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Review and Reflection on the 20-Year Development of Urban Transportation: Witnessing 20 Years of Achievements by the *Urban Transport of China*

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Abstract: The journal *Urban Transport of China* has experienced 20 years of development since its establishment in 2003. During this period, new concepts and technological methods for urban development have continuously emerged, leading to fruitful theoretical and practical achievements. This paper reviews the development of urban transportation in China in the 21st century from six aspects: the rapid growth of regional and urban transportation facilities, the correction of development models and construction for urban transportation, significant changes in the characteristics of urban transportation, the development of motorization and transportation demand management, the theoretical framework and standard system of comprehensive urban transportation planning, and the reform of urban transportation systems and institutions. While reviewing the splendid achievements in infrastructure and operational organization, the analysis highlights issues in urban transportation development. These issues include the lack of a refined development model, ineffective coordination in governance, limited regulations and economic policies, and insufficient institutional and mechanism reforms. In the process of developing and transforming urban transportation in the context of the modernization of China, technological innovations and transformative development concepts are expected to reshape the analysis, layout, organization, operation, and governance models of urban transportation.

Keywords: urban transportation; development concepts; transportation infrastructure; public transportation; motorization; transportation demand management (TDM); planning theory; systems and mechanisms

0 Introduction

The journal *Urban Transport of China* originated in 1999 as an in-house publication and later gained official journal status following approval by the Ministry of Science and Technology of the People's Republic of China and the former General Administration of Press and Publication in 2003. It has been published for two decades since then. This 20-year period stands out as the most significant and noteworthy chapter in China's urban development history. It may also be the only time when cities grew so fast and took shape. Before this period, China experienced a period of low urbanization rates; in the years since it has entered an era of high urbanization rate and development stage dominated by existing resources. Over the 40 years of reform and opening up, and notably in the rapid development of the past two decades into the 21st century, China has consolidated the spatial and transportation network framework of its urban areas. Similar to the transportation network in the old urban cores of developed Western countries and contemporary Chinese cities, this framework is likely to endure for an extended period of time, serving as a permanent hallmark of Chinese urbanism.

The initial two decades of the 21st century are set to be remembered as an unparalleled period in the developmental trajectory of Chinese cities. Not only have they shaped our urban landscapes and lifestyles, but they have also influenced our concepts and substantially propelled the progress of urban transportation and urban civilization in China. In the past two decades, China's per capita GDP has increased tenfold; the urban population has doubled; the number of individuals with a college education or higher has grown nearly sevenfold ①. Concurrently, as the population quantity and structure have rapidly changed, the physical space and facilities of cities have also experienced explosive expansion. The urban built-up area has expanded from 22,000 km^2 in 2000 to over 60,000 km^2 in 2019, tripling in size ②. Transportation land use has increased from 22,000 km^2 in 2004 to 95,000 km^2 according to the third national land survey in 2018 ③[1]. The number of civilian vehicles has surged from 27.42 million in 2004 to over 280 million in 2020, an increase of more than 10 times. The cities and urban transportation as perceived by people today have undergone a profound transformation, bearing little resemblance to those of 20 years ago. The significant changes in population, income, urban scale ④, and motorization not only impact the urban landscape but also deeply influence the thoughts, lifestyles, and concepts of city dwellers, reshaping their understanding of cities, urban transportation, and travel concepts.

With the reform and opening up and China's accession to the World Trade Organization (WTO), the opening of the

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country's doors has enabled us to closely interact with the world. Through learning and exchanging ideas with advanced countries and regions, China observed the development and changes in urban transportation around the world, guiding itself with advanced development concepts to address various issues arising from rapid urban expansion. This process helps the establishment of theories and standard systems suitable for the development stage of urban transportation in China, as well as planning, construction, and operation management systems that are tailored to China's national conditions. While gaining insights from the world, China also contributes its experiences and theories in urban transportation development and governance to the international community.

1 Rapid growth of regional and urban transportation infrastructure

1.1 Stages of urban development and its growth characteristics

The spatial development of Chinese cities can be roughly divided into four stages based on the characteristics of expansion. 1) In the 1990s, urban expansion progressed relatively slowly due to low levels of motorization. 2) In the first decade of the 21st century, there was an explosive expansion stage of urban space, urban motorization, and urban transportation infrastructure, driven by rapid private motorization and strong promotion of land finance. 3) Under the policy of controlling land expansion, the second decade of the 21st century witnessed a period of high-speed and steady expansion. 4) Currently, with the slowing pace of urbanization, cities have mostly entered a stage of development dominated by existing resources.

