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Next-generation innovation and development of intelligent transportation system in China

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Abstract As an integrated application of advanced technologies such as information technology, system control technology, and artificial intelligence in the transportation field, the intelligent transportation system (ITS) has been regarded as an efficient and effective solution for alleviating transportation issues that are encountered in several countries around the world. In this paper, the development history of the ITS in China is presented, and the problems and challenges faced by the ITS in China in the new normal state are clearly laid out. Three new ITS development requirements in China are then identified, and six development trends and directions are proposed. Through the successful application of the above guidelines, next generation innovation and development of ITS is expected to be realized in China, promoting and supporting the trends of urbanization, motorization, and informationization, which are resulting in fundamental changes in the development of the Chinese society and economy.

Keywords next-generation intelligent transportation system, innovation and development, integrated transportation system, traffic management and control, artificial intelligence

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1 Introduction

Since the inception of the Reform and Opening policy, the development of road transport infrastructure has reached great milestones, thus accelerating the process of urbanization and motorization in China [1,2]. The increase in the number of motor vehicles has exceeded the increase in road network construction. Consequently, many traffic-related problems have come into existence including severe traffic congestion, frequent traffic accidents, resource waste, environmental pollution, and economic losses, to name a few. The development of intelligent transportation system (ITS), i.e., the application of advanced technologies such as information technology (IT), system control technology, artificial intelligence, and system engineering, has played an irreplaceable role in alleviating traffic congestion and reducing traffic accidents. It has been proved that the ITS can improve the capacity of urban roads by two to three times,

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decrease the number of vehicle stops by 30%, and reduce the stopping time by 13% to 45%. In addition, there has been a significant reduction in traffic accidents [3]. Since 1980s, some developed countries, such as some European countries and the United States of America (USA), have carried out the study and application of ITS, achieving both theoretical and application results, which led to the modernization of the entire transport industry [4–6].

Traffic informationization has become an important way to improve the efficiency of transportation systems and hence realize the sustainable development of transportation systems, and thus, it has attracted great attention from the Chinese government and urban traffic managers. Compared to a few developed European countries and USA, research on ITS began relatively late in China; however, the Chinese government has attached great importance to the development of ITS and provided strong support in terms of policies, research conditions and funding. Significant achievements have been realized with the ITS in China after the completion of the Ninth, Tenth, Eleventh, and Twelfth Five-Year Plans [7, 8]. At present, a new generation of intelligent transportation technology has become the vital development direction both domestically and internationally, which emphasizes the application of new technology for developing low-carbon, green, and sustainable transportation systems. The development of the "Internet +" model is being pursued zealously, the Thirteenth Five-Year Plan is being implemented, and Support-side Reform is gradually deepening. Therefore, ITS is entering a new phase of development in China. The policy, application, and technology environments of ITS development are facing drastic change. Therefore, it is right time for us to make use of this historical opportunity to exploit the concept of "innovation, coordination, green, open and share," and actively promote the development of ITS.

The time period of the Thirteenth Five-year Plan is a major strategic transition period for Chinese economic and social development. Meanwhile, the transportation industry is also undergoing a major strategic transformation [9, 10]. In the ITS industry, China has some achievements under the guidance of "New-Type Urbanization," "One Belt and One Road," and "Smart City." The development of ITS is set to enter a golden period and it has become an important measure of the core competitiveness of cities. This is particularly important as traffic congestion is becoming increasingly prominent in many cities in China, which negatively affects the daily life of urban citizens and the competitiveness of these cities. Thus, there is a requirement for efficient urban transportation system control and management. In addition, the government of China is highly efficient in the construction of large-scale transportation infrastructure, which gives China an advantage over the western developed countries. Therefore, China should seize this important strategic opportunity and identify the development trend and direction. Based on the reality of China, a new generation of ITS with Chinese characteristics can be developed, thus promoting the process of traffic informationization and urbanization in China.

