PIU3 of GEF "Large City Congestion and Carbon Reduction Project"

TASK I: Research on Guidelines for Urban Intelligent Public Transport System Construction and Application

Research Report of Urban Intelligent Public Transport System Construction and Application

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Abstract

The research report is one of achievements of GEF "Large City Congestion and Carbon Reduction Project". With filling in the gap in engineering guidance for domestic intelligent public transport system construction as its core objective, this report updates the framework of urban intelligent public transport system of China, studies and proposes suggestions on construction and application of five sub-systems, namely intelligent dispatching system, signal priority system, information service system, bus lane management system and decision support system. Meanwhile, government-market relations and division of labor are discussed. Reasearch results provide theory and practical guidance for the development of urban intelligent public transport system in China, to improve the urban public transport dispatching and management level, increase attraction of public transport, alleviate city traffic congestion and reduce environmental pollution caused by carbon emissions from motor vehicles.

By organizing various forms of investigations on the intelligent public transport system construction and application in domestic and foreign typical cities, further research on the actual demands of the domestic urban transportation sector management department is done. On the basis of *Construction Guidance of the Urban Intelligent Public Transport Application Demonstration Project (No. TYZ[2014]105)* from Ministry of Transport, this report further improves the overall architecture of urban intelligent public transport system which includes application scenario, service functions, technical framework, physical architecture,etc. As obvious differences in the public transport development level and informatization condition exist among domestic cities, the study which includes function requirements, system framework, construction suggestions, system construction, operation and maintenance cost ,etc. is carried out to finish the *guideline of urban intelligent public transport system construction and application*.

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1 Research Necessity

1.1 Background

With the rapid economic development and accelerated urbanization process, the urban motorization in China has entered a period of rapid development. By the end of April, 2014, there are more than 256 million vehicles in China, among which there are 144 million cars. Ten provinces including Guangdong, Shandong, Henan, Jiangsu, Hebei, Zhejiang, Sichuan, Yunnan, Guangxi and Anhui have more than 10 million vehicles. Guangdong and Shandong provinces have broken 20 million.

The large amount of vehicles makes the traffic slower and prolongs the travel time, and therefore causes a huge economic loss. Because of the excessive growth of the number of private cars, traffic jams are extremely serious in large and extra-large cities such as Beijing and Shanghai. Meanwhile, the average energy consumption and the pollutant and carbon dioxide emissions have been rapidly increased. The air pollution and the greenhouse effect was strengthened as well. According to statistics, in most large cities, the average vehicle speed in rush hours is about 8~10 km/h, even slower than bicycles. According to media reports, in terms of air pollutants, the vehicle emission pollution accounted for 22.2% of the formation of PM2.5.

The increased traffic congestion and vehicle emissions have severely hampered a city's sustainable development and reduced the life quality of urban residents. Therefore, alleviating traffic congestion in big cities and reducing carbon emissions have become major issues for the municipal government. "Resource-conserving Environment-friendly Society" has become one of the national development strategies of China as early as 2004. In August 2009, the Chinese government made "solving global climate change" a basic national development strategy as well and also made a public commitment to the world: by 2020, carbon dioxide emissions per unit of GDP must decrease 40% to 45% compared with 2005. The Chinese government at all levels and relevant departments has brought the climate change into an interim and long-term development planning.

Ministry of Transport is the competent authority for guiding the management of urban passenger transport. In face of the increasingly serious traffic congestion and carbon dioxide emissions, Ministry of Transport gives the top priority to solving these problems. Therefore, there is an urgent need to learn from international experience, formulate effective laws and policies and take reasonable technical and economic measures to guide China's urban transport development, and to ease the urban traffic congestion and reduce carbon emissions.

In the above background, the "Large City Traffic Congestion and Carbon Emissions Reduction Project" has been approved by the Ministry of Finance and Global Environment Facility, and related preparation work has been already started. The World Bank is the international implementing agency for this project, while Ministry of Transport is the domestic implementing agency. “Research of Guidelines for Urban Intelligent Public Transport System Development and Application” is one of the subprojects of the “Large City Traffic Congestion and Carbon Emissions Reduction Project”.

1.2 Necessity

(1) Strong demand of the construction and application for urban intelligent public transport system

In order to solve urban traffic congestion of China, improve the environmental pollution caused by urban traffic congestion, The State Council promulgated the "Guiding Opinions of the Priority Development of Urban Public Transport" in 2012, priority to the development of public transport. In order to implement public transport priority, the Ministry of Transport launched "Intelligent Urban Public Transport Demonstration Project" in the pilot cites of "transit city". In addition, many provinces, such as Guangdong province, Hubei Province and Henan Province, start their construction and application of the urban intelligent public transport system in the medium and small cities. They have definite demands for intelligent public transport system construction.

(2) The overall framework of guiding urban intelligent public transport system needs to be more definite

For the urban public transport industry management department, in today’s rapid development of urban intelligent public transport system, they need relevant guidance documents as the basis reference to clearly the intelligent public transport system construction and application framework, system components, system functions, system performance, as well as construction, operation and maintenance, etc., in order to better guide the cities to carry out the intelligent public transport system construction and application.

In addition, the designer, construction unit and the application unit of the urban intelligent public transport system also need a guideline as the reference to better construct and use the urban intelligent public transport system.

The users of relevant existing references is the bus management department and the references focus on business function and lack general fundamental framework and institutional framework.

(3) The construction, operation and maintenance mode of intelligent public transport system needs guidance

The local departments needs experience and guidance in the construction, operation and maintenance mode, information service mode and institutional guarantee of system besides the technical needs in the construction and application of the intelligent public transport system. In addition, it needs suggestions especially in the aspect as how to grasp the relationship between the government and market.

2 Project Objectives and Research Range

2.1 Project Objectives

Aiming at filling the blank of lacking engineering steering of intelligent public transport system construction, update the APTA framework, put forward the construction and application requirements of intelligent dispatching system, signal priority system, information service system, bus lane management system and decision support system, discuss the relationship between the government and the market, define the responsibilities of government and enterprise respectively, put forward the suggestions of opening up intelligent public transport system information, provide theoretical support and practical guidance for the development of urban intelligent public transport system in China, improve the urban public transport dispatching and management, increase the attractiveness of public transport, and reduce private cars, alleviate the city traffic congestion, reduce the environmental pollution caused by vehicle carbon emissions.

2.2 Research Range

The research range is mainly the intelligent system used on urban bus and trolley bus, excluding the system used on tram and rail transport.

2.3 Using Object

The main use object of the project result is the traffic management departments of large medium and small cities. It also can provide a reference for urban intelligent public transport system construction contractor, to guide the construction of urban intelligent public transport system.

3 Task Breakdown and Technical Course

3.1 Task in the Work Plan

This project includes the following tasks:

Subtask 1: Survey and analyze the experience of urban intelligent public transport system construction and application domestically and overseas.

- Survey and analyze the main problems and successful experience of urban intelligent public transport system construction and application domestically and overseas.

- Survey the urban public transport system construction and application in the major large and medium cities in China.

  Choose cities with different size, including large city, medium sized city and small city. Survey the public transport production mode and the urban intelligent public transport system framework under different production mode. Survey the intelligent dispatch, signal priority for public transport, information service, bus lane management, decision support aspects according to the characteristic of urban intelligent public transport construction and application in different cities.

- Analyze the urban public transport system construction and application in the major large and medium cities in China.

  According to the survey results, analyze the construction and application of different business system.

- Survey the experience and effect of urban intelligent public transport system construction making use of the Internet of Things and the new generation information technologies in key cities, and analyze its applicability.

  The application of the Internet of things and the new generation information technology such as TD-LTE, cloud, has been gradually developed in the traffic field. However, these new technologies' application in urban public transport still needs to be validated. Survey the Internet of things application sample in Guangzhou and analyze the necessary and applicability of the Internet of things and the new generation information technologies application in urban public transport.

- Form the '*Application Cases Compilation of Typical Cities Domestically and Overseas*'.

Subtask 2: Establish the overall technical framework for the urban intelligent public transport system.

