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COMMENTS

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Future urban transport management

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Abstract The incorporation of disruptive innovations into the transportation industry will inevitably cause major upheavals in the transportation sector. However, existing research lacks systematic theories and methodologies to represent the underlying characteristics of future urban transport systems. Furthermore, emerging modes in urban mobility have not been sufficiently studied. The National Natural Science Foundation of China (NSFC) officially approved the Basic Science Center project titled "Future Urban Transport Management" in 2022. The project members include leading scientists and engineers from Beijing Jiaotong University, Beihang University, and Beijing Transport Institute. Based on a wide range of previous projects by the consortium on urban mobility and sustainable cities, this project will encompass transdisciplinary and interdisciplinary research to explore critical issues affecting future urban traffic management. It aims to develop fundamental theories and methods based on social and technological developments in the near future and explores innovative solutions to implement alongside these emerging developments in urban mobility.

Keywords future urban transport management, travel behavior characteristics, transportation operations, transportation emergency management, transportation decision intelligence

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1 Introduction

Transport and mobility are core components that support the operation and function of modern cities, and they evolve with the development of urban society. Nowadays, urban areas worldwide are expanding rapidly with high complexity (US Census Bureau, 2011; Wang et al., 2018; Guo et al., 2019), posing serious challenges to society (Gao et al., 2011; Stefaniec et al., 2020). Transport sustainability has long been a concern in virtually all large cities worldwide (Alonso et al., 2015). For example, most Chinese cities suffer from problems such as severe traffic congestion, high traffic emissions, and frequent traffic accidents (Zheng et al., 2004; Malta et al., 2009; Zhang et al., 2011; Qin et al., 2013; Sun et al., 2016; Bao et al., 2020; Stefaniec et al., 2020). It is very difficult to resolve these upshots of rapid urbanization using traditional methods of urban traffic management. With the rapid urbanization in China, there will be an increase in travel demand particularly in urban areas over the next decade, which will undoubtedly present significant challenges to urban traffic management.

As a typical complex and open system, urban traffic comprises many elements and tends to be dynamic and large-scale, often with incomplete information. These characteristics make the emergence and evolution of traffic issues even more complex, with fundamental scientific problems (Schönhof and Helbing, 2007; Barthélemy, 2011; Vlahogianni et al., 2014; Kirkley et al., 2018; Yildirimoglu et al., 2018; Saberi et al., 2020; Wu et al., 2021). The mission of traffic management science is to contribute to a better understanding of both the individual and aggregative behaviors of travelers, as well as the nature of urban traffic. Only when the mechanisms of urban traffic issues are properly understood can urban-traffic planning goals regarding sustainability and accessibility be consolidated through the modeling and analyses of the urban traffic system (Ledoux, 1997; Avila and Mezić, 2020).

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2022 (Grant No. 72288101). The project members include leading scientists and engineers from Beijing Jiaotong University, Beihang University, and Beijing Transport Institute. Based on a wide range of previous projects by the consortium on urban mobility and sustainable cities, this project will encompass transdisciplinary and interdisciplinary research to explore critical issues affecting future urban traffic management. It aims to develop fundamental theories and methods based on social and technological developments in the near future and explores innovative solutions to implement alongside these emerging developments in urban mobility.

2 Background of the project

Recent technological advancements such as big data, the Internet, and artificial intelligence have brought new opportunities to various industries, and have also helped to improve the intelligent management of urban transport systems. Furthermore, urban transport systems have rich multi-source data with various artificial-intelligence application scenarios, making the integration of big-data technology into intelligent transport systems more attractive (Sayegh et al., 2018; Bertsimas et al., 2019; Miglani and Kumar, 2019). As technology evolves, the coming decades will undoubtedly usher in the following features of the modernized urban transport system: 1) the implementation of novel technologies such as big data, artificial intelligence, cloud computing, self-driving vehicles, and holographic perception (Fagnant and Kockelman, 2015; Meyer et al., 2017; Zhang et al., 2019; Larson and Zhao, 2020; Lu et al., 2021; Liu et al., 2023); 2) innovative transit modes and vehicles, such as intelligent electric vehicles and multi-modal, seamless, and multi-dimensional traffic transfers; 3) innovative transport services, such as ride sharing, customized buses, and travel reservations (Furuhata et al., 2013; Mourad et al., 2019); and 4) personalized transport services with a diversified on-demand response, along with digital, precise, and intelligent urban-traffic management methods (Zhang et al., 2011).