2 History of ITS development in China

Research on ITS in China began in the 1990s, and at that time, some universities and research institutions started to study traffic signal control and traffic flow condition collection in the urban areas. The core technologies of urban transportation management and control systems used in China mainly relied on foreign brands such as the British Split Cycle Offset Optimizing Technique (SCOOT) system and Australia Sydney Coordinated Adaptive Traffic System (SCATS) system. With the increase in demand for intelligent traffic control, management, and services in China's metropolises, government and research institutions have been increasingly focusing on the development of ITS technology such as traffic simulation and control [11]. Supported by the National Plans, the transportation industry in China has developed rapidly, especially from the Ninth Five-Year system architecture to the post-Olympic era of the "Smart City." The intelligent transportation industry has developed an independent innovation capability, presenting the basis of accelerating innovation and development, and in the meantime, forming a number of independent intellectual properties of innovative scientific and technological achievements. The application of ITS in China will provide strong support for the management and control of the large-scale transport infrastructure networks, large-scale population travel and migration, and large-scale transport

of goods. Integrated applications and services of ITS have been integrated into social production and people's lives in all aspects, thus achieving significant social and economic benefits.

During the period of the Ninth Five-Year Plan, some ITS components were included in the national scientific and technological projects, the focus of which was to study and develop a "National Intelligent Transportation System Architecture" and "National Intelligent Transportation System Standard." This has laid a solid foundation for the follow-up development of ITS in China. The Ministry of Communication has also put forward "Strengthen research and development of intelligent roadway transportation system" as an objective, pointing out that traffic control systems, driver information systems, vehicle scheduling and guidance systems, vehicle safety systems, and toll management systems should be implemented in actual applications. On this basis, mature scientific and technological achievements can be imparted into available technology and products.

During the Tenth Five-Year period, in order to improve the management level, service level, and efficiency and safety of the entire transportation system, the Ministry of Science and Technology launched a major national science and technology project, i.e., "Key technology development and demonstration project for ITS." This project focused on intelligent traffic simulation and control, integrated information services, dedicated short-range communication, intelligent vehicle–road integration, and specification standardization through key technology development, environmental construction, and demonstration applications. The project was intended to lay the foundation for the development, application, and industrialization of ITS in China.

During the Eleventh Five-Year period, targeting the 2008 Beijing Olympic Games, the 2010 Shanghai World Expo, the Guangzhou Asian Games, and other large international events, the Ministry of Science and Technology launched a national science and technology support program, i.e., the "National Intelligent Transportation Technology Integration Application Demonstration." This project focused on the construction of integrated traffic management and comprehensive traffic service of large-scale international activities, proposing a number of key technologies such as intelligent traffic management and service. A number of representative intelligent traffic management and service demonstration systems and engineering applications have been implemented, e.g., the urban traffic management and control system, which is shown in Figure 1. At the same time, the Ministry of Public Security organized a major science and technology research and development plan, i.e., "Research and Demonstration of Key Technology for Road Traffic Safety." In cooperation with the Ministry of Public Security and Ministry of Communication, the Ministry of Science and Technology formally launched the Eleventh Five-Year national science and technology research and development program, "Application of Integrated Technology Development and Demonstration in Comprehensive Prevention and Disposal of Traffic Accidents" in 2009, in keeping with the strategic demand of "National Road Traffic Safety Science and Technology Action Plan." Thus, with the support of the national plans, China has made great progress in the field of ITS through extensive international communication and cooperation. Much experience has been accumulated for supporting the follow-up development of Chinese ITS technologies, particularly in the construction and development of large-scale systems.

During the Twelfth Five-year period, the development of ITS in developed cities advanced to the in-depth development phase. The industry investment for ITS has an annual growth of more than 20% in China. In 2011, the overall market size of the Chinese intelligent transportation industry reached 25.28 billion Yuan, which showed an increase of 25.21% from 20.19 billion Yuan in 2010. In 2012, with the development of intelligent city construction, the IT application in the intelligent transportation industry received an increased investment of 25.59%, with its scale reaching 31.75 billion. In 2013, owing to the governments investment for promoting the impact of intelligent city construction, the intelligent transportation industry investment increased to 40.8 billion Yuan, with the growth rate reaching 28.5%. The construction of basic intelligent transportation industry infrastructure has been accomplished. The scale of investment in such applications was nearly 70 billion Yuan. The Intelligent Transportation Technology Application Committee of the Transportation Association estimated that the size of the industry market would be 200 billion Yuan by 2020 [12, 13].

In summary, the ITS development history in China has gone through the budding period, developing

Figure 1 Beijing traffic control board command center.