- Establish the technical framework of the urban intelligent public transport system with the Internet of Things and the new generation information technologies.

  Firstly, put forward the traditional urban intelligent public transport system framework. Secondly, analyze the Internet of things, communication technologies such as TD-LTE and WiFi, assisted positioning, could, put forward the urban intelligent public transport system framework with the application of Internet of things and new generation information technologies. Finally, analyze the applicability of urban intelligent public transport system framework under cloud architecture for small city.

- Propose the data interface requirements among different sub systems of urban intelligent public transport system.

Subtask 3: Propose the technical indicator requirements of urban intelligent public transport system.

- Based on the construction architecture and the Internet of Things and the new generation information technologies, propose the intelligent public transport system application plan of typical urban public transport scenarios, such as intelligent public transport dispatch, bus lane management, for major cities in China.

  Propose the intelligent public transport system application plan of typical urban public transport on intelligent dispatching , signal priority, information service ， bus lane management and decision support. The application plan should present system composition, system function, interface between different business systems, system operation and maintenance requirements in these scenarios. Meanwhile, it also should mention the scale, layout, installation, usage and maintenance requirements of the related on-board devices, assistant positioning devices, signal priority devices and other data acquisition devices. And, the scale, layout, installation, usage and maintenance requirements of on-board WiFi, electronic bus stop sign and other information publishing devices should be given.

- Form the project research report and the '*Guideline of Urban Intelligent Public Transport System Construction and Application (draft)*'.

Subtask 4: Disseminate and promote the project achievements.

- Promote the project achievements by lectures in different provinces and related enterprises;

- Provide related technical support and consulting for achievement application.

3.2 The Overall Technical Course

The overall research technical course is as follows:

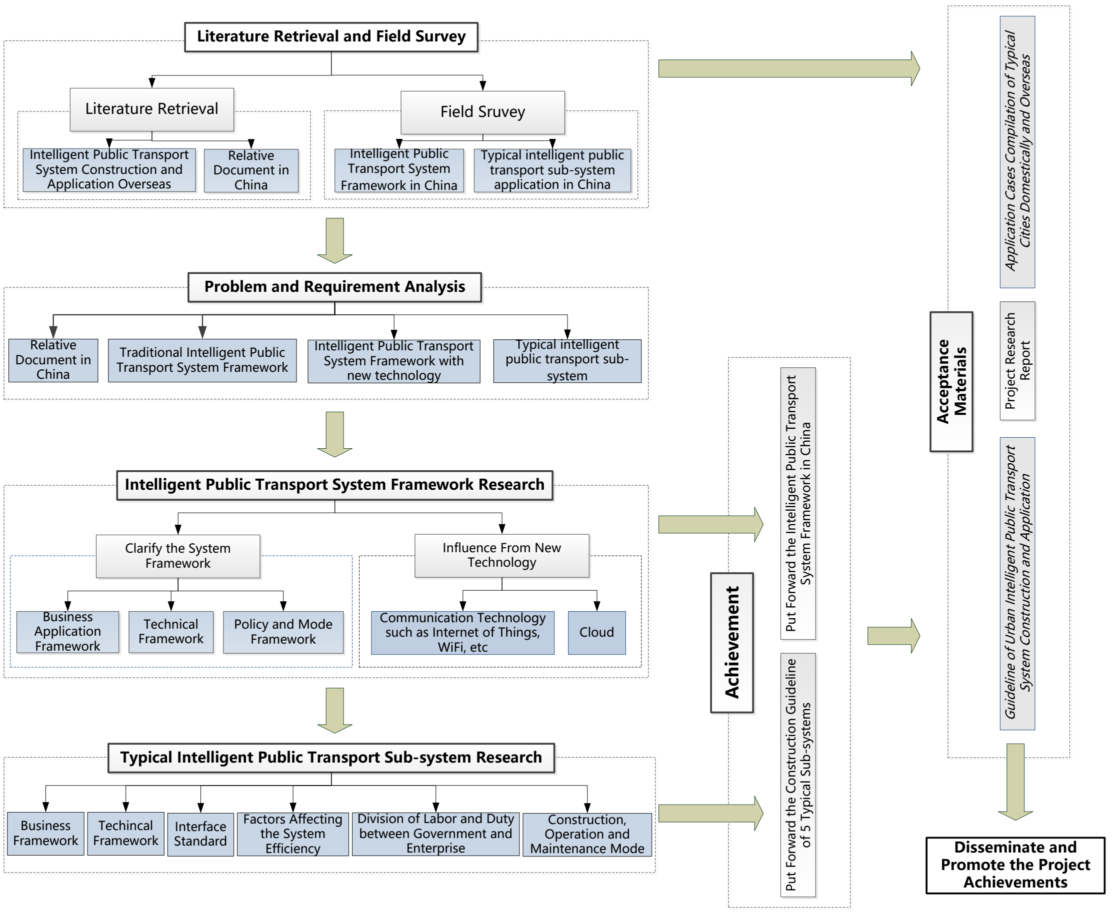


Figure 3-1 The Overall Technical Course

Firstly, the project team will do the literature retrieval of intelligent public transport system construction and application overseas; learn about the intelligent public transport system construction experiences, the system framework, and the application of new technologies. The team will collect the policy and standard documents, do the field survey of urban intelligent public transport system construction framework, the application of new technology in cities with different sizes, mainly focus on the survey of information service system, intelligent dispatching system, decision support system, signal priority system, and bus lane management system. The project team will summarize the survey results, and form one research achievements: *Application Cases Compilation of Typical Cities Domestically and Overseas*.

Secondly, the project team will carry out the problem and requirement analysis in accordance with literature review and field survey results, the analysis focuses on the related documents in China, the traditional intelligent public transport system framework, the intelligent public transport system framework with the new technology, as well as the five typical sub-systems.

Thirdly, according to the problems analysis of domestic relevant documents, traditional intelligent public transport system framework, as well as the requirement analysis result of intelligent public transport system framework with the new technology, the project team will research and clarify the urban intelligent public transport system framework from business framework, technical framework, policy and mode framework three levels. In addition, the construction, operation and maintenance cost will be considered. Besides, the project team will study the methods of policy guidance and market functions for urban intelligent transport system.

Fourthly, according to the problem and requirement analysis of five sub-systems, the project team will research and put forward the overall framework of the sub-system, including the business framework, technical framework and interface standards; research and proposed the implementation framework, including division of labor and responsibilities between government and enterprise, system construction, operation and maintenance modes, etc; analyze the various factors that affect the system and give the construction advices.

Based on the research results, the project will eventually form a project research report and *Guideline of Urban Intelligent Public Transport System Construction and Application (draft)*, and publish the guideline after being checked by the Ministry of Transport. The guideline will provide a reference for management department, as well as urban intelligent public transport system construction contractor and bus company. The project team will also promote the project achievements by lectures in different provinces and related enterprises, and evaluate the operation of the project results, and provide related technical support and consulting for achievement application.

3.3 Sub-task Breakdown and Technical Course

The following part is the sub-task breakdown and the technical course of each sub-task.

3.3.1 Task 1: Survey and Analyze the Experience of Urban Intelligent Public Transport System Construction and Application Domestically and Overseas

The technical course of task 1 is as follows.