Due to different modes of motorization, Chinese cities have shown two completely different development patterns around the turn of the 21st century. 1) In the 1990s, urban areas grew relatively slowly on existing urban foundations. However, after entering the 21st century, a confluence of factors including policies in the automobile industry, urban land capitalization, and China's accession to the WTO led to explosive growth in urban populations, urban construction space, the scale of transportation infrastructure, and the degree of motorization [2]. The urbanization rate in China increased from 36% in 2000 to over 65% by 2022, with the urban population doubling. Concurrently, as the population grew, the urban built-up area expanded nearly threefold. The average population density of cities witnessed a decline from 36,800 people/km^2 in 1990 to 26,600 people/km^2 in 2000, and then experienced a rapid descent to 9,850 people/km^2 by 2010, and further declined to 8,700 people/km^2 by 2019 ②. These changes in urbanization and average population density vividly illustrate the pace of urbanization. The exceptional pace at which urban spaces expanded in the first decade of the 21st century can be attributed to the rapid development of private automobiles and public transportation, providing cities with the impetus for motorization. Over the first 20 years of the 21st century, the length of urban roads in mainland China surged from 208,000 km in 2003 to 532,500 km in 2021. The number of cities with urban rail transit systems escalated from 4 to 45, with the total length of urban rail lines expanding from 186 km in 2000 to 7,969.7 km in 2020. The rapid expansion of urban and inter-city transportation infrastructure has led to profound changes in the appearance and spatial layout of Chinese cities.

1.2 Expansion and spatial restructuring of large cities

Following the gradual expansion of urban areas in the 1990s and driven by the development policies centered around large cities in the *Outline of the Tenth Five-Year Plan for National Economic and Social Development of the People's Republic of China*, large cities became the primary destinations for new urban populations. This trend was also supported by incentives from land finance, leading to a rapid spatial expansion of large cities, along with a substantial increase in infrastructure investment. The year 2000 marked the beginning of spatial restructuring in large cities with the initiation of the *Overall Urban Development Strategy Plan of Guangzhou*. Subsequently, major cities began earnestly exploring sustainable urban expansion strategies in the context of rapid urbanization, with many opting for a polycentric approach as the framework for future spatial expansion of large cities. This has served as the spatial planning foundation for the significant changes in urban and urban transportation network patterns over the past 20 years. Alongside urban spatial restructuring, the urban transportation infrastructure has also been spatially restructured. Under the impetus of continuously surging infrastructure investment, the framework of urban backbone transportation networks swiftly took form, establishing the transportation infrastructure framework essential for urban spatial expansion.

The increased capacity of large cities to absorb populations has spurred the continuous emergence of mega (super) cities in China, with urban clusters in coastal and inland major development regions experiencing continual growth. Entering the 21st century, the rapid construction of high-speed railways, expressways, and airports has further solidified the pivotal role of large cities in the national transportation system, enhancing their attractiveness to the population. As of the end of 2020, there were 18 cities with a long-time population exceeding ten million. The emergence of megacities has led to the continual expansion of the scope of urban functional layout and transportation connections, breaking away from the traditional organization of urban functions solely within the central city area and instead extending this organization across the entire urban area and urban clusters. This has given rise to regional transportation

that focuses on organizing urban functions within metropolitan areas and urban clusters, spanning traditional urban boundaries. Following the rapid development of transportation infrastructure in central city areas, the construction focus of supercities has gradually shifted to the city and regional levels. The spatial organization of cities is now significantly different from what it was 20 years ago. Since 2010, the planning of transportation systems in major urban clusters, along with the issuance of the *Guiding Opinions of the National Development and Reform Commission on Cultivating and Developing Modern Metropolitan Area* (Development and Reform Planning [2019] No. 328), has ushered in an era of mutual promotion between infrastructure networks and urban space organization networks within urban clusters.

The rapid growth of urban internal transportation systems has been accompanied by profound changes in urban external transportation systems. From the speeding up of railways to the construction of the "Eight Vertical and Eight Horizontal" high-speed rail network, China has quickly become the world leader in terms of the scale of the expressway system. Additionally, urban airports are continuously being constructed and expanded. In urban areas, the traditional model of "one city, one station" for external transportation has been replaced by a system featuring multiple transport hubs that complement the city's multiple centers.

In recent years, urban spatial structures have transitioned from being extensions of existing urban areas to undergoing spatial restructuring, eventually evolving into metropolitan areas. This transformation has led to the continual expansion, enrichment, and increased mobility of urban transportation networks, accompanied by a greater diversity of transportation modes. The organization of transportation systems in mega (super) cities has expanded from the central city area to encompass the entire metropolitan area.

Reflecting on the past 20 years of urban and urban transportation development, our understanding of the appearance and essence of cities and urban transportation has been continuously updated. The record of urban construction achievements, as measured by infrastructure, has been continuously rewritten, with cities undergoing significant transformations year by year, creating a developmental marvel in the history of world urban construction.

1.3 Major issues in the rapid development stage of urban transportation

While achieving significant progress in infrastructure scale, urban development has been accompanied by nearly all-encompassing challenges of coordination, roughness, and even contradictions, spanning from the development concepts of transportation systems to the integration between different systems.

Rapid urban development has given rise to a modular mechanism of construction management that focuses on investment segmentation and systematic dismantling, transitioning from intercity to urban development. Additionally, a standard system and an administrative framework centered around construction have been established. As a result, there exists a disconnect between the planning and construction of urban transportation infrastructure and its subsequent operation. From urban roads to public transportation systems, the envisioned plans often encounter implementation difficulties during the later operational stages. Furthermore, the substantial disparities in development speeds among different systems and regions have resulted in fragmented approaches, making transportation integration and system coordination increasingly challenging. This fragmentation hinders coordinating efforts, thereby limiting the comprehensive capabilities of the system and impeding the achievement of a rational urban transportation structure.