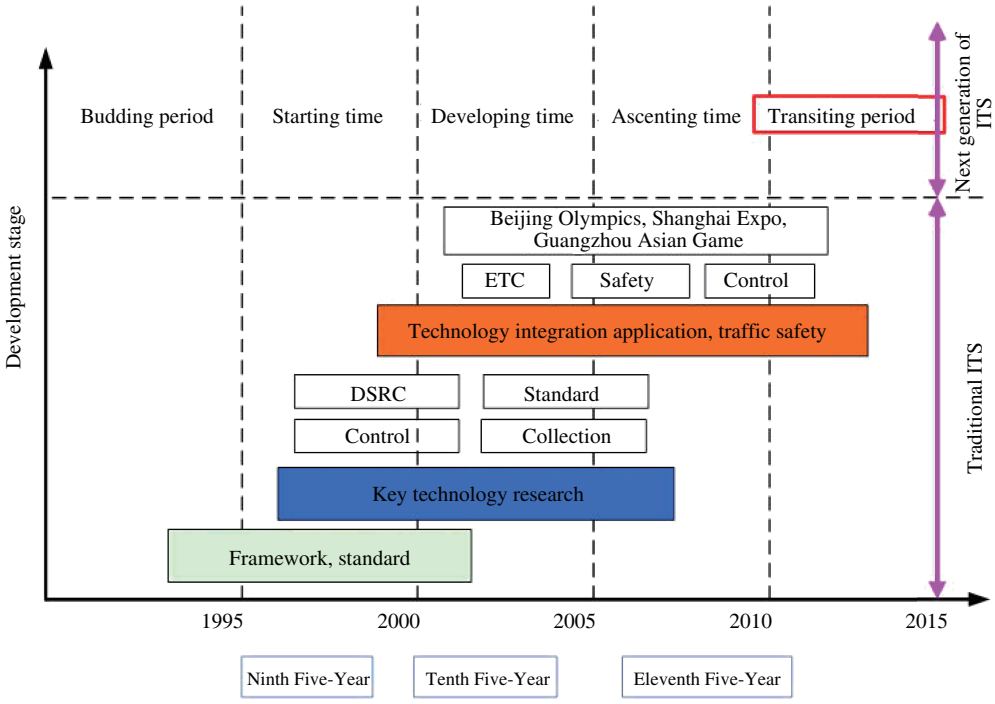

Figure 2 ITS technology development stages.

period, and promoting period, as shown in Figure 2. At this new historical starting point, with the new strategic requirements, overall development of domestic economy and traffic, and overall development of new technologies, the ITS in China is set to enter a strategic transition period.

3 Problems and challenges faced by ITS in China

Over the past 20 years, the ITS implemented in China has played a positive role in alleviating congestion, improving road traffic safety, and reducing pollution. Intelligent transportation technology has made several breakthroughs and a number of independent intellectual property rights with innovative

scientific and technological achievements, including traffic state perception and interaction, urban road network simulation and control, vehicle networking, vehicle-infrastructure coordination, and road safety intelligence management. Based on the mobile internet travel service, new formats and new models of intelligent transportation services have been realized, with practices proving that relying on independent technological innovations, China will enter a road of intelligent transportation development with Chinese characteristics. In some fields, we have secured the "lead" and "corner overtaking" positions, thus achieving leapfrog development and cultivating a new industry. However, at present, there are still several obstacles that could restrict the development of a Chinese ITS. The specific issues and challenges involved are described in the following subsections.

3.1 ITS theory research is insufficient, and it is necessary to establish comprehensive ITS theory framework

The development of ITS in China is strongly influenced by traditional traffic engineering technology. Generally, the application of ITS is simply introduced in the field of traffic engineering in the first stage. Many people intuitively believe that ITS is a simple combination of traffic engineering and IT, i.e., ITS = IT + traffic engineering. However, ITS is a multi-disciplinary subject and includes artificial intelligence, control theory, and system engineering. In addition, there is a lack of adequate scientific research and a complete ITS theory still cannot be established. The basic theory of ITS also makes use of traditional road traffic theory. However, though ITS is related to traditional traffic engineering, it is different from traditional traffic engineering. For example, most of the traditional traffic engineering applications are using acquired traffic information based on forecasting technology (traffic model). The traffic models themselves can complicate the traffic system, and thus cannot remain real. In contrast, an ITS application obtains traffic information in a real-time acquisition mode and provides the appropriate controlling measure for improving the performance of transportation systems.

