

Highway Smart Service Area Informatization Construction and Management Analysis

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Abstract: With the rapid development of expressways in China, the number of service areas has been increasing, and their functions and roles have undergone new changes. Service areas have become complexes integrating leisure, shopping, dining, and vehicle services. In recent years, relying on digital and information technology, many regions have vigorously promoted the construction of smart service areas and achieved positive results, but they also face some problems and challenges. Based on this, this paper focuses on the informatization construction and management of highway smart service areas. It first expounds on the concept, characteristics, functions, and basic framework of smart service areas, analyzes the problems and challenges in informatization construction and management, and puts forward countermeasures and suggestions from four aspects: strengthening top-level design and overall planning, promoting information data integration, improving operation and maintenance capacity and level, and innovating investment, financing, and operation models.

Keywords: smart service area; informatization construction and management; problems; countermeasures

1. Introduction

Recently, the Ministry of Transport issued the 2025 National Highway Service Area Key Tasks (hereinafter referred to as the Key Tasks). The Key Tasks clearly put forward measures such as “promoting the intelligent transformation of service areas; actively carrying out informatization and intelligent transformation of service areas, gradually realizing real-time monitoring, automatic collection, and external release of service area data and information” and “exploring the construction of provincial-level smart service area management platforms, and connecting them with the national highway service area management platform system.” These measures put forward new requirements for the intelligent and informatized construction of service areas. Under the premise of sufficient funds and budgets, smart service areas have become the preferred approach for upgrading traditional service areas and constructing new ones. At present, a number of distinctive smart service areas have been built and put into operation in China, receiving widespread praise. For example, the Jiuling Service Area in Guangdong Province created the province’s first “tidal” smart shared service area, which adopts a single-sided layout and connects to the main line through ramps, realizing the shared use of service resources. The service areas along the Xu-huai-Fuyang Expressway have built a service matrix integrating smart guidance, smart charging, smart services, and smart culture. However, it should also be noted that in the informatization construction and management of smart service areas, problems have also emerged, such as high initial investment, business homogenization, flashy but impractical functions, closed-loop data within each service area, and lack of sharing. These issues have led to low investment efficiency, poor user experience, and hindered sustainable development, all of which urgently need improvement and enhancement.

2. Overview of Smart Service Areas

2.1 Concept of Smart Service Areas

A smart service area refers to a new type of service area that relies on next-generation information technologies such as the Internet of Things, big data, and artificial intelligence to comprehensively empower expressway service areas. It builds an innovative service area with full-element perception, big data analysis, intelligent platform management, and visualized display and services. Compared with traditional service areas, smart service areas have significant improvements in service quality and management efficiency. They can provide the public with safer, more efficient, intelligent, and convenient services, and better meet the increasingly diverse travel and security needs of the public.

2.2 Characteristics of Smart Service Areas

Compared with traditional service areas, smart service areas possess distinct characteristics and functions such as safety, efficiency, intelligence, and eco-friendliness.

(1) Safety: Smart service areas, through technologies and functions such as checkpoint capture, ETC antenna recogni-

tion, panoramic AR monitoring, traffic monitoring, equipment monitoring, intelligent inspection, and platform scheduling, can provide more convenient services for users while ensuring vehicle passage and facility safety. Once problems occur, early warning and rapid response can be achieved.

(2) Efficiency: Relying on information platforms and big data technology, management efficiency of service areas can be significantly improved. On one hand, with smart systems, unmanned vehicle guidance, self-service operations, and services such as parking space and charging pile information inquiries can be realized, thus improving service effectiveness. On the other hand, front-end collection systems can widely collect real-time traffic and passenger flow information, classify different vehicles, and then analyze the data via big data platforms to provide decision support for managers. In addition, information technology can be widely applied to internal management and equipment operation and maintenance, improving internal operational efficiency.

(3) Intelligence: Smart service areas can provide users with diversified services, including free Wi-Fi, travel service apps, cloud malls, convenient payment, travel information release, as well as smart road signs, smart refueling and charging, and smart restrooms, enhancing the travel experience of drivers and passengers. Some service areas also integrate smart services with local landscapes and cultural features to create popular “internet-famous” service areas. For example, the Yangcheng Lake Service Area adopts the design concept of “dreamlike water towns, poetic Jiangnan,” blending Suzhou garden techniques with smart services to create a smart garden-style service area.

(4) Eco-friendliness: Through informatized management and operations, resources can be optimally allocated, energy consumption reduced, and green, low-carbon development achieved. In addition, some smart service areas make full use of dome space and adopt photovoltaic power generation to provide auxiliary power, greatly reducing external power consumption. For instance, the Bozhai Service Area on the Quannan Expressway utilizes rooftops, idle slopes, and small car parking spaces to build photovoltaic canopies, carports, and arrays integrated with the landscape. By relying on smart systems for unified management and allocation, it achieves both environmental protection and operational benefits, reducing carbon dioxide emissions by about 672 tons annually and creating a “near-zero carbon service area.”

2.3 System Architecture of Smart Service Areas

The basic architecture of a smart service area mainly consists of the data acquisition and perception layer, the platform control layer, and the application service layer.