Despite being a milestone in the urban development process, the research and practice of urban spatial restructuring have not been adequately reflected in the planning and construction of urban transportation network structures. Fueled by massive infrastructure investments, urban transportation networks, including main roads and public transit, have rapidly developed into radial networks centered around the old city. However, these networks struggle to seamlessly integrate with the multi-centered urban structure envisioned in spatial planning. The resulting radial transportation accessibility centered around the old city core has increased the difficulty of traffic dispersal from the old city. This situation is also one of the main reasons for the dilemma of residential and employment separation in megacities [2].

Moreover, at different stages of urban expansion and motorization development, there has been a lack of long-term vision in coordinating transportation facilities with the enhancement of urban mobility. For instance, the coordination between transportation networks and land use along them has continued the relationship between non-motorized transportation and land use from the non-motorized era. This has resulted in the overlapping of mainline organizations for all modes of transportation, increasing the difficulty of ensuring mobility for later mainline roads. This is also the main reason for the difficulty in coordinating the relationship between public transportation, walking, non-motorized transportation, and land use on either side of the road. The coordination challenges stemming from the development of the automobile industry, parking policies, and the sustainable operation of cities have persisted to this day. In order to leverage motorization to support rapid urban expansion, establishing a reasonable urban parking pricing system has been challenging. Additionally, automobile traffic has consistently maintained a dominant position in the coordination of road rights across different levels of roads.

Although urban external transportation systems have entered the era of multiple transport hubs, the continuous outward shift of urban external transportation hubs due to urban expansion, coupled with the large-scale and directional layout of transportation hubs, has resulted in a sharp contrast between the inefficiency of internal urban external transportation organization and the efficient connections between cities.

In the past two decades, China has established the basic spatial patterns and transportation system framework for various cities, especially the architecture of backbone public transportation systems and transportation hub systems. These developments have laid the foundation for the future spatial and socio-economic patterns of cities, forming the embryonic framework that exerts long-term influence on urban structure. China has achieved remarkable accomplishments in this regard. However, due to rapid and extensive yet less coordinated development, urban areas often face lingering issues with infrastructure and transportation systems. As cities transition into a development phase dominated by existing resources, they are increasingly confronted with the need to address the coordination problems left over from earlier phases of extensive development.

2 Correction of urban transportation development models and construction

In the first issue of the 2013 *Urban Transport of China* journal, an article titled *What can we learn from America's innovative land use/transportation strategy in urban renewal?* mentioned Peter Calthorpe's observation in an article published in the October 2012 edition of *Foreign Policy*. Calthorpe discussed the planning and construction models of many Chinese cities, likening them to the ideals of the renowned "urban destroyer" Le Corbusier. He argued that these models prioritized improving car efficiency at the expense of the environment and social aspects of urban life, thereby undermining the fundamental functions of cities [3].

"Many cities worldwide have fully recognized the negative impacts of excessive motorization and the development pattern favoring automobiles on issues related to urban economic vitality, social equity, environment, and resources, all of which are essential for sustainable development." "The goal of constructing livable, prosperous, and low-carbon or sustainable cities remains a key pursuit of urban transport development and urban planning." "Urban transport or urban planning should focus on the convenience of people's work and life, as well as the intensification and efficiency of land use, rather than the completeness and efficiency of the road traffic system." "The construction of car-friendly infrastructure does not necessarily improve urban mobility. For China's urbanization to be more sustainable and low-carbon, new urban DNA needs to be created." [4]

After 2014, the *Urban Transport of China* began to focus its special issues on streets, the integration of various urban transport modes, and the travel patterns of different groups within cities. The urban transport sector in China began a large-scale reflection on the issues arising from its long-standing strategy of high-speed and extensive development. By 2016, the *Several Opinions of the Central Committee of the Chinese Communist Party and the State Council on Further Strengthening the Administration of the Urban Planning and Construction* proposed to "promote a new type of urbanization centered around people" and "address prominent contradictions and deep-seated issues that restrict urban scientific development, and create a new situation in urban modernization construction." It also proposed strengthening the planning and construction of city blocks and promoting a city road layout concept of "narrow roads, dense road networks." Urban transport development began to reorient itself towards serving the creation of livable cities and transforming cities into homes where people live and work, rather than simply pursuing the efficiency of motorized traffic.

Since then, there has been a large-scale correction in the construction of urban transportation systems in the field of urban planning and transportation. This correction encompasses various aspects, ranging from the design of urban streets to the implementation of the "15-minute living circle" concept; from a focus on the travel environment for the elderly and children to the travel experiences of different groups during commuting; from a promotion of greenways to a revival of walking and cycling traffic and a rise in the planning of walking and cycling traffic. Combined with the concepts of "dual improvement" (referring to city betterment and ecological restoration) and "urban renewal," urban transportation practitioners' planning concepts and infrastructure development have also entered a new era of updates. Previously focused on main routes and long-distance, efficient motorized travel, urban transportation planning now considers the environment and quality of local activities, as well as the travel experience of different groups in cities.

