation Booking and payment cancelation

Table 3: Smile, Tuup, My Cicero, Moovel, Whim, WienMobile Lab

Scheme (Area)	Smile (Vienna, Austria)	Tuup (Turku Region, Finland)	My Cicero (Italy)	Moovel (Germany)	Whim (Helsinki, Finland)	WienMobil Lab (Vienna, Austria)
Status & Starting Time	Pilot (2014–2015)	Operational (2015–)	Operational (2015–)	Operational (2016–)	Operational (2016–)	Based on Smile project (2015–2016)
Transport Modes & Services	PT (e-)Bike sharing (e-)Car sharing Taxi Parking garages Charging stations Regional trains and ferry	PT Bike sharing Car sharing Car rental P-2-P car rent Taxi and shared taxi Parking rent Freight service*	PT Taxi* Parking spaces Permit for urban congestion charging zone Regional rail and bus	PT Bike sharing Car sharing Taxi Ferry Regional rail	PT Rental car Taxi Regional rail Bike sharing* Car sharing*	PT Bike-sharing Car-sharing Taxi Parking garages
Tariff Option	Pay-per-use	Pay-per-use	Pay-per-use	Pay-per-use	Three monthly packages and pay-per-use	Pay-per-use
Interface	App	App	App	App	App	App
Functions	Real time info. Trip planning Booking (shared modes / Taxi / Regional train) Ticketing Payment Invoicing Service alerts	Real time info. Trip planning Booking Ticketing Payment (for PT, taxi, and shared taxi)	Real time info. Trip planning Booking Ticketing Payment Invoicing Municipality services	Real time info Trip planning Booking Ticketing Payment Invoicing	Real time info. Trip planning Booking Ticketing Payment Invoicing	Real time info. Trip planning Booking Payment Invoicing
Stakeholders & Service Aggregator	Public and private actors PT provider	Public and private actors Third party	Public and private actors Third party	Public and private actors Third party	Public and private actors Third party	Public and private actors PT provider
Technologies	GPS / ePay	GPS / ePay (PayiQ)	GPS / ePay / e-Wallet	GPS / ePay	GPS / ePay	GPS / ePay
Demand orientation	Yes	Yes	Yes	Yes	Yes	Yes
Registration requirement	Yes, for usage and customisation	Yes, for usage and customisation	Yes, for usage and customisation	Yes, for usage and customisation	Yes, for usage and customisation	Yes, for booking and customisation
Personalization	Optimised trip plan to user's profile (i.e. annual ticket, subscription and membership)	Optimised travel plan based on user's daily agenda	Store types of ticket Record and share journey	Store favourites routes Personalised notification on disruptions	Calendar synchronization Personal info sharing Social interaction	Save personal mobility profile Store car & bike sharing membership
Customization	Enable mode filtering based on cost, time, and CO_2 footprint	Preferred modes, based on cost and CO_2 footprint	Preferred modes and payment Top-up	Link with social media accounts Booking cancellation	Cancelation Change of subscription Top-up	Preferred modes, based on cost, time, and CO_2 footprint

Table 4: Navigogo, EMMA, HelloGo, Shail, Zipster, Jelbi

Scheme (Area)	Navigogo (Scotland)	EMMA (Montreal, France)	HelloGo (Utrecht, The Netherlands)	Shail (Dubai, United Arab Emirates)	Zipster (Singapore)	Jelbi (Berlin, Germany)
Status & Starting Time	Pilot (2017–2018)	Operational (2014–)	Pilot (2017)	Operational (2017–)	Operational (2019–)	Operational (2015–Current)
Transport Modes & Services	PT Taxi Car sharing Bike sharing Train	PT Bike sharing Car sharing Parking rent	PT Train Taxi Bike sharing Car rent	PT Car sharing Taxi Ride-hailing Car rent	PT (Metro and bus) Taxi Bike sharing E-scooter	PT (Bus) Train Motor Scooter E-kick scooter Bike sharing Car sharing Taxi Ride hailing Shuttles Freight service
Tariff Option	Pay-per-use and weekly package	Pay-per-use	Pay-per-use	Pay-per-use	pay-per-use/Zipster card for post-paid public transport/monthly package	Pay-per-use/credit card, PayPal and debit in Jelbi
Interface	App	App	App	App	App	App
Functions	Trip planning Ticketing Payment (for PT, taxi, and shared taxi)	-	-	Real time info. Trip planning Booking Ticketing Payment Service alerts	Real time info. Trip planning Booking Ticketing Payment Insurance	Real time info. Trip planning Booking Payment
Stakeholders & Service Aggregator	Public and private actors PT provider	Public and private actors Third party	Public and private actors Third party	Public and private actors Third party	Public and private actors Third party	Public and private actors PT provider
Technologies	GPS	GPS / ePay	GPS / ePay	GPS / ePay	GPS/ ePay	GPS / ePay
Demand orientation	Yes	Yes	Yes	Yes	Yes	Yes
Registration requirement	Yes, for usage and customisation	Yes, for usage and customisation	Yes, for usage and customisation	Yes, for usage and customisation	Yes, for usage and customisation	Yes, for booking and customisation
Personalization	-	-	-	plan the journey based on traveler preferences	Calendar synchronization Personal info sharing Social interaction	Save personal mobility profile Store car & bike sharing membership
Customization	-	-	-	Link with social media accounts Booking cancellation	Preferred modes, based on cost	Preferred modes

Table 5: Qixxit, Hannovemobil 2.0, Incen Trip, MaaS Madrid, MinREjseplan

Scheme (Area)	Qixxit (Germany)	Hannovemobil 2.0 (Hannover, Germany)	IncenTrip (Washington, US)	MaaS Madrid (Madrid, Spain)	MinRejseplan (Copenhagen, Denmark)
Status & Starting Time	Operational (2013–)	Operational (2014–)	Operational (2018–)	Operational (2018–)	Operational (2018–)
Transport Modes & Services	PT Rental car Bike sharing Car sharing Taxi Train Plane Long distance bus	PT Car sharing Bike Sharing Taxi Parking	PT Bike sharing Car sharing Designated driver	PT Bike sharing Car sharing Taxi	PT (Bus and Metro) Train Taxi Ride hailing Rental car Bike sharing
Tariff Option	Pay-per-use	Pay-per-use	Pay-per-use	Pay-per-use	pay-per-use
Interface	App	App	App	App	App
Functions	Real time info. Trip planning Booking (shared modes / Taxi / Regional train) Ticketing Payment Invoicing Service alerts	-	Real time info. Trip planning Booking Ticketing Payment	Real time info Trip planning Ticketing Payment	Real time info. Trip planning Booking Ticketing Payment
Stakeholders & Service Aggregator	Public and private actors PT provider	Public and private actors Third party	Public and private actors Third party	Public and private actors Third party	Public and private actors Third party
Technologies	GPS / ePay	GPS / ePay (PayiQ)	GPS / ePay / e-Wallet	GPS / ePay	GPS / ePay
Demand orientation	Yes	Yes	Yes	Yes	Yes
Registration requirement	Yes, for usage and customisation	Yes, for usage and customisation	Yes, for usage and customisation	Yes, for usage and customisation	Yes, for usage and customisation
Personalization	Optimised trip plan to user's profile	-	Implement green points to induce travel	-	Calendar synchronization Personal info sharing Social interaction
Customization	-	-	Preferred modes, based on cost and CO2	-	Preferred modes, based on cost, departure time and travel duration

3 DEVELOPMENT STATUS OF MoD SERVICES IN CHINA

The boom of MoD services in China provides a timely opportunity for the development of MaaS systems. With the goal to provide shared and personalized mobility services, MoD service providers have already established the conceptual bases, user bases, and technical bases, which lay an excellent foundation for the development of MaaS systems. Therefore, before further discussing MaaS systems in China, this chapter mainly analyzes China's MoD development, current policy environment and key stakeholders.

3.1 The Development of MoD Services in China

This section will introduce the development of the main MoD services, including ride-hailing, dockless bike sharing, and car sharing services now existing in China. Milestones in the development process of these services are shown in Figure 2.

3.1.1 Ride hailing

Ride hailing services connect cars and drivers with passengers. Users can forward their travel demands to drivers through an online service platform. A nearby driver will accept the order, pick up the passenger(s), and drive them to their desired destination. Inquiry, matching, and payment requests are all processed within one system. The development of online car-hailing services in China can be divided into three periods: The exploration period (2010-2014), the market start-up period (2015-2016), and the high-speed development period (2017-present).

(1) Exploration period (2010-2014)

In 2012, the KuaiDi DaChe service and DiDi DaChe service were launched successively, after which other various kinds of ride hailing apps began to appear. During this period, car-hailing software was mostly limited to calling taxis. In May 2013, there were more than 40 kinds of car-hailing online platforms operating in China, and the vicious competition in their pricing policies and the absence of supervision of their services caught the attention of policy makers.

(2) Start-up period (2015-2016)

On July 28, 2016, the policy Interim Measures for the Management of Online Car-hailing Business Service[10] was issued by the MoT and five other national departments, which legalized online car-hailing services, making China the first country in the world to recognize the legality of online car-hailing services.

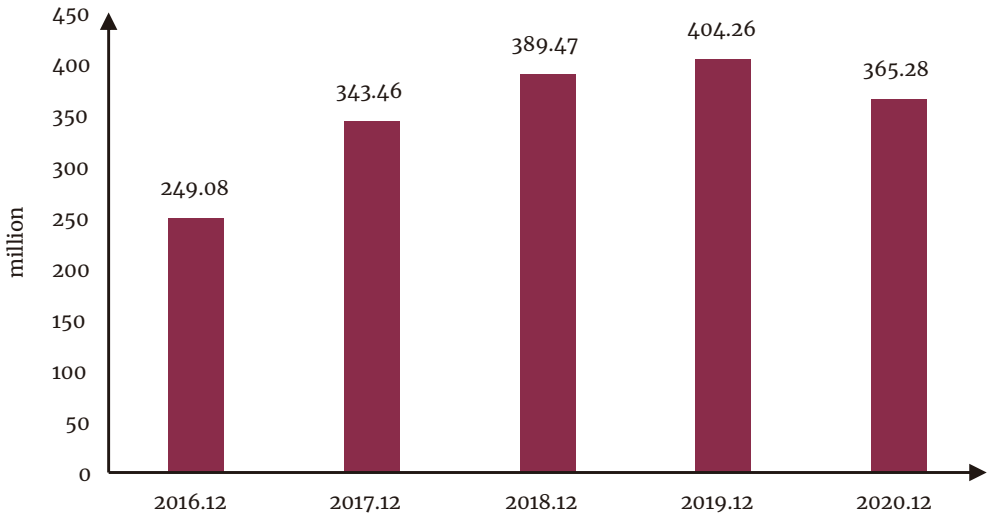
After the acquisition of Uber China in August 2016, DiDi Chuxing's (renamed from "DiDi DaChe") market share for car-hailing services in China exceeded 90%, underscoring its dominant position in the domestic market.

(3) High-speed development period (2017-present)

Since 2017, the number of car-hailing users in China has been growing steadily. On February 14, 2017, Meituan DianPing, a lifestyle e-commerce platform, launched a pilot online car-hailing service in Nanjing, Jiangsu Province. In July 2018, Amap, an online navigation provider, aggregated online car-hailing services into its app. In 2019, automobile OEMs (Original Equipment Manufacturers) have also successively launched travel platforms. As shown in Figure 1, by December 2020, China had 365.28 million ride-hailing users[15].

[10] 《网络预约出租汽车经营服务管理暂行办法》公布 http://www.gov.cn/xinwen/2016-07/28/content_5095584.htm

■ **Figure 1: Growth of Online Ride hailing Users from 2016-2020**



Source: China Internet Network Information Center. The 47th Statistical Report on Internet Development in China[R]. Beijing, 2021.

3.1.2 Dockless Bike-sharing

Dockless bike-sharing is a mode of bike-sharing in which bicycles are not bound to a fixed location but can be parked and unlocked anywhere within their service area. Such service areas are generally limited to city boundaries. The development of dockless bike-sharing in China can be divided into four stages: The embryonic stage, the rapid development stage, the shuffling stage, and the standardized development stage.

(1) Embryonic stage (2014-2016)

The embryonic stage was the birth period of two bicycle sharing companies, ofo and Mobike. In this period, other brands of dockless bike-sharing had not yet appeared, and there were concerns on whether the business model of dockless bike-sharing could be successful in China. At this stage, no regulation on dockless bike-sharing had been issued by the bicycle providers, as the providing companies' management departments maintained an inclusive and prudent attitude towards the new business form and hoped to give dockless bike-sharing enough space for development.

(2) Rapid development stage (2017- March 2018)

On August 3, 2017, the MoT and 10 other ministries and commissions jointly issued the Guidance on Encouraging and Standardizing the Development of Internet Bicycle Rental, which affirmed the positive role of dockless bike-sharing in facilitating short-distance travel and building a green and low-carbon transportation system. It also clarified the positioning of online bike-sharing within overall urban comprehensive transportation systems. Due to the support generated from this policy, the market scale of dockless bike-sharing further expanded. Before 2018, dockless bike-sharing operations were in 235 cities in China, with the number of bicycles put into operation nationwide reaching 23 million, and the total number of registered users in China exceeding 400 million individuals[11]. However, the rapid growth of the industry caused problems, such as significant bicycle oversupplies in some areas, and the indiscriminate parking of bicycles. As a result, cities including Beijing, Shanghai, Guangzhou, Shenzhen, and 8 second tier cities issued notices to suspend adding new shared bicycles into circulation[12].

[11] 2018 年共享单车用户规模增长至 2.35 亿人，有效改善居民出行结构 Shared bicycle users increased to 235 million to improve mobility, 产业信息网 Chanye Xinxi Website (2019,November 4th) https://www.chyxx.com/industry/201911/801307.html

[12] 北京市鼓励规范发展共享自行车的指导意见（行）/Instruction on Encouraging the Orderly Development of Shared Bikes in Beijing, 北京市人民政府网站 /Website of Beijing Municipality http://www.beijing.gov.cn/zhengce/gfxwj/201905/t20190522_60570.html

(3) Shuffling stage (March 2018-2019)

Following the rapid development of dockless bike-sharing operations, further problems emerged, such as financing, deposit security, urban management, and security issues. Driven by capital, companies were still attracting users and increasing their market shares through various preferential means, such as the provision of free rides, cheap monthly cards, and coupons. Marked by the provider company Xiaomin Danche's bankruptcy in March 2018, the shuffling stage of the industry saw the focus of enterprise operations shifting to compete for users through unreasonable price reductions, rather than optimizing operation efficiency and business models. Malicious competition practices pushed the vast majority of enterprises to withdraw from the market in 2018, as they could not attract the further investment which would have been necessary to sustain development.