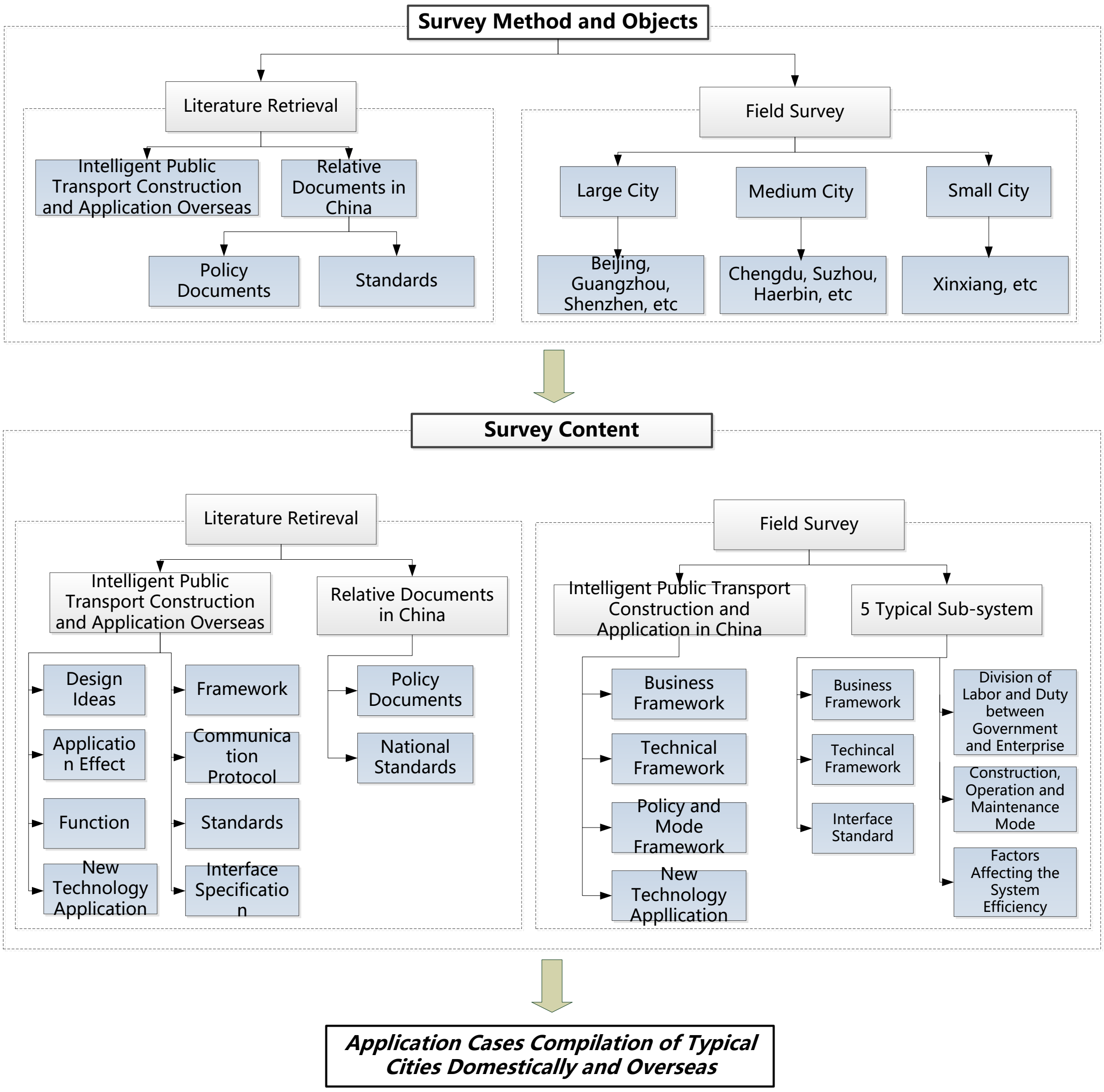


Figure 3-2 The Technical Course of Task 1

3.3.1.1 Survey Overseas

Survey and analyze the main problems and successful experience of urban intelligent public transport system construction and application overseas:

- Survey the typical urban intelligent public transport system overseas, include advanced ideas, function characteristics, application effect, the experience of achievements and existing problems.

- Survey the international intelligent public transport system construction framework, function design, intelligent public transport system standard, the communication interface between device and systems.

- Survey the innovation about the international intelligent public transport system realm, including the Internet of Things and the application of the new generation of communications technology.

3.3.1.2 Survey Relative Policies and Standards in China

Survey and analyze the policies and standards of urban intelligent public transport system, compare and analyze the existing national standards, industry standards and local standards to absorb the experience.

3.3.1.3 Survey Intelligent Public Transport System in China

In recent years, intelligent public transport system has developed rapidly in China. Cities of different sizes developed the intelligent public transport system according to their respective needs, and put into production operations. The work team will survey the construction and application, the system architecture, the typical application sub-system of intelligent public transport system in Suzhou, Chengdu, Harbin, Guangzhou, Shenzhen, Fujian, etc.

- Survey and Summarize the Intelligent Public Transport System Construction and Application in China

  The work team will survey and summarize the intelligent public transport system construction and application in China, including the system business framework, technical framework, policy and mode framework, as well as the new technology application such as the Internet of Things, TD-LTE, WiFi, Cloud, etc.

- Survey and Analyze the Typical Application System

  For the intelligent public transport system of city with different sizes, survey and analyze the intelligent dispatching subsystem, signal priority subsystem, information service subsystem, bus lane management subsystem, and decision support subsystem. Survey the subsystem overall framework, including business framework, technical framework and interface standards; survey the system implementation framework, including division of labor and duty between government and enterprise, system construction, operation and maintenance modes; analyze the factors affecting the system.

3.3.2 Task 2: Clearly Put Forward Urban Intelligent Public Transport System Construction and Application Framework

The technical course of task 2 is as follows.

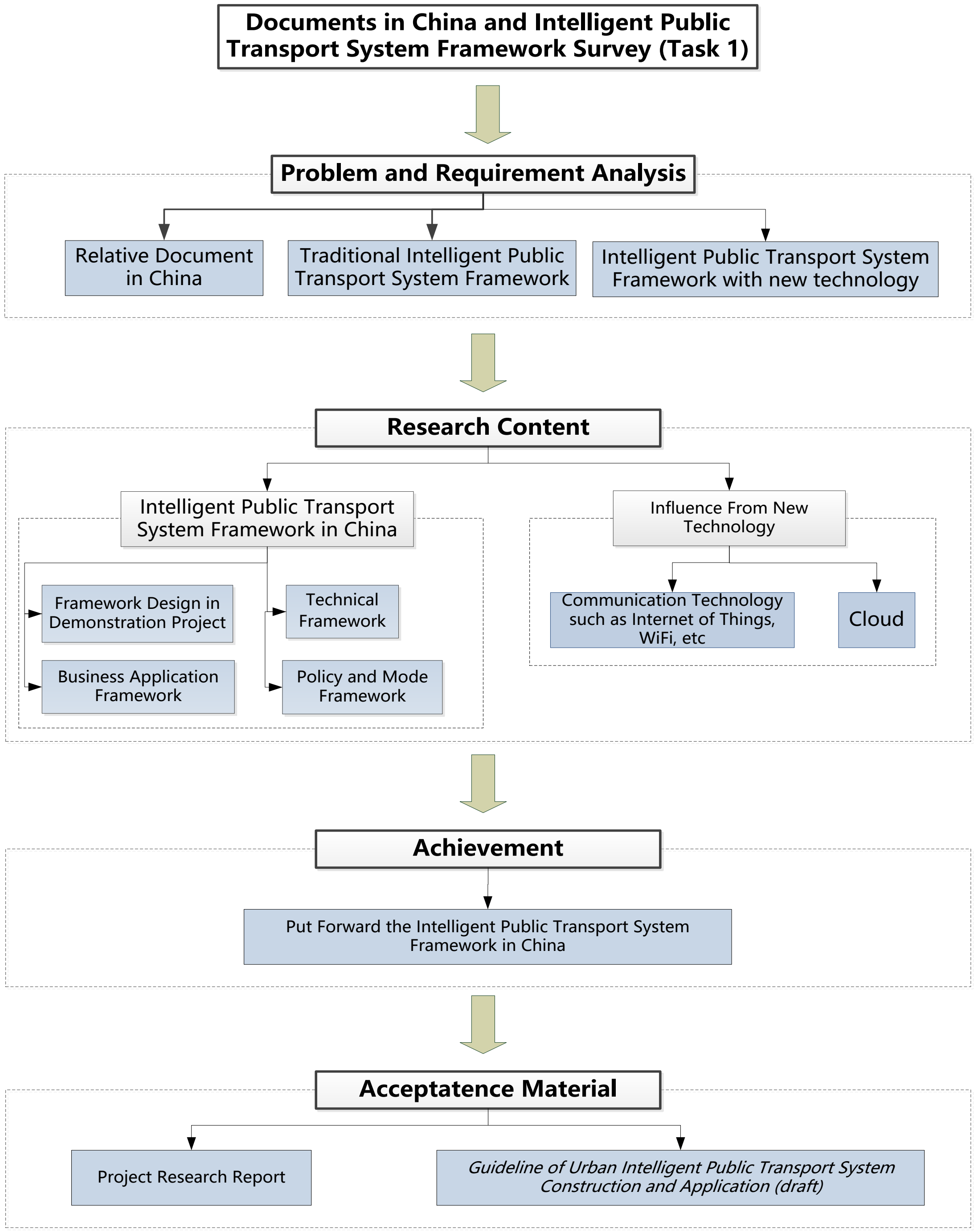


Figure 3-3 The Technical Course of Task 2

3.3.2.1 Analyze and Summarize the Traditional Regular Urban Intelligent Public Transport System Architecture

The construction framework and application framework is macro for the design of intelligent public transport system, is the guiding content of the system construction, all the details of the design is based on the framework and extension, any extension cannot conflict with the framework in order to guarantee the comprehensiveness, rationality and validity of the system overall design.

