



# New modes of urban public transport in China

Case analysis of on-demand bus services

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## 1. Overview

### (I) Research background

In recent decades, the continuous increase in transport volume has resulted in transport-related CO<sub>2</sub> emissions accounting for approximately 20 % of global CO<sub>2</sub> emissions. In Germany, the transportation sector is the only greenhouse gas (GHG) contributor without emission drop in recent years. On the contrary, the relative proportion of transport-related CO<sub>2</sub> emissions has increased from 13 % in 1990 to 23 % in 2023. The transition towards new types of public transport and new urban passenger transport modes is necessary to reduce CO<sub>2</sub> emissions in the transportation sector. In this context, on-demand transport services have been widely used in cities in China and Germany as an effective complementary solution to public transport. The concept features significant potential to both enhancing the attractiveness of public transport services, with higher feasibility, comfort and efficiency thanks to digitization technologies, and reducing CO<sub>2</sub> emissions. In China, the State Council issued *the Guidelines on Prioritising Development of Urban Public Transport* in 2012, which aims to consolidate the “public transport first” strategy in urban areas and to specify a range of major measures to give priority to the development of public transport systems. The Ministry of Transport, departments and offices under the State Council and local authorities have thoroughly implemented requirements in the guidelines and promoted and improved supporting policies to prioritise the operation of public transport. More investment has been channelled into public transport, cities are increasingly conceptualised as “national transit metropolises”, new-energy vehicles (NEV) have been better promoted for practical use, and comprehensive laws and regulations for urban public transport and relevant standards and criteria have been established. In recent years, urban buses and trolleys have been more capable of ensuring mobility services and assistance, and the quality of public transport has been steadily improved. In the meantime, certain challenges of urban buses in megacities or large/medium-sized cities, such as low travelling speed, inconvenient transfer, longer waiting time and less satisfactory comfort, have not yet been solved. The number of passengers

travelling on urban buses and trolleys has decreased year by year across the country.

Notwithstanding the rapid development of urban rail transit in Chinese cities, city buses and trolleys remain a major part of local public transport. However, given the road traffic conditions and the structure of the road network, their speed and comfort are hardly comparable to those of sedans or even rail vehicles. Therefore, the approach to high quality development of urban buses and trolleys has become a key issue for public transport services. In recent years, Internet+ and other relevant technologies have developed rapidly, and modern mobility services such as online car-hailing and bike-sharing are quickly gaining ground. The demand of urban citizens for individualised and on-demand quality mobility services with a certain degree of differentiation has also increased, and expectations of appropriate and satisfactory mobility in everyday life are becoming even higher. This creates the need for on-demand bus services.

The on-demand bus service is able to use internet-based big data to accurately match user demand with possible routes, coordinating available resources to create a customised route. It provides seating, air conditioning and Wi-Fi for passengers to significantly improve comfort; boarding and alighting stops are determined at the origin and the destination. When midway stops are not planned; the route planning via expressways and highways may improve operational efficiency and make the service more convenient.

The overall objective of the present study is to analyse the potential of on-demand bus services as a new, sustainable and accessible transport mode that can be integrated into the existing urban public transport network and to assess the various necessary parameters during its development in order to promote on-demand bus services as a driving force facilitating the transition and modernisation of urban passenger transport. The research will analyse the contribution of on-demand transport to the reduction of carbon emissions in urban passenger transport and investigate the functionality of new technologies to improve operational efficiency and route planning.

## (II) Main topics of the study

The present report focuses on 3 study topics.

1. *Analysis of the development of on-demand bus services in China:* This section clarifies the definition used in the study for on-demand bus services in China, and analyses national policies concerning the development of on-demand bus services, including laws and regulations, standards and plans. Specific responsibilities of stakeholders in the development of on-demand bus services and distinct modes of on-demand bus service types are further described.

2. *Case analysis of the development of on-demand bus services in China:* The study features case studies from two cities in China, Beijing and Hangzhou, including a thorough policy analysis and assessment, concerning but not limited to such points as: measures adopted in the cities in pursuit of advancing development of on-demand bus services, service modes, subsidy management, application of informatisation technology, vehicle electrification, bus fares and operating conditions. The study analyses the factors in these two cities which influence the attractiveness of on-demand bus services, and lists effects of on-demand bus services on the reduction of carbon emissions, reduction of traffic volume and transition of mobility modes. 3. *Assessment of current developments of on-demand bus services in China and formulation of recommendations:* A final section analyses the characteristics and key influential factors of successful

## (III) Study methods and data source

The report is based on an extensive literature review, primary survey and stakeholder exchange as well as data processing and analysis. In this study, data about on-demand bus services in 36 key cities in China (including municipalities directly under the central government, provincial capital cities, and municipalities specifically designated in the State plan) have been obtained based on a specific questionnaire survey carried out in 2021 by the authors as part of the China Academy of Transportation Sciences' (CATS) research. The survey had collected basic data, including the number of routes of on-demand bus service, passenger volume and number of vehicles from 2019 to 2021. Due to the onset of the COVID-19 pandemic in 2020, all data depicted significantly be-low-average numbers for transport operations and passenger demands and were hence considered inaccurate as reference points. For this reason, the relevant survey data used in this report is dating back to 2019. Data other than those labelled as online sources in this report come from were obtained by the research team from surveys of the management of public transport enterprises in Beijing and Hangzhou. As the definitions and boundaries of on-demand bus transport in China have not yet been clarified or generally accepted, the statistical criteria and indicators of different cities may vary. In addition, new forms of on-demand bus services are emerging, and each city is in the process of

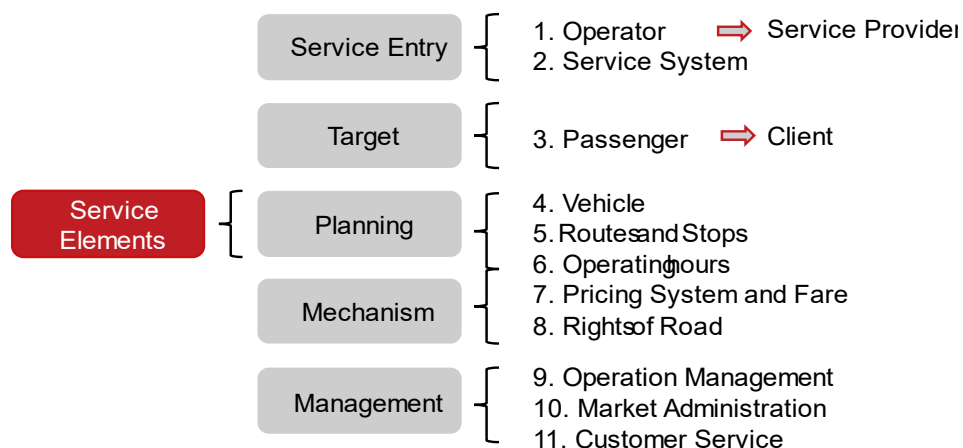


Figure 1: Elements of on demand bus services

on-demand bus services in China and subsequently provides policy recommendations and prospects for the short-term and mid-term development of on-demand bus services.

developing and researching corresponding patterns, so relevant basic data such as the contribution of on-demand busses to the structural transition of mobility and the reduction of carbon emissions have so far been less scientifically and

statistically analysed. Some of the data is therefore based on the experiences and subjective assessments of team members who participated in the surveys.

#### **(IV) Study scope and boundary of the report - definition of on-demand bus services**

On-demand city buses are a new form of high-quality public transport that provides an environmentally friendly, convenient and comfortable mobility service, where operators (often bus companies) use buses to provide a superior service to meet passenger mobility demands. The on-demand bus service refers to a means of public transport developed based on rapidly advancing Internet+ and big data technologies. It is physically served by public buses and trolleys and offers an individualized service. Technologically, Internet+ measures and big data analyses are used, including service elements shown in the figure 1-1. On-demand bus services are still relatively new in China and are a fresh concept that needs to be further explored in most cities across the country, so it has not yet been uniformly defined yet across China and its boundaries have not yet been clearly clarified. In addition, scholars in China and abroad give different definitions of on-demand bus service. Urban on-demand bus service features both the social welfare provided by public transport service and the service subject to individualisation. It is a public transport mode between conventional buses and taxis (or ride-hailing service), and uses online platforms, including websites and apps, to cover the commute of passengers who stay in the same geographical area and have the same travel time and mobility demand. Passengers share the same vehicle along a route tailored to their needs and have re-served seats. An on-demand bus will travel directly from origin destination or stop at a few major stops. Given the practicalities, shuttle buses and chartered buses were provided by bus operators for employers long before the concept of on-demand bus service was developed to meet commuting or other employee's mobility needs. It is an exclusive service, where people other than employees cannot ride, so that such offer is not considered an on-demand bus service from a research perspective. In local practice, services of the types are regarded as on-demand bus services by some cities in relevant surveys or for statistical purposes, e. g. the chartered Xin-dong bus for

local transport in Hangzhou, as the definition and scope of on-demand bus services are not yet clearly defined at the national level. In the following, shuttle bus and chartered buses will be excluded from the analysis where possible. On the other hand, shuttle buses are defined differently in different cities. The so-called business shuttle buses in Beijing, for example, are a public service in the CBD area for the mobility of businesspeople rather than a dedicated service for a specific organisation. Once the bus routes are publicised, any passenger can reserve a seat. Therefore, it is considered as a kind of on-demand bus service in the sense of this study. In general, the urban on-demand bus service can be defined as a differentiated, intensive and high-quality urban public transport service provided by urban bus and trolley bus operators using novel digital means and combining the demand of passengers in the vicinity for reserved mobility. This is a highly flexible approach. Simply put, any mobility service that is characterised by a "customised" process, "non-exclusive" customers, "digital means" for route planning and "differentiated", "intensive" and "high-quality" transport using "public buses and trolleys" can be considered an on-demand bus service. On-demand bus services are an important part of the local urban public transport system. On the one hand, they offer a mobility service in areas that are insufficiently covered by the basic service and, on the other hand, they satisfy passenger demand for individualisation and relatively high travel quality. In practice, small and intelligent NEV are often used in on-demand transport, which make up the largest share of local public transport nationwide.