(4) Consolidation stage (2019-present)

In 2019, bike-sharing gradually entered a period of standardized development. With a clear market structure and declining investments, industry competition slowed down, and with stronger regulation in various cities, the main operating companies gradually refined their operations by improving bike redistribution to decrease the blocking of roads and pathways, and by moving away from low-price competition practices to establishing more sustainable business models. Since 2020, some operators partly shifted their focus towards e-bike sharing, as they offer better revenue than bicycles,. The providers HelloBike, Meituan DianPing and Qingju have begun to provide shared e-bikes, and the number of operating e-bikes has now reached 4 million. However, since the MoT has not clearly indicated whether it supports the development of e-bike sharing, most cities are holding a conservative attitude towards the further development of e-bike sharing programs, with some cities even already moving to ban their operation.

3.1.3 Car sharing

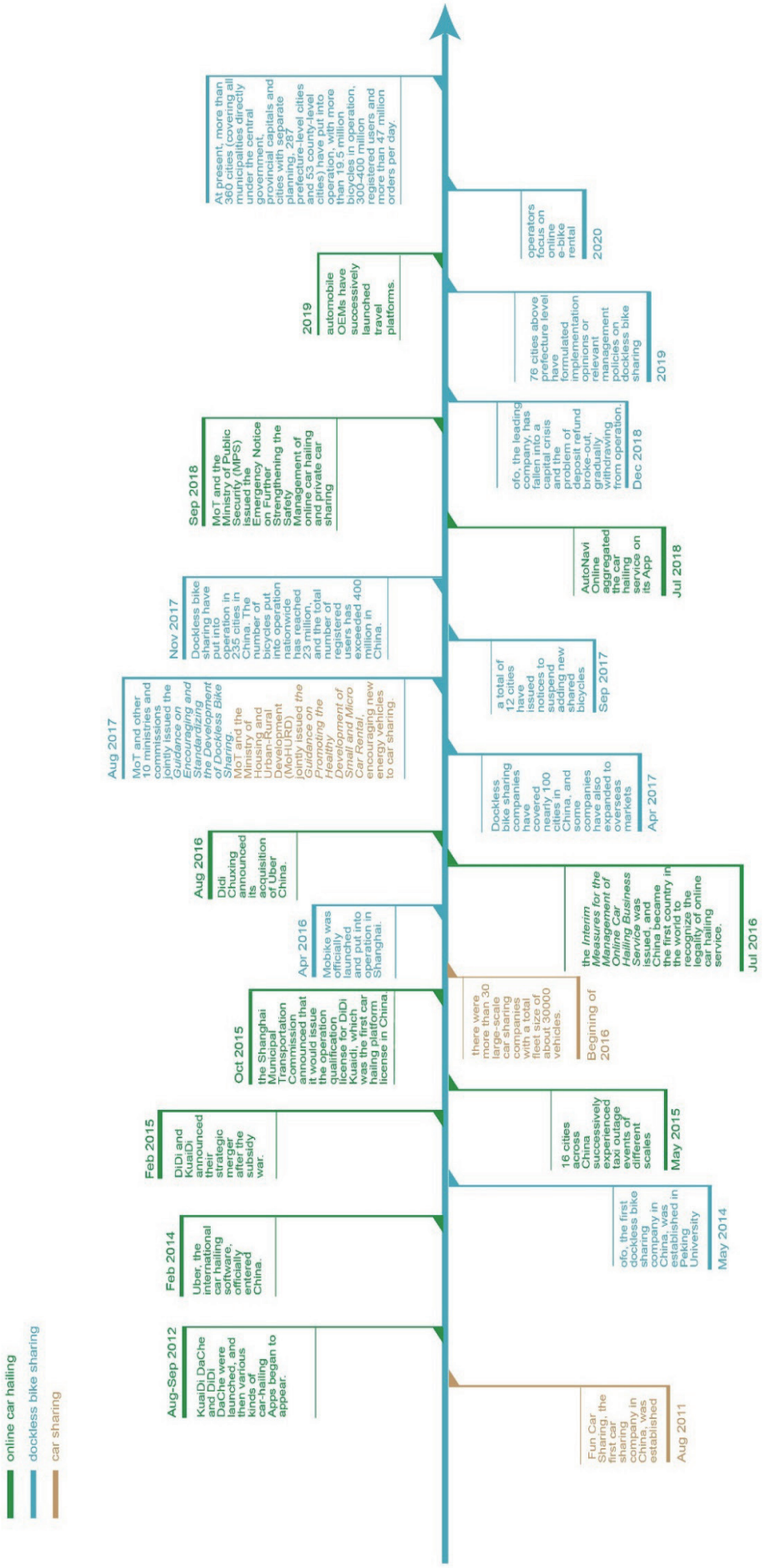
Car sharing services began to develop in the Chinese market after 2010, just as new energy vehicles (NEVs) were becoming commercially viable. Due to significantly lower charging and maintenance costs, NEVs are more economical than fuel cars. Additionally, auto companies hope to promote their NEV models through car sharing. As a result, NEVs have become the dominant vehicle type in China's car sharing market.

In August 2017, the MoT and the Ministry of Housing and Urban-Rural Development (MoHURD) jointly issued the Guidance on Promoting the Healthy Development of Small and Micro Car Rental, encouraging NEVs to be used in car sharing service models, and providing charging infrastructure support. With the support of this policy, the industry's development started to accelerate. At the end of 2017, there were 294 car-sharing companies active in China [16].

In 2018, due to fierce competition, several small and medium-sized operation platforms withdrew from the market. The majority of remaining operators gradually became concentrated within a few market-leading companies. In 2019, the development of the car sharing industry further slowed down, particularly in first-tier cities, where the development of these enterprises was restricted by vehicle number restriction policies[13] and a shortage of parking spaces.

[13] The vehicle number restriction policy means that residents can buy a motor vehicle only after they have obtained the qualification of buying a car through lottery or auction. The aim of this policy is to control the total number of cars in the city to ease traffic congestion. Getting the qualification to buy a car can be difficult, especially in densely populated first-tier cities. Taking Beijing as an example, the probability of winning the car plate lottery in 2020 was 0.000325.

■ **Figure 2: Milestones in the Development of MoD Services**



Source: CATS

3.2 Policy Analysis

This section will analyze national level policies relating to MoD services in China. An overview of all MoD-related national policies can be found in Table 4.

According to the released policies, the national government encourages the development of MoD services, such as dockless bike-sharing, car sharing and online car-hailing services, and hopes to achieve the development of MoD services in a way that is harmonized with the further development of traditional public travel services, such as bus and subway lines, which also provide public welfare services. In particular, the national government hopes to avoid excessive competition between emerging MoD services and traditional modes of public travel.

Table 4: National Policies and Regulations on MoD Services

Time	Name of Policy	Issuing Department	Objective
July 2016	Guidance on Deepening Reform and Promoting Healthy Development of Taxi Industry	General Office of the State Council	Bring car-hailing into the scope of taxi management.
August 2017	Guidance on Encouraging and Standardizing the Development of dockless bike-sharing	Ministry of Transport, Publicity Department of the CPC Central Committee, Cyberspace Administration of the CPC Central Committee, National Development and Reform Commission, Ministry of Industry and Information Technology, Ministry of Public Security, Ministry of Housing and Urban-Rural Development, People's Bank of China, General Administration of Quality Supervision, National Tourism Administration	Encourage the development of dockless bike-sharing, as it plays a positive role in building a green and low-carbon transportation system.
August 2017	Guidance Opinion on Promoting the Healthy Development of small and micro car Rental	Ministry of Transport, Ministry of Housing and Urban-Rural Development	Encourage the use of NEVs in the car-sharing industry and the construction of charging facilities.
May 2019	Measures for the Management of Users' Funds in New Transportation Formats (for Trial Implementation)	Ministry of Transport, People's Bank of China, National Development and Reform Commission, Public Security Commission, General Administration of Market Regulation, Banking and Insurance Regulatory Commission	Make specific provisions on the management of deposit and prepayment funds for users of new transportation formats (including online car-hailing, car-sharing and internet bicycle rental, etc.).

Time	Name of Policy	Issuing Department	Objective
May 2019	Green Travel Action Plan (2019-2022)	The Ministry of Transport, Publicity Department of the CPC Central Committee, National Development and Reform Commission, Ministry of Industry and Information Technology, Ministry of Public Security, Ministry of Finance, Ministry of Ecology and Environment, Ministry of Housing and Urban-Rural Development, State Administration for Market Regulation, National Government Offices Administration, All-China Federation of Trade Unions, China Railway Corporation	Promote the integrated development of MoD services. Transport enterprises are encouraged to provide high-quality travel services through internet technology.
September 2019	Outline for Building a Leading Transportation Nation	The CPC Central Committee, the State Council	Vigorously develop shared transportation, build a service system based on mobile internet technology, and develop MaaS.
July 2020	Opinions on Supporting the Healthy Development of New Business Forms and New Models, Activating the Consumer Market and Driving the Employment Expansion	National Development and Reform Commission, Office of Cyberspace Affairs, Ministry of Industry and Information Technology, Ministry of Education, Ministry of Human Resources and Social Security, Ministry of Transport, Ministry of Agriculture and Rural Affairs, Ministry of Commerce, Ministry of Culture and Tourism, Ministry of Health and Health Commission, State-owned Assets Supervision and Administration Commission, General Administration of Market Regulation, Medical Insurance Bureau	Expand the emerging sharing economy, encourage intelligent product upgrading and business model innovation in areas such as car-sharing, food-delivery, group buying, online drug purchasing, accommodation sharing, cultural tourism, and other fields.
September 2020	Opinions of the General Office of the State Council on Accelerating the Development of New Consumption with New Formats and New Models	General Office of the State Council	Further support the development of web-based services such as food-delivery, online car-hailing and accommodation sharing.

At the national level, policies for MoD services are concentrated on encouraging and standardizing the development of these initiatives. From the perspective of urban transportation, it is planned to vigorously develop MoD services to meet personalized travel needs of individuals.

The Guiding Opinions on Deepening Reform and Promoting the Healthy Development of the Taxi Industry issued by the General Office of the State Council in July 2016 was China's first policy involving MoD services. As a result, China became the first country in the world to give legal status to car-hailing services. The policy proposed to include car-hailing into the scope of taxi management, and noted that car-hailing is beneficial to alleviating traffic congestion and reducing air pollution and that municipal governments should encourage and regulate its development. In addition, the policy clearly stated that it was necessary to prioritize the development of urban public transportation, moderately develop taxis, and orderly develop car-hailing businesses in accordance with the principles of high-quality service and differentiated operation with taxis, to avoid competition or conflicts between these modes of transit.

In September 2019, the Central Committee of the Communist Party of China and the State Council promulgated the Outline for Building China's Strength in Transportation, which proposed to "accelerate the development of new business forms and new models, realize Mobility as a Service (MaaS)". According to the national government, MaaS comprised the future development direction of MoD services. MaaS was covered in the 2019 Outline in Section 4, entitled "Convenient and Comfortable Transportation Services - Cost-effective and Efficient", rather than in the Outline's Section 7 on "Green Development - Saving and Intensive - Low-carbon Emissions and Environmental Protection". This demonstrated that the national government first recognized MaaS as an opportunity to provide the public with higher-quality mobility services, rather than considering it initially as beneficial in promoting environmental and climate protection.

Current policies of China reflect the attitude of the government towards MoD. However, there are no specific implementation measures for MaaS mentioned in existing policies. For example, guidance is needed on how to provide the necessary infrastructure, technology and capital for the development of MaaS. Therefore, more detailed policy content is needed for the future development of MaaS, especially when it comes to data sharing, benefit distribution and other issues that need management support.

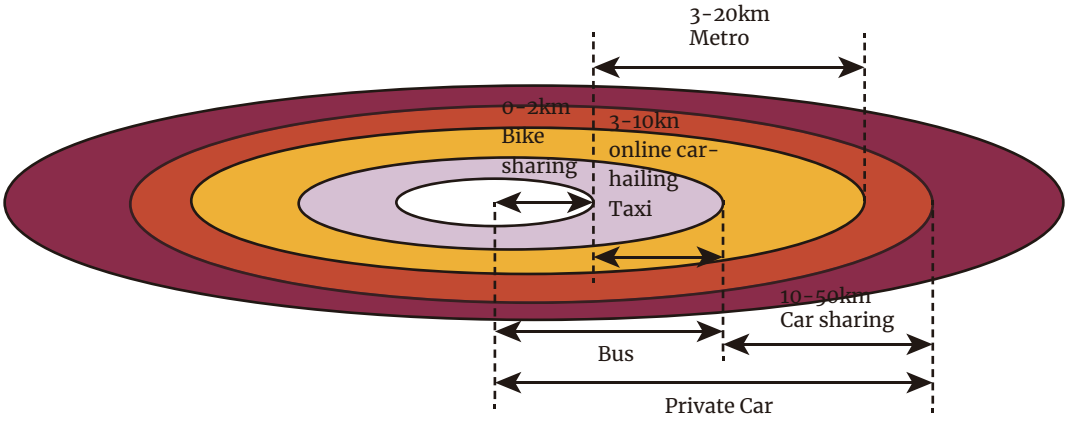
3.3 Analysis of the Impact of MoD Services on Traditional Public Transportation

The development of MoD services poses challenges to traditional transportation modes, but also offers synergies that can contribute to the attractiveness of traditional services such as bus and train networks. The root of competition between MoD and traditional transport services is the overlapping of service distances. For example, the average service distance of bicycle sharing operations is 3km, which is just within the average service distance of buses (see Figure 3), thus creating competition. Because of the same service mode, competition issues between taxi and online car-hailing operations are even more obvious. In contrast, one example of positive synergies between different transport services is the solution that dockless bicycle-sharing offers to the "Last-Mile" issue, rendering public transport to be more attractive to those that need an additional publicly available transport option to complete their personal transit route. The following report section will analyze the impact of MoD services on traditional transportation operations.

