Application and Development of Intelligent Transportation Systems in Highway Traffic Planning

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Abstract: With the development of economy and urbanization, transportation problems have become prominent, and efficient operation of highways is particularly important. Traditional management is unable to meet the demand, and intelligent transportation systems (ITS) have become a key solution. This study explores the application of ITS in alleviating congestion, reducing accidents, and optimizing resources, which can significantly reduce economic losses and emissions, improve safety and travel experience. For example, the United States loses hundreds of billions of dollars annually due to congestion, and ITS can be reduced by over 30%. Research and analyze its technological functions and development, evaluate economic benefits, environmental impact, and social benefits, while paying attention to challenges such as cost and privacy, and propose solutions to provide reference for smart transportation and urban construction.
***Keywords*:** intelligent transportation system; expressway; transportation planning; innovate

1. Foreword

The acceleration of urbanization has led to an increase in transportation demand. Although highways promote economic integration and improve logistics efficiency, they also face problems such as congestion, accidents, and pollution. Intelligent Transportation Systems (ITS) have become a key technology for solving problems by achieving real-time traffic monitoring and optimized management through information technology and artificial intelligence. Many countries around the world have incorporated it into their national strategies, but traditional planning methods are difficult to adapt to complex environments. ITS utilizes precise data collection and dynamic simulation modeling to assist in the efficient utilization of highway resources and balanced distribution of traffic flow. However, its development still faces challenges such as data security, cost, and coordination of technical standards. This study focuses on the principles, technologies, and applications of ITS, exploring its development trends and issues, and promoting the construction of an efficient, safe, and sustainable transportation system[1].

2. Overview of Intelligent Transportation System

2.1 Definition and Basic Functions

Intelligent Transportation Systems (ITS) integrate modern technology, optimize transportation resources, and enhance safety and efficiency. The functions include information collection, monitoring and command, and electronic toll collection, emphasizing user interaction, providing personalized services such as dynamic navigation, alleviating congestion, and enhancing travel experience.

2.2 Technological Development History

Intelligent transportation systems originated in the mid-20th century, with early emphasis on automated control of traffic lights. In the 1980s, the distributed system gradually replaced the centralized system, and in the 1990s, the Internet and wireless communication promoted its expansion to the field of public transport and logistics. Since the 21st century, technologies such as artificial intelligence, big data, and the Internet of Things have driven intelligent transportation into a new stage. Many parts of China have built multi-functional intelligent transportation networks, and the commercialization of 5G has helped the development of autonomous driving and collaborative ecosystems, profoundly changing future modes of transportation[2].

3. Analysis of the Current Traffic Situation on Highways

3.1 Traffic flow characteristics

As of 2024, the total length of highways in China has reached 170000 kilometers, with an average daily traffic volume

of over 35 million vehicles. There is a significant difference in traffic between weekdays and holidays, with traffic during the Spring Festival and National Day periods being more than 30% higher than usual. During peak hours in the morning and evening, the surrounding areas of the city are prone to congestion. The eastern coastal areas have high traffic, while the central and western regions have lower traffic, with freight vehicles accounting for 30-40%. Intelligent devices such as high-definition cameras and ETC gantry systems assist in real-time monitoring, providing scientific basis for dynamic management.

3.2 Main issues that exist

Although highways improve transportation efficiency, there are still many problems. During holidays, there is a surge in traffic and frequent accidents, such as the 10 kilometer congestion on the Jiangsu section of the Beijing Shanghai Expressway during the National Day holiday in 2023. Approximately 25000 accidents will occur nationwide in 2024, mostly due to fatigue driving, speeding, and adverse weather conditions. Part of the road sections are aging, with road surface damage and bridge and culvert diseases increasing the difficulty of maintenance. The pressure of environmental protection is high, with heavy-duty diesel trucks emitting about 20 kilograms of carbon dioxide per 100 kilometers, and exhaust and noise pollution urgently need to be addressed. These issues hinder the optimization and development of the highway system[3].

4. Application field of intelligent transportation technology

4.1 Data acquisition and processing

Intelligent transportation relies on data collection and processing, obtaining information such as vehicle speed and flow through sensors, and predicting trends through big data analysis and machine learning to support decision-making and early warning. The system adopts encryption and anonymization to ensure data security, providing a basis for traffic monitoring and scheduling.

4.2 Real time monitoring and warning

Real time monitoring is a key function of intelligent transportation, which tracks the road network status through videos, drones, and high-definition cameras, warns potential risks, and automatically alerts. The 5G trial in a certain city in 2023 will improve response speed and combine GIS to achieve positioning and planning. Algorithms can identify violations, generate reports to assist law enforcement, and improve efficiency and accuracy.

4.3 Road network optimization and scheduling

Road network optimization and scheduling are core technologies of intelligent transportation, which alleviate congestion and improve efficiency through dynamic path planning and signal control. For example, some urban expressways adjust signal timing based on real-time traffic flow to reduce waiting time; The intelligent public transportation system, with the help of GPS and demand forecasting models, has improved the punctuality rate of a large city by 30%. At the same time, road network optimization needs to consider environmental factors, such as adjusting routes to ensure safety in adverse weather conditions, integrating meteorological data for dynamic planning, and promoting green travel.

5. Key technical support and innovation

5.1 Application of Artificial Intelligence Algorithms

Artificial intelligence assists intelligent transportation systems, with deep learning predicting traffic flow with an accuracy rate of over 90%, and reinforcement learning optimizing signals to improve efficiency. Taking Shanghai toll stations as an example, travel time is reduced by 25%. NLP analyzes accident reports and feedback, improves emergency response capabilities, and jointly promotes system optimization.

5.2 Big data analysis technology

Big data analysis is the core of intelligent transportation and supports highway planning. Integrating multiple sources of data to form a traffic view, mining historical patterns and anomalies. For example, data from a highway in Beijing shows that on the eve of holidays, traffic surged threefold in the afternoon, aiding in traffic diversion. Real time data analysis is equally crucial, utilizing tools to quickly process data and provide feedback. In a project in Germany, real-time analysis is used to achieve dynamic speed limits, reduce accident rates, and improve efficiency.

5.3 Internet of Things and Sensor Technology

The Internet of Things and sensor technology assist in highway traffic planning. Through sensor nodes, road, vehicle,

and environmental conditions can be monitored. Some states in the United States use road sensors to detect temperature and icing conditions to optimize snow removal operations. The Internet of Vehicles (V2X) enables information exchange between vehicles, workshops, and roads, improving traffic safety and efficiency. In the Singapore pilot project, fleet collaboration reduces fuel consumption and emissions. Drone patrols detect obstacles or malfunctioning vehicles and quickly transmit information to the command center, improving response speed and management efficiency.

6. Conclusion

Intelligent transportation systems have broad prospects in highway planning, driven by technological advancements, social demands, and global cooperation. Artificial intelligence, big data, the Internet of Things, 5G optimization forecasting and decision-making, and edge computing improve monitoring efficiency. At the social level, reducing congestion and carbon emissions, pilot data shows that waiting time and emissions have decreased by 30 and 25, respectively. Global cooperation accelerates the unification of technical standards, such as the EU's "Digital Single Market" and China's "the Belt and Road" initiative to promote connectivity. The changing demands of users are driving the popularization of autonomous driving, and it is expected that by 2030, there will be over 500 million connected cars on the road worldwide. Future research needs to focus on system reliability, adaptability, and ethical issues to ensure that technology benefits society. Through joint efforts, intelligent transportation will achieve a safer, more convenient, and efficient transportation environment.

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