RESEARCH ARTICLE

Optimization Strategy of Railway Transportation in Guangdong, Hong Kong, and Macao Greater Bay Area Based on Intelligent Transportation System (ITS)

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Abstracts: With the rapid development of China's economy, the Guangdong-Hong Kong-Macao Greater Bay Area is experiencing rapid economic growth, increasing population, and extremely high regional foot traffic, which brings great challenges to the transportation system. To support the sustainable development of the Guangdong, Hong Kong(China), and Macao(China) Greater Bay Area, optimizing the rail transportation system of the Guangdong, Hong Kong(China), and Macao(China) Greater Bay Area has become an urgent task. At present, the construction of ITS has become an important trend in modern society, and the efficiency and convenience of transportation can be improved through the application of ITS and the implementation of optimization strategies. By optimizing line planning and design, rationalizing train operation schedules, and implementing intelligent scheduling and operation management to reduce congestion and increase operation speed and frequency, the efficiency of the overall rail transit system can be improved to provide more efficient, convenient, and safe travel options for residents, enterprises, and tourists, and to promote the economic development and sustainable urban development of the Greater Bay Area.

Keywords: intelligent transportation system; Guangdong, Hong Kong, and Macao Greater Bay Area; rail transit; optimization strategy

Introduction

Guangdong, Hong Kong(China), and Macao(China) Greater Bay Area is an important economic region located in the southern part of China, covering Guangdong Province, Hong Kong Special Administrative Region, and Macao Special Administrative Region, which is known for its geographical advantages and economic strength, and is one of the most dynamic and development potential regions in China. The Guangdong-Hong Kong-Macao Greater Bay Area is rich in resources and talent, as well as well-developed manufacturing, financial services, and innovative technology industries. It has a large population, frequent economic activities, and huge transportation needs. However, due to the vastness of the region and the complexity of the transportation network, the rail transit system in the Greater Bay Area faces many challenges, such as congestion and inconvenient interchange. Therefore, optimizing the rail transit system in the Guangdong-Hong Kong-Macao Greater Bay Area to improve the efficiency and convenience of transportation is one of the keys to achieving sustainable regional development.

1. Current situation and challenges of the rail transportation system in Guangdong, Hong Kong, and Macao Greater Bay Area (China)

The Guangdong-Hong Kong-Macao Greater Bay Area has built a certain scale of the rail transportation network, including metro and light rail lines, which

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connect major cities and important transportation hubs in the region and provide convenient travel for residents and tourists. Among them, the metro network in Guangdong Province is more maturely developed, covering major cities such as Guangzhou, Shenzhen, and Zhuhai, and is constantly expanding and extending. Meanwhile, Hong Kong (China) and Macau (China) also have their metro systems, providing convenient urban transportation services for residents and tourists.

With population growth and economic development, traffic congestion has become a prominent issue in the rail transit systems in the Guangdong-Hong Kong-Macao Greater Bay Area. High passenger volumes during peak hours result in crowded trains and slower operating speeds, causing inconvenient and uncomfortable travel experiences for passengers. Inconvenient transfers are also a common problem, as the design of transfers between lines is not optimized enough, passengers need to go through multiple transfers, which increases travel time and uncertainty. There are also challenges in rail transit connectivity between different cities, such as the potential lack of convenience and efficiency in cross-border transportation and intercity connections. According to the operational requirements of the rail transit system in the Guangdong-Hong Kong-Macao Greater Bay Area, safety and emergency response capability are also important elements that need to be paid attention to. Addressing these issues and challenges requires the introduction of ITS and advanced technologies to improve the efficiency, reliability, and convenience of the transportation system, taking into account various aspects such as route planning and design, scheduling and operations management, intelligent navigation, and travel services.

2. Application of Intelligent Transportation System in Guangdong, Hong Kong, and Macao Greater Bay Area (China) Rail Transit

2.1 Data Acquisition and Analysis

A comprehensive understanding of the operating conditions of the transportation system can be obtained by collecting a large amount of traffic data in optimizing the rail transit system in the Guangdong-Hong Kong-Macao Greater Bay Area, such as train running time, passenger flow, station congestion, etc. This data can be collected in real-time through sensors, surveillance cameras, intelligent terminals, and other devices, and combined with the relevant station, line, and passenger information, to confirm the rail transit system's operating situation (Lin, 2023). Through data analysis, it is possible to evaluate and optimize the transportation system from multiple perspectives, mainly for the statistics and analysis of traffic flow, which can identify congestion bottlenecks, peak hours, and hotspot areas, to formulate corresponding scheduling strategies and optimization plans. The analysis of passenger travel behavior data can reveal passengers' travel preferences, transfer habits, and travel demand, providing a basis for decision-making in route planning, station design, and service, and also identifying potential problems and hidden dangers, such as safety risks and equipment failures, so that timely measures can be taken to prevent and deal with them. To achieve effective data collection and analysis, intelligent transportation systems can use big data technology and artificial intelligence algorithms to achieve rapid data processing and deep mining. At the same time, the privacy protection and security of data need to be emphasized to ensure the legitimacy and credibility of the data collection and analysis process.