Car-hailing services have a significant impact on public transport networks in China. In a 2018 survey among car-hailing users in China, around 50% of ride hailing passengers switched from using public transport to car-hailing options (CATS, 2022). Ride hailing services have also had a significant impact on taxis. Since the introduction of online car-hailing, the annual passenger volume of taxis has continuously declined (see Figure 4), and the number of taxis has also decreased year by year (see Figure 5). In early 2017, after entering the Nanjing market, the ride hailing service Meituan DaChe competed fiercely with the ride hailing service of DiDi Chuxing,

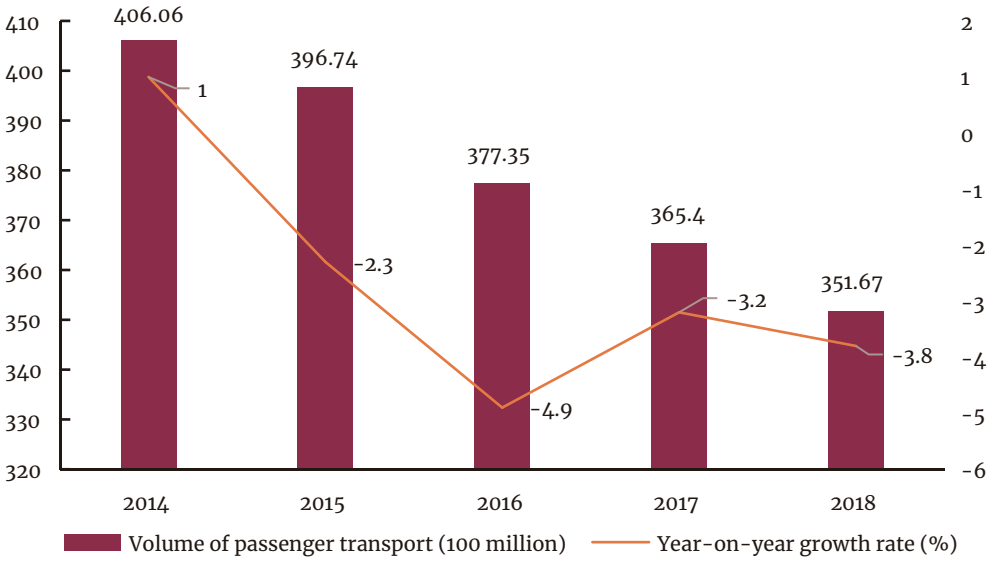
seizing the market by subsidizing drivers and passengers. In that year, the average number of daily orders of taxis in Nanjing decreased by half compared with the previous year. The decline of income for drivers led a decrease in the number of those choosing that profession. The Nanjing Transportation Bureau informed the research team of this study that more than 2,000 vehicles had been withdrawn by traditional taxi companies by the end of 2017, and more than 1000 vehicles were out of service by the first quarter of 2018. Interestingly, after 2018, with the start of cooperation between traditional taxi companies and ride hailing apps, traditional taxi services became available from car-hailing apps, and as a result, from 2018-2020, the number of taxis in operation has been steadily increasing, although the absolute number is still lower than it was in 2017 and previous years.

■ **Figure 3: Comparison of Travel Mode Service Scopes**



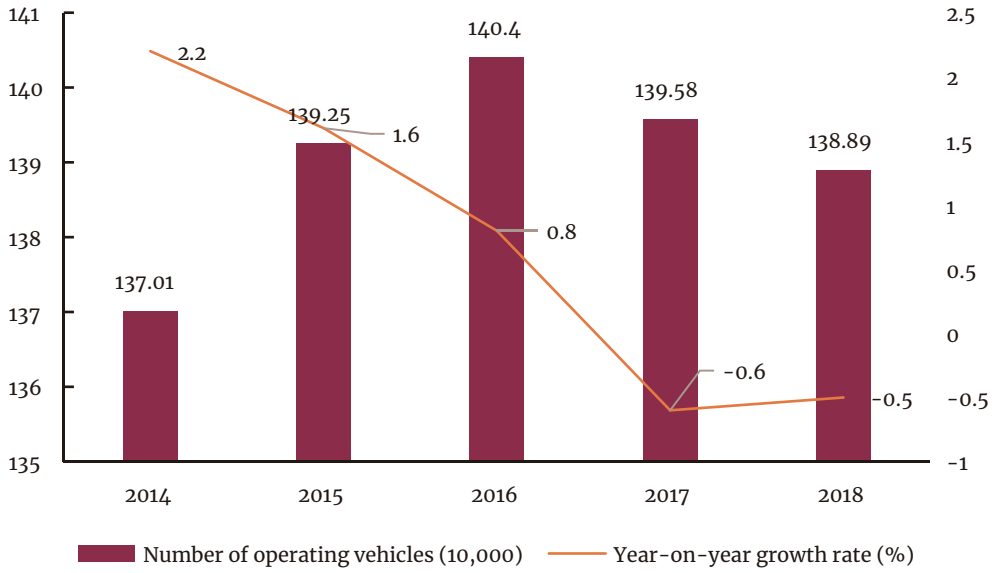
Source: CATS

■ **Figure 4: Annual Passenger Volume of Taxis in China**[17]



Source: CATS

Figure 5: Annual Number of Operating Taxis in China[18]



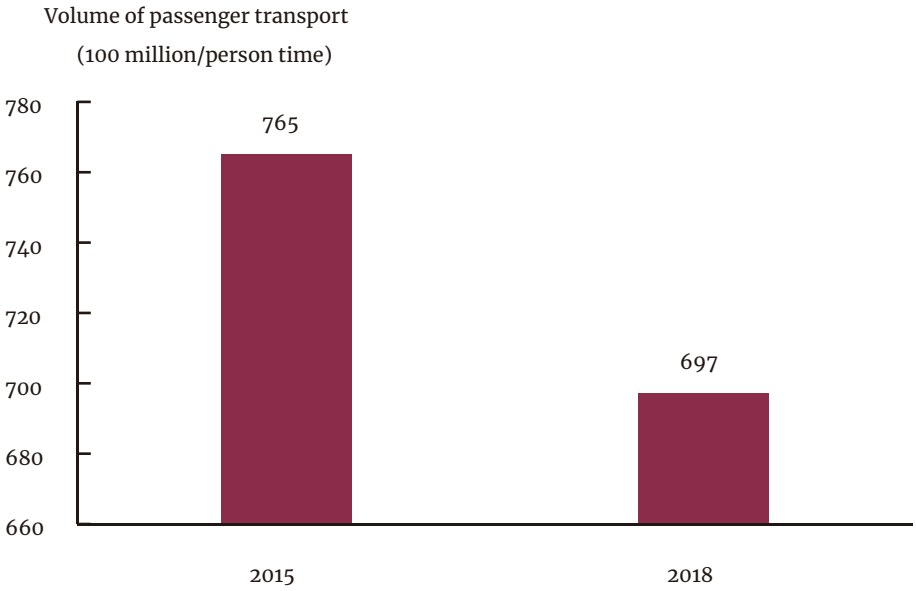
Source: CATS

There are two main reasons why ride hailing operations have had such a strong impact on taxis in China. First, users found online car-hailing to be more convenient than taxis. Passengers know how long they need to wait, allowing them to accurately arrange their trip. Second, car-hailing services provide more passenger-oriented services than taxis. Before the emergence of online car-hailing, the traditional taxi industry was monopolistic and often received complaints by passengers, for instance, about refusals to accept passengers, detours taken on selected routes, or poor attitudes of drivers. During bad weather, such as rain and snow, cases occurred where taxi drivers chose to maliciously raise their prices. Online car-hailing has clear regulations on travel prices, passenger and routing management, and nation-wide customer service networks. Passengers can choose their travel route on their mobile phones to avoid detours. Furthermore, the operation model of online car-hailing is completely market-oriented, which can protect the rights and interests of passengers and prompt drivers to improve their service levels, leaving the overall industry to provide win-win situations for both drivers and passengers.

However, the MoT does not want taxis to be completely replaced by online car-hailing, as taxis do have a certain degree of public welfare. For example, during public holidays, the administration can order taxi companies to increase their capacity at train stations and airports. However, car-hailing enterprises are purely private enterprises, reducing the influence the administration has on their operations. The administration therefore hopes that the competition between ride hailing platforms and taxis can make the taxi industry develop higher quality services, while still remaining operational and not being completely replaced by online platforms.

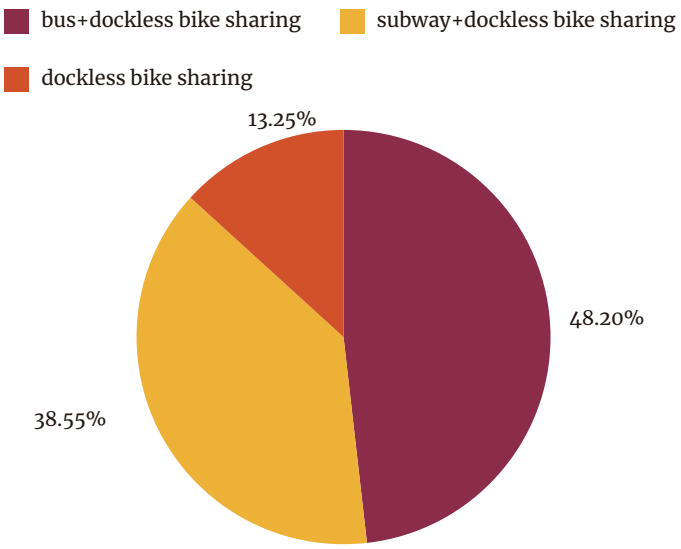
Bicycle sharing services are meeting the end needs of consumers, in particular the "Last Mile" problem. Dockless bicycle-sharing is quickly establishing itself in the travel market, with consumers choosing to use bicycles for short distance trips within 3 km. In Shanghai, for example, the average trip distance of bicycle sharing is 1.84km, and about 82% of the trips are within 3.5km[19]. In some areas, dockless bicycle-sharing schemes have expanded the service area of subway and bus stations (Cao, et al., 2019). However, rather than using them to complete their journeys, some users have switched from taking buses to only using shared bikes, which has resulted in a negative impact on the ridership of public buses (Yang, et al., 2017) (Figure 6). Though some users do use shared bicycles for the entirety of their trip (see Figure 7), bicycle sharing services are primarily combined by users with subway and bus routes to complete their journey's "Last Mile" which they would have previously covered by using an additional bus route or walking.

■ **Figure 6: Annual passenger volume of urban buses in China, in 100 millions**[20]



Source: CATS

■ **Figure 7: Proportions of combining dockless bicycle sharing with other travel modes in China**



Source: CATS

In order to maintain their competitiveness, the public transport and taxi industries are undergoing transformations in some cities in China. In August 2019, the public transport provider Zhenqing Bus and the private company DiDi Chuxing cooperated to try an on-demand responsive public transport service in Huangdao District of Qingdao City. Shenzhen, Nantong and other cities were also planning to provide customized public transport services after 2020, although the projects were delayed due to Covid-19 restrictions. To reduce the impact of online car-hailing operations on taxis, the MoT has been working on adjusting taxi pricing methods and increasing the income of taxi drivers. While the price of taxi fares is fixed, the price of online car-hailing fares is flexible and can be adjusted according to different periods and road congestion. At the Second Seminar on Reform and Development Policies of Cruising Taxis on August 31, 2019, representatives from the MoT encouraged cities to explore the government-guided pricing of taxis according to local conditions. Adjusting pricing mechanisms can increase the drivers' profits and increase the competitiveness of the taxi industry, particularly where car-hailing enterprises are also operating.

3.4 Stakeholders of MoD Services in China

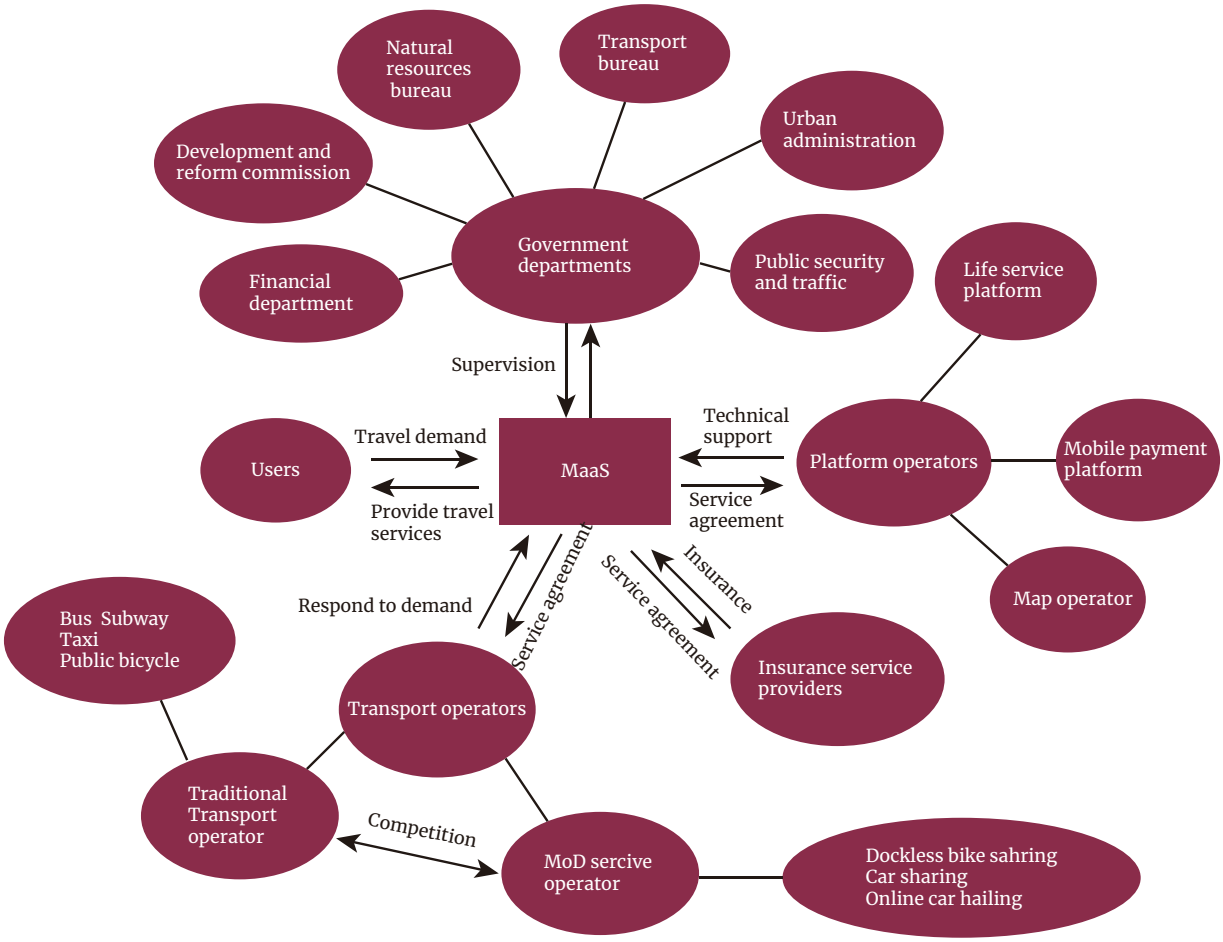
MaaS incorporates different modes of transportation into a unified platform. This integration allows users to complete the entire process of their desired journey – namely the steps of registration, planning, reservation, ticketing, payment, and fare clearing – within one system, which as well provides travel information to users and operators, and access to customer service. To be effective, this process poses considerable requirements on existing transportation modes and their management systems, such as the integration of planning, linkage, operation, and customer service stages for different modes of transportation, as well as the coordination of different mechanisms of relevant departments, and operation and management entities of various transit services.

During the initial phase of development, MaaS requires subsidies and support from governments in terms of fund supervision, credit supervision, and information security assurance. MaaS platform construction requires coordination among different stakeholders and their interests and ultimately the establishment of a MaaS system comprising these stakeholders, which specifies the relationship and responsibilities of all relevant stakeholders in the system (see Figure 8).