It should be particularly noted that in 2020, the Ministry of Transport issued the revision of the Management Rules of Transportation of Road Passengers and Passenger Transport Stations (MOT decree 2020 No.17), which defines "on-demand shuttle buses" as "passenger transport by shuttle buses organised by operators certified to operate shuttle lines for the transport of road passengers, with information on departure and destination locations announced on electronic commercial platforms, online ticket booking, and flexible departure and stop times depending on passenger demand". On-demand shuttle buses differ from the on-demand buses discussed in this study



in the following ways: On-demand shuttle buses are part of road transport and serve inter-regional transport (between provinces, cities and counties), while on-demand buses are part of local urban public transport and serve the demand for urban mobility on urban roads.

## **2. Background and environment of the development of on-demand bus services in China**

### **(I) Policy environment of the development of on-demand bus services in China.**

China's first on-demand bus route was put into operation in Qingdao city in 2013, and the government has been promoting the development of on-demand bus services ever since. The Ministry of Transport has successfully issued relevant policies to regulate and support diversified mobility services, including on-demand buses.

At the national level, many policies and guidelines issued by the Ministry of Transport refer to the promotion of on-demand bus transport. These are not mandatory requirements, while the policy direction to support the continuous innovation and exploration of on-demand bus services and its development trends as a new mode of urban public passenger transport is clearly defined. In June 2016, the MOT published the Outlines of the 13<sup>th</sup> Five-Year Plan for Development of Urban Public Transport, which laid out the requirements for the implementation of the Public Transport First Strategy, pertaining to the improvement of diversified public transport network, and measures to encourage special service modes including on-demand buses, so as to better satisfy the various needs of people for mobility. In March 2017, the MOT issued the Rules of Management for Passenger Transport via Urban Public Buses and Trolleys (2017 MOT decree No.5), which stipulates that “competent urban public transport authorities shall organise operating enterprises to provide diversified service means including community buses, on-demand buses and night-shift buses, which meet people’s needs for convenient public mobility and necessary optimisation of the route network of urban buses and trolleys”. In May 2019, the MOT, together with other relevant authorities, published the Notice on the Issuance of a Green Mobility Action Plan (2019-2022) by 12 authorities including the Ministry of Transport (JYF[2019]No.70), which states that “transport

companies are encouraged to actively explore diversified public transport modes, including on-demand buses, night-shift buses and community buses”. In October 2020, the MOT issued the MOT Opinions on Issues Concerning Advancing Modernisation of Traffic and Transportation Control Systems and Capacities (JZYF[2020]No.96), which called for “establishing on-demand mobility service systems such as on-demand buses”. In October 2023, nine governmental authorities, including the MOT jointly issued the Opinions on Promoting the Healthy and Sustainable Development of Urban Public Transport (JYF[2023]No.144), which frequently refer to the on-demand bus service, including the following: “On-demand bus routes and other passenger transport routes shall be subject to government-set fares or market-based fares”; “Stops of micro-circulation routes and on-demand bus routes shall be set-up flexibly, and bus bays shall account for a larger proportion”; “Urban bus and trolley bus enterprises shall be encouraged to make full use of transport resources to design and operate on-demand bus routes for daily commuting to work, schools and hospitals”; “Optimise the management of on-demand buses for higher efficiency”. On 17th October 2024, the Regulations on Urban Public Transport (PRC State Council Decree No. 793) were officially issued, which stipulate that “urban public transport enterprises are allowed to operate on-demand mobility services as long as basic public mobility is guaranteed. The price of the on-demand mobility service can be flexibly set according to practical market demand.” This is now the legal basis for on-demand bus service. At the provincial level, some provinces have laid out general requirements to promote the development of on-demand transport as part of public transport development planning and the Urban Public Transit First Strategies.

For example, the People’s Government of Henan Province has issued the Implementation Guidelines for the Thorough Application of the Urban Public Transit First Strategy and the Promotion of the Quality Development of Urban Public Transport in 2023, which requires to “actively develop special service measures, including on-demand buses and coaches, and encourage eligible cities to expand public transit networks to the suburban areas in all administrative regions and in



conjunction with adjacent cities (townships), and provide better public service at the same level. In 2021, Guangdong Province issued the *14<sup>th</sup> Five-Year Plan for a Comprehensive Traffic and Transport System in Guangdong Province*, which calls for “consolidating the status of the essential role of rail transit in megacities and supercities, optimising the design of the bus network layout, supporting the development of micro-circulation transit, on-demand buses, night-shift buses and other special public transport service modes, developing conventional patrol taxis and web-based taxi booking in coordination, and completing a multi-layered, dense basic urban public transport network.”

On the municipal level, some cities have issued policies to encourage the operation of on-demand buses. In 2016, Guangzhou issued the *Opinions to Encourage Implementation of Pilot Projects of On-demand (Booked) Buses Service*, which outlined specific requirements for operating vehicles, route planning, approval processes, and safety management. The policy explicitly excluded on-demand buses from municipal financial subsidies. Guiyang issued the *Opinions of the General Office of People’s Government of Guiyang on Operation of On-demand Buses in Guiyang City* (ZFBF[2016]No.27), which assigned tasks related to web-based service platforms, focused on key demands, established a market competition mechanism, intensified publicity and guidance, improved service supervision and control systems, refined market-oriented pricing mechanisms, and enhanced safety and security controls to promote the healthy development of on-demand bus services. In 2016, Shenzhen introduced its *13<sup>th</sup> Five-Year Plan of Comprehensive Transport in Shenzhen City*, which aimed to “encourage and standardise the development of diversified market service products, including web-based on-demand buses and community micro-buses, to meet the needs for individualised business mobility, commuting, and tourism via public transport”. In 2009, Xiong’an New Area issued the *Traffic Advancement Guidelines*, emphasising efforts to “strive to develop on-demand buses with passenger convenience in mind, offering accessible, comfortable and high-quality individual public transit.” With regard to standards and regulations, by the end of 2020, the Ministry of Transport (MoT) issued the *Service Regulations on Urban On-demand Buses* (JT/T 1355—2020). For the first time, these regulations legally

defined on-demand buses as a component of urban public transport and provided general guidelines concerning operating routes and vehicles. The standard specifies three types of on-demand bus routes currently available:

1. On-demand commute routes designed to meet passenger needs during morning and evening rush hours, offering direct express services or routes with major stops.
2. On-demand routes at transit hubs where most passengers board or alight, originating at traffic hubs (e.g., railway stations, high-speed train stations, airports) and heading directly to destinations or providing transit services with major stops. These routes meet passenger transfer demands.
3. On-demand business routes connecting key urban points of interest, business districts, hotels, hospitals, schools, and transit hubs to meet business and tourism needs.

In general, no dedicated national subsidies are yet appropriated for on-demand buses, in contrast to conventional bus service sector in terms of policy environment. While on-demand bus services are encouraged and supported on both national and provincial levels, cities are expected to operate them based on specific conditions. There are currently no uniform and mandatory requirements for specific operation processes, conditions or vehicle dispatch. Cities are actively exploring and testing various on-demand bus service models and scopes.

## **(II) Responsibilities of competent authorities at all levels for on-demand bus service**

### **(1) Ministry of Transport**

As the national authority, the MoT defines the role of on-demand bus services within the broader framework of urban public transport by setting policy directions and encouraging the implementation of measures by various levels of government and relevant authorities.

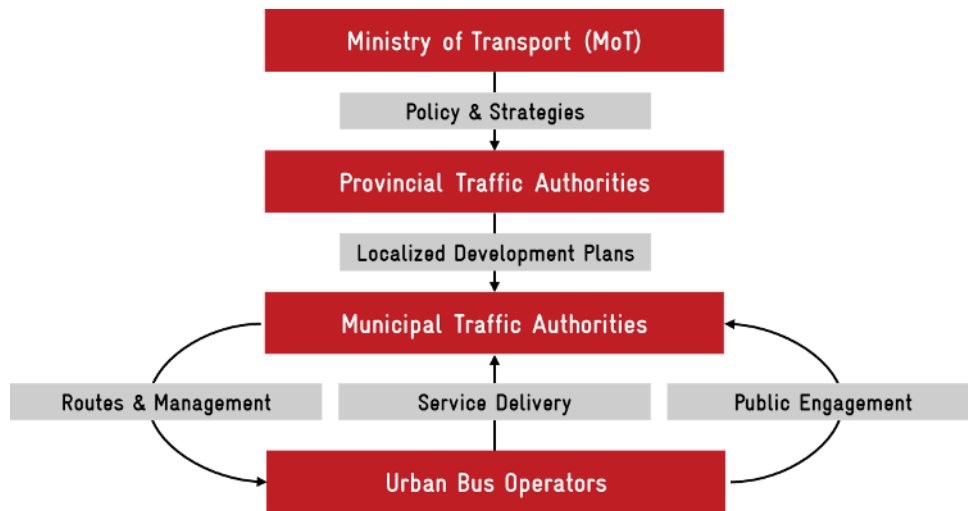


Figure 2: Responsibilities of competent authorities

## (2) Provincial authorities for traffic and transport

Provincial authorities act under MoT’s guidance and translate set policies into localized development strategies that reflect urban conditions, often formalized through public documents and specific plans.

## (3) Municipal authorities for traffic and transport

Municipal authorities organise bus and trolley operators to design and provide on-demand bus services in accordance with the directives from national and provincial authorities and play a crucial role in operational oversight, including route registration, service approval, and addressing challenges during implementation.

## (4) Urban buses and trolleys operating enterprises

Urban bus operators focus on identifying unmet mobility demands and conducting public awareness campaigns to foster service acceptance. Moreover, operators are encouraged to use advanced dispatch systems powered by technologies like big data, and artificial intelligence. Further, by cooperating with technical support enterprises they can establish intelligent dispatch passenger information systems and improve service quality and operating efficiency.