With the broadening of planning perspectives and the return to fundamental concepts, Chinese cities have initiated actions to reshape their urban DNA. Cities have adjusted their transportation planning methods, integrating design into planning to address the issues of disconnected planning and design, as well as the challenge of implementing planning concepts. Moreover, they have incorporated negotiation and coordination among different transportation participants into planning, making planning a shared outcome for all transportation participants and more closely aligned with the real lives of different groups in the city.

3 Transformational changes in urban transportation characteristics

3.1 Changes in residents' travel characteristics

In the fast-developing 20 years of the 21st century, urban expansion and the increased level of motorization have completely transformed people's lifestyles. Compared to the late 20th century, the travel characteristics of residents in large cities have undergone dramatic changes.

The impact of urban spatial expansion on residents' travel characteristics is primarily reflected in increased travel distances and heightened demands for motorized travel modes. For instance, in Beijing, where travel distances have always been relatively long, the average travel distance for residents increased from 7.6 km in 2001 to 11.3 km in 2020, an increase of nearly 50%. During the same period, the number of motor vehicles increased from 1.51 million in 2000 to 6.57 million in 2020, while the number of public buses increased from 9,700 to 24,000, and the operational mileage of urban rail transit expanded from 114 km in 2003 to 727 km [5–6]. The significant increase in the level of urban transport motorization has greatly supported urban expansion and the growth in residents' travel distances.

Along with the increase in travel distances and mobility, the proportion of motorized transport in urban residents' travel has rapidly increased. The modal shares of public buses, urban rail transit, and cars in urban residents' travel have risen concurrently, gradually taking the lead in major cities, until recent years when the modal share of public buses has declined. For example, as residential spaces expanded outward, the commuting distance for residents of Shenzhen increased from 5.5 km in 2000 to 11 km in 2012. The modal share of cars in motorized transport modes for commuting increased from 13.9% to 42% [7]. At the same time, due to the increase in travel distances and worsen cycling environments, the popularity of bicycle transportation, which was prevalent in cities in the 1990s, gradually declined. For example, the modal share of cycling in Beijing decreased by more than 20 percentage points from 2004 to 2012. Non-motorized lanes that were once crowded with bicycles during peak hours became sparsely populated and gradually converted into parking spaces for motor vehicles, until electric bicycles, which offer better mobility, emerged in various transportation systems.

However, bicycle transportation has not faded from the sight of travelers. As cities rapidly grow and the population in peripheral areas increases rapidly, coupled with the low service level of public transportation and the city's focus on constructing backbone transportation systems while neglecting secondary and branch systems, the shortcomings in transportation connection and the "last mile" have become increasingly prominent. Since 2007, major cities have begun piloting public bike-sharing programs to address the last-mile connectivity gaps in transportation infrastructure. Subsequently, shared bicycles quickly dominated the urban bicycle transportation market. The modal share of cycling increased, and the emergence of electric bicycles significantly boosted the modal share of bicycles (including electric bicycles) in a short period. Within a few years, bicycles rapidly became one of the main modes of transportation in cities, favored by workers in delivery and food delivery services.

As cities have grown like tree rings, the residential population in peripheral areas has increased. The curve of residents' travel scale over time or distance has changed from a normal distribution to a wave-like curve, posing increasing challenges to urban transportation organizations.

With the increase in travel distances for residents in large cities and the emergence of faster and higher-grade transportation infrastructure, there has been a growing prevalence of intermodal transfers and transitions between different modes of transportation. The research and facilitation of trip chaining have become increasingly crucial, especially in large urban centers where the impact of transport hubs and their connections on travel has significantly increased. Since 2010, there has been a gradual increase in the study and practice of hub planning and design in *Urban Transport of China*.

3.2 Perpetuation of urban traffic congestion

The confluence of population growth, increased travel distances for residents, and the dominance of motorized transport has led to a sharp rise in the total transportation demand. Between 2000 and 2014, the travel distance for Beijing residents increased by 50%, while passenger turnover nearly tripled [8]. Despite the substantial expansion of transportation infrastructure, urban traffic congestion remains a prominent issue in this era. As urban roads and public transportation systems continue to upgrade and expand, the congestion of urban traffic fluctuates with changes in the scale of infrastructure construction, tending towards normalization.

Due to the gradual increase in land prices and housing costs in urban areas, the scale of residential areas on the outskirts of cities has been continuously expanded to accommodate more new urban residents. In megacities like Beijing and Shanghai, large residential communities housing hundreds of thousands of residents have emerged on the outskirts, while in the central areas, more job opportunities have been created to replace the relocated population. This exacerbates the imbalance between work and residence in cities, leading to inter-city commuting. On one hand, the commuting time for residents in peripheral areas has rapidly increased, exceeding 1 hour in some cities, making extreme commuting a focal point of social concern. On the other hand, the transportation connections between central and peripheral areas in large cities exhibit increasingly pronounced tidal patterns, especially along the radial transportation corridors of megacities, which have become major areas of traffic

congestion. This poses a severe challenge to the operation of public transportation and road systems in large cities, leading to the emergence of tidal flow lanes.

4 Urban motor vehicle development and TDM

Since the release of the second edition of China's automobile industry policy in 2004, the production and sales volume of automobiles has surged, with China ranking first globally in 2009 and maintaining this position to date. The rapid development of the automobile industry has led to a swift rise in the number of vehicles in urban areas. Passenger cars have begun to enter households on a large scale, resulting in a gradual increase in the modal share of cars. While the development of passenger cars provides mobility for urban expansion, the management of their ownership and use has become a crucial issue in urban traffic planning, construction, and management.