In this project, we will analyze and summarize the domestic and overseas typical cities' construction and application framework and put forward the national general framework. The typical model is designed according to the regional characteristics and city characteristics. These models for loading on the basic framework from conform to the requirements of construction and application framework.

Specific researches are as follows：

- Research on the architecture design features of urban public transport intelligent application demonstration project construction guidance, and analyze the universality, rationality and guiding significance throughout the country intelligent public transport system construction.

- Analysis of the traditional city under construction or already built system framework which different from the construction guideline, analysis of reasons for these differences, analysis of these differences because of whether local construction and business characteristics cannot be copied or the generalizability innovative design.

- From business application framework, technical framework, policy and mode framework three aspects, summarize the construction and application framework of several cities after a large number of urban research, then classify each module of the framework that basis on generalization and particularity. According to the level of each module, forming urban intelligent public transport system construction and application framework suggested design scheme, and mark which modules is widely used and which modules can be chosen.

3.3.2.2 Conventional Urban Intelligent Public Transport System Architecture Analysis under New Technology

(1) Analysis of Internet of Things, TD-LTE, WIFI communication technologies application and auxiliary positioning, cloud services, and the urban intelligent public transport system that suitable for all kinds of city have the characteristics of the Internet of Things and a new generation of information technology. The research key point is the feasibility of the information communication binding by WIFI between car and car, car and thing, car and people.

(2) Application Feasibility Analysis of Urban Intelligent Public Transport System Framework under Cloud Architecture

China has thousands of public transport enterprises that vary in size. The enterprises in small cities may only have hundreds of buses or dozens of buses and their information technique is very poor. Even though the buses are installed with intelligent service terminals, the terminals can only monitor the bus trajectory and the enterprises lack the ability of constructing, operating and maintaining the dispatch platform.

The strong expansibility, high efficiency, load balancing, high reliability and other features of cloud infrastructure are accord with the performance requirement of bus intelligent. Meanwhile, as the data transmission of cloud platform is virtual, it make the rate and reliability of data transmission improve, they can make each department of transportation industry in docking and realize the integration of entirety data of intelligent transport system. The research key point is research the feasibility of cloud application in intelligent transport system framework.

(3) Consider the effects of emerging business, such as customized buses, station passenger collection techniques and new energy electrical vehicles, on the intelligent public transport system.

3.3.3 Task 3: Propose the Technical Indicator Requirements of Urban Intelligent Public Transport System

The technical course of task 3 is as follows.

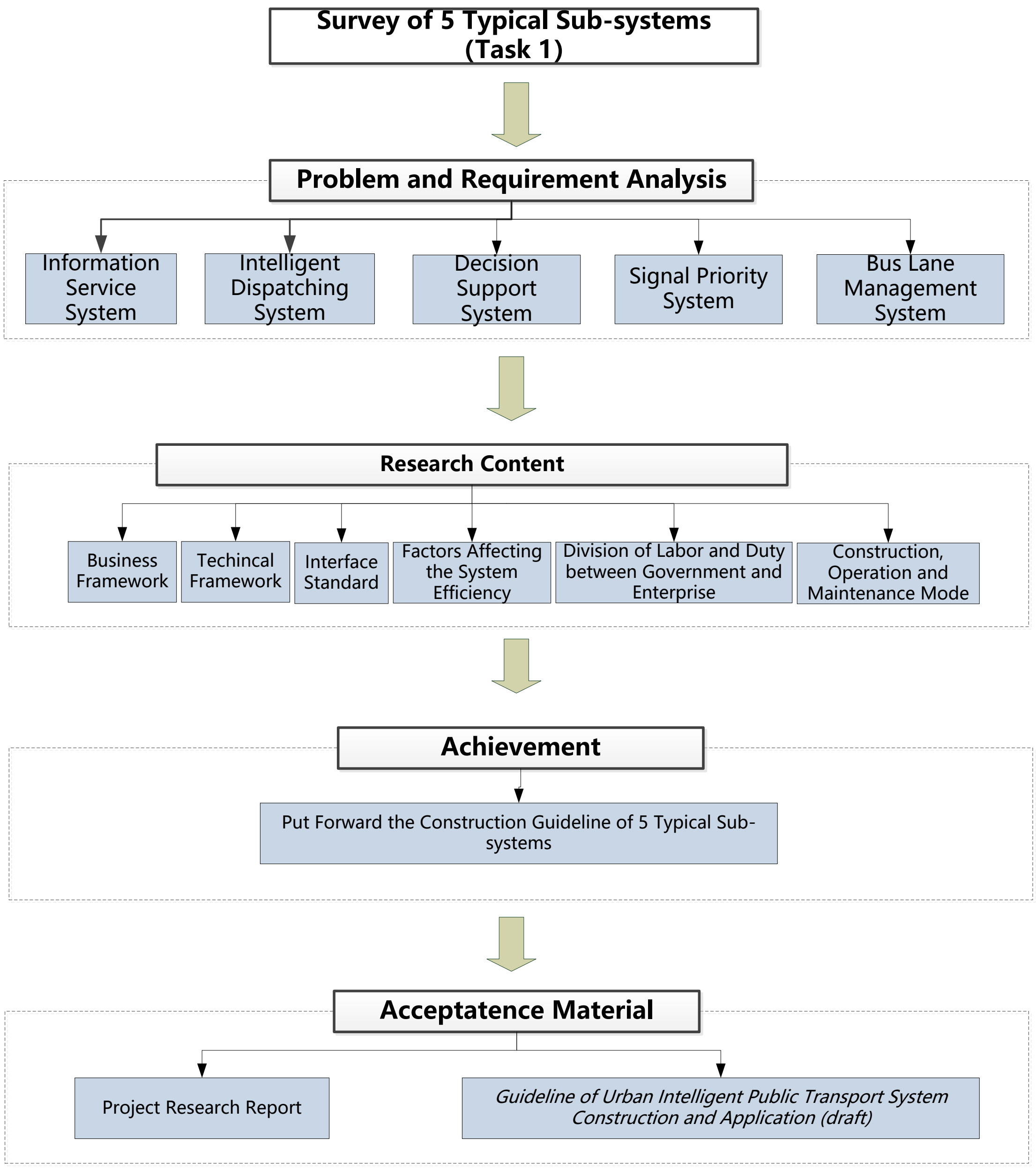


Figure 3-4 The Technical Course of Task 3

Based on the proposed urban intelligent public transport system construction and application framework, the Internet of Things and the new generation information technologies, propose the intelligent public transport system application plan of typical urban public transport on intelligent dispatching, signal priority, information service, bus lane management and decision support, which is suitable for major city, related to the service quality and operation efficiency of public transport industry.

3.3.3.1 Intelligent Dispatching System Application Plan Research

The intelligent dispatching system application plan research will mainly focus on studying the overall framework of the system which includes business framework, technical framework and interface standard; putting forward the implementation framework of the system which includes the work and responsibilities of government and enterprise respectively and the construction, operation and maintenance mode of the system; analyzing the factors affecting the system efficiency, such as positioning accuracy, layout, dispatching mode, device stability, use system, etc. It will also focus on the application requirements of intelligent service terminal, devices with new technologies and outfield auxiliary devices, analyze the new generation communication technology application possibility, analyze the key requirements of system, system construction, operation and maintenance.