## (III) Overall situation of development of on-demand buses in China

According to data from a 2021 survey of 36 key cities, on-demand bus services transported 178

million passengers in 2019. However, urban mobility patterns were profoundly reshaped by COVID-19, with many on-demand bus routes between 2020 to 2022, making data for these years incomparable. After 2023, public transport passenger volumes have shown slow recovery, while on-demand bus service have grown significantly due to their flexible and diverse service model. As of August 2024, all 36 key cities in China have implemented urban on-demand bus services, with more than 6,000 routes and 8,000 buses nationwide. For instance, Beijing recorded 1.7 million passengers in 2019, increasing to over 20 million in 2024, with daily peaks exceeding 66,000 passengers.<sup>[1]</sup> Megacities like Beijing, Guangzhou, Shenzhen and Hangzhou are characterised by a large population, which leads to a high mobility demand and hence facilitates the large-scale operation of on-demand bus services.

## (1) Service modes

As described above, the industry standard *Service Regulations on Urban On-Demand Buses (JT/T 1355—2020)* defines three types of on-demand bus routes:

1. **Commuter Routes:** Designed for morning and evening rush hours, providing direct or semi-direct express services.
2. **Traffic Hub Routes:** Connecting major transit hubs (e.g. railway stations, airports) to destinations or transfer points.
3. **Business Routes:** Serving urban points of interest, business districts, hotels, hospitals, and schools.

Of the operational on-demand bus routes in 36 key cities in China, commute routes account for 65 %, traffic hub routes for 3 %, and business routes for 32 %.

## (2) Operating entities

Public transport operators dominate the provision of on-demand bus services due to several advantages, including fleet availability, operational infrastructure, and access to government support for land, vehicle upgrades, and digitisation projects. The expansion of rail transit has reduced passenger volumes on traditional bus routes, leaving public transport enterprises with surplus capacity that can be utilised for on-demand services. Moreover, on-demand bus services allow public transport operators to make better use of idle capacity during off-peak hours, increasing efficiency and helping to offset financial losses from conventional public transit operations. These advantages make public transport operators the primary providers of on-demand bus services, enabling them to diversify offerings and sustain their operations effectively.

In the past, internet-based platform enterprises, such as Didi, used to adopt “asset-light” business in major cities like Shenzhen, connecting passengers and transport providers via platform solutions. However, as internet-based platform enterprises were excluded from preferential policies, they faced noticeable cost disadvantages compared to public transport operators, making profitability limited. Additionally, platform enterprises lacked their own transport resources, leading to unstable supply capacities. For example, during the Spring Festival travel rush, Shenzhen's on-demand bus services operated by platform enterprises frequently violated transport regulations. Moreover, there were not clear policies supporting internet-based platform enterprises as responsible operators of on-demand bus services. Consequently, since 2018, most platform enterprises have gradually exited the market.

Today, urban buses and trolley operators remain the primary suppliers of on-demand bus services, while internet-based platform enterprises have shifted to a technical support role, leveraging data analysis, internet technology, and algorithms to assist with route planning and improve operational efficiency for on-demand buses in some cities.

## (3) Routes management

Cities adopt various route management mechanisms:

1. **License mechanisms:** Cities such as Guangzhou, Haikou, Nanning and Lanzhou require operators to obtain route approvals, including details on operational hours, vehicle standards, and service agreements which will be authorised by the perspective traffic and transport authorities.
2. **Registration System:** Cities such as Beijing, Hangzhou, Qingdao, Wuhan, Shenzhen, Chongqing, Chengdu, Xi'an, Xining, Hefei, Hohhot and Nanning allow route adjustments based on demand, requiring operators to report changes to the authorities for record-keeping. As for registration details, local requirements may vary.
3. **Independent operation:** Cities such as Dalian, Jinan, Zhengzhou, Guiyang, Kunming, Shijiazhuang and Taiyuan do not issue requirements for operation of on-demand bus routes for the moment, and thus operators are allowed to operate or adjust routes independently.

## (4) Pricing management

Most cities nationwide adopted market-oriented fares for on-demand bus services. Influential factors, listed in order of importance, are route length, passenger demand and vehicle type. In addition, affordability, corporate operating cost and bus-first mobility strategy are also taken into consideration. In other cities, including Zhengzhou, Guiyang, Haikou, Shenzhen and Lanzhou, fares for on-demand services are set by local governments, similar to that of conventional buses. On-demand buses in Urumqi follow the rough recommendations by the government, too. Because costs of vehicle purchase and personnel for on-demand bus services are assumed by local governments and public transport operators in most cities, fares of on-demand buses are lower than that of other market-driven passenger transits and are priced in average between 0.4 RMB/km and 1 RMB/km.

### Vehicle Purchase Subsidies:

In most cities, on-demand bus services are operated solely by urban public transport operators, who are also responsible for procuring the buses. As a result, vehicles used for on-demand bus services are eligible for purchase subsidies under local schemes.

### Operational Subsidies:

On-demand bus services are typically classified as market-oriented operations. Consequently, they are not covered by government financial support policies for conventional public transport. This includes subsidies for new energy vehicle (NEV) buses, comprehensive operational support, or funding under government procurement policies. Cities like Beijing, Hangzhou, and Nanning view on-demand bus services as an efficient way to utilise idle vehicle resources during off-peak hours. This approach ensures that the existing capacity of conventional buses remains sufficient without requiring additional vehicles or drivers. Therefore, differentiated subsidy policies for on-demand services are not considered necessary.

### (IV) Characteristics in development of on-demand buses in China

Currently, the majority of on-demand bus routes available in cities are business shuttle buses, in addition to certain tour buses, school buses and urban-rural shuttle buses. Moving forward, it will be necessary to expand the scope of on-demand bus services and develop specifically designated routes to meet the diverse needs of passengers.

In general, the development of new urban public transit modes in China has progressed through distinct stages.

**Stage 1:** On-demand buses designed to cater specific needs

**Stage 2:** On-demand transit services to adapt to flexible needs

**Stage 3:** Integrated Mobility as a Service (MaaS) integrating various modes of mobility. Currently, most cities in China are in stage 1, focusing on implementing on-demand buses as a primary new public transit mode.

operations by business terms (e.g. long-term operation or provisional operation), by passenger demand (e.g. commute buses, school buses, or POI tour buses), or by operational hours (e.g. rush-hour, or holiday-special buses). To logically distinguish service scenarios, the study defines three specific on-demand bus service modes based on route stops and paths.

### I. On-demand interconnection buses:

*Definition:* Fixed first and last stops, specified mid-way stops, and pre-determined paths based on demand surveys.

*Primary Use:* Rush hour or tourism seasons, catering to commuters, students, and tourists.

*Route Characteristics:* Stops are typically located near residential communities, schools, urban business centres, or scenic spots.

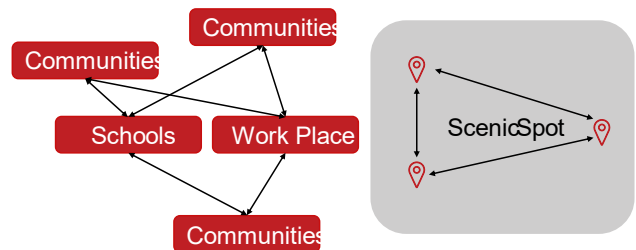


Figure 3: Illustration of routes of on-demand interconnection buses

### II. On-demand traffic hub buses:

*Definition:* Dynamic routes and stops generated in real time based on passenger inputs via a service system.

*Primary Use:* Travel to and from large transport hubs, such as airports, train stations, and high-speed rail stations.

*Route Characteristics:* Flexible one-time routes tailored to provide reliable and premium service during high-demand or off-service hours.



Figure 4: Illustration of routes of on-demand traffic hub buses

### III. On-demand patrol buses:

*Definition:* Operate along designated stops with dynamically adjusted routes and stop sequences using algorithms.

*Primary Use:* Last-mile connections in designated areas, such as urban CBDs or residential neighbourhoods.

*Route Characteristics:* Flexible routes optimised in real time based on passenger demand, ensuring localised and efficient service.

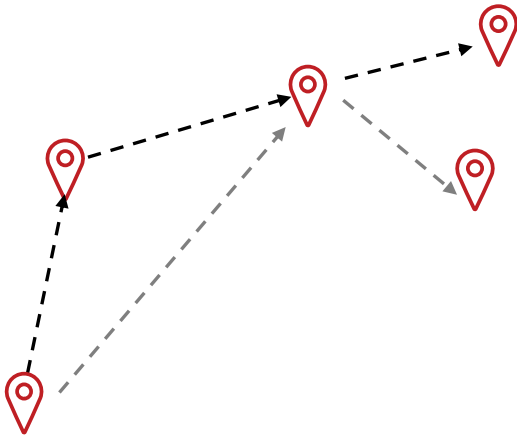


Figure 5: Illustration of routes of on-demand patrol buses

#### (2) Applicable scenarios of on-demand bus modes

On the basis of the classification mentioned above, on-demand bus modes are used in various scenarios.

I. On-demand interconnection buses: Applicable to cities with cluster or belt-layout, and cities where residential areas and business areas are clearly separated, featuring distinct point-to-point traffic. In these cities, there is clear pattern of tidal traffic during rush hours, the characteristics of commuting or commute-related mobility are similar, and travel by private car is not convenient due to traffic congestion or parking restrictions.

II. On-demand traffic hub buses: Applicable to large comprehensive passenger transport hubs, such as high-speed train stations, railway stations, and airports of large and megacities. They are particularly effective when rail transit and conventional buses are out of service at night, in cases of intensive arrivals causing a poorer travel experience with other transport modes, or when adequate mobility service is not available.

III. On-demand patrol buses: Applicable within a designated area, such as urban CBD areas or residential communities, for last-mile connections.

### (3) Analysis on profitability of various modes of on-demand bus services

#### I. On-demand interconnection buses.

According to surveys on the operation of domestic urban on-demand bus services, the on-demand interconnection buses for commuting are currently profitable in Shenzhen. <sup>[21]</sup> As shown in the figure of route designs, these services provide commutes between residential areas in the outskirts and downtown business areas, and the relevant routes feature intensive stops at both ends but travel along express ways or high ways without stops or with limited stops, significantly reducing journey times. Because the service is positioned as commute-oriented, a stable passenger volume is ensured. This has led to Shenzhen's on-demand interconnection buses achieving an average seat reservation rate of approximately 80%. Meanwhile, passengers generally accept the higher pricing of on-demand buses compared to that of conventional buses, thanks to Shenzhen's overall level of economic development, which serves as a key condition for the service's profitable success.