3.4.1 Macro-level Stakeholders

Based on an analysis of the development of MoD towards MaaS systems in China, the main stakeholders involved in MaaS systems include platform operators, government departments, transport operators, insurance service providers, and end users. The responsibilities and interests of different MaaS stakeholders in China are summarized in Table 5.

■ **Figure 8: Stakeholder Model of MaaS**



Source: CATS

3.4.2 Stakeholders at the City Level

At the municipal level, the government departments, transport operators and platform operators involved in MaaS may be analyzed in a more detailed manner.

(1) Government management departments

Government departments mainly include the local transport planning authority under the national MoT (Transport Bureau), the public security and traffic management bureaus, urban administration bureaus, development and reform commissions, natural resources bureaus, and financial departments. Their respective responsibilities are displayed in Table 6.

(2) Transport operators

Transport operators can mainly be divided into operators of traditional transport modes and operators of MoD services. Operators of traditional transport modes and MoD services differ significantly in the way that they operate (see Table 7). Bus, subway and taxi enterprises are limited to the city they operate in and do not compete with operators in other cities, whereas MoD service providers expand nation-wide – without being limited by urban boundaries – and compete with other providers on a national level (see Table 8 for a list of MoD enterprises currently in China).

■ **Table 5: MaaS Stakeholders**

Stakeholders	Responsibilities	Aspiration
Internet-basedMoD operators	Designing and providing MaaS products in response to customer demands; having the capability of integration of real-time information, travel planning, payment, and ticketing; having the license approved by the administrative department; having the capability of platform operation and maintenance	Owning the platform and related travel data
Government departments	Formulating laws, rules, policies and guaranteeing measures related to service license, credit system, data exchange, information security and privacy protection	Coordinating the development between different transport operators, enhancing industrial vigor, and improving transportation efficiency
Transport operators	Providing travel services, covering different transport modes including (electric) buses, subways, bikes, taxis, Ride Hailing, car-sharing and dockless bicycle sharing	Attracting new customers, maintaining old customers, increasing operating revenue and striving for maximum benefits
Insurance service providers	Providing insurance for personnel, passengers, and vehicles	Specifying the responsibilities of all participants in the travel process, and developing innovative insurance models
Users	Providing necessary personal information and travel requests to transport operators	Enjoying customized service with lower travel costs, higher comfort and better protection of personal privacy

Table 6: Urban Administrative Departments and Responsibilities

Name of departments	Responsibilities
Transport bureaus	Formulating traffic policies and systems, coordinating the positioning of different modes of travel, and preparing development frameworks
Public security and traffic management bureaus	Maintaining traffic order through law enforcement management
Urban administration bureaus	In some cities, taking charge of operation management of dockless bike-sharing
Development and reform commissions	Formulating guiding policies and opinions on infrastructure
Natural resources bureaus	Formulating land use planning on public transport and slow-moving traffic from the urban level
Financial departments	Raising funds for traffic development, supervising payment institutions and guaranteeing payment security

Table 7: Classification and Characteristics of Urban Transport Operators

Category of operators		Business nature	Characteristics
Operators of traditional traffic modes	Bus companies	State-owned enterprise	1. Requiring financial subsidies from the government for public benefit; 2. As state-owned enterprises, bus and subway enterprises lack momentum to attract users; 3. Profitmaking is not the primary task of enterprise development (taxis excepted); 4. Mastering travel data of passengers; 5. Enterprise development is guided by government departments.
	Subway operators	State-owned enterprise	
	Taxis	Private enterprise	
	Public bikes	Private enterprise	
Operators of MoD Services	Ride hailing	Private enterprise	1. Operators are private enterprises and market-oriented; 2. Actively exploring customers' travel demands and accordingly providing travel services; 3. Strong technical capability in data analysis and platform operation; 4. With advanced development concepts, enterprises advocate the development of MaaS.
	Dockless bike- sharing	Private enterprise	
	Car sharing	Private enterprise	

Table 8: Representative Enterprises of MoD in China

Ride hailing	Online leased bikes	Car sharing
DiDi Chuxing	Qingju Bike	GoFun Travel
Hellobike	Meituan Bike	Global Carsharing
Meituan	Hellobike	Panda Travel
Caocao	Local small-brand enterprises	
Shouqi Limousine & Chauffeur		
Local small-brand enterprises		

(3) Platform operators

Online platform operators include digital map service providers such as Baidu and Amap (Gaode Maps), mobile payment platforms such as Alipay and WeChat, and life service platforms, such as Meituan DianPing (see Table 9). These platforms are characterized by having efficient operational technology and a large number of users. Having access to position-based travel data, Baidu and Amap platforms enjoy advantages for the development of MaaS.

The fact that China's mobility sector involves such diverse stakeholders means that it will be challenging to promote MaaS in China. Because the demands of various stakeholders are different, cooperation is possible only when a mode satisfactory to all parties is found. The next chapter of this report will introduce MaaS programs in China and their current and prospective development models.

Table 9: Classification of Platform Operators in China

Platform Operators		Characteristics	Common Points
Map operators	Baidu Map	Position-based travel data	1. Having large user bases 2. Enterprises have abundant funds and strong technical R&D capacity
	AMAP		
	Tencent Map		
Mobile payment platforms	Alipay	A payment platform that started with online shopping but has gradually transformed into a lifestyle service platform.	
	WeChat	A software application that provides instant messaging services for users, with more than 1.2 billion active users per month.[21]	
Life service platforms	Meituan	This platform has formed an ecosystem including travel, accommodation, entertainment, shopping and takeout services.	

4 FROM MoD TO MAAS – EXPLORATIONS BY CHINESE CITIES

Both Chinese public and private stakeholders have made efforts to date in developing MaaS. Chinese public transport services providers, mostly State-owned Enterprises (SOEs) in monopolistic positions, lack the required motivation to develop MaaS. The difficulties they face mainly lie in the fragmented governance system of the transport sector, since public urban passenger transport methods (including urban rail, buses, water transport and other sectors), urban rural transport, and inter-city transport all fall under different governance systems. Thus, the integration of all of these systems would require high-level and systematic approaches to alter management methods. Though there are some degrees of integration of different types ofurban transport via unified mobile ticketing platforms, such as the Beijing Yikatong[14] app, these public examples are currently limited in nature. On the other hand, MoD service providers such as Didi Chuxing and navigation apps such as Amap or Baidu are keen on developing MaaS and already have the management potential to provide nationwide operation. However, it is still extremely difficult for such platforms to integrate public transport sectors with private sector transport options, as initiated in MaaS platforms.

This chapter introduces several local initiatives that aim at developing a MaaS systems now, or potentially in the future. Each of the case cities discussed here as already achieved certain degrees of integration of different modes of transport, including between public transport options and new public and private mobility services. Based on the varied levels of MaaS travel integration[15] referred to in chapter 2, cases discussed in this section of the study are still considered to be at very early phases of MaaS. Although all the initiatives are called "MaaS" by local authorities, the actual MaaS phase that each of these transport initiatives has reached greatly varies. The slow development and high variety of these initiatives show that MaaS systems are still being developed in China in a decentralized manner, and that local transport authorities play a guiding role in their development. The case cities and regions covered here include the Greater Bay Area as a whole, the city of Shenzhen, Guangzhou and Foshan, and the city of Beijing.

[14] Beijing Yikatong （北京一卡通）: A card issued by the transport authority of Beijing. Users of Beijing can take public transport including buses and rail transit within the Jing-jin-ji area and enjoys some discount on fares while using these centralized cards in Beijing.

[15] October 2017， Source: https://www.itf-oecd.org/new-shared-mobility-study-helsinki-confirms-ground-breaking-lisbon-results

4.1 Regional Integration through MaaS in the Greater Bay Area

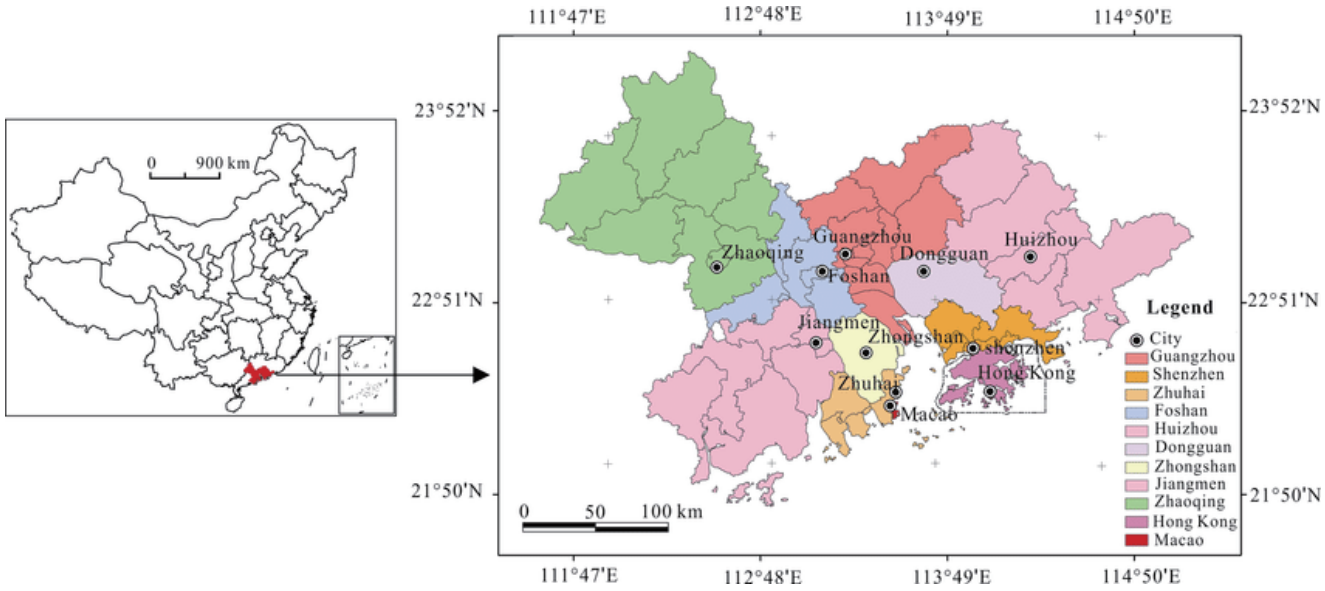
4.1.1 Overview of the Greater Bay Area

The Guangdong-Hong Kong-Macao Greater Bay Area (generally referred to as the Greater Bay Area) is an urban agglomeration consisting of eleven cities in South China's Guangdong Province (see Figure 9). These cities include the two special administrative regions of Hong Kong and Macau as well as the cities of Guangzhou, Shenzhen, Zhuhai, Foshan, Zhongshan, Dongguan, Zhaoqing, Jiangmen, and Huizhou. The integration of the entire region as an economic and business hub is a major governmental scheme. The Greater Bay Area covers an area of 56,000km^2 and has a population of over 70 million, making it the world's largest urban agglomeration. Its total Gross Domestic Product (GDP) exceeded 12.6 trillion yuan (1.8 trillion euro) in 2021.

Prior to the establishment of the Greater Bay Area as a jurisdictional entity, some of the cities, such as Guangzhou and Foshan, had already developed strong intercity transportation linkages. The development of a MaaS system for the region could benefit the region's further infrastructure and socio-economic integration and increase its economic viability.

The Outline Development Plan for the Guangdong-Hong Kong-Macao Greater Bay Area[22] issued by the Central Committee of the Communist Party and the State Council of China[16] in 2019, laid the foundation for the further integration of the transport systems of the region. The Outline aims at connecting the mainland with Hong Kong and Macau, the east and west coasts of the Pearl River Estuary, and thus achieve "one hour access" for any location within the region. These goals will be achieved by building an intercity rapid traffic network of high-speed railways, intercity railways, and high-grade highways. In July 2019, the government advisory board Guangdong Provincial Leading Group for Promoting the Construction of the Guangdong-Hong Kong-Macao Greater Bay Area[23],[17] issued the Three-year Action Plan for Guangdong Province to Promote the Construction of the Guangdong-Hong Kong-Macao Greater Bay Area (2018-2020) to encourage third-party service providers to develop "one-order" and "one-ticket" intermodal passenger transport services with "access to the entire Greater Bay Area."

■ **Figure 9: The Guangdong-Hong Kong-Macao Greater Bay Area**[24]



Source: CATS

[16] The Central Committee of the Communist Party of China is the core power organ of the Communist Party of China elected by the National Congress of the Communist Party of China. The State Council is the highest state administrative organ.

[17] OThis group is formed by officials in the provincial government. Its main task is to formulate development plans in Guangdong Province in accordance with the requirements of the central government.

Although not specifically mentioning the development of a MaaS system, the Action Plan proposes the innovative and integrated application of information technologies, such as the Internet of Things, cloud computing, and big data for the transportation field.

The development of MaaS in the Greater Bay Area has unique advantages. First, the Greater Bay Area has the infrastructure to develop into a world-class transportation region. Guangdong, Hong Kong and Macao Dawan District have airports and ports connecting China and the world, as well as railway hubs connecting the Pan Pearl River Delta[18] and Southeast Asia. It has more than 2,500 kilometers of railways and intercity rail transit, and nearly 1,000 kilometers of urban rail transit. The highway mileage of the Greater Bay Area is about 65,000 kilometers, and the density of the expressway network has reached 7.96 kilometers / 100 km^2. The density of the road network in the core area has exceeded that of the three bay areas of New York, Tokyo and San Francisco. Secondly, urban agglomeration in the Greater Bay Area has considerable scale, and economic and urban-rural integration have reached a profound stage in this area. Daily intercity travel within the Greater Bay Area has become the norm for residents. For example, the number of average daily cross-city commuters between Shenzhen, Dongguan and Huizhou has exceeded one million. With the dense distribution of the eleven cities in the region, the close linkage of intercity public transportation infrastructure and services, and the high-density urban design of each city[19], the Greater Bay Area poses a strong basis to develop the first cross-city MaaS system in China. Furthermore, as one of the urban agglomerations with the highest GDP globally, the Greater Bay Area, has a solid economic foundation for developing a MaaS system.

Besides the Greater Bay Area's broad endeavor to establish a joint MaaS platform for the region, public and private actors in the region's cities are also exploring the development of MaaS platforms for the individual city areas. The status of development in Shenzhen, Foshan, and Guangzhou are summarized further below.

Shenzhen is a forerunner region for data sharing and management. Foshan is unique due to its developed transit alliance which integrates the services of different bus operators, and Guangzhou provides an example of a region with an app that offers the option for users to create joint booking for buses and shared bikes. These are all relevant case study examples that can be together seen as first steps towards the development of a broader MaaS platform for China.