3.2 ITS resources are separated by industry barriers, resulting in low degree of sharing

The Chinese government plays an important role in leading the development of ITS technology, which includes the policy development, financial investment, and promoting the Chinese ITS industry in recent years. Owing to institutional and market reasons, there are several main stakeholders in China that are still lagging behind in terms of resource integration; information sharing; multi-sector, multi-user intelligent traffic management and control; and service platform development. Industry barriers and redundant construction exist in ITS applications. As the industry data cannot be of service to society, the universities, enterprises, and research institutes that own ITS technologies cannot obtain real industry data, thus resulting in a technical mismatch and a waste of many social resources. Furthermore, the development of most application systems focuses on hardware construction and data representation, which means that there is a lack of support that could be obtained by using techniques such as traffic flow theory, system control theory, data mining, and data fusion.

3.3 Industry development is unbalanced, standardization is not sufficient, and core technologies and products are desperately required

Intelligent traffic development and control has made great progress, particularly in the case of a few key technologies. The application of intelligent traffic systems has penetrated into buses, taxis, parking, urban traffic coordination and management, comprehensive information services, and other fields. However, there are large differences among the cities in China. Some of the cities are entering into the deep development phase. However, the majority of the mid-west cities have just entered the initial phase of development. The imbalance among these cities is the basic starting point for our traffic management and service work. At the same time, typical mixed traffic is the core characteristic of the traffic system in China, which is obviously different from foreign transportation systems. Some of the original core technologies depend on imported products. For example, several cities' signal control systems are still dominated by SCOOT or SCATS systems that are developed in foreign countries. The majority of the

traffic flow collection equipment or devices are dependent on foreign products. These systems cannot adapt to the aforementioned mixed traffic characteristics in China. Many simulation systems, testing equipment, and system construction methods still exhibit great potential for improvement for adapting to China's national traffic conditions. At the same time, owing to the development of ITS technology, the corresponding ITS construction specifications and data standards are insufficient.

3.4 Traditional model for focusing on infrastructure construction is facing challenges owing to the changes in technologies and models

With the rise of shared economy in China and the application and development of new technologies such as big data, mobile internet, Internet of Things, system control, and artificial intelligence, ITS applications have been integrated into the new technologies, thus creating new challenges for the development of the model and concept of ITS. For example, the government has invested a large sum of money for building many traffic collection and distribution systems. Many internet companies (e.g., Baidu and Gaode) have been using their own mobile data resources to build information systems that could provide accurate and free traffic information services, compared with the government investment on traffic data collection and provision. The number of visits to these companies websites is much greater than the number of visits to the governments websites. In June 2013, for traffic information service content, the number of visits on the Baidu website from PC-terminals was more than 200 million, and the number of visits from mobile terminals was more than 150 million. In contrast, the number of visits to Chinas many government websites was a few hundred to a thousand every day in some cities. Many new technologies and models, including flexible, mobile, and interconnected bicycles (or OFO) and fixed public leasing bicycles, have posed a greater challenge to traditional transport development, as well as put forward higher demands and challenges for management wisdom of our government agencies.

3.5 Industry innovation investment model is facing capital-driven "new normal development model."

The investment model of the government for transportation and other public welfare will undergo an important change under the new normal state of the economy in China. With the increase in public financial investment, in order to alleviate the short-term financial pressure, there will be a trend of some local governments executing intelligent transportation construction projects, which would receive society capital through financial models such as the Public-Private Partnership (PPP) model. Thus, the enterprises in the intelligent transportation industry would switch from single-technology research to full development under the new normal development model. The intelligent transportation industry has a greater tendency to integrate industry solution providers to enhance their comprehensive competition in the industry.

4 New requirements of ITS in China

During the period of the Thirteenth Five-Year, the ITS has entered a new phase of development in China. However, traffic congestion, traffic pollution, low traffic efficiency, low traffic service, and frequent traffic accidents still occur for a certain period in many Chinese cities, unremittingly promoting the development of ITS in China. Nowadays, the development of new strategies, such as new urbanization, regional coordinated development, and smart city, is fast. At the same time, new technologies such as big data, mobile internet, Internet of Things, simulation and control, and artificial intelligence have also entered a period of rapid development. The policy environment, application environment, and technology environment of ITS are changing. With these new changes, this comprehensive development scenario gives rise to new development requirements in the new generation of ITS [14]; the specific requirements are described in the following three subsections.