Taking the present-day development in China's cities into consideration, on-demand interconnection bus services are highly possible to make profit if the conditions below are satisfied. First, route length: For example, routes longer than 30 kilometres each that shuttle between remote suburban areas and downtown areas. Second, a stable passenger volume: Strong demand is observed for routes starting at residential communities and ending at urban CBD centres or urban traffic hubs. Third, higher individual incomes: In relatively economically developed cities, higher fares than those of conventional buses are affordable and generally accepted by passengers. Fourth, the absence of better alternative mobility options: For example, in areas without subway service that feature higher costs of private car use due to expensive parking, expressway tolls, and fuel consumption.



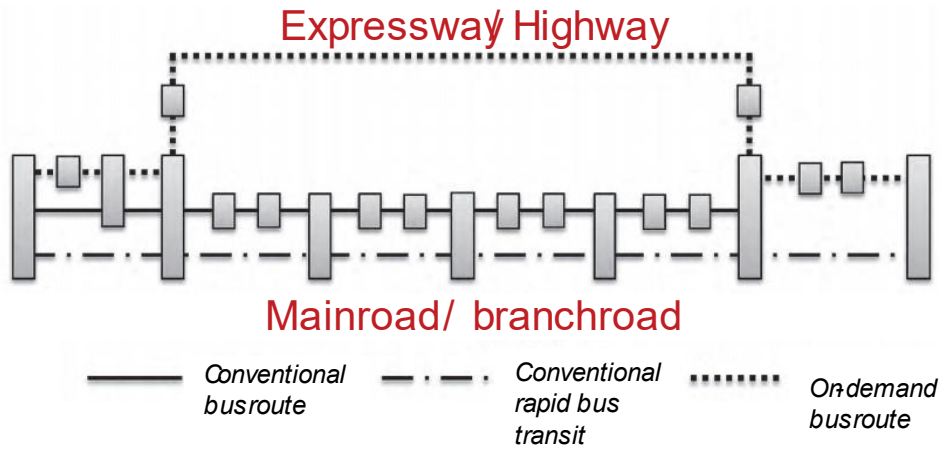


Figure 6: Design mode of Shenzhen on-demand bus routes

## II. On-demand traffic hub buses.

Because of influential factors such as awareness and communication intensity, on-demand traffic hub buses are less frequently selected at traffic hubs such as high-speed train stations and airports. They are often the last choice for passengers, selected only when other mobility means are inconvenient or unavailable (e.g. outside operating hours), compared to stable rail transit, comfortable taxis, and private cars. Passenger volume is inconsistent and usually low. In addition, on-demand traffic hub buses drop passengers off at multiple stops along the routes, requiring passengers traveling to farther destinations to stay longer on the bus. This negatively affects the riding experience and reduces the service's competitiveness. Hangzhou has introduced on-demand traffic hub buses, mainly operating at night during the Spring Festival travel rush, when rail transit is unavailable, and taxi capacity is limited. However, on-demand traffic hub bus services are usually supplementary mobility options and rarely scalable or profitable.

## III. On-demand patrol buses.

On-demand patrol buses are now available, but do not have a stable passenger base yet. In view of their operating mode, which features fixed stops and unfixed routes, vehicle dispatch is relatively challenging. In case of a larger area coverage or routes with dispersed needs, reservations can be slowly to respond, making the mode less competitive. Additionally, on-demand patrol buses are often operated within special areas for door-to-door service, and travel distance of each route is usually shorter than 5 kilometres. Given the relatively limited distance, the fare of an on-demand patrol bus

is not more competitive than that of bicycle sharing service. In the long run, profitability may be possible if stable passenger volume during rush hours can be ensured, based on the flexible selection of available vehicles and constant optimisation of algorithms for route design.

## (V) Relation between on-demand bus service in China and other mobility means

Considering the rapid growing of urban rail transit in the past years, the service mileage of urban rail transit in China continues to increase, providing convenient mobility for citizens. Optimised routes for on-demand buses are designed to smoothly connect rail transit stations, which enlarges the service coverage of rail transit and enhances its attractiveness. Designated school bus routes, on-demand special routes, and other transport modes are designed and operated in order to make interconnection with the subway system more convenient and to construct a green traffic system featuring Rail Transit + Public Transport and Slow Pedestrian Traffic.

Meanwhile for areas not covered by ground public transport or those with lower service efficiency, on-demand buses serve as a complementary means to refine the overall service quality of public transport and improve its coverage. In downtown areas, buses are being discontinued when they compete with rail transit lines along similar or identical routes over long distances. At the same time, denser branch bus routes are being introduced in areas not covered by rail transit networks. Additionally, micro-circulation transit and on-demand bus services are being developed. Furthermore, mobility modes such as interconnection



routes between outskirts of cities, where operational on-demand bus services connect to downtown areas, and tour buses connect main urban traffic hubs with points of interest in suburban areas, are significantly enhancing the refinement of urban passenger transport, making the system more comprehensive.

### 3. Analysis on on-demand bus service cases

#### (I) Selection of cities for case analysis

According to high-level statistics from the China Road Transport Associations, more than 60 cities in China currently offer on-demand bus services. However, large-scale operations have only been established in a few cities, driven by their demand for mobility. Most cities are still in early stages, offering fewer bus routes, and their passenger flow needs further development.

Among the cities with large-scale development, Beijing and Hangzhou were selected for this analysis due to their unique characteristics. Beijing, with its high passenger volume, has launched an on-demand patrol bus service with fixed bus stops and variable routes, which is an innovative approach nationwide. Meanwhile, Hangzhou has developed a diversified service model to meet different needs, such as commuting to work and school, and shuttling between subways and destinations. In recent years, Hangzhou has also made new attempts to offer on-demand bus service in scenic areas and instant online bus reservation.

While Shenzhen has profitable on-demand bus routes, its model involves multiple enterprises operating business in different regions. As a result, the on-demand bus service offered by each enterprise is relatively small-scale. Moreover, the profitability of these routes is closely linked to Shenzhen's unique economic features, which cannot be replicated in other cities. For these reasons, Shenzhen is not selected as a case city for in-depth analysis.

#### (II) Beijing Municipality

##### (1) Development status of urban public transport system

Currently, Beijing's transport system includes nearly 200 main bus routes in a "chess board + ring roads + radiating routes" network structure (see Figure 1). More than 700 common bus routes

complement the rail transit service with adequate stops and varied directions. They connect key passenger flow centres and meet short- and middle-distance mobility needs in urban areas, as well as mobility needs of suburban areas. More than 300 micro circulation lines serve as extensions at the ends of the bus route network, connecting rail transit and main bus routes. In addition, a night shift route network comprising 37 bus routes covers major backbone roads within the 3<sup>rd</sup> ring road, as well as regions with high mobility demands, such as Huilongguan-Tiantongyuan Area and Tongzhou District.

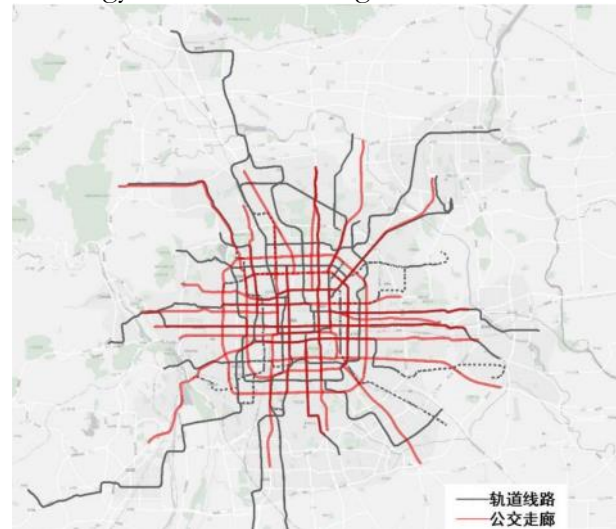


Figure 7: Schematic diagram of main bus routes in central urban area of Beijing Municipality

Dozens of multi-city bus routes offer services to cities and counties in Hebei Province, such as Langfang, Baoding, Zhangjiakou and Chengde, supporting the coordinated development of Beijing, Tianjin and Hebei Province. In view of the decline in the number of bus passengers nationwide or even worldwide, the public transport sector has to transform and improve, in order to offer more precisely targeted services for passengers and continually improve service quality. Accordingly, offering diversified bus service modes is one of the ways to transform and upgrade the public transport industry. The *Overall Planning of Ground Bus Route Network in Beijing Municipality* has developed a "3+1" tiered system for the city's bus route network: "3" refers to main routes, common routes, and micro-circulation routes, collectively called conventional routes. "1" refers to on-demand bus services<sup>[3]</sup>.

### **“3+1” Tiered System of Beijing Bus Service**

The “3+1” tiered system comprises main routes, common routes, and micro-circulation routes, collectively referred to as conventional routes. The “1” refers to on-demand bus services.

#### **Main Routes:**

Main routes serve as the backbone of the bus route network. Based on service areas, they are classified into two types:

**City-suburb main routes:** These connect outer suburbs and central urban areas, offering shuttle services for long-distance commuters, shoppers, and travellers. They are primarily established along expressways, highways, main roads, and other major passenger flow corridors.

**Urban main routes:** These provide service within central urban areas and surrounding residential neighbourhoods. They primarily cater to adults and students commuting to work or school for middle and long distances along the city’s main corridors, including directional roads, ring roads, and radial routes. Urban main routes are also primarily established along expressways, highways, and major roads, supporting fast commuting between residential areas and workplaces.

Main routes adopt an operational model that provides both fast and slow transportation services, addressing the shortcomings of rail transit and alleviating its pressure:

#### **Common Routes:**

Common routes primarily serve central urban areas, targeting passengers with short- and middle-distance mobility needs, such as visits to hospitals, parks, shopping malls, and other dispersed destinations from residential areas. These routes are mainly established along secondary thoroughfares, such as side roads of highways, main roads, and secondary roads, filling gaps in rail transit services.