Emerging technologies such as the Internet of Everything and holographic perception will inevitably revolutionize how we transport commodities, as well as travel and commute; nonetheless, new challenges will also emerge. First, the equilibria of the traffic system will be considerably more difficult to understand owing to the increasing complexity of travel behaviors and the supply–demand imbalance. Second, an ultra-large-scale urban traffic system with intelligent network operations will be difficult to model. Third, the cascading effect of future urban-traffic innovations will increase significantly, continually resulting in systems with highly sophisticated resilience and smart emergency response. Fourth, it will be difficult to accurately predict the operating status of complex multi-level, multi-modal, and multi-business transport systems and respond decisively in real time.

To address these challenges, developed economies have promoted strategic plans for future transport systems. For example, the US released the "2050 Long-Range Transportation Plan" in May 2021. The UK government published the white paper, *The Future of Transport: A Network for 2030*, covering policies on all forms of transport in UK. The European Commission also published white papers on integrated transport-network policy and smart sustainable mobility strategies. In recent years, China also issued the *National Comprehensive Three-dimensional Transportation Network Planning Outline* and the *Outline for Building China's Strength in Transport*. These documents identify three major objectives. First, develop fast intelligent urban transport systems. Second, promote the deep integration of modern technologies such as big data, the Internet, and artificial intelligence into the transportation industry. Third, coordinate the development of intelligent connected vehicles and smart cities. To this end, the Ministry of Science and Technology of the PRC and the NSFC have successively deployed a number of related infrastructure projects (National Science and Technology key projects, NSFC key projects, Major Research Plan, Basic Science Center projects, etc.).

In recent decades, scientists have conducted promising theoretical research on integrating leading-edge technologies such as big data, the Internet, and artificial intelligence into the transportation industry. Hundreds of research outcomes have been published in reputed academic journals, including *Nature*, *Science*, *Proceedings of the National Academy of Sciences*, *Operations Research*, and *Transportation Science* (Zheng et al., 2017; Bhoopalam et al., 2018; Sayegh et al., 2018; Vazifeh et al., 2018; Bertsimas et al., 2019; Kasliwal et al., 2019; Zhou et al., 2020; Liu et al., 2021; Simini et al., 2021; Wang et al., 2021; Yang et al., 2021; Zhao and Zhang, 2021). However, the development and incorporation of such disruptive technologies into the transportation industry will inevitably lead to major upheavals in the transportation sector. These may hinder the contributions of existing research in addressing the challenges facing urban-traffic management systems in the future. In addition to the four major challenges mentioned above, the most critical issue is that existing research lacks systematic theories and methodologies to represent the underlying characteristics of future urban transport systems. Furthermore, emerging modes in urban transport have not been sufficiently studied. Therefore, there is an urgent necessity to study and establish management theories and methods for future urban transport systems. Cutting-edge research outcomes and contributions are essential in order to support the sustainable development of the urban transport system in China and promote interdisciplinary analyses in this area.

3 Future urban transport management

To address potential management challenges with regard to urban traffic in the foreseeable future, the proposed project focuses on the analysis of residents' travel behavior, the operation optimization of the traffic system as well as its resource allocation, and the simulation and deduction of the traffic situation from the perspective of systems science. It comprises four working packages (WPs), as illustrated in Fig. 1. It aims to build a smart urban-traffic simulation platform and develop management theories and methods for future urban transport, which will boost the development of urban-transport management science. The outcomes of this project can thus provide insights and support for the scientific development and technical application of smart urban transport in China. The project aims to achieve innovative theoretical outcomes in future urban traffic management, promote innovative multidisciplinary research, cultivate high-level researchers and scientists, and create opportunities for international cooperation and exchange. A detailed introduction of the four WPs is provided below.