4.1 National innovation-driven strategies and policies give rise to significant development opportunities in ITS

In May 2016, the Central Committee of the Communist Party of China (CPC) and State Council issued the "Outline of National Innovation-Driven Development Strategy," clarifying the goals, directions, and key tasks of innovation-driven development for the next three decades. In recent years, the State Council promulgated the "Opinions of the State Council on Promoting the Development of Informatization and Safeguarding Information Security," "Guiding Opinions on Promoting the Healthy Development of Intelligent Cities," "Opinions of the State Council on Strengthening Urban Infrastructure Construction," "National Science and Technology Innovation planning in the Thirteenth Five-Year," and a series of policies, thus putting forward the relevant deployment and requirements for the development of ITS. In "Made in China 2025," which was issued by the State Council in 2015, the overall layout for promoting the research and industrialization of intelligent vehicles is clearly presented. In September 2016, the relevant government agencies jointly issued "promote 'Internet +' convenient traffic to promote the development of the intelligent transport program." The insights and requirements of these policy documents created a good opportunity for developing ITS. According to the overall deployment of the national science and technology system reform, the Ministry of Science and Technology will plan the layout of the key scientific and technological projects in the Thirteenth Five-Year period. "Integrated Transportation and Intelligent Transportation" will be one of the key plans in the Thirteenth Five-Year period in the field of transportation science and technology. These innovative strategies and policies will give rise to great development opportunities in Chinese intelligent transportation innovation.

4.2 Chinese economy and social development demand high transportation modernization

ITS is the core of the establishment of modern transportation systems. Its essence is to—through the effective application of IT, system control technology, and artificial intelligence— maximize the existing transport infrastructure and potential and manage and control the traffic to obtain a reasonable traffic behavior. After the rapid development in recent years, the intelligent transportation industry has entered into an actual development and application phase from the exploration phase. In addition to playing a role in mitigating traffic congestion, reducing air pollution, and improving transportation safety, the intelligent transportation industry has become a strategic emerging sector that supports the national strategy and enhances the core competitiveness of cities. At the same time, it has great industrial value. By 2015, the overall market size of the Chinese intelligent transportation industry reached nearly 70 billion Yuan, and the industry began to take shape. However, in the new period of economic and social development, the modernization and development of intelligent transportation gave rise to more challenging requirements, which are as follows. Firstly, the transformation and upgradation of the industrial structure as well as industrial layout adjustment, which are the new norms of Chinese economic and social development were required. Transportation is an important engine that supports economic and social development and promotes the implementation of major national development strategies. In the context of the new economic background, by targeting the major demands for changing the requirements of economic development, we must strengthen the coordinated operation of various modes of transportation, enhance the efficiency of transportation, and then improve the basic public services and traffic safety and security system. For the sustainable development of the national economy and society, we must speed up the construction of low-carbon, convenient, and integrated intelligent transport systems. Secondly, for "Beijing-Tianjin-Hebei coordinated development," "Yangtze River Economic Zone," and other regional development strategy requirements, the transportation system support leads the new urbanization innovation and development. We must speed up the construction of an integrated transportation system with wider coverage, connectivity, security, and comprehensive ability. Thirdly, the transportation system itself is also facing the major realistic requirements of transformation and development. The development mode is driven by the ability to make full use of the infrastructure to realize the full potential. The management mode is shifted from satisfying the business demand to protecting the efficient use of public resources. The service mode is shifted from the operation of organizations to the strengthening of the

market. The transport mode is shifted from a single mode transport to multimodal transport, and the information sensing and utilization patterns are shifted from the "island" or isolated mode with closed systems to shared mode with open systems. Adaptation to the new normal state, vigorous development of integrated transportation, intelligent transportation, green transportation, and safe transportation are the strategic choices for the future development of transportation systems in China.