Night-shift bus routes form an independent network, connecting transportation hubs, hospitals, factories, and residential areas to ensure uninterrupted mobility throughout the day and night:

#### **Micro-Circulation Routes:**

Micro-circulation routes provide localised services around rail transit stops and main bus stops. They offer shuttle connections between residential areas, workplaces, rail transit stops, and main bus stops, or serve short-distance commutes and school bus needs. These routes are mainly established along secondary roads, branch roads, and community roads that cater to dispersed passenger flow corridors. They are primarily used to carry passengers between rail transit systems and main bus routes.

#### **On-Demand Bus Service:**

On-demand bus services act as a supplementary and upgraded form of conventional bus services. Using online reservations, ride-sharing, intelligent deployment, and other innovative measures, these services accurately meet diverse passenger needs in specific scenarios. As a new type of ground public transportation, they provide diverse, intensive, and high-quality services.

Currently, Beijing’s on-demand bus services primarily include business shuttle buses, commute shuttle buses, and designated buses for schools, hospitals, and scenic spots. They also feature regional on-demand patrol buses and buses tailored for holidays and festivals.



Figure 8:  
Destinations  
and major  
stops of first  
on-demand bus  
service

## (2) Operating entity of on-demand bus service

The on-demand bus service was formally launched in September 2013 in Beijing Municipality. The Beijing Public Transport Corporation designed routes based on passengers' similar mobility needs, collected through an online platform. On-demand bus routes primarily address commuting needs between large communities and workplaces where self-driving mobility is heavily relied upon. By soliciting passengers and offering seat reservation and online payment via an on-demand bus service platform, Beijing Public Transport Corporation can establish on-demand bus routes based on agreed times, places and directions. The first 24 routes served commutes between Zhongguancun and Huilongguan, Changping urban area, and Yanjiao, as well as between the CBD and Guanzhuang, Guoyuan, Liyuan, and Yanjiao. A total of 168 stops were set up along these routes, benefiting nearly 100 communities. Bus fares range from 8 RMB to 32 RMB, significantly lower than the 50-150 RMB cost of taking a taxi for the same distance. Whilst conventional buses cost only 2-3 RMB per ride, on-demand buses remain competitive due to their ensured seating for every passenger and rapid transit with stops only at major points<sup>[4]</sup>. The operating entity of Beijing's on-demand bus service is Beijing Public Transport Corporation, which employs a group management

mode. In 2021, the corporation established the Ninth Branch Company of Passenger Transport, consolidating all on-demand bus routes previously operated as individual branch companies. This led to the formation of a large-scale operation model.

## (3) Modes of on-demand bus service

To date, 826 on-demand bus routes have been established across Beijing, covering 13 administrative districts. With 2,489 buses dispatched daily and a maximum passenger volume exceeding 66,000 persons, Beijing's on-demand bus service ranks first nationwide in scale. These routes primarily cater to intra-urban commuters, tourists traveling between scenic spots, and other mobility scenarios. On workdays, nearly 600 operational buses run on 2,300 shifts, with an average daily transport capacity of 42,000 passenger. Most on-demand buses are battery electric vehicles. These buses are flexibly dispatched based on passenger numbers and actual scenarios. Different vehicle models, seating 12-50 passengers, are available to accommodate diverse mobility needs. For instance, short-distance on-demand patrol services within a region use small 6-meter-long vehicles due to their high flexibility and easy maneuverability, while long-distance commuter services utilise large or medium-sized buses for passengers with similar destinations. While focusing on effective commuting, Beijing Public Transport

Corporation has expanded into new scenarios of on-demand bus service. In its initial phase, the service primarily reservations for business shuttle buses. Today, it encompasses multiple service categories, such as business shuttle buses, holiday and festival routes, collective mobility, and leisure travel routes. Its specific products are:

**Business shuttle buses:** Through reservations, these buses offer high-quality commuting services, including guaranteed seating, direct routes to destinations, or stops at a few key locations.

**Holiday and festival routes:** Non-stop routes to scenic spots are opened during holidays and festivals. Passengers can access these services by reserving tickets or purchasing them on-site.

**Special routes connecting high-speed rail stations:** To facilitate passenger mobility from high-speed rail stations at night, diversified service lines are available, connecting Beijing South Railway Station to various destinations. Passengers can reserve tickets or buy them on-site. The buses drop passengers off sequentially at stops near their destinations, without preset intermediate stops. In 2021, Beijing Public Transport Corporation launched an “on-demand patrol bus service” in Wangjing, offering a dozen stops in the region. Passengers can freely select getting-on and getting-off areas among these stops. Using algorithms, vehicles automatically match orders during operation, providing near “door-to-door” service between subway stops and surrounding office buildings.

Wangjing is located in an area formed by four crossing main routes, including Beijing northeast 4<sup>th</sup> ring road, Beijing-Miyun Route, the northeast 5<sup>th</sup> ring road, and Beijing-Chengde Expressway, where the industrial and residential function is highly integrated. Industrial parks with major employment opportunities, such as Zhongguancun Chaoyang Park, Grand Wangjing Business District and Chaoyang International Service Zone of Scientific and Technological Innovation, are located in this area. There are more than 1,000 large-scale internet, AI, technological innovation and culture enterprises and over 80,000 people work in office buildings every day, leading to a serious

commuting tidal phenomenon. During the rush hour in the morning, a mass of commuters swarms into each office building from subway stops, causing a substantial increase in the passenger volume in a short time. It is difficult to find a shared bike outside subway stops in the morning rush hour, while in the evening, randomly placed shared bikes and online ride-hailing vehicles block the routes. For passengers working in the office buildings far from subway stations, on-demand patrol buses can shorten commute times and offer diverse mobility options<sup>[5]</sup>.

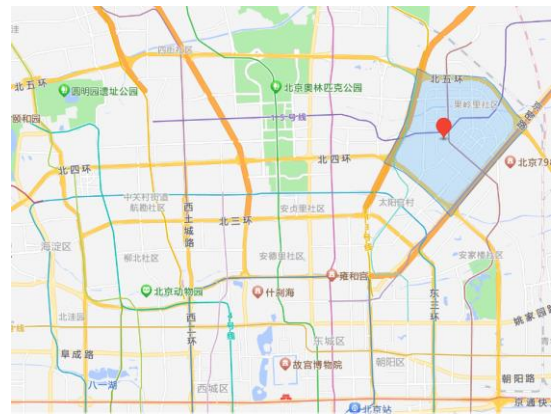


Figure 9: Location of Wangjing region in Beijing

#### (4) Models of on-demand buses and electrification level

There are varied models of on-demand buses in Beijing Municipality to meet the needs of different passenger groups. Recently, along with the promotion of NEVs and the popularization of green mobility, on-demand buses have been gradually electrified. To be specific, on-demand buses include small battery-driven vehicles, minibuses, and some conventional fuel-driven models (though the share of fuel-driven models is gradually decreasing).

**Small-sized battery-driven vehicles:** The on-demand buses in Beijing include several small-sized battery-driven vehicles, such as 12-seat and 14-seat buses. They not only boast comfortable softly padded seats, but also offer USB interfaces for passengers, allowing them to charge their electronic devices.



**Battery-driven minibuses:** Apart from small-sized battery-driven buses, some battery-driven minibuses are used as on-demand buses in Beijing. These minibuses can carry a moderate number of passengers, sufficiently meeting the mobility needs of larger groups.

**(5) Opening procedure of on-demand bus service**

First, an on-demand investigation module is set up to collect passengers’ mobility needs for on-demand bus service. Second, the on-demand information submitted by passengers is collected and sorted in an online platform, and the system automatically matches the residential areas and workplaces with high demand, sequencing them accordingly. Third, staff members design routes in a “point-to-point” manner based on the data, conducting onsite surveys to test the feasibility of the routes. After passengers submit their required arrival times, staff members calculate the departure times considering actual traffic conditions. Fourth, multiple schemes are designed for the same route, making full use of public transportation special lanes and urban highways. After accounting for signal light timings at intersections, stop positions, road conditions along the route, and other factors likely to affect the operation of business shuttle buses, staff members finalize the optimal scheme with the shortest time and/or distance. After the initial scheme is developed, onsite surveys and tests are repeatedly conducted to optimise the plan further, setting running time scientifically. Preparations are then made for arranging buses and trained personnel, updating and maintaining platform data, finalising route products and updating platform information. The service is launched on the new route recruitment module of the on-demand bus platform, allowing passengers to reserve and purchase the service. Once recruitment begins, this information is shared with passengers who initially expressed interest (and provided their contact information). The route is opened once more than half of the seats are reserved by passengers. On-demand bus service share the same stop positions with conventional bus routes. All on-demand buses can only stop at conventional bus routes to pick up and drop off passengers, effectively avoiding traffic congestion and security issues caused by random stops.