In 1995, before China's substantial increase in private car ownership, the *Beijing Declaration: China's Urban Transport Development Strategy* proposed managing transportation demand, internalizing the negative externalities caused by motor vehicles, and establishing a reasonable system for managing motor vehicle use. Over the past two decades, in response to the challenges posed by motorization, such as traffic congestion and pollution, Chinese cities have conducted extensive research and exploration regarding the management of motor vehicle parking, ownership, and use.

4.1 Exploration of management strategies for motor vehicle parking

During the rapid urban expansion in China, the construction of motor vehicle parking facilities primarily followed a model that emphasized parking facilities within buildings, with on-street parking playing a supplementary role. In the 1990s, standards for equipped parking facilities in urban areas were established. Since then, many cities have continuously adjusted these standards based on the development of motor vehicles. Particularly in newly developed areas on the outskirts of cities, where public transportation services are limited and vehicle management is less stringent, the standards for equipped parking facilities have been continually raised, leading to the construction of a large number of parking facilities. At the same time, a large number of parking spaces have been designated on-street. However, the low parking fees contradict the fundamental purpose of using economic leverage to scientifically and reasonably utilize road space and regulate urban traffic flow [9]. As the demand for parking grows, urban motor vehicle parking has encroached upon spaces designated for walking, cycling, and other modes of transportation. To address the problems of inadequate parking spaces and misaligned layouts in cities, several national ministries have issued policies to promote the planning and construction of parking facilities. However, the policy focus remains on subsidizing parking rather than promoting comprehensive marketization. Due to the incomplete development of the parking market, the shortage of parking spaces remains one of the main contradictions in transport supply and demand in urban areas. The evaluation results of the parking management policy adjustment in Shenzhen show that after the adjustment of the parking pricing mechanism, the average turnover rate of on-street parking in the pilot areas during weekdays increased by approximately 48.6% [10].

In the early stages of motorization, Chinese cities implemented differentiated parking fee policies and continuously adjusted parking rates based on the development of motor vehicles and the operation of road traffic. However, overall, it is still difficult to meet the requirements of a market-oriented parking system. The current system fails to reflect the actual costs of constructing parking facilities and land, making it challenging to achieve a virtuous cycle in the building and operation of the parking market.

4.2 Exploration of motor vehicle ownership and use management

In terms of motor vehicle ownership management, Beijing once implemented the "Parking Permit" policy in 1998, which required units and individuals in the eight districts to provide parking permits when registering and inspecting vehicles. This policy effectively controlled the growth of motor vehicles for a period but was canceled in 2004 due to conflicts with the automobile industry policy. During the 2008 Olympic Games, Beijing implemented policies such as odd–even license plate restrictions and restricted areas for motor vehicles during peak hours, ensuring the normal operation of Olympic traffic. After the Olympics, the policy of restricting certain areas for motor vehicles was continued, and parking prices were adjusted. These measures were put in place to maintain the normal functioning of urban traffic. However, the restriction policy also led to a rapid increase in motor vehicle ownership. In 2010, Beijing implemented the *Interim Provisions on Quantity Control for Mini and Small Passenger Cars*, controlling the growth of motor vehicle ownership through a lottery-based system. Subsequently, regional restrictions and lottery policies have been implemented in many large cities across the country, becoming one of the important policies for managing transportation demand in major Chinese cities.

Shanghai implemented motorization management measures in the early process of urban motorization, based on the principles of total volume control and regional differentiation, contrasting with Beijing and other cities, which managed transportation demands in the later stages of rapid motorization. The total volume control mainly targets vehicles with central city access rights, managing their total traffic volume through auctioning. Regional differentiation

refers to applying different transportation policies in city centers and suburbs [11].

China's urban TDM policies have always followed the automobile industry policy, primarily using administrative measures rather than economic ones. To support the automobile industry policy, cities provide a significant amount of explicit or implicit "subsidies" for automobile development, making it challenging to establish a rational pricing system based on a "user-pays" principle from ownership to usage. Parking management is a recognized measure in TDM. In the special feature *Urban Parking Policies and Management* in the 4th issue of *Urban Transport of China* in 2016, Professor Donald Shoup of the University of California, Los Angeles, discussed that parking policies can change the world [12]. However, the field insiders believe that the main reasons for insufficient parking facility construction and misalignment in layout, as well as the difficulty for social capital to participate, are high construction costs rather than an unsound pricing system or unreasonable policies. Therefore, various preferential and subsidy policies have been adopted by national and city governments to promote the construction of parking facilities, leading to peculiar incidents where urban governments apologize for parking fees.

Another vehicle that enjoys a large number of subsidies in its development is electric vehicles. Under the support of new policies in the automobile industry, electric vehicles benefit from both price subsidies and purchase incentives, promoting the growth of demand for ownership. Additionally, they are not subject to driving restrictions in use, and their cost per kilometer is comparatively low. With substantial subsidies at both the usage and ownership ends, the number of electric vehicles has witnessed a surge in major cities in recent years, and their daily kilometers traveled exceed those of fuel-powered vehicles despite the existing shortcomings in charging infrastructure.