2.2 Real-time traffic management

The construction of intelligent transportation systems in Guangdong, Hong Kong, and Macao Greater Bay Area (China) can implement real-time traffic management to monitor the traffic flow, vehicle location, and passenger information in real-time, which can make timely adjustments and management of the transportation system, improve operational efficiency and reduce congestion. In real-time traffic management, an intelligent transportation system is used to collect traffic data, confirm the location and operation status of trains, the congestion level of stations and carriages, passenger flow and transfer information, etc., and process and analyze these data in real-time to obtain accurate traffic conditions and operation. This allows real-time adjustment of the

train operation plan to optimize the train departure interval and running speed according to the passenger flow and traffic congestion, to ensure the efficiency of train operation and reduce passenger waiting time. And according to the real-time passenger flow, adjust the station's import and export flow distribution, optimize the route and process of passenger transfer, improve the transfer efficiency, and prevent serious congestion in the rail transit system. The intelligent navigation provided by the ITS can provide passengers with real-time traffic information and recommended travel routes to help passengers plan the best travel plan. In this way, passengers can choose the optimal route and transportation mode according to real-time conditions, improving the convenience and efficiency of travel. It should be noted that real-time traffic management requires a reliable data acquisition and processing system, as well as an efficient communication network to support the transmission and distribution of data, and the configuration of reasonable algorithms and decision-making models to make fast and accurate adjustments and decisions based on real-time data (Shi, & Liang, 2023).

2.3 Passenger information service

Under the ITS, passengers use information services to obtain real-time and accurate ride information and navigation services, providing passengers with a convenient and personalized travel experience. Intelligent passenger information services provide passengers with real-time transportation information, including train arrival time, train operation status, and carriage conditions. Through this information, passengers can know the arrival time of the train and the train condition in advance, to reasonably arrange the travel time, and at the same time, they can also choose the best travel plan according to the recommendation of the intelligent transportation system. Intelligent passenger information services can also provide navigation services to help passengers plan the optimal travel routes and transfer programs, and in the intelligent navigation system, passengers can obtain accurate navigation guidelines, transfer tips, and station information to reach their destinations smoothly (Lu ,

2023). And the intelligent transportation system can do according to the passenger's travel preferences and needs, and provide personalized recommendations and customized services, for example, the system can be based on the passenger's history of travel records and preferences, recommending suitable travel modes, preferential fares, and special services. The realization of passenger information services requires the use of smart terminals, mobile applications, and Internet technologies to facilitate passengers' access to information anytime and anywhere, which not only improves passengers' travel efficiency and satisfaction but also promotes the sustainable development of the rail transit system in the Guangdong-Hong Kong-Macao Greater Bay Area.

3. Optimization Strategies of Guangdong-Hong Kong-Macao Greater Bay Area Rail Transit Based on Intelligent Transportation Systems

3.1 Network Planning and Route Design

Predict future transportation demand based on the development of the Guangdong-Hong Kong-Macao Greater Bay Area. Transportation demand prediction can be based on historical data and trend analysis to predict future population growth and migration patterns. By analyzing factors such as population distribution, employment status, and residence trend, the future population size and population movement in the Guangdong-Hong Kong-Macao Greater Bay Area can be predicted to gain insights into the potential changes in the future transportation demand in the Guangdong-Hong Kong-Macao Greater Bay Area. It also analyzes the economic growth, industrial restructuring, and urban development plans of the Guangdong-Hong Kong-Macao Greater Bay Area to analyze the trend of future changes in transportation demand. For example, the construction of new business districts, industrial parks, or residential areas may give rise to an increase in transportation demand, and hence the need to adjust and expand the transportation network accordingly. The Guangdong-Hong Kong-Macao Greater Bay Area, as a more economically developed region, is not only an important tourist choice, but also many large-scale activities or events will choose to be held in these

areas, so it is also necessary to analyze the traffic demand caused by social factors and special events in planning, such as specific activities, holidays, large-scale conferences, or sports events, which may cause a temporary increase in traffic demand (Wu, et al., 2023).

The use of ITS for data collection, modeling, and analysis of rail transportation in traffic demand forecasting, combined with the application of big data technology and artificial intelligence technology, improves the accuracy and precision of traffic demand forecasting, which helps to ensure that the scale and capacity of the transportation system can match future demand, provide efficient, convenient and sustainable transportation services to meet the travel needs of the residents of the Guangdong-Hong Kong-Macao Greater Bay Area and visitors. and make corresponding traffic management and scheduling arrangements to meet short-term peak demands. And in the case of high-pressure rail transit operation in Guangdong, Hong Kong, and Macao Greater Bay Area (China), new lines can be expanded and existing lines can be extended, and the construction standards of ITS can be directly integrated into the line design by setting up monitoring and control systems, sensing systems, and integrating IoT technology, artificial intelligence, and big data technology so that the coverage of rail transit can be increased and at the same time, a more comprehensive and convenient service can be provided to satisfy the ever-growing population and travel demand (Qian, et al., 2021).