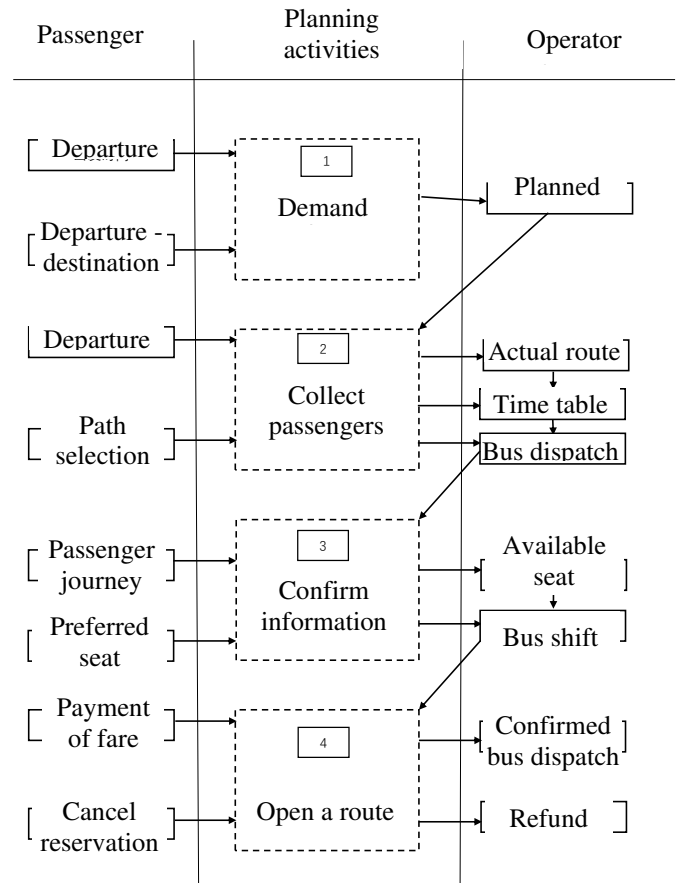


Figure 10: Opening flowchart of on-demand bus routes

**(6) Tickets and subsidy of on-demand bus service**

The ticket for on-demand bus services in Beijing consists of two parts: the seat reservation price and the fare paid by passengers upon boarding the vehicle and swiping their public transport card. The seat reservation price is determined based on the route length. For routes up to 20 km, the price is 8 RMB. An additional 3 RMB is charged for every 5 km increment. This price is approximately half the fuel cost of a privately-owned car for the same distance and one-fifth of the taxi fare. The fare paid by swiping a card for taking an on-demand bus in Beijing is 0.4 RMB, which is mainly used to verify whether passengers take the bus or not. Passengers can reserve bus seats on the on-demand bus service website or the corresponding app. Once a reservation is successful, the platform sends a text message with ride details to the passenger. Passengers may apply for refunds if they are unable to take the bus due to their own or the operator’s fault, provided they meet the refund conditions.

### (III) Hangzhou

#### (1) Development status of urban public transport system

Hangzhou currently has 1,147 routes of battery-driven buses and 9,065 operating vehicles, with 3,838 operating in the main urban district. The city has established a public transportation service system, with common bus routes playing a leading role, supplemented by tourist routes, on-demand bus lines, connection lines and micro bus lines for communities. A total of 666 on-demand bus routes in Hangzhou carry an average passenger traffic volume of 44,000 people daily. The routes cover 10 urban districts of Hangzhou, with additional bus routes connecting Hangzhou to surrounding cities/counties.

#### (2) Operating entity of on-demand bus service

The on-demand bus service in Hangzhou is mainly operated by the Hangzhou Public Transport Group Limited Company. Established in 1953 after the nationalization process, it was restructured in October 2004 into a solely state-owned enterprise. The company focuses on passenger services as its main business and provides subsidiary services like bus rentals, repairs, tourist transportation, and public bicycle system development.

#### (3) Modes of on-demand bus service

According to needs for different routes, Hangzhou uses various battery-electric vehicles with differing passenger capacities for on-demand bus services, including “schooling special buses” with max. 10 seats and personalized “Xin-xiang bus” services using conventional 12-meter buses. There are 5 modes available according to operating ways and service targets.

1. **Chartered bus to metro:** This service connects subways and ground transportation, catering to employees within a 1-15 km radius of subway stops. Enterprises and institutions can customize shuttle services for employee commutes. Introduced in June 2018, the service enhances connectivity between subway stops and workplaces. For instance, in February 2021, Hangzhou Public Transport Group opened 5 on-demand night bus routes by cooperating with Alibaba Group and Ant Group, setting an example of offering on-demand bus service for groups in large-scaled parks.

2. **Schooling special bus:** Launched in September 2018 in Binjiang District, these routes address traffic congestion around schools by offering dedicated routes for students and their parents. These specialised buses carry parents and their children to middle and primary schools, kindergartens and training agencies, thus solving parents’ difficulties in driving their children to school and parking. By 2021, 519 schooling special bus routes serving 175 schools had been introduced. The service alleviates the periodical congestion problem caused by transporting students and secures their mobility safety. At the same time, it advocates the low-carbon and green collective mobility way and adopts the mechanism of “non-profit position and market-oriented operation”.

3. **Cozy bus:** Introduced during the 2019 Spring Festival travel rush, the service offers roughly door-to-door transportation for passengers with similar directions. The routes have the features of “no fixed directions and fixed stops, offering service late, and dropping passengers off at stops in sequence from the near to the distant”. The service philosophy of the “Cozy bus” is “accompanying you on your way home”. It makes up for the shortage of individualised services with conventional buses and shortens passengers’ waiting time for taxis or online ride-hailing cars during rush hours. Besides, it effectively curbs illegal transportation to some degree, winning unanimous praise from East Railway Station Management Committee, sectors of railway, public security and city management, media and passengers. In November 2019, the “Cozy bus service” was upgraded again to launch the “Cozy bus service - Pengbu”, continuously offering on-demand service for passengers to Dingqiao, Changmu, Tianducheng and other directions from Pengbu Subway Stop.

**Digital tour route:** Based on tourists’ mobility needs, this service connects major scenic spots through themed routes, integrating conventional transport services with internet-based innovations. Based on digitalised services and experiences, it combines conventional traffic service with tourism. The routes connect all major scenic spots according to different themes.

**Connection Lines Based on Big Data Analytics:** Designed to connect residential areas with transportation hubs and rail transit, these routes ensure seamless mobility. Hangzhou Public



Transport Group launched a series of service measures, offering “routes connecting subway stations” which feature “a short distance, a short departure interval and speediness” when Hangzhou Subway Line 1 was opened. With its service of seamlessly connecting rail transit, the public transport group offers “zero transfer” services between subways and buses. In the following years, Hangzhou Public Transport Group aims to focus on subway stops, while enhancing the connection between the residential areas, building groups, and industrial parks in a 3-5 km radius from subway stops and rail transit.

#### **(4) Models of on-demand buses and electrification level**

Among the on-demand buses in Hangzhou, battery-electric buses account for a considerable proportion. With the advantages of zero emission, low noise and smooth operation, battery-electric buses have become an important carrier for promoting green travel in Hangzhou. These battery-electric buses cover various lengths of transport routes and can meet a variety of mobility needs from short-distance commuting to long-distance travel. In terms of the total numbers, more than 70 % of buses and trolleys in Hangzhou are battery-electric buses.

#### **(5) Opening procedure of on-demand bus service**

Hangzhou’s filing system is adopted for opening and operating on-demand bus routes. Public transport operators design routes and stops based on passenger demand and report relevant information, such as operation time and fare, to the relevant authority for approval. Hangzhou has developed and launched an online system to approve the opening and operation of on-demand bus routes online, which is faster and shortens the cycle from demand survey to route operation.

#### **(6) Tickets and subsidy of on-demand bus service**

Fares for on-demand buses in Hangzhou are based on mileage, meaning a passenger is charged according to the travel distance needed. Within 5 km (inclusive), the fare is 5 RMB, with an additional 3 RMB charged for every 5 km increment. Seat reservation fees are calculated as the cost per

ride multiplied by the number of rides per day and the riding days. Fares are collected online in advance via on-demand bus platform.

### **(IV) Analysis on factors of cities nationwide which influence the development of on-demand buses**

According to the analysis of typical domestic cities, the following conditions are necessary for large-scale development of on-demand buses:

1. The urban population must be no smaller than 5 million. On-demand buses serve passengers with similar mobility demands, which require a certain mobility volume directly determined by the population size.

2. The economic development of the city must be above average. Given the relatively high-quality and convenient service provided by on-demand buses, the fare is higher than that of conventional services. A sufficient passenger volume can only be ensured if passengers are willing to pay more for better service.

3. Public transport operators must have advanced technical capabilities. Currently, innovative on-demand bus services in China rely heavily on big data analysis and route planning algorithms. Operators must have the ability to widely apply internet technology and perform necessary updates, which are prerequisites for effectively implementing this innovative service model.

Additionally, the average travel distance also affects the development of on-demand bus services, according to the average development in cities in China. In cities with relatively small urban areas, electric bikes are capable of providing door-to-door mobility while being less affected by road conditions. This makes electric bikes grow rapidly, while on-demand bus service is less advantageous and can hardly scale up.

### **4. Analysis on Carbon Reduction Benefit of On-demand Buses**

#### **(I) Carbon reduction strategy**

With the rapid development of the online platforms, "on-demand buses" have emerged as innovative solutions. The establishment of on-demand bus service platforms, coupled with increased publicity and promotion, has led to their recognition and acceptance by the public. At the same time,

by utilising innovative technology, the "on-demand bus" can determine specific service routes according to travel demand, thus achieving higher efficiency in travel services and producing more significant carbon reduction effects.

The primary factors influencing urban transport carbon emissions include urban spatial planning, transport equipment, the structure of traffic modes, and intelligent transport technology. The two main carbon reduction strategies of on-demand buses are:

### 1. To promote new-energy public transport vehicles

Urban buses are a primary focus for promoting new-energy vehicles in China. By integrating new-energy vehicles into on-demand bus services, the energy structure of public transport is optimized, vehicle electrification is enhanced, and significant carbon reductions are achieved.

### 2. To optimise mobility networks

Because different modes of transportation have varying carbon emission intensities, carbon reduction can be achieved by optimising the overall transportation and mobility networks. On-demand buses offer a new type of service that supplements conventional trolleys and buses. Given their requirement for a certain passenger volume to operate effectively, their carbon reduction effect is amplified in practice. Since the operational carbon emissions of full-electric vehicles are zero, on-demand buses emit far less carbon than conventional buses or trolleys. By developing on-demand bus services, passenger numbers for urban public transport will increase, which will play an important role in improving the proportion of mobility by urban public transport, optimising the network of traffic and mobility and implementing carbon reduction of urban transport.

### (II) Establishing a carbon reduction accounting method

The ASIF method, proposed by Schipper in 1999, is a transport carbon emission assessment method based on transportation activities, and is the most widely used "bottom-up" assessment method in the field of urban transport. See formula (1) for the calculation method of urban transport carbon emission.

$$TE = \sum (VKT_{i,j} \times E/VKT_{i,j}) \quad (1)$$

Where:

$i$ : mode of transportation;

$j$ : fuel type;

$TE$ : total carbon emission (t);

$VKT_{i,j}$ : traffic activity level (vehicle per kilometre, km);

$E/VKT_{i,j}$  is the carbon emission of the average traffic activity level (ton/km).