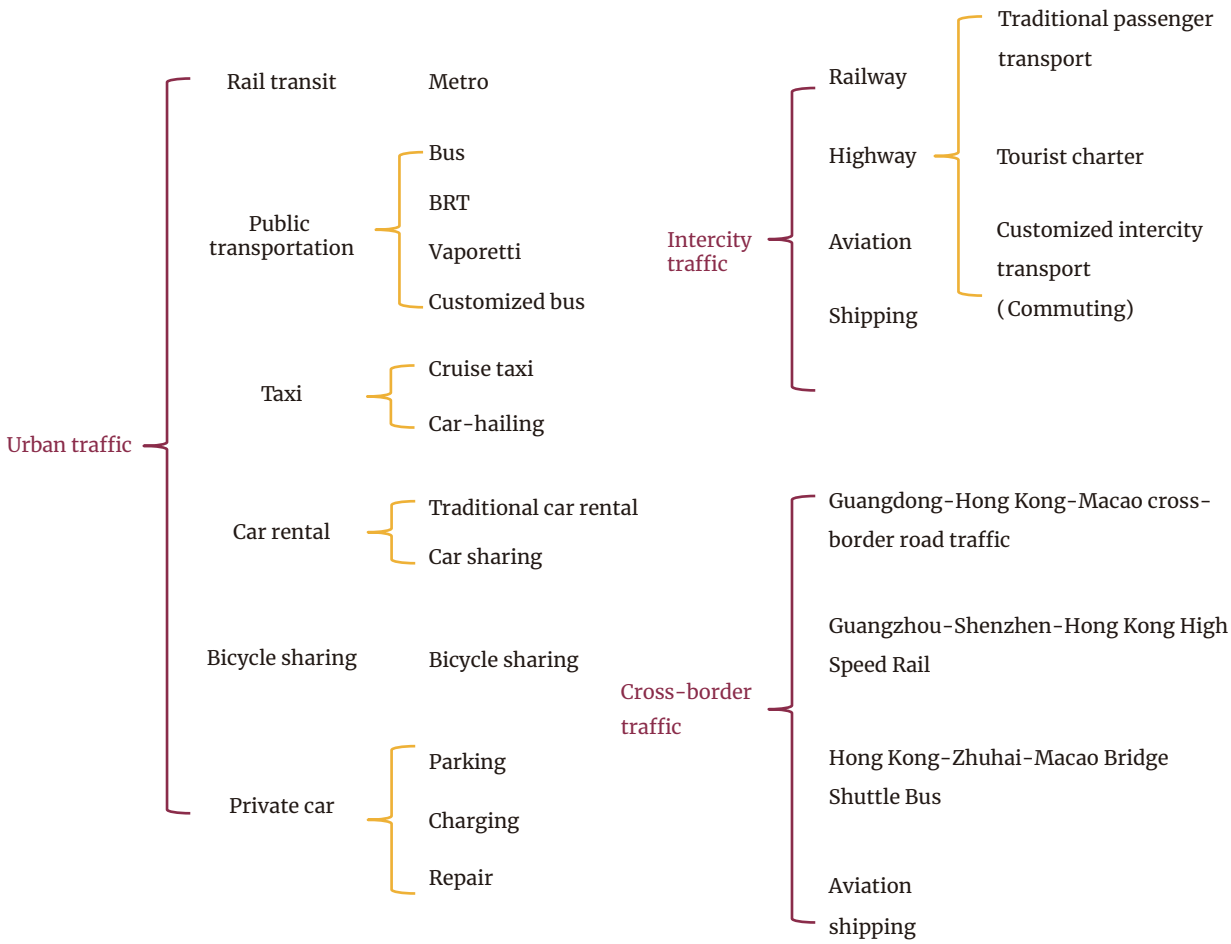
4.1.2 Status and Challenges

Transport methods in the Greater Bay Area includes urban transport, intercity transport, and cross-border transport options with a high variety of transportation modes and services available, as shown in Figure 10. This variety of transportation modes is managed by public and private operators. The Greater Bay Area has begun to explore integrated transportation plans, including across travel methods and city boundaries. At the end of 2018, the Guangzhou-Foshan subway line was put into operation. With 15 stops in Foshan and 10 in Guangzhou, the subway is a combination of intercity and urban rail transit. It is the first subway line to cross prefecture level administrative boundaries in China, and an important corridor connecting Guangzhou and Foshan. Guangzhou has launched a trial of a "One Code Pass" for public transport in the Greater Bay Area. The public transport group Yangcheng Tong Limited from Guangzhou cooperates with Alipay to enable Hong Kong residents to take Guangzhou's public transport by paying with Hongkong Dollar in the AlipayHK app. However, these efforts are not enough to make a coordinated system function smoothly, and there are still many problems in the Greater Bay Area's transport integration efforts.

[18] The Pan-Pearl River Delta, which consists of 9 provinces, Fujian, Jiangxi, Hunan, Guangdong, Guangxi, Hainan, Sichuan, Guizhou, Yunan and 2 Special Administrative Regions of the People's Republic of China, Hong Kong and Macao, is also commonly known as "9+2".

[19] BA high density city refers to a city with a high population and building density. High density cities provide a certain basis for the development of MaaS.

■ **Figure 10: The transportation modes and services of each type of traffic in the Greater Bay Area**



Source: CATS

The key challenges to develop a MaaS system in the Greater Bay Area are as follows:

- **Integration of ticketing services for intermodal travel:** There is no service platform integrating all travel modes. Each travel service currently has a separate app for ticket purchasing;
- **Transfer between travel modes:** Since travel services are operated independently, options to transfer between different modes have not been considered during the construction and operational management stages of current existing services. This disconnection in planning for linked services leads to inconveniences, for example, long transfer distances between subway and bus stations, not enough bicycle parking spaces around bus stations, and repeated security inspections when transferring between subway and railway stations;
- **Data management:** There is a general lack in data on traffic demand or user preferences and profiles. This gap is rooted in missing coordinated data management and data sharing between different providers, as well as a lack of transport surveys of users. This shortcoming results in non-personalized transport planning and provision, for example, a lack of data on preferred travel modes of cross-city passengers or demands for travel efficiency and comfort means that transport authorities do not have the information they need to effectively formulate appropriate and relevant development plans for cross-city travel.

4.1.2 Analysis of Causes for Challenges

The causes of the aforementioned challenges include: the lack of centralised coordination and management of infrastructure and transport service planning and operation, nonuniform standards, differing methods of governance, and varied monetary systems used in transit services in the region.

(Challenge 1) There is a lack of coordinated intercity and interdepartmental planning and operation of different transport services.

- The development of intermodal passenger transport and MaaS in the Greater Bay Area requires the involvement of multiple authorities. Currently, there is no cooperation mechanism between these authorities in place. The authorities show a lack of management over intercity transport options. Under the governance principle of "One Country, Two Systems"[25], it is particularly difficult to coordinate between Hong Kong, Macau, and cities in the Guangdong Province. For example, differences in data protection under different local systems causes difficulties in travel data sharing.
- Due to the lack of a centralized operating institution, each travel service provider operates with its own independent network, technology and management systems, making it difficult to align these services.

(Challenge 2) The foundation for the integration of ticketing services for intermodal passenger transport in the Greater Bay Area is weak. This is due to the lack of data sharing mechanisms and a lack of coordination between the management of these services, leaving to a lack of compatibility or mutual recognition of ticketing service criteria. For example, the types of tickets, criteria for ticket payment, clearing and settlement, as well as standards for ticket inspection and security checks are different for various types of transport in the region.

- Each city has its own passenger transport management system and mechanisms. The standards and structures of databases used in various transportation modes are different, and data availability is uneven across different cities.
- There are considerable differences in ticket service industry standards and business norms among Hong Kong, Macau, and other cities in Guangdong Province, as well as between different modes of transportation within single cities. For example, each city has its own unique rules and preferential policies for public transport fares. The coordination of rules for fares and benefits will be a major challenge for the integration of different travel modes both within and between cities.

(Challenge 3) Differences in currencies and subsidies lead to a lack of interconnection and interoperability between travel services.

- There are three independent currencies in circulation in the Greater Bay Area: the Renminbi, Hong Kong Dollar, and Macau Pataca. Each location that uses different currencies also have their own currency regulatory policies, and are exposed to risks of foreign exchange control and exchange rate fluctuations, making a harmonization of fares even more challenging.
- Different cities use different subsidy systems and pricing policies for public transportation. This situation results in different subsidy allocation and amounts both between different services and between and within varying locations.

(Challenge 4) A lack of coordination of safety supervision systems demands a new coordinated, mutual recognition of security inspection methods both between cities and across transportation modes.

- There are differences in the laws, regulations, and policies related to passenger safety and data security across locations and travel modes. This variance complicates the construction of an effective MaaS system, as they require unified standards for the collection, protection and use of user travel data.
- Security inspection standards differ between transportation modes and cities. Subways, high-speed trains and urban and rural passenger transport modes all have their own security inspection systems. Currently, passengers are required to repeat security inspection every time they transfer between different modes of transport. A coordinated, mutual recognition of security inspection systems between all modes of transportation in the Greater Bay Area would reduce the number of security checks faced by users, and thereby improve travel efficiency.

4.2 Shenzhen: Government Initiation in Data-Sharing

4.2.1 MoD in Shenzhen

Located on the south coast of Guangdong Province, Shenzhen is one of the most important economic hubs in China. At the end of 2020, the city had a total area of 1,997.47km^2, a built-up area of 927.96km2 and a permanent population of 17.56 million residents. In 2020, the GDP of Shenzhen reached 2,767 billion yuan (395.7 billion euro).

Shenzhen has 933 bus lines and 11 subway lines, ranking fifth in the mileage of urban rail transit in China. The total number of motor vehicles in the city is 3.6 million, including a total of 394,000 NEVs (accounting for 11.0% of all motor vehicles). By the end of 2019, about 808 kilometers of bike lanes had been built, and more than 300 kilometers of new bike lanes were to be built each subsequent year. Table 10 outlines the scale of the main modes of transportation in Shenzen in 2021.

The Shenzhen municipal government has adopted an intelligent way to manage MoD services by building intelligent monitoring platforms and requiring all MoD providers to transmit data to these public hubs. These platforms, including an online car-hailing platform, a bicycle sharing platform, and a public transport platform, are all managed by the Shenzhen Transportation Bureau. Through these platforms, the Shenzhen Transportation Bureau can trace the daily operation of all types of registered transport, including for example, dockless bicycles and ride-hailing vehicles.

By 2021, there were three dockless bicycle sharing companies (Hello Bike, DiDi Bike[20], Meituan Bike) operating in Shenzhen, with a total of 480,000 bicycles and 900,000 daily orders. Shenzhen has imposed a total control on the number of shared bicycles available in the city. The number of bicycles each company is allowed

Table 10: Scale of transportation modes in Shenzhen, 2021

Transportation Mode	Average daily passenger volume (Unit: 1000)	Scale	Operators
Public bus	4,355,000 passengers	933 bus lines	Shenzhen Western Bus Co., Ltd. Shenzhen East Public Transport Co., Ltd Shenzhen bus group
Subway	5,538,000 passengers	11 subway lines	Shenzhen Metro Group Co., Ltd
Taxi	1,133,000 passengers	20,609 taxis	64 companies
Dockless bicylce sharing	900,000 users	480,000 bicycles	Hello Bike DiDi bike Meituan bike
Ride-hailing	699,000 passengers	64,144 cars	27 companies: DiDi Cao On Time

[20] The share bike scheme of Didi Chuxing.

to operate is dynamically adjusted according to the service quality of the three companies. Based on the data retrieved from the bicycle sharing platform, the Shenzhen Transportation Bureau assesses the service quality of the three companies quarterly. On the premise that the total number of shared bicycles in the city remains unchanged, companies with positive assessments are allowed to operate more bicycles, while the number of bicycles of enterprises with less positive assessments will be reduced. The standards and results of the service quality assessment are made public. This management mode provides a level playing field and positive incentives for the development of the industry.

4.2.2 Government-led Data Sharing

By 2021, the number of online ride-hailing vehicles in Shenzhen was 64,144 with an average daily order of 699,000 rides. All ride-hailing vehicles are connected to ride-hailing information platforms. Shenzhen has adopted a market-based regulation method for online ride-hailing, and the transport bureau regularly publishes the average income and average daily orders of ride-hailing drivers in Shenzhen on its website. Figure 11 shows an illustration of a car management platform interface in Shenzen.

The Shenzhen Transport Bureau has set up fair competition rules for MoD services, such as service quality assessments. This fair competition environment has enhanced the confidence and willingness of enterprises to cooperate with the government, which is conducive to the further cooperation between the two sides in the development of MaaS. It also benefits end users in ensuring their access to monitored, quality services.

In addition, Shenzhen became the first city in China that actively shares public transport data with a private company. With the aim to improve bus services, the Shenzhen Transportation Bureau (as the responsible governmental transport planning authority) has signed a strategic cooperation agreement with the private transport provider Hailiang Technology Co., Ltd., and shares data from the Shenzhen Transportation Operations Coordination Center (TOCC) with the company to support its exploration of MaaS. TOCC is a comprehensive transportation platform, which collects, monitors, analyses, forecasts, and dispatches data on urban traffic passenger flows. Even though many Chinese cities are building their own TOCCs, there is not yet another case in China of such active data sharing from the government with a private transport company.

Although the Shenzhen Transportation Bureau is open to data sharing, private companies do not intend to make their data resources available to the public in the near future. For example, in a discussion with DiDi Chuxing, the company expressed their concern to the research team about sharing their data with other companies. This concern is especially true for companies that already have a large share of the market and are aiming to become industry 'unicorns'. Sharing data with other companies is not perceived to be conducive to their own successful development.