Another measure of TDM is the reform of refined oil taxes. From the pilot reform of fuel surcharges accompanying the automotive industry policy in 1994 to the implementation of the refined oil tax reform in 2009, the progressive rise in fuel prices has had a notable impact. Despite continuous improvements in engine technology and fuel efficiency, the mechanism of refined oil price has remained a crucial factor in regulating the demand for motor vehicle travel and optimizing the urban traffic structure.

In addressing urban traffic congestion, Chinese cities have gradually recognized that simply increasing road supply cannot effectively solve the congestion problem. They have thus transitioned from traditional motor vehicle-centric transportation planning to mobility management plans centered around people. Mobility management has been integrated into government action plans to support green travel initiatives [13].

5 Theory and standard system of urban comprehensive transport planning (CTP)

5.1 Promotion of CTP concept

Over the past two decades, the theories and standard systems of comprehensive transport planning and construction in China have transitioned from initial introduction to self-improvement, aligning with international trends while incorporating distinctive Chinese characteristics. This period marks a critical phase in the development of China's own planning theory and standard system.

The planning and development concepts of urban comprehensive transport have closely followed international advanced concepts, which have addressed many issues in urban transportation development and reduced the cost of remedial measures after initial construction. As early as 1995, the strategic study on urban transportation development in China identified sustainable development as the cornerstone of transportation development. Similarly, the inaugural issue of *Urban Transport of China* in 2003 emphasized sustainability as a pivotal keyword, and throughout its development, the journal has persistently introduced globally advanced transportation development concepts to readers and professionals.

After Beijing's successful bid for the 2008 Olympics in 2001, the urban transportation development concepts such as equality, inclusiveness, environmental friendliness, technological advancement, people-oriented approaches, and prioritization of public transportation were implemented in the progress of Olympic project construction and deeply rooted in people's hearts. These concepts have since become a legacy of the post-Olympic era, continuing to be applied in the preparation, construction, and hosting of subsequent events such as World Expos, Asian Games, University Games, and the Winter Olympics. Through government promotion and implementation, these concepts have become deeply ingrained in people's minds and integrated into transportation infrastructure development and traffic organization schemes, greatly promoting the implementation and dissemination of advanced transportation concepts in urban transportation planning, construction, and management across the country. Furthermore, in 2007, China launched its first "Car-Free Day" and "Public Transportation Week" activities, promoting sustainable transportation development concepts through these events.

The prioritization of public transportation has been a steadfast concept in China's urban transportation planning since the 21st century, forming a crucial part of the national development strategy. This principle has been diligently implemented in planning and construction endeavors. In planning, the implementation of public transportation priority primarily centers on ensuring the provision of public transportation facilities. However, there has been a relatively

limited focus on research regarding the integration and operation of public transportation. This development strategy has led to rapid growth in urban public bus and trolleybus stations, vehicles, dedicated bus lanes, and hub facilities as cities expand. However, in recent years, urban public bus and trolleybus passenger volumes have faced a downturn, which is attributed to the expanding scale of urban rail transit in large cities and the growth of electric bicycles in medium and small cities.

5.2 Development of theoretical system for CTP

The development of complex transportation systems in megacities has spearheaded trends in urban transportation theory research, the practical application of advanced concepts, and the establishment of comprehensive transport planning and construction systems. For example, cities like Beijing, Shanghai, and Guangzhou have taken the lead in research on comprehensive transport integration, informatization, and demand management [14]. Through initiatives like publishing a white paper titled *Development of China's Transport* and ensuring transportation for events such as the Olympics and World Expos, these cities have gained a consensus throughout society, serving as exemplars for urban transportation theory research in China.

The continuous hosting of various forums and seminars on urban transportation research in China has promoted in-depth research and practice in urban transportation theory. Among them, the China Urban Transport Development Forum, which is dedicated year-round to the study of urban transportation theory and practice, has been particularly noteworthy.

By absorbing advanced international concepts and theories on transportation development and integrating practical solutions to urban transportation problems in China, the country has developed planning theories to guide the rapid development of cities and the construction of transportation infrastructure, as well as to navigate the development stage dominated by existing resources based on the extensive experience gained from large-scale transportation planning and construction practices.

The development of the theoretical system for urban transportation is mainly reflected in scientific standardization and quantitative analysis. The establishment and improvement of standards are the main indicators of the maturity of theoretical systems for planning and construction. The field of urban planning in China began setting up a basic set of standards in the 1990s. By the early 2000s, as planning techniques and theories improved, China drew on foreign experience to establish a technical standard system tailored to its own urban and rural planning development and management needs. This effort led to the establishment of a four-level standard framework, including comprehensive, fundamental, general, and specialized standards. Around 2010, the establishment and formulation of the comprehensive transport standard system in China began, gradually forming a city's comprehensive transport planning and design standard system supported by various specialized standards, with the *Standard for Urban Comprehensive Transport System Planning* (GB/T 51328-2018) as the foundation. This development marked a significant shift from the situation in the 1980s when urban transportation relied solely on the *Code for Transport Planning on Urban Road* (GB 50220-95) as the industry norm. The *Code for Transport Planning on Urban Road* established a planning theoretical framework centered around ensuring motorized traffic, starting from demand and extending to infrastructure scale, thereby guiding the grading and layout of infrastructure. In contrast, the *Standard for Urban Comprehensive Transport System Planning* adjusted this framework to focus on ensuring the normal operation of cities, integrating the grading, classification, and operation of transportation infrastructure with a focus on transport priority ⑤ and demand management.