Building on this method and considering the characteristics of on-demand buses in China, the carbon reduction accounting method incorporates key indicators such as passenger traffic volume, driving distance, and carbon emission factors. The method uses scenario analysis to evaluate different development contexts: In the baseline scenario, there are no on-demand buses in operation. Passenger traffic volume needs to be accommodated through cars, taxis, buses, by walking and cycling. In the customised transit scenario, on-demand buses have become a primary daily travel mode, achieving the same passenger traffic volume within the same timeframe.

The accounting method for determining the carbon reduction of on-demand buses is shown in Formula (2), Formula (3) and Formula (4).

$$ER = BE - DE \quad (2)$$

Where:

$ER$ : annual carbon emission reduction of on-demand bus (tCO<sub>2</sub>);

$BE$ : annual carbon emissions in reference scenario (tCO<sub>2</sub>);

$DE$ : annual carbon emissions of on-demand bus (tCO<sub>2</sub>);

$$DE = \sum (PV_{i,j,t} * DIS_{i,j,t} * PEF_{i,j,t} * 10^{-3}) \quad (3)$$

Where:

$PV_{i,j,t}$ : passenger traffic volume of on-demand buses;

$DIS_{i,j,t}$ : average travel distance of on-demand buses on different routes;

$PEF_{i,j,t}$ : emission factor of on-demand public transport mode (tCO<sub>2</sub>/pkm);

$i$ : type of energy, such as available petrol, electricity, natural gas and diesel;

$j$ : type of on-demand bus routes (on-demand buses for scenic spots, business regular buses, cruise buses, etc);

$t$ : coach driver.

$$BE = \sum (PV_{i,k} * DIS_{i,k} * PEF_{i,k} * 10^{-3}) \quad (4)$$

Where:

$PV_{i,k}$ : Passenger traffic volume of different modes of transport;

$DIS_{i,k}$ : Average travel distance by different modes of transport (cars, taxis, buses, walking, bicycles, etc.);

$PEF_{i,k}$ : emission factors of different modes of transport (tCO<sub>2</sub>/pkm);

$i$ : types of energy, such as available petrol, electricity, natural gas, diesel;

$k$ : different modes of transport (trolleys and buses, taxis, cars, bicycles, etc.).

The carbon emission factors of various mobility modes are shown in Table 3-1.

Modes of transport	Carbon emissions (kg/pkm)
Walking	0
Cycling	0
Bus (diesel-powered)	0.026
Bus (natural gas-powered)	0.022
Bus (electric-powered)	0
Bus (gas-electric hybrid)	0.011
Car	0.071
Taxi	0.12
Subway	0

Table 1: Carbon emission factors of various mobility modes

### (III) Accounting results

#### 1. Beijing

According to data for Beijing on-demand bus services, of the passengers, there are 30 % private vehicle owners, 30 % come from public transit, 35 % are passengers who used to take taxis, and 5 % are previous pedestrian and bicyclists. This data will be used as an input parameter for the reference development scenario.

After processing and analysing the data, using formula (3), the annual carbon emissions in reference scenario are calculated to be 10,860 tons, in which the carbon emissions of small cars, taxis and public transport are 3,491 tons, 6,285.1 tons and 1,083.9 tons, respectively.

Next, using formula (4), the annual carbon emissions of on-demand buses are calculated to be 4,436.8 tons.

Finally, using formula (2), the annual carbon reduction achieved by on-demand buses in Beijing is calculated to be about 6,423.1 tons.

#### 2. Hangzhou

The same modal shift data of passengers changing to on demand bus service users in Beijing is also applied as a reference for the Hangzhou case.

By using the above formula (2), formula (3) and formula (4), the annual carbon emissions of on-demand buses are calculated to be 1,536.5 tons, the annual carbon emissions of reference scenario are 6,155.7 tons, achieving an annual carbon reduction of approximately 4,619.3 tons.

### (IV) Conclusion

The development of on-demand shuttle buses has significant impact on carbon emission reduction. It not only reduces the use of private cars and carbon emissions, but also improves the efficiency and resource allocation of public transport systems, promotes the upgrading of public transport vehicle technology and increases the public participation in green travel.

Moreover, with the rapid development of on-demand buses, public transport companies actively strengthen technological innovation and vehicle upgrading. To reduce the carbon emissions and exhaust emissions of public transport, clean energy vehicles, such as electric vehicles and natural gas vehicles, are preferential for on-demand bus operations.

For example, among the on-demand public transport vehicles of Beijing Public Transport Holdings (Group) Co., Ltd. Ninth Passenger Transport Branch, battery-electric vehicles account for 49.0 %, and green public transport vehicles (natural gas, hybrid, battery-electric) account for 82.7 %. In Beijing, the proportion of green buses used for on-demand services is significantly higher than the proportion of 73 % for public transport, as shown in Figure 3-1. At the same time, the public transport companies also further reduce the energy consumption and emissions of vehicles by optimising driving behaviour and improving the level of vehicle maintenance. These measures not only help to improve the environ-

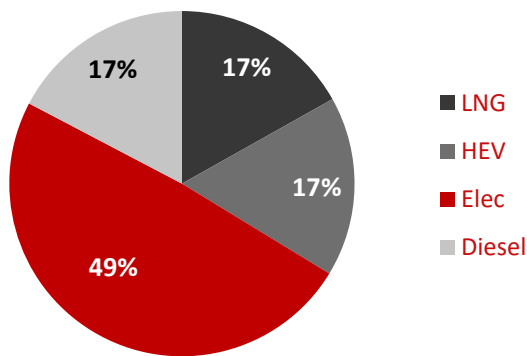


Figure 11: Energy structure of on-demand buses in Beijing

mental performance of public transport systems, but also play a leading role in promoting carbon reduction.

## 5. Experiences and Prospects

### (I) Experience in the development of on-demand buses in China

#### 1. Strengthen the application of intelligent technology in on-demand bus service

Based on the advantages of local digital enterprises, Hangzhou promotes the transformation and upgrading of traditional bus services through digitalisation. This is achieved by building the Hangzhou Public Transport Data Brain 3.0, which integrates existing business subsystems into a visual, controllable, and evaluable "digital bus" cockpit.

This integration allows the analysis of passenger flows, route network management, intelligent dispatching, intelligent stations, information service for on-demand busses, public bicycles, and digital security. Hangzhou has independently developed a public transport cloud dispatching system, which integrates public transport operation data, real-time mobility data provided by the city brain and the real-time data of third-party mobility platforms such as Amap. The system uses cloud computing to automatically adjust the schedule and departure times, ensuring that capacity and demand can be organically combined to achieve "more efficient command, more accurate service and more streamlined personnel". According to statistics, after implementing the system, the planned scheduling time has been shortened from 3 hours to 10 minutes, and the per capita dispatching capacity has been increased from 80 vehicles to 260 vehicles. This improvement optimises the timeliness of routes and schedules. With the empowerment of public transport data, the "one route, one policy" approach will continuously optimise the operation plan, and gradually realise the timeliness of routes and schedules.

#### 2. Responding to the travel needs of different groups of people

Hangzhou has introduced short-distance, small-scale, high-frequency microcirculation buses connecting subway stations, residential areas, business zones, schools, and hospitals. Additionally, it has implemented the "staggered peak and station" subway connection line and the "micro-bus entering the community" service model to meet diverse travel needs. To reduce transfer time for passengers, Hangzhou promotes the service of "bus departs as soon as subway arrives". In peripheral urban areas with blank subway coverage and obvious commuting characteristics, the city opened the "express line + express line" subway connection line, combining long-distance and short-term operations. The community shuttle bus adopts the ways of waving to stop and greeting stops to facilitate people's travel. At the same time, combined with the travel needs of sightseeing to scenic spots, commuting to primary and secondary schools, and commuting to public parks, high-quality on-demand special routes such as tourist special routes, schooling special routes and



chartered Xin-dong bus-to-metro transit have been newly opened and optimised.

### **3. Make full use of various forms of advertising to publicise on-demand bus service**

On-demand bus services typically use a variety of publicity modes to raise service awareness through both offline and online channels, encouraging passengers to choose on-demand buses for their travel needs. Offline publicity mainly refers to activity posters, carriage painting advertisements and other means by using bus and trolley stops and carriages, leveraging the high foot traffic at bus stops and the mobility of buses. Online publicity mainly refers to the company's official websites and major media presence to publish publicity articles such as rules of use and ride experience of on-demand buses.

## **(II) Suggestions on promoting the development of on-demand bus services**

### **1. Establish a sound system of laws, regulations and policies**

Currently, the development of on-demand buses in most cities in China is still in the exploratory stage, with significant differences between service modes and operational approaches, varying from city to city. In regard to the positioning, connotation and boundary of on-demand buses, there needs to be a clear top-down approach to achieve better standardisation.

The first step is to promote the enactment of comprehensive and industry-wide laws and regulations, and to clarify and standardise the attributes and characteristics of on-demand buses. The second is to issue a policy document to encourage the development of diversified public transport service modes, clearly defining the important role of public transport services as a diversified service mode of urban public transport service in guiding citizens to choose intensive and green travel modes. Simultaneously, such a policy document should encourage public transport operators to fully leverage their market initiative and stimulate market vitality. Lastly, existing regulations must be revised to incorporate mechanisms for the operation of on-demand buses, including access, qualification of operating enterprises, fare policies, subsidy systems, and supervision.

### **2. Improve the standard specification system for on-demand buses**

As an innovative service mode of urban public transport, on-demand bus services need to build a system to standardise the operation and management process of on-demand buses. First, it is important to formulate standards for the opening and adjustment of on-demand bus routes, focusing on relevant requirements under the coordinated planning system of on-demand buses and conventional buses, so as to better integrate the travel needs of urban residents and improve the efficiency of on-demand bus operation services. Second, criteria for evaluating the effectiveness of on-demand bus operations should be developed to assist industry authorities and operators in assessing service performance, improving planning, and managing these services more effectively.

### **3. Develop technical guidance for on-demand buses**

City governments or transportation authorities should define the technical approach for establishing on-demand bus services. This should include criteria for launching on-demand buses, operating procedures, and the basic structure of the management platform. The goal is to optimise route planning and daily operations, ultimately improving the passenger experience. Enhancing data-driven capabilities through the integration of digital services, big data, cloud computing and other new generation technologies, the on-time matching of travel demand and supply service capabilities can be achieved.