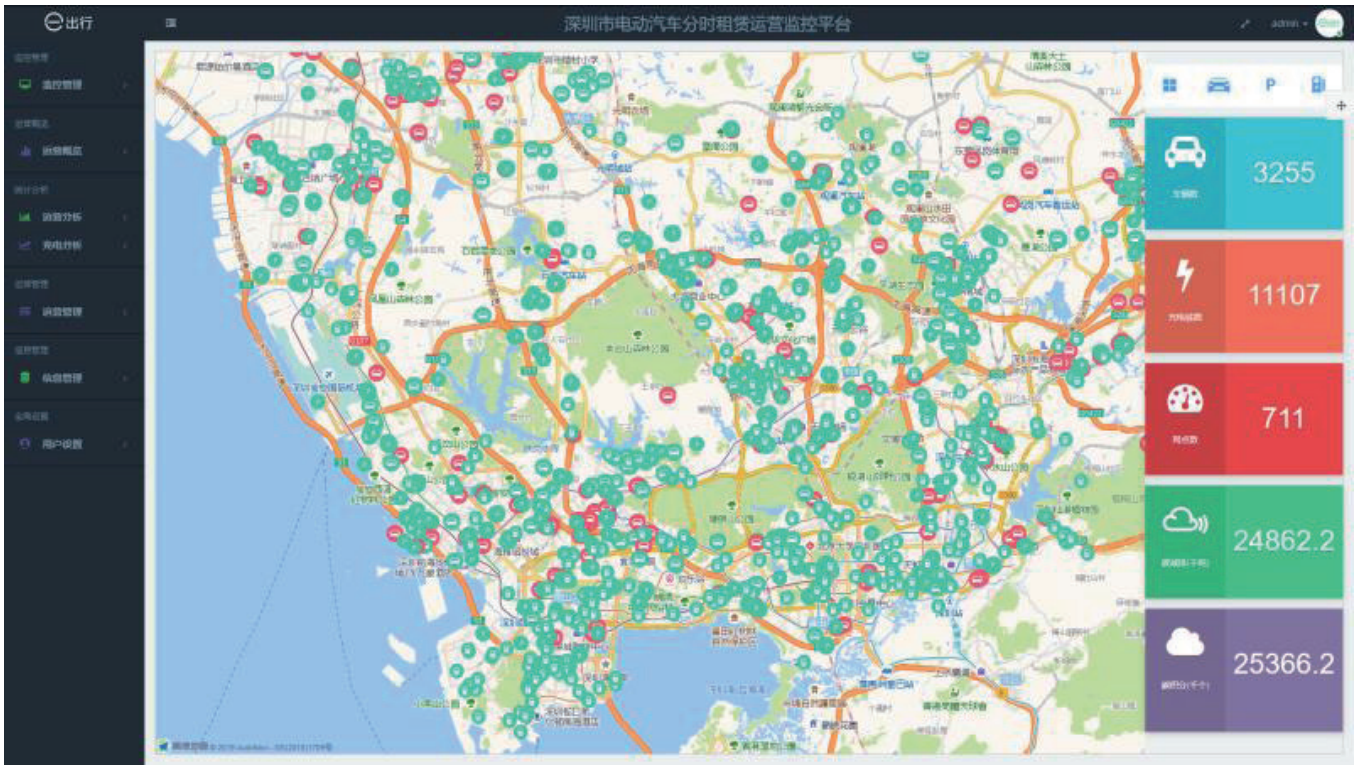
Shenzhen is currently exploring data legislation to lay the foundation for more comprehensive data sharing of public data. In July 2020, the Shenzhen Municipal Bureau of Justice solicited opinions on the publication Data regulations of Shenzhen Special Economic Zone[21]. The purpose of this document is to promote the disclosure and comprehensive sharing of public data and to explore how to conduct public-private data interactions. The document proposes to build a public data resource management system and open public data to society. This initiative would help to promote data sharing in the transportation industry and solve the problem of data shortages faced by MaaS.

4.2.3. On-demand Bus Pilot

As an early trial of a MaaS initiative, an on-demand bus pilot is being explored by the Shenzhen Bus Group – 5th Branch Office and Hailiang Technology Co., Ltd. The project is called Maishi Chuxing (麦诗出行), a phonic translation of MaaS Mobility in Chinese. Through the "MaaS Travel" app, passengers can select the time, boarding station, and destination station in the pilot area where their end to end travel can be made, with guaranteed seats. In the first phase of the pilot, this service was used by almost 10,000 passengers (see Figure 12).

[21] The Shenzhen Special Economic Zone was established in 1980 and was the first pilot city in China to develop a market economy.

■ Figure 11: Shenzhen car sharing management platform interface



Source: CATS

■ Figure 12: MaaS Shuttle Bus under operation

Source: CATS

4.3 Foshan: Transit Community as a Potential MaaS Platform

Foshan City is another unique case location in the Greater Bay Area. Located in the central part of Guangdong Province and adjacent to Hong Kong, Macau, and Shenzhen, it takes less than one hour to travel to these three cities from Foshan by high-speed rail. Foshan has a total land area of 3,797.72km^2. In 2019, it had a population of 8.16 million residents, and is a national advanced manufacturing base and an important manufacturing center for Guangdong Province. In 2021, Foshan achieved a regional GDP of 1,215.7 billion yuan (174.0 billion euro), ranking 3rd in Guangdong Province and 17th in the whole country.

Foshan city has a total of 6,487 buses, 674 bus lines and an average daily passenger flow of 1.48 million people. There is only one subway line in operation in the city, which connects Foshan and Guangdong, with a total length of 37.96 kilometers. It is the first subway line that runs across prefecture level administrative regions in China.

By the end of 2020, there were 36,402 online ride-hailing vehicles in Foshan, with an average daily order volume of 351,200 rides. Three bike-sharing companies (HelloBike, DIDI Bike (by Didi Chuxing), and Meituan Bike) have registered 440,000 bikes in Foshan (see Table 11).

In 2008, Foshan was the first city in China to introduce the transit alliance concept. What the city calls their "transit community" or "TC" is an alliance of bus operators, established with the goal of balancing both public service and market-oriented operations of public transport. The TC model contributes to the improvement of the service quality of public transportation and might potentially increase passenger flow on future MaaS platforms. This operating model has therefore already laid the foundation for the development of MaaS in the city.

Under the traditional bus operation model in China, a city usually has only one bus operator. The operators are state-owned and receive annual government subsidies. In the TC model, bus operators are selected through a bidding process and only those private operators with a good performance record can be granted the opportunity to expand their operation on more routes and thus win larger profit margins. In this model, local transport authorities play the role of the evaluator to prevent companies to operate only with pure market-driven behaviors with excessive competition tendencies. Therefore, the TC model does not only avoid an industry monopoly as caused by traditional modes of management, but also acknowledges bus services as public welfare provisions.

Table 11: Transportation services in Foshan

Transportation Mode	Average daily orders/passenger volume (Unit: 1000)	Scale	Operators
Regular bus	Passengers: 1,530	674 lines	–
Subway	Passengers: 1,484	1 line	Foshan Railway Investment and Construction Group Co. LTD
Cruise taxi	–	36,402 taxis	64 companies
Dockless bike sharing	Orders: 1,000	440,000 bicycles	Hello Bike DIDI bike Meituan bike Liu Bike
Ride-hailing	Orders: 400	36,402 cars	16 companies DIDI UCAR CAO

The TC model is composed of government decision-makers, a management unit and single bus operators and acts as a managing system for bus operations, which makes it a unique institution in China's transport landscape. Table 12 lists the responsibilities of each participant in the TC model. Government authorities are responsible for planning and decision-making processes, granting bus operators the right to operate routes in a competitive manner through service contracts, providing financial subsidies based on cost accounting, and authorizing the TC management unit to supervise the overall operation and services of bus operators. Furthermore, the government collects fares in a unified manner and puts forward service quality requirements for operating companies.

The responsibilities of the TC management unit include route planning, bidding for operators, managing ticket revenues, fee settlement with bus operators, and the assessment of bus operators' services. The bus operator who wins the bid is required to provide bus services in accordance with the contract.

Foshan's TC model already features some basic characteristics of MaaS with elements of public-private cooperation, the introduction of multiple private stakeholders into public transport operations, and unified ticketing modes among various private operators. However, it still lacks a passenger-oriented platform interface, where passengers can plan routes and make travel reservations. The model unifies more than a dozen bus companies in one platform, while the government authorizes the TC company to be responsible for the operation of the platform, and allocates and manages the operating routes in the whole city. The bus operators are only responsible for providing bus services, while the revenue from operating data is managed by the TC company. This cooperation offers the foundation for the development of a MaaS platform, even if it currently only features bus services. In this case, the TC company acts as the MaaS platform provider, and the bus operators are equivalent to the travel service providers in a MaaS platform. In the future, providers of ride-hailing services and shared bicycles could be included in the TC platform, and the TC company can gradually develop into a MaaS provider that integrates multiple travel modes into one system.

The prerequisite for the TC model is that the government has strong financial resources and can provide sufficient capital to operating companies. Because bus tickets in China are very cheap – in Foshan, for example, the one-way fare is 2 yuan (0.27 euro), and passengers can get a discount after applying for a card – the annual revenue of the bus operators is far below their operating costs. For this reason, although the TC model grants certain benefits to the bus operators in bidding, it still relies on government subsidies. Due to Foshan's economic strength, the government has sufficient financial resources to implement the TC model.

As one of the industry and innovation hubs in China, Foshan acts as a role model for other cities in China. This is why the TC model has already been replicated by other cities in the region. The city could also inspire other cities in China to develop MaaS platforms by following the same path, and is a particularly valuable reference case for economically developed cities in eastern China, rather than for poorer western cities. Furthermore, due to its location in the central part of Guangdong Province, Foshan can play a central role in the development of a MaaS platform for the whole region.

Table 12: Hierarchy of TC model

Government decision-making level (Administrative authority)	1. Research and preparation of policies and public transport development plans; 2. Macro guidance, supervision and coordination
Operation management level (TC management unit)	1. Collection of bus fares and settlement of operating expenses; 2. Route planning and operation bidding; 3. Service supervision and assessment
Operation service level (Bus companies)	1. Provision of bus passenger transport services in accordance with the service standards agreed in the contract

4.4 Guangzhou: First Chinese City to Enable Payment Integration

Guangzhou is the capital city of Guangdong Province, with a total area of 7434.40km^2 and a population of 18.67 million residents. In 2020, The GDP of Guangzhou reached 2501.911 billion yuan. Guangzhou has 1,243 bus routes, carrying an average of 2.42 million passengers per day. Guangzhou Metro operates 14 lines, with an operating mileage of 531.1 km and an average daily passenger volume of 4.56 million passengers. Guangzhou has 77 taxi companies with a total of 21,561 taxis serving 880,000 passengers every day. Table 13 illustrates the travel services currently available in Guangzhou.

On demand travel services in Guangzhou include dockless bike sharing and ride-hailing companies. There are 69 ride-hailing companies, with a total of 112,162 cars and an average daily order of 1.13 million rides. In July 2019, three bicycle enterprises (Meituan Bike, HelloBike and Didi Bike) won a bidding contest to operate in the central urban area. The total bicycle limit is 400,000 bikes, according to the city's designated shared bicycle quota. Like Shenzhen, Guangzhou has also adopted a service quality assessment mechanism to dynamically adjust the enterprise operation quota of the number of bicycles that each company can have available, according to the assessment results.

Guangzhou's first exploration towards MaaS was a payment initiative that integrated payment options for bus and dockless bike sharing. This so-called "Green Pass" (lvtongpiao) was launched in December 2020 and was jointly issued by the Guangzhou Yangchengtong, a state-owned company providing an electronic payment system for Guangzhou public transport, and the private transport provider DiDi Chuxing. Passengers can buy one tickets through the DiDi Chuxing app and use them for both bus and bike-sharing services (see Figure 13). Moreover, passengers can buy a weekly ticket (the price is 10 yuan/1.43 euro) that includes an unlimited number of bike rides and 14 public transport trips for 0.01 yuan (0.0014 euro) each. The access of both services through the DiDi app eliminates the need to switch between physical cards and different apps, improving the convenience of travel.

Table 13: Transportation options in Guangzhou

Transportation Mode	Average daily orders/passenger volume (Unit: 1000)	Scale	Operators
Regular bus	Passengers: 2,420	576 lines	Guangzhou Metro Group
Subway	Passengers: 4,560	14 lines	Guangzhou Public Transport
Cruise taxi	Orders: 880	21,561 taxis	71 companies
Dockless bike sharing	_	399,800 bicycles	Hello bike DIDI bike Meituan bike
Ride-hailing	Orders: 1,138.4	112,162 cars	69 companies DIDI UCAR CAO

Source: http://jtj.gz.gov.cn/jtzt/jtsj/jtysyb/content/post_7408012.html

■ Figure 13: Green Pass purchase pass

Source: CATS

The Green Pass was enabled through a successful public-private cooperation between a bus payment company - Yangchengtong and a MoD service provider – DiDi Chuxing. Yangchengtong benefits from the customers brought by Didi Chuxing (fees generated by app discounts are provided by DiDi Chuxing), and DiDi Chuxing can strengthen its relatively weak public transportation business and attract more users through the partnership. In addition, by working with public transportation, DiDi can further establish a good relationship with local transportation authorities, and use the collaboration as an opportunity and advantage for expanding its MoD services in the future, such as launching more shared bikes.

As a next step, the Green Pass is planned to gradually include subway, online ride-hailing, taxi, and other modes of travel ticketing options, and launch a variety of combined mode services such as "bus + subway + shared bike" and "bus + subway + shared bike + online ride-hailing." At present, the Green Pass is funded and operated by DiDi Chuxing. If more modes of transportation are included in the future, there will be new management issues to be considered. For example, methods would need to be agreed upon to distribute revenues, it would need to be seen if the initiative would continue to be funded by DiDi Chuxing, and a decision on who would lead and oversee such a multi-stakeholder project would need to be determined. Whether this model can be extended to other cities is also uncertain. Furthermore, all discount fees provided to users are currently borne by Didi Chuxing, and the model itself does not generate any profit. Therefore, the sustainable development of this model depends on whether MoD companies could obtain agreed-upon benefits through such cooperative models.

4.5 Beijing: Combination of MaaS Platform with Carbon Credit System

Beijing is the capital of the People's Republic of China, with a total area of 16,410.54km^2. By the end of 2020, the population of Beijing was 21.89 million residents. Beijing has 1,158 bus lines with a total length of 27,632km. Beijing was also the first city in China to build a subway system, with 23 lines running for 699km. In May 2019, Beijing opened its first dedicated bike lane. The total length of the bike path is 6.5 kilometers. Among this length, 5.46km is a completely closed section of track, with a net road width of 6m and a speed limit of 15km/h, and pedestrians, electric bikes and motor vehicles are not allowed to enter the bike path. Additionally, there are 15 taxi companies in Beijing with 78,000 drivers and 607,930 daily orders. By the beginning of 2020, there were 12 ride-hailing companies operating in Beijing, with 12,020 cars and an average daily order of about 70,000 rides. The operation data and GPS data of ride-hailing networks are connected to the Beijing ride-hailing supervision platform, and the transportation department of the city can dynamically monitor the industry.

The total number of shared bikes in the central urban area of Beijing was limited to 800,000 in 2021. Combined with the total scale and the credit assessment results of bike sharing service quality in 2020, the maximum number of vehicles that each operating company can put into the central urban area is 400,000 for Meituan Bike, 210,000 for Hello Bike and 190,000 for Qingju Bike (see Table 14).

The "Beijing Traffic Data Sharing Management Guideline (Trial)[22]" was published in 2019 to allow traffic big data sharing with private sector companies, with the overall goal of developing a MaaS platform. Under this trial, in a public-private cooperation model, the government provides traffic data to private MaaS operators and evaluates their performance and ensures their compliance. At the same time, private stakeholders provide the technical foundation needed to build and operate the MaaS platform and related services.