3.2 Scheduling and Operation Management

In optimizing the Guangdong, Hong Kong, and Macao Greater Bay Area (China) rail transit system, the optimization of train scheduling needs to take into account passenger demand and traffic flow, through the intelligent transportation system analysis of historical data and prediction models, accurately predicting the passenger flow and traffic demand in different periods, to formulate reasonable train departure intervals and operation plans. While the ITS carries out real-time monitoring and data analysis, it uses advanced scheduling algorithms and decision-making models to calculate optimized train scheduling and operation plans. By analyzing factors

such as the length of the line, the spacing of stations, the signaling system, and the performance of the vehicles, it is possible to formulate the appropriate train speeds and operation intervals to maximize the line's operating capacity and throughput.

Operational monitoring in ITS applications involves real-time monitoring of key elements such as trains, signaling systems, station facilities, etc. Information such as train location, operating status, door opening and closing conditions, and passenger flow is obtained through intelligent devices, and this data is transmitted to a central control center, where operators can view and master traffic operating conditions in real-time through the monitoring system (Yi, H,et al., 2022). Intelligent operation monitoring can help to find and solve potential problems and failures, the daily operation of rail transit will produce a large amount of data information, and the intelligent transportation system can be used in the big data technology for massive data processing, through the data analysis and anomaly detection, the timely detection of train operation abnormalities, signal failures, damage to equipment and other problems, and take appropriate measures to repair and deal with them, which can help to improve the reliability and operational stability of the transportation system and reduce the impact of emergencies on operations.

3.3 Intelligent Navigation and travel services

Passenger travel unchanged is a situation that needs to be emphasized in the optimization of the Guangdong, Hong Kong, and Macao Bay Area rail transit system. Intelligent navigation systems and passenger information services can be provided in the ITS to provide passengers with accurate ride guidance and real-time transfer information, and through smartphone applications, electronic displays, voice prompts, etc., passengers can obtain detailed transfer guidelines and station information to reduce getting lost and making incorrect transfer This reduces the risk of getting lost and making wrong choices, and improves the smoothness and efficiency of transfers.

Among the travel services provided by ITS, travel planning and recommendation can provide passengers with personalized and efficient travel plans, calculating the best travel routes based on passengers'

origins, destinations, and time requirements, combined with real-time traffic data and passenger preferences. By taking into account the running time, frequency of trips, transfer stations, and possible congestion on different routes, the system can determine the optimal travel plan so that passengers spend the least amount of time in the travel process. In intelligent travel services, other factors can be considered for travel planning and recommendation, such as attractions, business districts, cultural activities, etc. Combining these factors, the system can provide passengers with customized travel plans, so that they can take into account the time efficiency and travel experience as much as possible in the travel process (Ai, 2021).

Mobile payment and ticketing services belong to the necessary functions in today's intelligent transportation system, mobile payment provides passengers with a convenient way to purchase tickets, passengers can download the relevant mobile applications, and ticket operation on the phone, avoiding the inconvenience of waiting in line in the traditional way of purchasing tickets, which makes the process of purchasing tickets more efficient and can be purchased at any time and any place. While mobile payment provides a variety of payment options, passengers can use a variety of payment methods, including bank cards, mobile payment platforms, and cloud flash payment to meet the payment preferences and needs of different passengers, and this flexibility makes the payment process more convenient and personalized (Li, 2023). Through the mobile application, passengers can view their personal ticket purchase records, balance information, and trip history, making it easy to manage and inquire about their personal transportation consumption information, and this integrated service provides passengers with a more comprehensive and convenient ticket management experience. It achieves the goal of effectively improving the service quality and user satisfaction of the rail transit system in Guangdong, Hong Kong, and Macao, and promotes the modernization and intelligent development of the transportation system.

Summary

Optimizing the Guangdong-Hong Kong-Macao Greater Bay Area rail transit system requires comprehensive consideration of multiple aspects, including ITS-based fine-tuned scheduling and management, data collection and analysis, real-time traffic management, passenger information services, train scheduling optimization, operation monitoring and control, travel planning and recommendation, and travel services. The ITS is used to modernize, intelligent, and efficiently operate the rail transit system in the Guangdong, Hong Kong, and Macao Greater Bay Area (China), to enhance the level of transportation services, to meet the growing population and travel demand, and to contribute to the sustainable development of the region.

Conflict of Interest

The authors declare that they have no conflicts of interest to this work.

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