4.3 Development of new technologies will give rise to important opportunities for Chinese intelligent transportation innovation

ITS is the essence or outcome of the integration of advanced IT, system control theory, artificial intelligence, etc. with transportation technology. Through traffic information perception, processing, and publishing, ITS achieves information sharing and cooperation among people, vehicles, and infrastructures, thus alleviating traffic congestion, reducing traffic accidents, and decreasing traffic energy consumption and pollution. The development of a new generation of IT, which is represented by Internet of Things, cloud computing, big data, mobile internet, and artificial intelligence, causes changes in the technical system and overthrows the concept and mode of traditional transportation development. The development of mobile interconnection and vehicle routing systems greatly broadens the content of traffic information, facilitates the procurement of real-time traffic status information, and remotely perceives the running state, emissions, and other data of the vehicle. At the same time, sharing completely changes the traditional mode of traffic information collection. Large-scale data technology improves the processing and analysis capabilities of traffic data. Traffic cloud analysis, intelligent monitoring and analysis, and integrated traffic coordination and control effectively support traffic management, decision-making, planning and operation, services, and active security. They also provide new ideas, patterns, and means for public security and social management. The new technology and its insights recreate the transportation system with the ITS technology undergoing major changes and stimulating emerging markets and industries.

5 Development trend and direction of ITS in China

Under the new situation, more challenging requirements have been put forward for the functions of the transportation system. It is important to guarantee the realization of urbanization and modernization in China, and we should ensure the safety and mobility of the transportation system, and improve the service level and efficiency of the transportation system using contemporary science and technology. ITS is an application-oriented and highly practical discipline, having features of professional and multi-disciplinary properties and multi-technology integration. The development of new technology, change in application requirements, and progress of related disciplines have profound influences on the development of ITS, which is entering a new era. We can call the next generation of the ITS "smart transportation" or "intelligent transportation system 2.0" [15]. The future of Chinese intelligent transportation innovation should focus on strengthening the aspects described in the following subsections.

5.1 Focus on the top level strategic planning of ITS innovation development and strengthen the basic research of ITS

Intelligent transportation strategic planning and top-level design determines the direction of the cities intelligent traffic development and implementation. The lack of top-level design of ITS has been an important reason for the development of the industry being held back. However, it also leads to repeated construction of many systems with which it is difficult to meet the actual requirements. From the 1990s, China began studying ITS architecture and standard systems. Until recently, we also provided important theoretical and technical guidance for the construction and development of ITS [16]. However, when faced with ever-changing technology and the rapid increase in the demand for transportation services, the limitations of the original architecture system have become increasingly prominent. Therefore, we should focus on planning intelligent transportation innovation strategy and strengthening the top-level design. Based on the infrastructure network, intelligent transportation management and control tools,

integrated operation, personalized service, etc., are all indispensable for transportation industry development. Combining the development of cutting-edge technologies in information, control, intelligence, manufacturing, and ecology, we should revise and perfect the architecture of ITS in a timely manner, and establish a new system architecture that can provide effective guidance for future ITS development.

5.2 Increased demand and problem-oriented ITS key technology development and application

Information interaction, system control theory, and artificial intelligence are important future areas of technical development. The wide application of various intelligent terminals and wireless networks in the transportation system will cause great changes in the mode and efficiency of traffic information acquisition, system control and interaction, and application services. By focusing on problems in the transportation system, we should further enhance key technology development, which mainly includes road condition perception and coordination, intelligent vehicle network control, intelligent monitoring and intelligent infrastructure management, traffic information integration and intelligence service, integrated transportation operation optimization, ITS management and control, and active transportation safety and risk control. These specific problems include the development of transportation infrastructure, dynamic traffic information sensing, intelligent vehicular networking, traffic simulation, system control and coordination, transportation hub co-operation, multi-way integrated transport service, and integrated transport safety risk prevention and emergency rescue. The intelligence level of transportation and service quality can be demonstrated through applications.

5.3 Strengthen the integrated transport system and intelligent services

Recently, comprehensive transportation systems have shown the characteristics of weak system management and control ability, low efficiency of cooperative operation, poor capability of transportation safety management, and weak integrated service. Therefore, we should study the intelligent development of integrated transportation systems and break through the technical bottlenecks of restricting the efficient operation of information communication, system management and control, facility interconnection, operation integration, and collaborative service of integrated transportation system in order to solve the problem of integrated transportation system coordination at three levels of the hub, route, and network. This results in formulating integrated traffic monitoring, control, regulation, service, and the intelligent technology system and related equipment, which would thus provide support for the integrated transport system operation and intelligent services.