In November 2019, Beijing launched China's first dedicated MaaS platform, aiming to provide residents with a one-stop travel service that includes smart routing and full navigation services, and green incentives. The platform has integrated travel data for public transport modes, such as bus, metro, and suburban railway lines, as well as for active and shared mobility options, such as walking, cycling, and ride-hailing services. It provides various functions, such as bus arrival forecasts, information on carriage crowding, and reminders for transfers and disembarkation. The green travel carbon credit incentive and trade mechanism built into the platform is a further expansion of the MaaS platform services, and demonstrates an attempt to promote green mobility from being a conceptual proposal to actual incentive-based guidance, and to facilitate the opportunity for a substantial shift in travel behavior.

■ Table 14: Transportation options in Beijing

Transportation Mode	Average daily orders/passenger volume (Unit: 1000)	Scale	Operators
Regular bus	Passengers: 8,580	1,158 lines	Beijing Public Transport
Subway	Passengers: 10,850	23 lines	Beijing Metro Operation Co., LTD Beijing MTR Corporation
Cruise taxi	Orders: 607.93	69,000 taxis	15 companies
Dockless bike sharing	_	900,000 bicycles	Hello bike DIDI bike Meituan bike
Ride-hailing	orders:7.11	12,020 cars	12 companies DIDI ShouQi UCAR

[22] 北京市交通委员会关于印发《北京市交通出行数据开放管理办法（试行）》的通知 http://www.beijing.gov.cn/zhengce/zhengcefagui/201911/t20191105_483739.html

Functions of Beijing MaaS

Intelligent trip planning. Users can search routes on Baidu Map or Amap apps to obtain comprehensive travel information regarding congestion updates, optional routes, occupancy rates of different transit modes, required walking distances and other related types of information. The platforms also provide users with a variety of travel planning suggestions, such as "subway priority", "less walking", "fewer transfers", and "shorter time" information flags. Users can switch between different preferences to customize their journey.

Whole-journey guidance during the trip. Because the platform is connected to bus GPS data, it can query real-time locations of buses. Users can check nearby bus routes on the app, as well as bus locations and estimated arrival times. Furthermore, the app provides information on the congestion of subway stations, chosen routes, remaining stops and travel times to final destination, or reminders to change or exit trains.

Post-trip incentives for choosing low carbon travel. In September 2020, the Beijing MaaS platform launched the Carbon-trading incentive programme, granting post-trip benefits to users for choosing low carbon travel modes, such as biking or walking. Users can choose to reduce carbon emissions generated by their travel mode choices by using buses, subways, shared bikes and walking. Carbon reduction credits generated by users can then be exchanged to public transport coupons and shopping vouchers on the platform. If 100,000 users participate in the scheme, roughly 100 tons of carbon reduction could be generated per day. Currently, the carbon reduction scheme is sustained by Amap's and Baidu's own funds.

Data sharing is a prerequisite for the implementation of the Beijing MaaS platform. In November 2019, the BMCT issued the document Beijing Traffic Trip Data Open Management Measures (Trial)[6] that gives guidance on how to manage open data. According to the document, the Beijing Municipal Commission of Transport (BMCT) made 14 types of traffic data available to the public, including bus route codes, station numbers, congestion, and real-time traffic information. By sharing traffic travel data with the public, the city hopes to promote cooperation between the transportation industry and tech-companies such as the afore-mentioned Baidu and AMAP, and utilize the technological advantages of internet companies to optimise and improve travel guidance services.

The current phase of Beijing MaaS does not yet have a dedicated app, meaning that users can still only access it through the Amap (as shown in Figure 14) or the Baidu Maps app. Also, even though it is called a "MaaS" system, it does not yet have functions to accept payments or book itineraries. The current functions that the app can provide at the moment is intelligent, trip planning information that includes data from a comprehensive selection of public transport and MoD services, whole-journey guidance during the trip, real time data on public transport arrivals and crowdedness, and incentives for low carbon travel after the trip. The platform's main function is to provide citizens with transportation planning information based on "green travel modes" such as public transportation, subway and bicycle services, so as to guide and incentivize more people to choose public transport options and reduce the use of private cars. Another issue to be further improved with the Maas service is that at present, it only shares public transport data with the public, while data from other modes of transport, such as online ride-hailing, bike-sharing and taxi services are not yet shared. This is also the main reason why the Beijing Maas platform can only be used at the moment for public transport travel planning. Though there is strong potential in the platform, the issue of how to include and then access other forms of data through MaaS services still needs to be addressed.

■ Figure 14: Maas platform on Amap

Source: GIZ

4.6 Summary

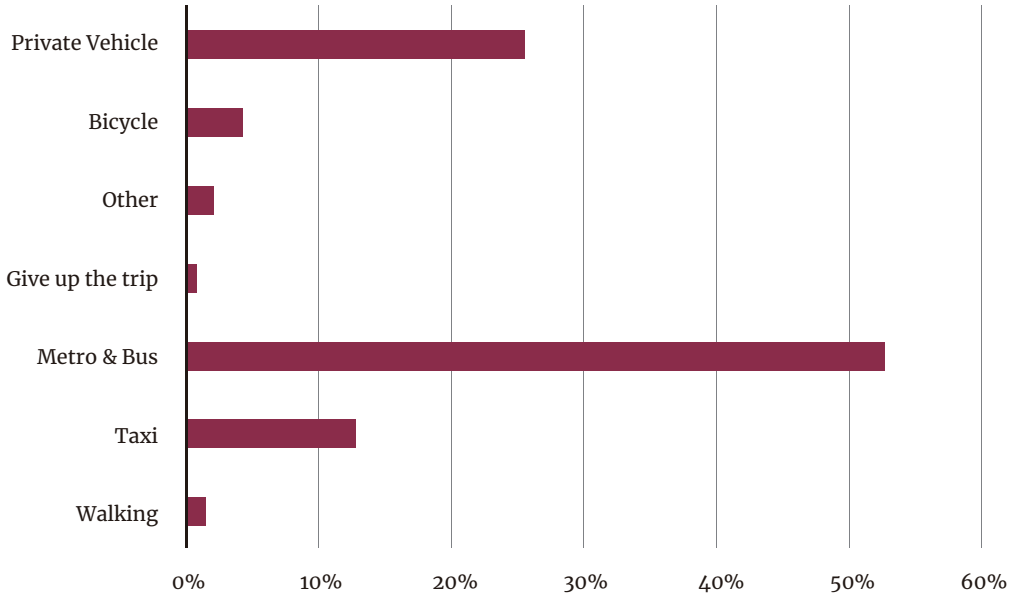
This chapter analyzes the development of MaaS in several cities in China. Through these experience of highlighted case cities, the following lessons can be learned:

A fair competitive environment is an important factor in promoting cooperation between private enterprises and transport authorities. Shenzhen, Guangzhou and Beijing all evaluate the services of bike sharing enterprises through service quality assessments, and reward or punish individual companies according to their results. This assessment mechanism not only creates a fair competitive environment for the industry, but also enhances the trust between private enterprises and transport authorities. This mechanism also lays a foundation for cooperation in promoting data sharing.

The understanding of MaaS varies from city to city. MaaS programmes in case cities discussed here vary from real time public transport information and planning sharing services to integrated platforms that accept payments for public transportation and bike sharing, all of which are referred to as MaaS. This reflects the fact that there is not yet a clear definition of MaaS in China. The lack of a unified understanding of what characteristics MaaS systems should have has led to different forms and approaches taken by local cities to each promote their own form of MaaS. Though this means that MaaS systems in China can be developed in unique and diverse ways, it also means that there is a risk that 'gimmicks outweigh substance', such as the possibility that some companies may package themselves with the MaaS name rather than actively promoting sustainable transport.

As a new model for promoting sustainable urban mobility, MaaS must be centered on public transport methods, which can help people reduce their dependence on cars. It is already seen that MoD like ride hailing services have been drawing more users of public transport than those that drive private vehicles. In a recent survey conducted by the China Academy of Transport Sciences, MoT, in answering the question "What would be your choice of transport if ride hailing is not available?" 52.7% of the participants choose metro and bus systems, while only 25.6% of the participants chose private vehicles (see Table 15). If not planned carefully with appropriate incentives for users, MaaS may induce users who have already adopted green and low-carbon modes of travel to instead use taxi hailing and car sharing services, which is clearly the opposite of the intention to promote sustainable and low-carbon travel – a key problem which MaaS needs to avoid.

■ **Table 15: What would your choice of transport be if ride hailing is not available? Transport Survey Responses**



Data Source: China Academy of Transport Sciences, MoT, 2019

5 IDENTIFICATION OF KEY FACTORS OF MAAS

Based on the development status quo and lessons of the case study cities described in Chapter 4, a Delphi survey was conducted by the project team to identify the most critical factors affecting the development of MaaS in China. The survey, done in the form of a questionnaire, was distributed to a total of 27 stakeholders from enterprises, industry management authorities and scientific research institutions. Respondents included 12 participants working in traditional public transport companies in Ningbo, Guiyang and other cities at HelloBike, Ctrip, BaiduMap, Meituan[23] and other internet-based companies, 4 managers from transportation governance authorities in Beijing, Nanchang and Ningbo and 11 researchers from a number of Chinese and foreign research institutions.

The results of the survey are summarised here in Chapter 5, and the questionnaire is presented in Annex 3.

5.1 Challenges for the Development of MaaS

Judging from the practice of MaaS in Chinese cities, the main challenges encountered during the development of MaaS are related to a variety of factors, including systems of infrastructure, technology, data sharing, business models, travel culture and policy.

Infrastructure

As MaaS consists of the combination of a variety of smart travel modes, the quality of related transportation infrastructure such as the condition of roads, parking facilities, vehicles, as well as overall IT infrastructure such as server quality and quantity, greatly affects the development of MaaS.

Technology

One of the functions of MaaS is to integrate the services of booking, ticketing and payment functions. This integration requires the incorporation of external technologies such as mobile payments and safe transaction technology. Another technical issue is the applicability of the data from different Application Programming Interfaces[24] (APIs) of travel service providers. The applicability of an API data interface and interoperability of various systems are the prerequisite for the operating entities involved in developing a unified MaaS interface. However, few operators open their API data interfaces to others, and the API interfaces of some mobility service providers do not follow compatible data formats, therefore a certain degree of standardisation work is required for collaborative efforts to be effective.

Travel Culture

From social and environmental perspectives, the goal of MaaS is to reduce people's dependence on private cars and promote the development of seamless and sustainable greener transportation options. The prevalence of car culture will cause residents to rely on private cars, thereby reducing the attractiveness and overall social benefits of MaaS, which is dominated by the use of public transportation modes. Therefore, the prevailing preference for the concept of car travel is regarded as an overall obstacle for the development of MaaS.

Data sharing

Data sharing is a core component of MaaS. The data involved in MaaS includes mobility service data (such as timetables and real-time car location information), ticketing data, traveller data and infrastructure data (updates on real-time road status, public transportation stations, parking lots, etc.). These data are owned by different departments and service providers. To integrate all mobility services into one platform, mobility service providers should share their data and open API interfaces to MaaS platform operators. However, mobility service providers are reluctant to disclose their data to competitors. If there is no trust mechanism among service providers, data sharing cannot be achieved and MaaS will be impossible to develop. Therefore, fostering a trust mechanism among MaaS participants is another challenge for the development of MaaS. In addition, one of the important foundations for achieving good data openness and sharing is a common data standard amongst participating companies and partners.

[23] Meituan (Chinese 美团 ; pinyin: Meituan "), formerly Meituan-Dianping, is a Chinese shopping platform for locally found consumer products and retail services including entertainment, dining, delivery, travel and other services. https://about.meituan.com/en/details

[24] An application programming interface (API) is a connection between computers or between computer programmes. It is a type of software interface, offering a service to other pieces of software.

Policy

The biggest challenge for the implementation of MaaS is government policy, rather than technology. The emergence of this new transportation organisation method is disrupting the mobility sector, and requires the government to gather all stakeholders to participate in the establishment of a MaaS platform. During the development of MaaS, the development of infrastructure, cultivation of a travel culture beyond the use of private cars, the formulation of management standards and good governance of market orders should be coordinated through policies and regulations. Therefore, government capabilities and policy guarantees are key factors affecting the development of MaaS.

5.2 Survey Results

After collecting the questionnaire results, an analysis of findings was conducted by combining quantitative and qualitative methods. The quantification of responses was carried out based on an averaging of the scores of different questions (see Annex 3). The score in the column "Please evaluate the importance of this factor to the successful implementation of MaaS" reflects the respondents' subjective evaluation on the importance of the evaluated factor, while the score in the column "Please comment on the current status of this factor in China" reflects the participant's perspective on the development status of this factor in China. The lower the score is, the higher is the participant's evaluation of this factor. The results of the questionnaire can be concluded as follows:

1. The conclusion that MaaS is not fully developed can be drawn. In comparing the scores of "perceived importance" to the scores of "development status", all factors pointed to having a perceived importance but lower development status.

2. The five factors considered to be the most important for the development of MaaS were found to be: user mobility and personal data security, policy support, data sharing, business models, and data availability and standardisation.

3. The five factors considered to be the least important to the development of MaaS were found to be: the degree of diversification of service providers, data ownership, coordinated pricing among mobility modes, data processing quality and travel culture.

4. The five factors with the best development level in China were found to be: quality of transportation infrastructure, integrated payment methods, platform back-end support technology, data processing quality, and policies/investment/attitude towards public transportation and shared transportation.

5. The five factors with the worst development in China were found to be: user mobility and personal data security, business models, coordinated pricing between mobility modes, government capabilities and data ownership.

6. The five factors with the smallest difference between "perceived importance" and "development status" were found to be: the diversification of service providers, the quality of transportation infrastructure, attitudes to public transportation and shared transportation, integrated payment and data processing quality.

7. The five indicators with the biggest difference between importance and current development were found to be: user mobility and personal data security, business models, data sharing, government capabilities and policy support.

8. The response from governance authorities has the smallest gap between its evaluation of the importance of each factor and its current development status. Therefore, it is considered that governance authorities believe that the current development status of the factors is satisfactory.

9. Research institutions believed that institutional and political factors are important but gave low scores to their current development level, while government representatives instead believed that the current status of institutional and political factors was developing well.

10. Research institutions and the industry management believed that economic factors were the most important, while the government believed that social factors were equally important.

POLICY RECOMMENDATIONS 6

In Chapter 5, the key factors affecting the development of MaaS were identified through a Delphi survey. Based on the results of the survey and the practices of discussed case cities, this chapter will provide specific policy recommendations for the further development of MaaS in China.

6.1 Enable Effective Data Sharing

Why is data sharing important?

Numerous demonstrations, experiments and studies have shown that data sharing – such as the need to obtain real-time data of all mobility modes – is the foundation for the development of MaaS. Even though data sharing is becoming more open, there are still specific challenges for MaaS. For example, current methods of data collection, storage, management, sharing, and transmission do not adhere to an agreed format of standards. Also, mobility service providers regard travel data as highly confidential information and worry about it been leaked to their competitors. According to the results of the Delphi survey, participants believe that data sharing, data availability and standardization, and data security are the three most critical factors in terms of MaaS data management.