(1) Data Acquisition and Perception Layer: This is the front-end layer of a smart service area, responsible for data collection and information perception. It mainly relies on IoT sensing devices such as video surveillance, millimeter-wave radar, and sensors to perceive and collect data on traffic flow, passenger flow, energy consumption, parking spaces, charging piles, and more.

(2) Platform Control Layer: The platform control layer is mainly responsible for collecting, integrating, aggregating, and analyzing various types of data and information, providing data support for early warning and decision-making. As the “brain” of a smart service area, this layer relies on big data and algorithm models to achieve full-process automation of event perception, decision analysis, and command issuance, thereby significantly improving decision-making efficiency.

(3) Application Service Layer: The application service layer transforms the results of data collection and analysis into underlying logical data, which is ultimately used to support management and serve users. Smart service areas can provide various applications and services such as smart guidance, smart parking, smart charging, smart dining, smart information release, and personalized services based on big data. For example, the Fenhu Service Area in Jiaying established a driver community to extensively collect dynamic needs and convert them into service projects. The “Xiangao Yi” unmanned convenience store of Huachang Expressway in Hunan uses visual recognition technology to realize “grab-and-go” frictionless payment.

3. Problems and Challenges in the Informatization Construction and Management of Smart Service Areas

3.1 Insufficient Top-Level Design and Planning, Weak Overall Coordination

Although the state issues the Key Tasks every year to provide macro-level guidance for the construction of smart service areas, at the implementation level, some cities and regions lack adequate top-level design. Their directions are unclear, their goals are overly ambitious and detached from reality, and thus cannot effectively guide practice. During construction, multiple parties are involved, including expressway operators, service area operators, relevant local government departments, and various business merchants. Sometimes they act independently or are restricted by conflicting interests, lacking overall coordination. This leads to repeated construction or resource waste. The participation of multiple construction and

management entities makes it difficult for smart service areas within a province to achieve unified standards, unified data, and unified interfaces, thereby forming data barriers and increasing the difficulty of subsequent integration work.

3.2 Proliferation of Data Silos, Difficulty in Integrated Applications

A smart service area contains multiple subsystems, including video surveillance, parking management, energy monitoring, environmental monitoring, business management systems, public service systems, and safety early warning systems. These subsystems are generally provided by different suppliers, with varying technical architectures, data formats, and data types, making integration very difficult and preventing effective data flow within the service area. As a result, subsequent data analysis, situational awareness, early warning and forecasting, and optimization of service chains become disconnected. For example, traffic flow, passenger flow, and charging duration data cannot be effectively linked, and thus cannot provide valid guidance for drivers and passengers. There are also cross-departmental data barriers between service areas and cultural tourism departments or emergency departments, and the lack of coordination mechanisms makes it impossible to form effective linkages. This limits road network collaboration, emergency response, and the development of the cultural tourism industry. In addition, differences in technology and data across service areas make it difficult for provincial-level service area management platforms to coordinate effectively, affecting subsequent work.

3.3 Emphasis on Construction over Management, Insufficient Operation and Maintenance Capacity

In the informatization construction and management of smart service areas, many local service areas emphasize construction over management, and hardware facilities over software development. Their operation and maintenance capacity needs to be improved, leading to a mismatch between investment and returns, and weak user experience. Some smart service areas are willing to invest in hardware, but supporting platform software lags behind, lacking independent development and sufficient customization. For example, interfaces may be unfriendly, visualization and humanization insufficient, operating procedures complex, elderly-friendly systems absent, and functions unstable, all of which negatively impact user experience. In addition, some service areas do not provide adequate daily operation and maintenance support, lack professional management teams, and have personnel with insufficient competence, making it difficult to effectively leverage informatization management.

3.4 High Construction and Operation Costs, Great Pressure on Sustainable Development

Smart service areas, compared with traditional service areas, add hardware such as cameras, sensors, display screens, and servers, as well as various platform software, which greatly increases upfront construction costs. In operation, the maintenance of various equipment, software upgrades, security protection, professional operation and maintenance, and personnel salaries all raise daily expenditures. However, compared with traditional service areas, smart service areas do not generate much additional revenue, still mainly relying on traditional leasing models, with insufficient development of digital value-added income. In the short term, costs are difficult to cover effectively, with ROI cycles generally exceeding five years, which places significant pressure on sustainable operations and development.

4. Countermeasures and Optimization Paths for the Informatization Construction of Smart Service Areas

4.1 Strengthen Top-Level Design and Overall Planning, Enhance Coordination

It is recommended that, on the basis of the Key Tasks, the state accelerate the formulation and release of the Technical Standards and Specifications for the Construction and Management of Smart Service Areas, with a focus on clarifying standards for data collection and exchange, as well as technical standards for key systems, so as to lay the foundation for subsequent software and hardware interconnection. This is also an effective measure to realize the requirement in the Key Tasks of promoting the connection of provincial platforms with the national highway service area management platform system. Each province should have its transportation department take the lead in establishing a leadership group for smart service area construction, integrating various forces to carry out core tasks such as planning approval, supervision of standard implementation, coordination of major projects, and resource allocation. The construction of smart service areas should adhere to the principle of integration and innovation, with appropriate forward-looking planning, while being closely integrated with industry management, business operations, and public services. It is necessary to select capable local state-owned enterprises or specialized enterprises, such as provincial expressway companies, as the leading entities of smart service area projects in the region, taking unified responsibility for planning, project approval, bidding, construction management, and subsequent

operation and maintenance, so as to avoid fragmented management and uncoordinated actions. The informatization requirements of various business merchants should be uniformly incorporated into the owner's overall framework and comply with unified standards.