3.3.3.2 Information Service System Application Plan Research

The information service system application plan mainly includes mobile internet application and electronic stop sign application. The research will focus on studying the overall framework of the system which includes business framework, technical framework and interface standard; putting forward the implementation framework of the system which includes the work and responsibilities of government and enterprise respectively and the construction, operation and maintenance mode of the system; analyzing the factors affecting the system service quality, such as information accuracy, service combinations, electronic stop sign coverage rate and layout, etc. It will also focus on the industrialization mode research.

3.3.3.3 Decision Support System Application Plan Research

The decision support system application plan research mainly focuses on studying the overall framework of the system which includes business framework, technical framework and interface standard; putting forward the implementation framework of the system which includes the work and responsibilities of government and enterprise respectively and the construction, operation and maintenance mode of the system; analyzing the core function requirements, data requirements, analyzes the big data application possibilities, analyze the system construction, operation and maintenance requirements.

3.3.3.4 Signal Priority System Application Plan Research

The signal priority system application plan research will mainly focus on studying the overall framework of the system which includes business framework, technical framework and interface standard; putting forward the implementation framework of the system which includes the work and responsibilities of government and enterprise respectively and the construction, operation and maintenance mode of the system; analyzing the factors affecting the system efficiency, such as technical realization mode, layout, priority rules, etc. It will also focus on the conditions of signal priority, system construction, operation and maintenance requirements.

3.3.3.5 Bus Lane Management System Application Plan Research

The bus lane management system application plan research mainly focuses on studying the overall framework of the system which includes business framework, technical framework and interface standard; putting forward the implementation framework of the system which includes the work and responsibilities of government and enterprise respectively and the construction, operation and maintenance mode of the system; analyzing the factors affecting the system efficiency, such as devices layout, enforcement rules, fine using methods, etc.

3.3.4 Task 4: Disseminate and Promote the Project Achievements

- Promote the project achievements by lectures in different provinces and related enterprises, and evaluate the operation of the project results.

- Provide related technical support and consulting for achievement application.

Table 3-1 is the expected meeting to promote the technical exchange and project achievements which is project capacity building.

Table 3-1 Capacity Building

No.	Time	Address	Name	Person
1	2015.10	Chengdu	Technical exchange meeting of *Construction and application guidance of the urban intelligent public transport system*	30
2	2016.7	Beijing	Technical exchange meeting of *Construction and application guidance of the urban intelligent public transport system*	50

The technical exchange meeting will be held in Chengdu, is an additional meeting, not included in the Project Implementation Agreement and Work plan. The cost of the new meeting is to be determined.

4 Summary of Project Completion

By the time this report submits, all the four tasks of the project have completed except holding a meeting for training and propagandizing in Beijing in July 2016.

The deliverables includes:

1） *Application cases compilation of typical cities domestically and overseas (Final report)*

2） *Research Report of Urban Intelligent Public Transport System Construction and Application (Final report)*

3） *Guideline of Urban Intelligent Public Transport System Construction and Application (Final report).*

5 Research Overview

5.1 Development of Overseas APTS

5.1.1 Overseas APTS

Intelligent public transport system is an important part of the urban transport system, its orderly and efficient operation plays an important role in improving traffic conditions in the entire city. Since the 1980s, public transport departments of many countries started the application of advanced information and communication technologies in vehicle positioning, vehicle monitoring, automatic driving and route guidance, computer-aided dispatch to improve the level of service. Countries such as the United States, Japan, Canada, UK, France, South Korea have invested a great lot in the research of intelligent public transport system, use technology like GIS, GPS, communication technology to improve the operation efficiency of public transport, and have achieved remarkable achievements.

(1) The United States

The Urban Mass Transportation Administration (UMTA) launched the intelligent public transport system project "the Advanced Public Transport Systems (APTS)"in the 1980s, focusing on the real-time scheduling theory based on dynamic public transport information, the theory of real-time information release, and the use of advanced electronic and communications technology to improve the public transport efficiency and service level, including the fleet management, traveler information, electronic toll collection, traffic demand management, etc. Fleet management includes communication systems, geographic information system (GIS), automatic positioning system (GPS), automatic passenger counting (APC), bus operating software and transit signal priority, etc. The application of intelligent public transport system can significantly improve service level of public transport and attract more travelers to adopt the public transport mode, thereby achieving social benefits such as reduction of traffic congestion, air pollution and energy consumption. In the United States, the communication technology used in the APTS-based fleet management includes low earth orbit satellite system, FM subcarrier RDS system, personal communication systems, divergent spectrum system, sharing spectrum technology, wireless communication system, radio system, integrated communication system, etc.; automatic vehicle locating technology consists of locating technology and data transmission technology, monitoring each bus's location and transmitting the information to the dispatching center in real time. The APCs is composed of the statistical method of passenger numbers, locating technology and data management system. The GIS has been widely applied in the public transport system of the United States, including urban public transport line management, dispatching management, and relevant information transmitting, etc.

In 1994, U.S. Department of Transportation issued the "Advanced Public transport Systems: Evaluation Guidelines", which contains the planning, performing of the evaluation of APTS, as well as the content and organization of the evaluation report. The guideline aims to foster consistency of evaluation philosophy and techniques, and comparability and transferability of results to improve the quality and utility of information obtained from the APTS program. This guideline is mainly used to provide the reference for the evaluation contractor of intelligent public transport system. It also provides a reference for the construction of intelligent public transport system.

(2) Europe

The Europe has established the EUROPEAN Framework, showing the overall framework of intelligent transport, also including public transport. In the European action plan for intelligent transport system released by the European Commission in 2008, the implementation of traffic and travel information service process in the E.U. are defined in order to provide road, traffic and travel data for all the travelers. In the 2011 WHITE PAPER Roadmap to a Single European Transport Area, Goal 8 was put forward, namely "By 2020, establish the framework for a European multimodal transport information, management and payment system", in order to promote the intelligent system development and utilization of interoperability, collaborative dispatching, information service, online reservation system and intelligent ticket sale.

Based on the actual urban conditions, some countries in Europe vigorously develop the bus priority policy, set up exclusive bus lanes and transit signal priority, and establish intelligent public transport monitoring and dispatching system, etc., in order to greatly improve speed and service quality of public transport, to attract the public to take public transport for traveling, alleviating urban traffic congestion and achieving remarkable social and economic benefits.

(3) The Japan

Japanese drew up its ITS framework and the development of Japanese urban intelligent public transport experienced three stages. In the late 1970s, Japan began to use the bus positioning system - bus approach display system. In the early 1980s, it began to use public transport operation management system, including the number of passengers automatically count, operation monitoring and operation control functions. In 1990s, in order to relieve the serious traffic jam from the increase in number of vehicles, Bureau of Transportation Tokyo Metropolitan Government has developed the Centralized Transit Control System (CTCS), which aims to improve the bus services and win back passengers.

The CTCS can master vehicle operating status and passenger flow data through video image processing and public transport passenger flow detection technology in order to provide accurate and stable public transport service. It has the functions of operating statistical data, passenger flow counting and monitoring as well as controlling vehicle operation, thereby establishing two-way communication information exchange between online vehicles and the dispatching center to provide service information for the driver and passengers. In terms of the design and integration of intelligent transport system of these countries, the basic idea is to apply new technologies in the fields of communication, control, computer, etc., in order to make the dispatching administrator get real-time information in full, and to realize smooth communication of information between the administrator and the dispatched operators, as well as dispatching visualization for the dispatcher.

5.1.2 National ITS Framework of America

(1) Outline

America has developed National ITS Architecture 7 version from 1999 which described the ITS framework including public transport. The National ITS Architecture includes user service, logical architecture, physical architecture and standard framework, etc.