WP I: Travel behavior mechanism in future urban transport

The transport industry in China is entering a new era with high demand for convenience, comfort, and eco-friendliness. Nowadays, the discrepancy between people's growing expectations for a better life and the unbalanced and inadequate development in urban transport has become a principal contradiction. With the development of science and technology and the social economy, and changes in the urban demographic structure, the future urban transport system will increasingly exhibit salient travel demand characteristics, such as customized services, convenience, low carbon emissions, safety, and comfort. Furthermore, future urban transport systems will feature emergent characteristics in the technical-method layer (such as mixed traffic flow involving human-driven vehicles and autonomous vehicles, the coexistence of vehicles consuming different types of energy, human–vehicle–road collaborative interconnection, and fusion of multivariate traffic data) and the operational-organization layer (such as network sharing, trip chain integration, multi-modal complexity, and instant responsiveness). These reforms provide new opportunities to solve the principal contradiction in transportation and reshape the spatiotemporal distribution of micro travel-choice behavior and macro traffic demand. However, these reforms also challenge the management of future urban transport systems. Therefore, this work package explores pertinent features of future urban transport, including the evolution of future urban lifestyles and activity chains, the generation and flow evolution of future urban traffic demand, and the design of corresponding guidance and management mechanisms. Moreover, the work package will develop appropriate traffic-demand estimation methods. Through research in this direction, we will clarify the basic operational rules and evolutionary characteristics of future urban transport, thereby providing novel theoretical support for future urban transport management.

WP II: Resource allocation and operation optimization of future urban transport systems

The rapid development of advanced technology will lead to a comprehensive and significant transformation of urban transport. The future of urban transport is full of

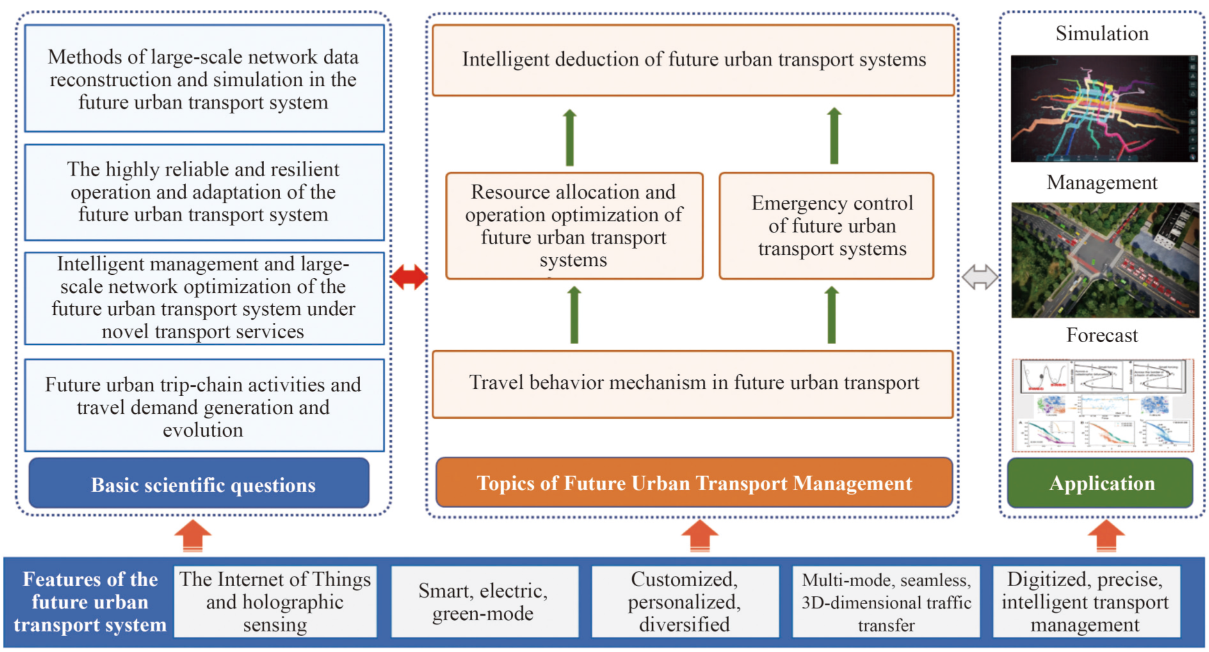

Fig. 1 Research on future urban transport management.