5.4 Speed up cross-border integration of traffic systems for regional integration

Integrated regional development has become a national development strategy. The full integration of regional traffic information resources will become a new trend in the development of ITS, which will also give rise to new modes in the transport and industrial structure. Therefore, we should study the intelligent transportation technology system and plan for the coordinated development of the urban traffic system. The key areas include urban traffic management and control systems and urban traffic demand management technology. Meanwhile, the development of intelligent transportation innovation should follow a pattern of modern transportation development and have a great vision of global technology development. With the development of professional and technological innovation, we should pay close attention to the cross-border integration development in smart cities and accelerate the development of "intelligent transportation + industry," which includes cross-industry integration of electronic payment platforms, transportation and environment protection (energy savings), traffic and weather, and traffic and social security. Cross-industry integration of electronic payment platforms are required to open up key links urgently and establish an integrated electronic payment platform. Transportation and environment protection (energy savings and emission reduction) involves research on energy savings and emission reduction strategies, research and development of new energy vehicles, analysis of motor vehicle emission factors, traffic demand management based on energy savings and emission reduction, urban

traffic system control measure based on vehicle emissions reduction, and analysis of public transport development based on energy savings and emission reduction. The study of traffic and weather involves urban traffic conditions and control measures in adverse weather conditions. The study of traffic and social security involves ITS and public security networking models, which facilitate safe city and safe transportation development.

5.5 Induce development mode and develop ITS concepts

The development of new transportation tools and new technologies has caused a huge change in the transportation system. Large capacity, intelligent transportation tools, new rail transportation, cross-regional transport, cross-industry electronic payment, electronic identification, vehicular networking [17], etc., will have a profound impact on the development of ITS in China. Facing these ongoing or future changes, we should actively take the initiative to deal with and study deeply the operating mechanism of the resulting traffic system and mode of change to improve and enrich ITS. We should focus our attention on the application of new technologies and take the initiative to investigate new technologies that bring in new models and new concepts. The emergence of a networking bus in the shared background introduces a serious challenge to the traffic industry management and service model in "Internet +" in the development of the transportation industry. The popularity of smart phones, mobile internet applications, and the integration of traffic information services and other services introduces new application experiences to travelers, which will fundamentally change the traditional mode of information collection and navigation services. The integration of internet into vehicles will provide people with more intelligent and more convenient transportation services. Furthermore, the in-depth application of big data and artificial intelligence will result in greater changes. Green and sustainable development theory will further penetrate the field of intelligent transportation. Therefore, we should take the initiative to explore the changes through the development of new technologies and create a new ITS in order to facilitate sustainable development.

5.6 Establish a sound system of safeguard measures

The development of ITS cannot be separated from the external environment, such as social and economic development, the country's macro-policy, and the transportation industrys development strategy. ITS involves various systems that support each other with mutual restraints. In order to ensure that the future ITS smoothly realizes the functions of the transport industry in an integrated fashion, we must systematically support and ensure the healthy development of ITS by establishing a sound system of safeguard measures from the perspectives of industry policies, regulations, technical standards, scientific and technological support, industrial and personnel environment, and other related aspects.

6 Conclusion

ITS, as an integrated application of advanced technologies such as system control theory, IT, and artificial intelligence in the transportation field, has given rise to the development of a number of key technologies and theoretical breakthroughs after 20 years of rapid development in China. Throughout the development of the intelligent transportation industry, large cities in China such as Beijing, Shanghai, Guangzhou, and Shenzhen along with other large and/or medium-sized cities have realized the construction of the basic intelligent transportation management systems. They play an important role in terms of urban traffic dynamics monitoring, urban traffic system management and control, urban congestion mitigation, and the handling of emergencies. However, facing the impact of emerging technologies (e.g., mobile internet, Internet of Things, big data, and cloud computing) and the actual requirements of national strategic adjustment and economic and social development in the new period of China, the ITS has developed new connotations in China. Meanwhile, there also exist some problems with ITS, for example, there is a lack of basic theoretical systems or techniques for ITS—for example, some core technologies and products rely heavily on imported foreign products—and industry barriers still exists. At present, China is in a period of structural transformation, and the transportation industry is also facing an important opportunity for

structural transformation. Therefore, we should take advantage of this important strategic time period and identify the development trend and direction for ITS development. Based on the reality in China, the next generation of ITS with Chinese characteristics will be developed, and the ITS industry in China will be cultivated to formulate a new safe, efficient, and green intelligent transportation network in China for comprehensive coordination and control.

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