The National ITS Architecture provides a common framework for planning, defining, and integrating intelligent transport systems. The National ITS Architecture reflects the function of every component and their relationship. The overall architecture of the system is as follows:

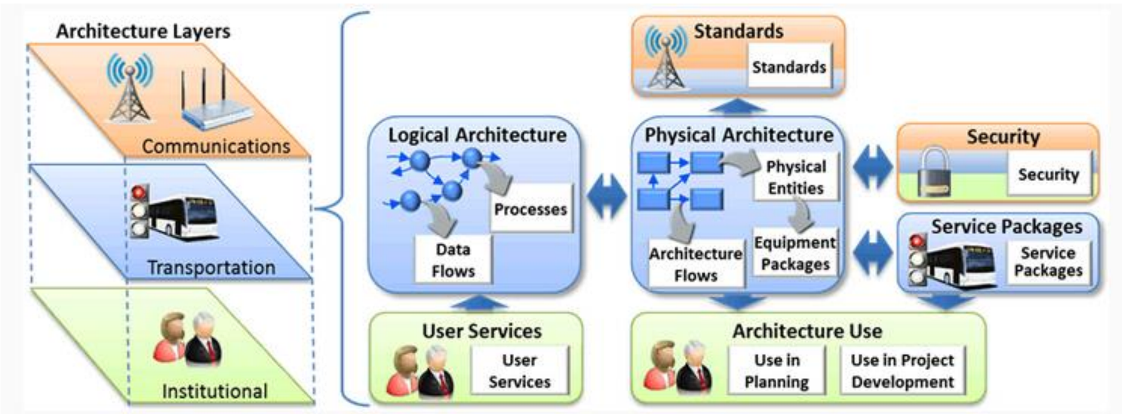


Figure 5-1 America National ITS Architecture

User Services describe what the system will do from the user's perspective. User services demands can correspond to the components of the ITS Architecture through the description of user service section in order to fulfill the demands of every user. All users' demands come from the institutional layer demand analysis for participating roles of ITS. This can guarantee reasonable demands and ensure corresponding solutions to the demands.

The Logical Architecture defines the Processes (the activities or functions) that are required to satisfy the User Services. Many different Processes must work together and share information to provide a User Service. Data Flows identify the information that is shared by the Processes.

The Physical Architecture forms a high-level structure around the processes and data flows in the Logical Architecture. The physical architecture defines the Physical Entities (Subsystems and Terminators) that make up an intelligent transport system. It defines the Architecture Flows that connect the various Subsystems and Terminators into an integrated system. The subsystems generally provide a rich set of capabilities, more than would be implemented at any one place or time. Equipment Packages break up the subsystems into deployment-sized pieces.

Service Packages represent slices of the Physical Architecture that address specific services like traffic signal control. A service package collects together several different subsystems, equipment packages, terminators, and architecture flows that provide the desired service.

(2) Layer composition

The National ITS Architecture is comprised of three Layers. The Institutional Layer includes the institutions, policies, funding mechanisms, and processes that are required for effective implementation, operation, and maintenance of an intelligent transport system. The Institutional Layer is shown as the bottom layer because solid institutional support and effective decisions are prerequisite to an effective ITS program. The Transportation Layer is where the transportation services are defined in terms of the subsystems and interfaces and the underlying functionality and data definitions that are required for each transportation service. This is the heart of the National ITS Architecture. The National ITS Architecture focuses on system integration and system integration requires effective communications. A general description of the communications services and technologies that support ITS is defined in the Communications Layer.

1) Institutional Layer

The Institutional Layer considers the policies, funding incentives, working arrangements, and jurisdictional structure that support the technical layers of the architecture. The Institutional Layer provides the basis for understanding who the implementers will be and the roles these implementers could take in implementing architecture-based ITS systems.

The Institutional Layer is the source for objectives and requirements for the surface transport system, including the User Services that are the driving requirements for the National ITS Architecture. The Institutional Layer also includes the policies and processes for architecture use to support transportation planning and project development.

The Institutional Layer consists of the public sector and the private sector. Within the realm of public sector investment, the relationships between the actors have become rather established. This is in large part because ITS deployment decisions can be considered part-and parcel of the larger transportation investment decision-making process. This process has matured over the last 50 years of major infrastructure development (e.g., the interstate highway system). A cornerstone of this process is the strong legislative underpinning stemming from Title 23 of the United States Code (USC), the most recent reauthorization of which was the Safe

Accountable Flexible Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). From the vantage of the private sector, both the automotive and communications industries have been major participants in developing various consumer products and services related to ITS. The actors described in the following paragraphs have defined relationships to the subsystems included in the National ITS Architecture.

- **Federal Government**

In general, Congress sets the overall policy direction for the country (such as through the ISTEA, TEA-21, and SAFETEA-LU transportation acts), determining the level of funding for transportation, programs to be emphasized, and mandates to be met. The U.S. Department of Transportation influences, interprets, and implements the legislation.

USA Federal match fund requirement plays an important role to support and sustain the Public Transport planning and ITS APTS system deployment in USA. Since 2000, USA requires all jurisdictions must use the ITS System Architecture, ITS standards, etc., as a part of any projects receiving Federal/State 80%/20% matching funds for the sustainable ITS implementation that facilitate system interchangeability/interoperability. MPO (Metropolitan Planning Organization) is required to review all major transport investment with the mandate that all highway project funding must reserve at least 10% for supporting the public transport elements.

In USA, the UMTA implemented ITS APTS before 1991. After 1991, the FTA (Federal Transit Administration), and the ITS JPO (ITS Joint Program Office) later in 2014 into a part of the RITA (Research, Innovation, and Technology Administration) was responsible for coordinating the ITS APTS implementation in USA.

- **State/Local Government**

The state legislature and state departments of transportation perform similar functions for each state. In some states, transportation policy and funding is also shaped by voter initiatives, which can affect the level of revenue (e.g. through bonds), and the use thereof (e.g. for transit). There are also a host of related agencies (e.g. state level air resource boards) that can provide a regulatory framework for transportation (and hence ITS) deployment. Metropolitan planning organizations (MPOs) develop regional transportation plans and programs, playing a crucial role in developing regional system designs and public funding priorities for ITS. The state, county, and local government agencies are the primary transport system operators and implementers of ITS. The nation's cities are hubs for jobs and traffic, and are responsible for managing the largest transit and rail systems. The state DoT's are primarily responsible for the freeway systems and state arteries which handle most of the long distance and high volume traffic.

- **Non-Profit/Advisory**

The non-profit sector plays a key role in advising the public sector, and integrating public and private sector needs. This sector includes advisory organizations (such as ITS America), standard setting bodies (such as IEEE), advocacy groups (such as environmental and consumer groups), and educational organizations.

- **Private Sector**

Private sector expertise is necessary to develop ITS technologies and to help ensure that new transport system infrastructure is properly operated and maintained. While legislation and documented practices aid in characterizing public sector decision-making relative to ITS, private sector decision-making is even more diffuse. ITS has a variety of private sector participants, from automobile manufacturers (OEMs), to telecommunications companies, to product entrepreneurs, to major trucking companies. The private sector has established expertise in many areas including technology, traffic engineering, marketing, finance, research, and operations. It is driven to expand these areas by reinvesting revenue from product and service sales back into its business area.

- **General Public**

Ultimately, ITS enhances the transportation services that are provided to the general public. A range of travelers are intended beneficiaries, including drivers, transit users, bicyclists, and pedestrians. Commercial users are vital stakeholders since they represent key early beneficiaries and adopters of ITS technologies. The general public also includes the public at large since many ITS services provide broad system benefits that are "used" by the public at large. Ultimately, the General Public pays for everything -- either directly through user fees and direct purchase of on-board or on-site equipment, or through taxes.

2) Transportation Layer

The Transportation Layer defines the functions that are performed, the subsystems that provide these functions, and the interfaces that are required to support the ITS User Services. This layer, the heart of the National ITS Architecture, provides a framework for applying technology in a consistent, progressive, and effective fashion to improve the surface transport system. The majority of the National ITS Architecture definition focuses on the Transportation Layer. The Physical Architecture defines the subsystems and interfaces, the Logical Architecture defines the functions that are performed and the data that is exchanged between functions, and the Service Packages provides a menu of the transportation services that are provided.