To achieve sufficient data openness and sharing methods, it is important to build common data standards. Currently, the data content, data formats, and data quality of travel service providers are all different, which brings great difficulties to data sharing initiatives and seriously hinders data flows and sharing across various operators and software systems. Therefore, an established data standard would allow all MaaS participants to easily access and contribute to MaaS platforms.

The security and management of user identity information is still a key factor in the development of MaaS. Mobility service providers should guarantee the data security of users and ensure that no other participants in the MaaS system can illegally access their data. As a result, the development of a MaaS platform must require high data security standards. In addition to ensuring the security of personal privacy, it is also necessary to ensure the security of services and payment modes.

Recommendations

(a) Establish data sharing standards

It is recommended that the MoT formulates and publishes data storage standards for mobility service providers and standardizes the data used in the establishment and operational phases of MaaS systems. Also, the MoT could publish regulations and/or industrial guidelines that force all participants of MaaS systems to adhere to their standards in their data submissions. At the local level, local governments can use financial incentives to encourage service providers to adopt data collection systems and storage systems under a unified technical standard to achieve interoperability among different systems. In addition, the maintenance and enforcement of data standard should be strengthened at local levels.

(b) Promote a data classification and hierarchical protection system

In order to fully protect public data security, user travel data can be managed hierarchically. For example, the data hierarchy can be classified by the scope, objects and degree of impact caused by data leakage or destruction. Sensitive data should be especially marked as sensitive and encrypted. Data Masking (DM) services should be provided for such data when making it available to multiple stakeholders.

(c) Establish a comprehensive data security supervision and management system

It is suggested that municipal-level transportation authorities adopt pre-supervision, in-event supervision, and post-supervision roles over data security. In the pre-supervision process, authorities should strictly control the access standards of mobility service providers. Those operators who lack user data security measures would be prohibited from joining. In the process of in-event supervision, authorities should regularly check data protection conditions to prevent operators from divulging users' data for profits. In the process of post-supervision, authorities should stop and penalise the violation of user data protection efforts if they occur.

(d) Form a data sharing mechanism for MaaS systems

It is suggested that municipal-level authorities lead the establishing of a data sharing mechanism for MaaS systems. Firstly, authorities should work together with

MaaS participants to determine the data required to establish MaaS platforms. Secondly, the authorities should determine who provides what types of data among MaaS participants. The scope of data sharing should be also clarified, including which parties are allowed to access what types of data. Finally, authorities should formulate a Code of Conduct for data sharing and clarify the responsibilities and authorities of each party. For example, participants shall provide their data in accordance with the prescribed standards, to ensure that their data is not compromised or leaked.

6.2 Use MaaS as a Tool to Promote Sustainable Transportation

China has a solid foundation for the development of MaaS in terms of existing infrastructure, macro policies and travel culture. From the perspective of national policy orientation, it should be emphasised that the goal of MaaS is to promote the decarbonisation of urban transportation in line with the country's 2030 carbon dioxide peaking and 2060 carbon neutrality goals.

Recommendations

a) Advocate for municipal governments to follow the principle of sustainable development and establish MaaS in accordance with their city's target visions for carbon dioxide peaking and carbon neutrality. In future policy formulation at the national level, MaaS should also be perceived as an important tool for the promotion of sustainable and low-carbon transportation options. At the same time, it should be made clear by the MoT that the goal of MaaS should be to guide residents towards the use of sustainable mobility modes such as walking, cycling and public transportation services.

b) The allocation and use of public resources such as roads and parking spaces should be reconsidered. Priorities should be given to sustainable transportation modes including public transportation and shared bicycles in MaaS. Based on the "user-pay" and "responsibility sharing" principles, carbon credit measurement and incentive mechanisms for individual users are recommended to be created in MaaS systems to guide the public to use public transportation and shared bicycles as main green travel modes.

c) Carry out comprehensive impact assessment work on the development of MaaS. These assessments should include identifying changes in passenger flows, user satisfaction, social equity, and environmental benefits of different transportation modes brought about by MaaS. Such evaluations could increase the understanding of MaaS by different stakeholders such as government actors, traditional transportation companies, and new mobility enterprises and facilitate consensus building for MaaS amongst these groups as well as users. In the future, cyclical impact assessments of MaaS systems could be considered as part of their national regulatory framework.

d) Provide equity for users with special needs, such as elderly, children, and disabled people. Though widely accepted in China, smartphones as the fundamental carrier of MaaS services, are still not accessible to all user groups. Thus, off-phone applications such as integrated mobility cards, off-line service interfaces, and discounts for special groups would increase their attractiveness and equitable access to all users. At the same time, linking MaaS projects to MoT's barrier-free city initiative, could provide further incentives for barrier-free transport infrastructure projects. For example, bus or subway lines or stations with barrier-free infrastructure could be labelled in the MaaS system so that users with special needs could choose and plan their trip in a customized manner.

e) Using MaaS as a platform for urban-rural mobility connection. The application of MaaS at a regional level is already achieved in some countries. In China's urban-rural integration efforts, the promotion of multi-level mobility systems is already underway where public transport lines are being adjusted in a hierarchical manner to serve specific purposes. For example, some of the connecting lines of travel routes to hubs and between suburbs and cities are suitable for the development of on-demand buses that could link currently separate routes. In the long-term, a regional mobility pass or online platform with unified options could largely contribute to the development of smooth urban-rural linkages.

6.3 Establish a Sustainable Business Model

The effectiveness of MaaS is based on the willingness of platform service providers, transportation service providers, and payment and ticketing companies to cooperate and their ability to establish sustainable business models. This means establishing a value network that – through cooperation – creates and distributes value for the use of MaaS among all participants. The establishment of such a value network requires trust between participants. As traditional transportation companies and new mobility service providers face limitations in perceptions, capabilities and credit environments, the development of a MaaS ecosystem requires long-term efforts by governments, enterprises and the public to incentivize and unify all users and partner systems.

Recommendations

(a) Encourage market innovation

For the construction of new business formats and MaaS platforms, the government should maintain bottom-line safety regulations, but refrain from overregulating the market. Excessive supervision beyond safety regulations will curb innovation. When regulating new business formats, the goal should be to reasonably define the boundary between the government and the market, while maintaining a stable and fair competition environment. Though they should be foreseen and prevented if possible, if any issue occurs that affects safety and undermines fair competition, it should be treated accordingly.

(b) Encourage flexible and diverse cooperation between public transportation companies and MaaS-related service providers

Public transportation enterprises are the institutions with the largest scale of mobility services in a city and occupy a dominant position in the urban transportation system. MaaS will have a certain impact on public transportation management and use. Firstly, cooperation with private mobility service providers can help supplement, expand or improve the services provided by public transportation companies. Other mobility service providers, such as online car-hailing and car sharing companies, can provide mobility services for residents in less densely populated districts. Secondly, cooperation with private mobility service providers will help reduce the financial burden of governments. Public transportation companies sell tickets through third parties and adjust their ticket types so that they can be bundled with other mobility modes to increase passenger flows and revenue.

(c) Encourage the application of blockchain technology to build a trust system

Blockchain technology can be used to establish a decentralized and distributed service link network within the MaaS ecosystem. This approach allows the decentralisation of the storage of data and transaction details, while transaction and payment certificates are kept, so as to form smart contracts among participants where information security and transaction transparency of users and all participants can be guaranteed. This approach establishes an objective trust system in the MaaS ecosystem, where transaction costs will be reduced to form trust among participants. This customised transparency ensures that the algorithms providing residents with mobility options are fair, open and transparent, which ensures competition among all large and small providers in the market.

Annex 3. Questionnaire: Evaluation of Factors for MaaS in China

Explanation: Please evaluate the influential factors listed and described below firstly on their importance for the successful establishment and operation of MaaS generally, and secondly their current status in China.

For example, if you feel that 'data sharing' heavily influences the successful establishment and operation of MaaS, please rate it 1 – Highly important, but if you feel the factor is not adequately addressed in China, rate its status as "4 – Not developed/occurring".

At the end of the table, please list the three factors that you consider to be the most important.

	Influential factor	Description	Please rate the importance of this factor for the successful implementation of MaaS: 1 – Extremely important 2 – Very Important 3 – Somewhat important 4 – Not important	Please rate the current status of this factor in China: 1 – Highly developed/occurring 2 – Somewhat developed/occurring 3 – Not particularly developed/ occurring 4 – Not developed/occurring
Institutional and political factors				
1	Political support	Political support for MaaS from national level, e.g. in statements by policymakers or by providing relevant policy incentives or regulations.	1 2 3 4	1 2 3 4 Please provide at least one example of a policy incentive you consider important for the successful implementation of MaaS:_____ _____ _____
2	Political and investment focus on public and shared modes	High political support and thus more investment for public and shared modes compared to individual modes, such as private automobiles.	1 2 3 4	1 2 3 4
3	Institutional capacity of governments	Capacity of local governments to lead MaaS development and to manage information and data by providers (e.g. that they have experience, innovative strategies and integrated planning approaches, adaptable structures, decision processes, etc.).	1 2 3 4	1 2 3 4
4	Provider landscape	The degree to which the landscape of transport service providers participating in MaaS is fragmented, i.e. having many individual providers for the different travel modes.	1 2 3 4 Please indicate which of the below scenarios you feel to be more conducive to successfully establishing and operating MaaS (e.g. Could one draw more users to the MaaS platform? Would one be more efficient?): Having many individual providers for the different modes Having fewer providers covering multiple modes	1 2 3 4
5	Willingness of travel providers to integrate	Willingness of travel providers to integrate into a MaaS system and share responsibilities under an overall coordinating entity.	1 2 3 4	1 2 3 4

Influential factor		Description	Please rate the importance of this factor for the successful implementation of MaaS: 1 – Extremely important 2 – Very Important 3 – Somewhat important 4 – Not important	Please rate the current status of this factor in China: 1 – Highly developed/occurring 2 – Somewhat developed/occurring 3 – Not particularly developed/ occurring 4 – Not developed/occurring
6	Willingness to share data	Willingness of travel providers to share user travel data, between public and private providers, and between travel providers and public authorities.	1 2 3 4	1 2 3 4
7	Data management responsibility	Allocating data management responsibility, i.e. who manages the user data generated by a MaaS platform. Please indicate in your response who you think should hold ownership over the user data.	1 2 3 4 Please indicate who you think should manage user data provided by individual providers: Government Public transport companies A 3rd party business enterprise of a new format	1 2 3 4
8	Security of operators' and user travel and personal data	Securing collected operator and user travel data, i.e. protecting personal information of users and preventing travel information of private operator's from being compromised and harming their competitiveness, e.g. by having clear regulations on data storage and management.	1 2 3 4	1 2 3 4
Economic factors				
9	Business model	Having a mature MaaS business model, i.e. in terms of who leads the platform and how profit is made.	1 2 3 4	1 2 3 4
10	Coordination of pricing between travel modes	The coordination of pricing and distribution of profits among different modes of transport, including who coordinates user payments overall.	1 2 3 4 Please mention who you think should be responsible for the overall coordination of pricing and profit:_____ Government Public transport companies A 3rd party business enterprise of a new format	1 2 3 4

	Influential factor	Description	Please rate the importance of this factor for the successful implementation of MaaS: 1 – Extremely important 2 – Very Important 3 – Somewhat important 4 – Not important	Please rate the current status of this factor in China: 1 – Highly developed/occurring 2 – Somewhat developed/occurring 3 – Not particularly developed/ occurring 4 – Not developed/occurring
Technological factors				
11	Unified payment	Unifying payment for different modes of transport.	1 2 3 4	1 2 3 4
12	Availability and standardization of data	Availability of mobility data for optimal route planning, including open data on public transport or data on the location and availability of shared vehicles following a unified standard, allowing for interoperability between operators of individual travel modes.	1 2 3 4	1 2 3 4
13	Quality of data procession	Quality of data procession as part of data management, i.e. analysis and visualization of existing data to better support data-driven policy making.	1 2 3 4	1 2 3 4
14	Platform back-end support technology	Back-end support technology of a MaaS platform (such as path planning, matching of supply and demand, human-computer interaction, etc.).	1 2 3 4	1 2 3 4
15	Quality of transport infrastructure and services	The quality of the transport infrastructure and services, including the availability and punctuality of public transport, the availability and reliability of Mobility-on-Demand services, such as bike sharing or ride-hailing, and the extent of the network of various travel providers.	1 2 3 4	1 2 3 4

	Influential factor	Description	Please rate the importance of this factor for the successful implementation of MaaS: 1 – Extremely important 2 – Very Important 3 – Somewhat important 4 – Not important	Please rate the current status of this factor in China: 1 – Highly developed/occurring 2 – Somewhat developed/occurring 3 – Not particularly developed/ occurring 4 – Not developed/occurring
Social factors				
16	Travel culture	Compatibility of MaaS with the residents' own concept of travel, including their existing travel behavior, the main purpose of travel, and their use of different travel modes.	1 2 3 4	1 2 3 4
17	Attitude towards using public and shared modes	Raising travelers' awareness of and stimulating their preference for using public or shared modes.	1 2 3 4 Please specify for what reason you think some people are reluctant to use public/shared modes, e.g. preference for owning private automobiles; health concerns; issues of accessibility or convenience; etc.:_____	1 2 3 4
18	User experience	The overall user experience, including the convenience and intuitiveness of the user interface, the speed and reliability of provided information, and possible additional incentives for users.	1 2 3 4	1 2 3 4
Environmental factors				
19	Emission reduction potential	MaaS having an obvious emission reduction effect. MaaS	1 2 3 4 Could this factor positively affect some of the factors listed above (e.g. travel culture or political support)? Please specify if you agree: _____ _____ _____	1 2 3 4

	Influential factor	Description	Please rate the importance of this factor for the successful implementation of MaaS: 1 – Extremely important 2 – Very Important 3 – Somewhat important 4 – Not important	Please rate the current status of this factor in China: 1 – Highly developed/occurring 2 – Somewhat developed/occurring 3 – Not particularly developed/ occurring 4 – Not developed/occurring
20	MaaS outreach and brand awareness	Establishing brand awareness, a public perception of MaaS as an intelligent, green, and convenient integrated transport ecosystem.	1 2 3 4 Please specify what core message for MaaS branding you think would attract the most users – high-tech innovation; green mobility; convenience, intermodality; etc.: _____	1 2 3 4
21	Which three factors do you consider to be the most important for a successful establishment and operation of MaaS? Please list them in order of importance and add a brief justification for your choices: (The 1st being the most important, the 3rd being the third most important) 1. _____ Why?_____ 2. _____ Why?_____ 3. _____ Why?_____			
22	Considering the aforementioned influential factors of MaaS establishment and success, how do you assess the overall potential and feasibility of MaaS in China? 1 2 3 4			
23	If you feel there are any other factors that are highly important for a successful implementation of MaaS, please add them here: _____ _____			

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