The changes in the theoretical framework of urban transportation planning are well reflected in the management of urban traffic congestion. During the rapid expansion phase of urban development, the primary approach to congestion management mainly focused on increasing infrastructure supply to balance the growth and changes in transportation demand. However, after 2010, as seen in the white papers on urban transportation development in cities like Beijing, Shanghai, Shenzhen, and Hangzhou, there has been an exploration of pathways to manage congestion successfully by enhancing the quality of public transportation services. This shift in urban transportation development and congestion management has moved towards a focus on transport priority and demand management.

Considering the increasing inadequacy of traffic planning and management theory from an engineering perspective to cover and address urban transportation challenges, Wang Guangtao has established the theoretical framework of urban transportation science based on a series of studies, The research objective of urban transportation science is to serve the needs of people (living needs and employment needs) and to organize the sustainable, efficient, safe, and low-consumption (low energy consumption and low pollution) operation of cities. The key focus is on meeting the reasonable needs of urban residents and improving the overall operational efficiency of cities, emphasizing multidisciplinary thinking and systems theory. The core of the research is the construction and operation of urban transportation networks [15–16].

5.3 Comprehensive development of quantitative analysis techniques in transportation

As the foundation of CTP, traffic models and quantitative analysis have been featured in special issues of *Urban Transport of China* almost as frequently as public transportation issues in the 20 years since its inception, making them important components of research in urban

transportation theory and practice. Experts and scholars have conducted extensive research on the scientificity of traffic prediction and managing uncertainties in urban development, effectively supporting decision-making in infrastructure construction, particularly in planning and building urban road and rail systems.

The application of big data has supplemented some of the shortcomings of traditional quantitative analysis in transportation studies and significantly expanded the scope of quantitative analysis. In 2014, big data was included in the annual government work report of the State Council, and in 2016, *Big Data and Urban Transportation* was featured as a special issue in *Urban Transport of China*. In the foreword, Professor Yang Dongyuan from Tongji University wrote, “Big data brings not only a technological change but also a transformation in research methodology.” He further elaborated that big data enables researchers to observe the research object from multiple perspectives, in a comprehensive and continuous manner, driving technological advancements in understanding the complexity of urban transportation and revealing new pathways to uncovering its underlying mechanisms.” The development of big data enables continuous observation of complex transportation systems, enriches the perspectives of traditional transportation survey techniques, improves and expands transportation analysis methods, enhances the understanding of complex transportation systems, and improves the ability in transportation governance and services. In recent years, big data has become an important tool in transportation surveys, enhancing the accuracy of transportation demand analysis and expanding the field of transportation demand analysis. Various urban transportation operation reports using big data analysis from different perspectives are emerging one after another. In terms of transportation planning and operation management, big data makes process management more precise. Many cities and enterprises have established analysis platforms based on big data to improve the governance and decision-making of transportation systems, and it has become a crucial support for the development of intelligent transportation. Big data analysis has been deeply integrated into urban transportation planning, construction, governance, and operation services, and will promote a transformation in urban transportation planning theory [17].

5.4 Theoretical exploration of urban development transformation

The formulation process of the “14th Five-Year Plan” from the national level to various cities is a systematic study that comprehensively implements high-quality development and urban development transformation from theory, policy, to practice nationwide. It focuses on one theme and five key questions, namely, focusing on the theme of high-quality development and scientifically answering the five key questions related to carbon peaking and carbon neutrality, people-centered development, planning system transformation, changes in spatial patterns, and implementation of the strategy for building a transportation powerhouse [18]. Managers, researchers, and technical personnel in the field of urban transportation are thinking deeply about the development path of comprehensive urban transportation in the next step. The special issue of *Urban Transport of China* on “14th Five-Year Plan” for urban CTP in 2022 showcased the research achievements and practical applications in Chinese cities regarding low-carbon initiatives, metropolitan area development, transit-oriented development (TOD), urban renewal, improvement of travel environments for diverse groups, and increasing the resilience of urban transport systems using innovation-driven approaches through the "14th Five-Year Plan" planning of four first-tier cities. It demonstrated the comprehensive transformation and development of urban transport, transitioning from a focus on speed to an emphasis on development quality, from prioritizing public transport to embracing low-carbon solutions, from pursuing system optimization to addressing the needs of diverse urban populations including the elderly and children, from emphasizing efficiency to resilience, and from macro-level traffic and spatial structure considerations to the integration of TOD and station–city fusion, as well as from a focus on new construction to the revitalization and transformation of existing infrastructure.

Over the past two decades, the development concepts of China’s urban transportation have kept pace with those of international advanced cities. While rapidly constructing transportation systems, China has also developed planning theories that are in line with the stages of urban development and suitable for the management and development characteristics of Chinese cities. Overall, there has been a lot of in-depth and fruitful research on the layout, operation, and organization of transportation infrastructure. However, there hasn’t been as much research on the impact of changes in urban social structure on transportation systems, collaborative governance between government and the public, regulations and economic policies, pricing systems, and other aspects.