4.2 Build a Data Hub for Service Areas and Promote Information Integration

In response to the current phenomenon of "data silos" in smart service areas, it is necessary for provincial transportation management departments to establish a centralized service area data hub platform, which will handle the access, cleaning, integration, analysis, and service of data from service areas within the province. All newly built and renovated systems should be required to adopt standardized protocols and unified data formats and types. Around elements such as "traffic," "users," "facilities," "energy," "safety," and "commerce," thematic databases should be constructed to promote data association and integration, facilitating data mining, analysis, and comprehensive utilization. Conditional smart service areas should, based on various types of data, establish a panoramic situational awareness system for service areas, visually displayed on smart large screens, showing key information such as traffic flow, passenger flow, parking, charging, restrooms, restaurants, environmental indicators, and equipment operating status, to facilitate on-site coordinated decision-making and provide precise services to the public. Using historical data and real-time information, personalized service guidance can be provided to drivers and passengers through apps, mini-programs, or on-site guidance screens, such as indicating available charging piles or five-minute waiting times at restaurants. Big data systems can also be used to analyze consumption preferences, distribution of stay durations, and other factors to provide service support for the commercial business formats of service areas. Coordination mechanisms should be established to promote cross-departmental data sharing, enabling service area data to be co-constructed and shared with cultural tourism and emergency departments, thereby promoting interconnection and interaction.

4.3 Strengthen Software System Construction and Improve Operation & Maintenance Capacity

In the informatization construction and management of smart service areas, it is essential to adhere to the principle of giving equal emphasis to both software and hardware, as well as construction and management. Investment in platform software and big data algorithms should be increased to build or upgrade a unified provincial smart service area integrated management platform, which consolidates and centrally manages all types of information and data. The application of big data and algorithms should be deepened in scenarios such as video analysis, energy optimization, demand forecasting, and personalized recommendations, so as to provide professional suggestions and improve operation and maintenance levels. A development strategy that prioritizes user experience should be adopted, with continuous upgrades and optimization of apps, mini-programs, and various on-site interactive terminals to ensure a clean and intuitive interface, smooth operations, accurate and timely information, and stable and reliable functions. Accessibility options should be provided for the elderly and persons with disabilities. Service area operators are advised to recruit professionals, establish specialized operation and maintenance teams, and strengthen the training of grassroots staff to improve their competence in information technology applications. A sound operation and maintenance assessment mechanism should be established for smart service areas, with regular performance evaluations of operation and maintenance enterprises. Enterprises with long-term poor operations and unsatisfactory performance should be forced to withdraw through an exit mechanism, with provincial expressway companies or professional institutions taking over management to ensure stable operations.

4.4 Innovate Investment, Financing, and Operation Models to Ensure Sustainable Development

Given the high investment and operational costs of smart service areas, it is crucial to actively explore diversified funding channels. Provincial governments should continue to increase special financial allocations, while local governments are encouraged to enhance their support, with joint efforts to build service areas into regional cultural and tourism showcases. Innovative commercial development models should be promoted in smart service areas, with market-oriented investment and financing channels explored for charging stations, smart retail, advertising media, and data value-added services, thereby reducing input costs and guiding business entities toward sustainable operation. Based on de-identified passenger flow profiles and scenarios, high-conversion-rate targeted advertising can be provided to increase revenue. Efforts should also be made to promote deep integration of smart service areas with local cultural tourism industries and commercial formats, further amplifying the effect of smart service areas as commercial complexes and broadening income sources. A comprehensive support mechanism should be explored, whereby public facilities such as restrooms, mother-and-baby rooms, and public information systems are financed by government funds, thus reducing the financial burden on operations. A whole-life-cycle cost management mechanism should be implemented, covering the entire process from project initiation to operation and maintenance, enabling scientific evaluation and precise calculation of operation and maintenance costs to ensure sustainable and efficient management of service areas.

5. Conclusion

The construction of smart service areas is the general trend of future expressway service area development. Each region should take into account its own circumstances, adhere to local conditions, highlight its unique characteristics, and actively promote the informatization construction and management of smart service areas. Efforts should always be guided by public needs, with the objectives of improving operational management efficiency, promoting revenue-expenditure balance, and enhancing user experience. By continuously strengthening top-level design, reinforcing overall coordination, enhancing system construction, promoting data integration, and innovating operation models, the informatization construction and management of smart service areas can be elevated to a new level, driving the high-quality development of the smart service area sector.

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