In addition to subsystems, the Transportation Layer also defines terminators that represent all of the other systems, people, and physical conditions that the surface transport system must interface with.

The entities are grouped into four classes:

- **Center**

Centers provide management, administration, and support functions for the transport system. The centers each communicate with other centers to enable coordination between modes and across jurisdictions within a region. The centers also communicate with field and vehicle classes to gather information and provide information and control that is coordinated by the centers.

- **Field**

The entities in this class provide the direct interface to the roadway network, vehicles traveling on the roadway network, and travelers in transit. They support direct surveillance, information provision, and control plan execution in the surface transport system. All field subsystems interface to one or more of the center subsystems that govern overall operation of the field subsystems. The field subsystems also generally include direct user interfaces to drivers and transit users and short-range interfaces to the Vehicle Subsystems to support operations.

- **Vehicle**

These entities are all vehicle-based and share many general driver information, vehicle navigation, and advanced safety systems functions. The vehicle subsystems communicate with the field subsystems and center subsystems for provision of information to the driver.

- **Traveler**

These entities include the equipment that is typically owned and operated by the traveler. Though this equipment is often general purpose in nature and used for a variety of tasks, it is specifically used for gaining access to traveler information within the scope of the ITS architecture.

3) Communications Layer

The National ITS Architecture provides the framework that ties the transportation and telecommunication worlds together to enable the development and effective implementation of the broad range of ITS User Services. There are multiple communications options available to the system designer. The flexibility in choosing among various options allows each implementer the ability to select the specific technology that meets the local, regional, or national needs. The Communications Layer of the Physical Architecture identifies four major types of communication to support the communications requirements among the 22 subsystems, and between the subsystems and terminators. These are fixed-point - fixed-point, wide area wireless, field - vehicle, and vehicle - vehicle communications. The four communication types are shown as ovals on the Subsystem Diagram. A short description of these four types of communications is given below:

- **Field - Vehicle Communications**

A wireless communications channel used for broadcast and interactive is close-proximity communications between vehicles and the immediate infrastructure. It supports location-specific and situation relevant communications for ITS capabilities such as toll collection, transit vehicle management, driver information, and automated commercial vehicle operations as well as connected vehicle applications. This communication channel is supported by technologies such as 5.9 GHz Band Wireless Access in Vehicular Environments (WAVE) / Dedicated Short Range Communications (DSRC), Wi-Fi, WiMAX, and wireless mesh networks.

- **Fixed Point - Fixed Point Communications**

A communications link provides communications among stationary entities. It may be implemented using a variety of public or private communication networks and technologies. These links support a variety of maintenance, monitoring and management services. It can include, but is not limited to, twisted pair, coaxial cable, fiber optic, microwave relay networks, spread spectrum, etc. Since the transportation layer defines all information flow as point-to-point transfers between source and destination entities, the architecture appears to recommend a point-to-point network topology. This is not the case. Any physical network topology (including all three provided examples) that can support the identified information transfers is consistent with the communications layer and the National ITS Architecture.

- **Vehicle - Vehicle Communications**

A short range wireless communications link among vehicles (e.g. mobile system to mobile systems). Advanced vehicle services may use this link in the future to support advanced collision avoidance implementations, road condition information sharing, and active coordination between advanced vehicle control systems. Technologies that could support this communications channel include 5.9 GHz Band Wireless Access in Vehicular Environments (WAVE) / Dedicated Short Range Communications (DSRC).

- **Wide Area Wireless (Mobile) Communications**

A wireless communication system offers broad coverage, enabling communications with vehicles and traveler mobile devices at any location on or off the road network. Both broadcast (one-way) and interactive (two-way) communications services are grouped into wide-area wireless communications in the National ITS Architecture. These links support a range of services in the National ITS Architecture including real-time traveler information and various forms of fleet communications. Technologies supporting this type of link include cellular networks, WiMAX, wireless mesh networks, and any other wireless network technology that offers broad regional coverage.

(3) User Services Bundles -- Public Transport Management

User Services describe what the system will do from the user's perspective. User services demands can correspond to the components of the ITS Architecture through the description of user service section in order to fulfill the demands of every user. All users' demands come from the institutional layer demand analysis for participating roles of ITS. This can guarantee reasonable demands and ensure corresponding solutions to the demands.

The user service of public transport management contains the following four aspects:

1) Public Transport Management

The Public Transport Management user service automates the operations, planning and management functions of public transit systems. It provides real-time computer analysis of vehicles and facilities to improve transit operations and maintenance. It monitors the location of transit vehicles, identifies deviations from the schedule, and offers potential solutions to dispatchers and operators. This service will help maintain transportation schedules and assure transfer connections from vehicle to vehicle and between modes and can be coupled with traffic control services to facilitate quick response to service delays. Information regarding passenger loading, vehicle running times, accumulated miles and hours and vehicle maintenance will help improve service and provide managers with a wealth of information on which to base decisions. Service schedulers will have timely data to adjust trips. Personnel management will be enhanced with the automatic recording and verification of operating and maintenance task performance. Security of transit personnel will be enhanced through providing access management of transit vehicles.

2) En-route Transit Information Service

The En-Route Transit Information user service provides information to travelers using public transport after they begin their trips. Real-time, accurate transit service information will be available on-board the vehicle, at transit stations and bus stops to assist travelers in making informed decisions and itinerary modifications while a trip is underway.

3) Personalized Public Transit Service

The Personalized Public Transit user service supports flexibly routed transit vehicles. Small, publicly or privately operated vehicles provide on-demand routing to pick up passengers who have requested service and deliver them to their destinations. Route deviation schemes, where vehicles would leave a fixed route for a short distance to pick up or discharge passengers, is another approach employed to improve service. Vehicles providing this service can include small buses, taxicabs, or other small, shared-ride vehicles.

4) Public Travel Security Service

The Public Travel Security user service creates a secure environment for public transport patrons, operators, and support staff. It provides systems that monitor the environment in transit facilities, transit stations, parking lots, bus stops and on-board transit vehicles and generates alarms (either automatically or manually) when necessary. The service also provides systems that monitor key infrastructure of transit (rail track, bridges, tunnels, bus guideways, etc.).

(4) Service Packages/ Application System -- Public Transport

Service Packages functionally consolidate many subsystems, device end and communication contents and it can solve the relevant industry problems. The operating principles of a service package provide how to form narrative description for service through combining different framework components.

1) Transit Vehicle Tracking

This service package monitors current transit vehicle location using an Automated Vehicle Location System. The location data may be used to determine real time schedule adherence and update the transit system's schedule in real-time. Vehicle position may be determined either by the vehicle (e.g., through GPS) and relayed to the infrastructure or may be determined directly by the communications infrastructure. A two-way wireless communication link with the Transit Management Subsystem is used for relaying vehicle position and control measures. Fixed route transit systems may also employ beacons along the route to enable position determination and facilitate communications with each vehicle at fixed intervals. The Transit Management Subsystem processes this information, updates the transit schedule and makes real-time schedule information available to the Information Service Provider.