possibilities. On the one hand, emerging technologies, such as big data, artificial intelligence, cloud computing, the Internet of Things, and new-energy vehicles, are increasingly involved in urban transport systems (Bertsimas et al., 2019; Lu et al., 2021). On the other hand, novel transport services such as smart transport, customized services, and autonomous vehicles are becoming the main features of urban transport (Zhou et al., 2020; Liu et al., 2021; Zhao and Zhang, 2021). Considering the requirements of eco-friendliness and efficient operation, future urban transport systems will largely differ in travel modes, operation and organization methods, and management strategies. Smooth, efficient, safe, and green travel have become the prevailing themes to ensure the sustainable development of future urban transport systems (Stefaniec et al., 2020). Therefore, based on the new features of future transport, it is necessary to conduct in-depth and systematic studies on the operation rules, management theories, and evolution of future urban transport modalities with emerging technologies. Thus, this work package covers 1) smart travel management and coordination optimization of future urban transport, 2) carbon neutrality-oriented operational management and structural optimization of future urban transport, 3) collaborative operation and optimization of future urban rail transit systems, and 4) network optimization and computing technology for large-scale networks of future urban transport. It aims to develop innovative theoretical methods for future urban transport and provide insights into intelligent management and large-scale network modeling for future urban transit systems.

WP III: Emergency control of future urban transport systems

It can be foreseen that future urban transport should be an orderly and intelligent travel-service system with a high degree of human–vehicle–road–environment coordination, meeting the basic travel needs of millions of users. Its stable and reliable operation is the fundamental guarantee for efficient urban spatiotemporal activities. However, the highly intensive future urban population, resources, and activities will exert enormous pressure on the reliable and resilient operation of the transport system, and small perturbations will significantly impact its reliability. It is easy for serious traffic problems to emerge under extraordinary conditions, such as essential holidays, major social activities, or emergencies (such as sudden traffic accidents and extreme weather events). For example, this would cause supply–demand imbalances, interrupt orderly travel behaviors, decrease daily traffic capacity, reduce operational reliability, and even trigger local or widespread paralysis of the transport system (Alghamdi et al., 2021; Zheng et al., 2021; Acharya and Singleton, 2022; Bi et al., 2022). Therefore, many scholars in China and abroad have evaluated the emergency-control capability of urban transport systems, which aims to ensure the smooth operation of urban transport even under adverse conditions and realize the intelligent operation of future urban transport systems. Accordingly, this work package will entail in-depth and detailed research on several major topics, including 1) the reliability assessment method for future urban transport systems, 2) real-time emergency response and intelligent diagnosis of future urban transport systems, 3) dynamic induction and spatial–temporal regulation of future urban-transport network demand, and 4) multi-modal coordination and emergency dispatch in future urban transport systems. It aims to enhance the intelligent emergency response capability of the future urban transport system, realize its resilient operation under various emergencies, and reduce the cascade effect. These related studies will facilitate the innovation of fundamental theories and methods of future urban-transport emergency control, as well as the realization of safe and reliable operation.

WP IV: Intelligent deduction of future urban transport systems

A future urban transport system will be based on the Internet of Things and holographic sensing. With new transportation infrastructure, the system will provide novel demand-responsive transport services. Meanwhile, the application and integration of new information technologies, such as big data, artificial intelligence, and digital twin technology, will bring new opportunities for the development of high-quality urban transport systems. However, because large-scale multi-modal transport systems are complex and sophisticated, it is very challenging to make sound deductions and decisions. Therefore, it is important to study an open, dynamic, and adaptive deduction method for such systems. This will help reexamine and understand the internal mechanisms and predict the status of the system. Additionally, the research findings can promote the development of transport operation and service modes and provide insights and a theoretical foundation for the intelligent management and operation of urban cities in the new era. This work package will focus on the following aspects of future urban transport systems: 1) data reconstruction in the holographic-sensing environment, 2) simulation and deduction of the operational state, and 3) construction of a digital twin. The goal of this work package is to realize fast construction, accurate reproduction, and trend deduction of the operation status of the urban transport system and build a simulation and deduction platform suitable for large cities in China.

The aforementioned research topics focus on the theoretical and methodological aspects of future urban transport management, which aims to counteract the impact of technological advancements on urban transport management. Several other topics on future urban transport management remain to be explored in future studies, namely, the collaborative design and optimization of transport and logistics in the future urban transport system; the zero-transfer and seamless connection in modern integrated travel services; the coordination and evolution of urban-function orientation and transport systems; the joint collaborative operation of future urban transport vehicles such as flying cars and capsule cars; and the design of transport systems for urban agglomeration. These topics can be investigated thoroughly in the future.

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