6 Reform of urban transportation system and mechanism

The reform of urban transportation systems and mechanisms has a profound impact on the planning, construction, and operation of urban transportation. A well-thought-out system and mechanism are essential to support the design and implementation of urban transportation infrastructure and policy measures. Research on the system primarily focuses on how to address the issues of national institutional reform at the urban level, rather than systematically studying the overall impact of the system on industry development. Reforming systems and mechanisms

is important for the development of systems and this field, but there is not enough research in this area. On one hand, the institutional framework and mechanisms governing urban transportation management dictate all decision-making and coordination processes in urban transportation, including planning, design, investment, construction, and operation. China's approach to TOD, comprehensive transport hub construction, regional transportation development, and other aspects is greatly influenced by the transportation systems and mechanisms, as exemplified by the question raised in the 2018 fourth issue of *Urban Transport of China*: *Who is the principal party in the planning and design of passenger transportation hubs?* [19] On the other hand, research on the systems and mechanisms seems elusive and difficult to grasp, to the extent that, in the 20-year history of *Urban Transport of China*, there have been almost no articles systematically studying the reform of the systems and mechanisms.

The functions of urban transportation management in China are relatively decentralized, both at the central and local government levels, leading to difficulties in coordination and decision-making bias. In simple terms, China possesses the knowledge for sustainable urban transportation development; however, it faces challenges in transforming this knowledge into tangible results due to insufficient supportive policies and institutional capacities [20]. In the past two decades, major reforms in China's urban transportation system, from central to local levels, have primarily included two key changes. Firstly, in 2009, there was a reform in the management of the urban passenger transportation market. This reform separated the management of the passenger transportation market (i.e., the operational side) from the planning and construction of urban transportation. Secondly, in 2018, a reform in the national spatial planning system was carried out, leaving an uncertain status for urban transportation planning within the spatial planning system. Both of these reforms, in terms of their horizontal coverage of functions and vertical implementation of decisions, have had a significant impact on the construction and operation of urban transportation systems. In general, the urban transport system has progressively decoupled in its key functions of planning, investment (including land), construction, and operation. This separation has resulted in high administrative costs for the high-quality development of urban transport, making it difficult to turn good ideas and strategies into action. Consequently, this has significantly affected the research on urban transport technology and the development of the industry. These issues are particularly noticeable today as cities enter a stage of development where existing resources dominate.

7 Conclusion

The past 20 years have been the most significant period in the history of urban development in China, experiencing the most diverse urban development processes in the world. During this period, new ideas, theories, and practices have emerged continuously; technological advancement has been constant, leading to remarkable construction achievements and yielding fruitful outcomes in both theory and practice. As a nexus for theoretical and practical research in the field, *Urban Transport of China*, with nearly 2,000 papers published since its inception and a special feature in every issue, has closely followed the pace of urban development, documenting the 20-year academic research journey of urban transportation in China.

As stated by Wang Jingxia, the chief editor of *Urban Transport of China*, in the commemorative article *New benchmark, new stride: the 10th anniversary of publication of Urban Transport of China*, "Policy, planning, research, and practice have consistently been the focal points of our editorial direction. Over the years, it has documented the academic research and planning practices in urban transportation, from congestion due to inadequate infrastructure during the early stages of reform and opening up, to the realization that road network construction always lags behind the growth of transportation demand; from the singular focus on road traffic infrastructure, to the adoption of advanced foreign planning concepts, and the exploration of transportation engineering theories and methods, from confronting challenges posed by rapid motorization around the turn of the century, when cities faced the most severe traffic congestion in history, to the integration of advanced concepts such as public transport priority, TOD, TDM, green transportation, and low-carbon transportation into policy-making and planning." [21]

Currently, we are once again at a new starting point for the modernization and transformation of urban transportation in China. In this new era, technological advancements and transformative development concepts are becoming ingrained in the DNA of urban transportation development, continuously reshaping the modes of analysis, layout, organization, operation, and governance of urban transportation. It is believed that in the next 10 or 20 years, urban transportation will witness a new era of continuous innovation in theory, technology, and practice, driven by advancements in technology and new development concepts.

Anotation

① The data is from the *National Population Census of the People's Republic of China* in 2000 (http://www.stats.gov.cn/sj/pcsj/rkpc/5rp/index.htm) and the *Main Data of the Seventh National Population Census* in 2020 (http://www.stats.gov.cn/sj/pcsj/rkpc/d7c/202303/P020230301403217959330.pdf)).

② The data is from the *China Urban Construction Statistical Yearbook 2019*.

③ The data is from the *Main Data Bulletin of the Third National Land Survey* (https://www.mnr.gov.cn/dt/ywbb/202108/t20210826_2678340.html).

④ Urban scale typically refers to population size, often defined by the long-term population of urban areas; sometimes, it also refers to the spatial extent of cities, such as land area or built-up area. The urban scale discussed in this article is from the perspective of urban space.

⑤ Transport priority refers to the granting of right-of-way or operational priority to certain parts or elements of the transportation system.

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