### **4. Strengthen the supporting role of new technologies in the development of on-demand buses**

The "Internet +" and big data revolution has given rise to on-demand bus services, which rely heavily on online platforms for ticket reservations, route planning, and demand analysis. The application of online service platforms to carry out demand research, route design and booking for ticket purchase is crucial for the future development of on-demand buses. Using technologies such as big data, cloud computing and artificial intelligence, the intelligent dispatching system can schedule buses in real time and optimise the path planning, to realise the rapid matching of travel demand and supply service capacity, thus enhancing the travel experience of on-demand bus

passengers. Big data and AI technologies can also analyse passenger demand and traffic patterns, helping operators refine their routes and vehicle scheduling. Additionally, Internet of Things (IoT) technology can connect buses, road infrastructure, and passenger devices to enable real-time information sharing, enhancing service accuracy and safety. Once mature, autonomous driving technologies could further improve the safety and reliability of on-demand buses, reducing human errors.

### **5. Strengthen the publicity and promotion of on-demand bus service**

Effective publicity and promotion activities can increase public awareness of on-demand bus services. Combined with advertisement on conventional and new media channels, such as microblogs on WeChat, the concept of on-demand buses can be further promoted to create a favourable public opinion for the development of on-demand bus services. In addition, according to the characteristics of the city and the demand for passenger flow, a variety of ticket systems and discount activities can be introduced to attract passengers to choose on-demand buses for travel. Further, a steady passenger flow can also be maintained by promising preferential fares during the service period.

## **(III) Development prospect of on-demand buses**

### **1. The overall market size will continue to expand**

With the rapid development of urban rail transit in China, conventional bus services have lost competitiveness due to changes in citizens' travel habits and increased car ownership. As a result, bus ridership has declined, and public transport companies face financial challenges. To address this, in 2023, 9 governmental authorities including the MoT issued jointly the Opinions on Advancing Healthy and Sustainable Development of Urban Public Transport (JYF [2023] No.144), which put forward the idea of "encouraging the development of microcirculation bus services and applying miniaturised buses according to demand for passenger flow. The objective is to support urban buses and trolley enterprises to make full use of transport resources to design and operate on-demand bus routes for daily commute to work, schools and

hospitals." Microcirculation bus service and on-demand bus service are regarded as one of the important means to promote the sustainable development of public transport enterprises. It is expected that on-demand bus travel service will become a new breakthrough point of the public transport industry in the future, facing rapid growth in the overall scale.

### **2. On-demand travel services will cover more application scenarios**

At present, on-demand bus services are mostly available in urban core areas. However, with increasing urban-rural integration, the characteristics of scattered and random travel demand in suburban areas make it suitable to adopt demand-responsive travel services. In mixed urban-rural areas, population is increasing, and economic development is enhancing, which together results in increasing challenges for transport solutions. On-demand buses, with their flexible route planning and scheduling, are well-suited to address these challenges. They can alleviate congestion, reduce reliance on private cars, and connect urban and rural areas, facilitating mobility and supporting economic and cultural exchange. Additionally, with the aging population, there is an increasing demand for medical transportation services. At present, some cities in China have opened special medical routes connecting large communities to surrounding general hospitals. In the future, further barrier-free measures will be implemented to serve the elderly and disabled populations.

### **3. Technological innovation continuously improves service levels**

In the "Internet +" era, urban transport services are evolving. The application of new technologies such as autonomous driving, vehicle connectivity, and data analytics will continue to enhance the service levels of on-demand buses. By developing value-added services related to on-demand buses, such as green points, preferential activities, trial ride, pocket money in "red envelopes" for user, free lucky draw, discount-based cashback, points exchange, etc., passengers will be incentivised to switch to other modes of transport. Additionally, by building digital platforms, especially focussing on network platforms and mobile phone, giving full play to the role of WeChat, will effectively support the establishment and use of on-demand bus services. Lastly, using the internet to promote



and publicise on-demand bus services and release the information of new and running routes of on-demand buses in real time, will further increase acceptance and usage rates.

#### **4. Service modes will be further diversified**

To further subdivide the passenger transport market and provide diversified service modes that facilitate the daily travel of urban residents, the focus should be on meeting the demand for more convenient connections for short distances, more comfortable rides for medium and long distances, personalised travel times, and high-end services for holiday passenger flow. Attention should also be given to the intensive travel needs of group

customers such as government agencies, enterprises, institutions, parks, and universities. The advancement of unit-use vehicle reforms should be leveraged to launch specialised services for these major customer groups. This includes designing and implementing travel demand surveys for group customers, customising intensive travel plans, and providing diversified transportation services. A one-stop service should be offered, covering consultation, planning, resource integration, operation, and a complete package of solutions to support the intensive travel needs of group customers.

## Annex

Annex 1: Table 1-1 Comparison of on-demand, conventional and chartered buses

Elements	Conventional bus	On-demand bus	Chartered bus
Operating enterprise	Enterprise with public transport operating licence	Enterprise with public transport operating licence	Public transport operating enterprise, road passenger transport enterprise or other enterprise operating vehicle rental service
Passenger	Open to all persons	Open to all persons	Persons or groups purchase charter service
Service system	Offer information on routes and en-route stops	Elicit demand and sell tickets via online system	Generally, not applicable
Routes and stops	Often fixed routes with regular optimisation for route adjustment; stops are relatively evenly set along a route	Stops are set according to passenger demand and often at conventional bus stops; routes are relatively more flexible and distances between stops can be less equal	Stop on request and passengers can get on or off at other places than conventional bus stops
Operating hours	Based on fixed intervals and shifts	According to various service modes, a service can be operating during rush hours or on demand of passengers at where the majority of passengers get on/off	On demand of passengers without fixed timetable
Ticketing system and fare	Welfare-oriented low fare, uniform fare or mileage-based cascade fare	Fare is between welfare-oriented low fare and market price, and is decided according to route mileage	Market price
Vehicle	Urban buses and trolleys that satisfy relevant standards	Vehicle models can be flexible in response to passenger demand	Vehicle models can be flexible in response to passenger demand
Right of road	Subject to bus-first right of road	Subject to bus-first right of road	In general, not subject to bus-first right of road, while bus-first right of road can be granted to intensive mobility in line with requirements of local policy
Operational management	Routes can only be adjusted, operational or out of service after approval or filing by competent industrial	Routes can be adjusted, operational or out of service flexibly by an operator according to passenger demand, and relevant information shall	Operational or out of service on demand of passengers

	authorities with necessary public announcement.	be announced on service system platform.	
Market administration	Competent industrial authorities are responsible for examination and assessment of service quality, and an operating enterprise can be subject to operational subsidy	Competent industrial authorities are responsible for supervision and inspection of operational safety	Competent industrial authorities are responsible for supervision and inspection of operational safety
Customer service system	Work as industrial and corporate channels of compliant and service	Relatively comprehensive presales and aftersales service	Work as industrial and corporate channels of compliant and service

*Annex 2: Table A-2 Function positioning, setting and basic service standards of routes at each tier*

Tier		Function positioning	Establishment	Length	Interval	Dispatching frequency
Main routes	City-suburb main routes	Service area: offering shuttle service between outer suburbs/new towns and central urban areas. Their terminuses are set at the hubs or subway stops outside of the 3 <sup>rd</sup> ring road Service targets: long-distance commuters, shoppers and travellers Route type: offering both fast and slow transportation service Interaction with rail transit: filling in the blank of the rail transit service	Expressways, highways, main roads and other major passenger flow passageways	Shall not be greater than 70km	Greater than 1km	Rush hour: cross-section passenger flow volume of more than 500 persons lasts for less than 5 min; cross-section passenger flow volume of less than 500 persons lasts for less than 10 min Non-rush hour: cross-section passenger flow volume of more than 400 persons lasts for less than 10 min; cross-section passenger flow volume of less than 400 persons lasts for less than 15 min
	Main routes in urban areas	Service area: offering service in central urban areas and their surrounding residential areas Service targets: adults and students commuting to work and schools for middle and long distances along the city's passageways of all directions, ring	Side roads of highways, main roads, secondary roads and other secondary passageways of passenger flows	Shall not be greater than 25km	800m-1km	Rush hour: cross-section passenger flow volume of more than 500 persons lasts for less than 5 min; cross-section passenger flow volume of less than 500 persons lasts for less than 10 min Non-rush hour: cross-section passenger flow volume of more than 400 persons lasts

	roads and radiation routes, as well as people requiring fast commute between main residential areas and work places  Route type: offering both fast and slow transportation services Interaction with rail transit: sharing rail transit pressure				for less than 10 min; cross-section passenger flow volume of less than 400 persons lasts for less than 15 min
Common routes	Service areas: offering service in central urban areas Service targets: people with short- and middle-distance mobility needs, such as going to hospitals, parks, shopping malls and other disperse places from their residential areas Interaction with rail transit: filling in the blank of rail service	Side roads of highways, main roads, secondary roads and other secondary passageways of passenger flows	Shall not be greater than 20km	500-800m	Rush hour: cross-section passenger flow volume of more than 400 persons lasts for less than 10 min; cross-section passenger flow volume of less than 400 persons lasts for less than 15 min Non-rush hour: cross-section passenger flow volume of more than 250 persons lasts for less than 15 min; cross-section passenger flow volume of less than 250 persons lasts for less than 20 min
Micro circulation lines	Service areas: centred around main stops of rail transit and main bus routes Service targets: shuttle connection between residential areas / work places and rail transit stops / main bus stops; short-distance commute/school buses Interaction with rail transit: carrying rail transit passengers	Secondary roads, branch roads, community roads and other roads for disperse passenger flows	Less than 10km	300-500m	Rush hour: less than 5 min Non-rush hour: 10-15 min
On-demand bus	It is a supplementary to and upgrading of regular bus service. By adopting on-line reservation, ride-sharing, intelligent deployment and other innovative measures, it can accurately meet citizens' needs in different scenarios.	It can be set up flexibly according to customers' needs.			

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