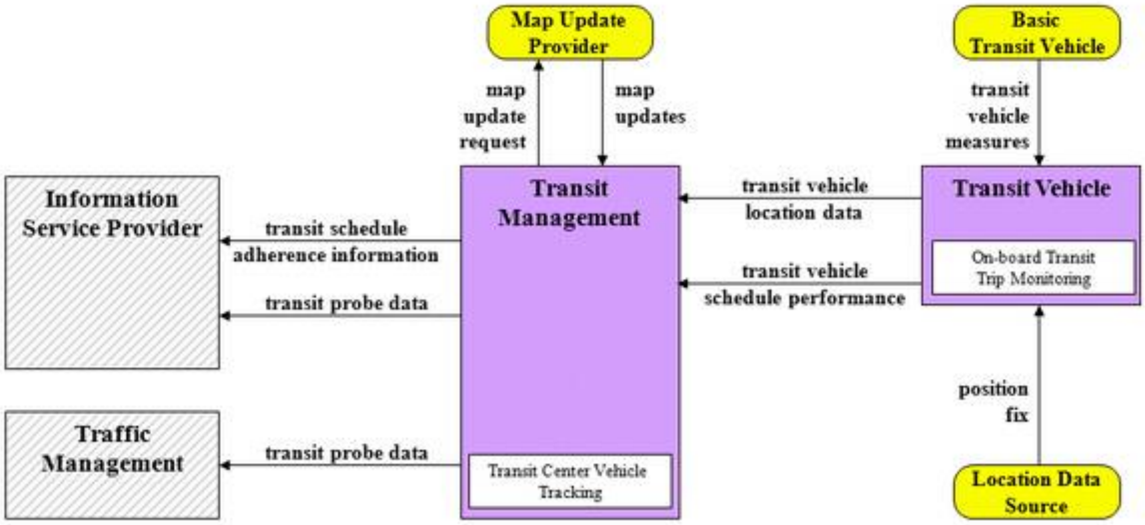


Figure 5-2 Service Package Architecture

2) Transit Fixed-Route Operations

This service package performs automated dispatch and system monitoring for fixed-route and flexible-route transit services. This service performs scheduling activities including the creation of schedules, blocks and runs, as well as operator assignment. This service determines the transit vehicle trip performance against the schedule using AVL data and provides information displays at the Transit Management Subsystem. Static and real time transit data is exchanged with Information Service Providers where it is integrated with that from other transportation modes (e.g. rail, ferry, air) to provide the public with integrated and personalized dynamic schedules.

3) Demand Response Transit Operations

This service package performs automated dispatch and system monitoring for demand responsive transit services. This service performs scheduling activities as well as operator assignment. In addition, this service package performs similar functions to support dynamic features of flexible-route transit services. This package monitors the current status of the transit fleet and supports allocation of these fleet resources to service incoming requests for transit service while also considering traffic conditions. The Transit Management Subsystem provides the necessary data processing and information display to assist the transit operator in making optimal use of the transit fleet. This service includes the capability for a traveler request for personalized transit services to be made through the Information Service Provider (ISP) Subsystem. The ISP may either be operated by a transit management center or be independently owned and operated by a separate service provider. In the first scenario, the traveler makes a direct request to a specific paratransit service. In the second scenario, a third party service provider determines that the paratransit service is a viable means of satisfying a traveler request and makes a reservation for the traveler.

4) Transit Fare Collection Management

This service package manages transit fare collection on-board transit vehicles and at transit stops using electronic means. It allows transit users to use a traveler card or other electronic payment device. Readers located either in the infrastructure or on-board the transit vehicles enable electronic fare payment. Data is processed, stored, and displayed on the transit vehicle and communicated as needed to the Transit Management Subsystem. Two other service packages, ATMS10: Electronic Toll Collection and ATMS16: Parking Facility Management, also provide electronic payment services. These three service packages in combination provide an integrated electronic payment system for transportation services.

5) Transit Security

This service package provides for the physical security of transit passengers and transit vehicle operators. On-board equipment is deployed to perform surveillance and sensor monitoring in order to warn of potentially hazardous situations. The surveillance equipment includes video (e.g., CCTV cameras), audio systems and/or event recorder systems. The sensor equipment includes threat sensors (e.g., chemical agent, toxic industrial chemical, biological, explosives, and radiological sensors) and object detection sensors (e.g., metal detectors). Transit user or transit vehicle operator activated alarms are provided on-board. Public areas (e.g., transit stops, park and ride lots, stations) are also monitored with similar surveillance and sensor equipment and provided with transit user activated alarms. In addition this service package provides surveillance and sensor monitoring of non-public areas of transit facilities (e.g., transit yards) and transit infrastructure such as bridges, tunnels, and transit railways or bus rapid transit (BRT) guideways. The surveillance equipment includes video and/or audio systems. The sensor equipment includes threat sensors and object detection sensors as described above as well as, intrusion or motion detection sensors and infrastructure integrity monitoring (e.g., rail track continuity checking or bridge structural integrity monitoring).

The surveillance and sensor information is transmitted to the Emergency Management Subsystem, as are transit user activated alarms in public secure areas. On-board alarms, activated by transit users or transit vehicle operators are transmitted to both the Emergency Management Subsystem and the Transit Management Subsystem, indicating two possible approaches to implementing this service package.

In addition the service package supports remote transit vehicle disabling by the Transit Management Subsystem and transit vehicle operator authentication.

6) Transit Fleet Management

This service package supports automatic transit maintenance scheduling and monitoring. On-board condition sensors monitor system status and transmit critical status information to the Transit Management Subsystem. Hardware and software in the Transit Management Subsystem processes this data and schedules preventative and corrective maintenance. The service package also supports the day to day management of the transit fleet inventory, including the assignment of specific transit vehicles to blocks.

7) Multi-modal Coordination

This service package establishes two way communications between multiple transit and traffic agencies to improve service coordination. Multimodal coordination between transit agencies can increase traveler convenience at transit transfer points and clusters (a collection of stops, stations, or terminals where transfers can be made conveniently) and also improve operating efficiency. Transit transfer information is shared between Multimodal Transportation Service Providers and Transit Agencies.

8) Transit Traveler Information

This service package provides transit users at transit stops and on-board transit vehicles with ready access to transit information. The information services include transit stop annunciation, imminent arrival signs, and real-time transit schedule displays that are of general interest to transit users. Systems that provide custom transit trip itineraries and other tailored transit information services are also represented by this service package.

9) Transit Signal Priority

This service package determines the need for transit priority on routes and at certain intersections and requests transit vehicle priority at these locations. The signal priority may result from limited local coordination between the transit vehicle and the individual intersection for signal priority or may result from coordination between transit management and traffic management centers. Coordination between traffic and transit management is intended to improve on-time performance of the transit system to the extent that this can be accommodated without degrading overall performance of the traffic network.

10) Transit Passenger Counting

This service counts the number of passengers entering and exiting a transit vehicle using sensors mounted on the vehicle and communicates the collected passenger data back to the management center. The collected data can be used to calculate reliable ridership figures and measure passenger load information at particular stops.

11) Multimodal Connection Protection

This service package supports the coordination of multimodal services to optimize the travel time of travelers as they move from mode to mode (or to different routes within a single mode). A near term function supported by this service package would be for a single transit agency to coordinate crossing routes so that passengers on one route would have the opportunity to transfer with minimum wait time to another route within the same transit system. The next level of complexity of this service package would be for this coordination to occur across transit agencies, or between transit agencies and other modes of transportation. The most advanced functions of this service package would be to track the route of an individual traveler and ensure that connections are properly scheduled on an individual basis. This final capability represents a long-term functionality, which could be managed either through an Information Serviced Provider or through a Transit Management subsystem.

5.1.3 ISO Reference Model Architecture

The core content of International standard ISO/DIS 14813-1.2 “Intelligent transport systems, the Reference model architecture(s) for the ITS sector - Part 1: ITS service domains, service groups and services” is the ITS service framework. First of all, Chapter Five shows the definitions and classification of ITS service domains/service group/ service items, and service classification is a bit different from that in the United States/European ITS system architecture; secondly, Chapter Six summarizes the specific classification of ITS service domains, including traveler information service, traffic management, vehicle service, cargo transportation, public transport, emergency service, payment concerning traffic fees, personal safety related to roads, monitoring weather and environmental conditions, disaster response and coordination, national security, ITS data management, performance management (simulation evaluation); thirdly, Section 6.2 describes the relationship between ITS service and Cooperative-ITS (Connected-vehicles called in some countries), and the conclusion is that service content concerning Cooperative-ITS are basically included in that of ITS. The Cooperative-ITS distinctive attribute is to make full use of the vehicle-road and vehicle-vehicle communication to better share vehicle information, and see TR17465-1:14 for the definition of Cooperative-ITS consistency. The core content of ISO standards is shown in Table 5-1.

Table 5-1 Core Content of ISO Standards

Service Domains	Service Portfolio	Service	Terms of Reference
Travel information	Real-time traffic status information	Road information	A.2.2.1
		Public transport information	A.2.2.2
		Information of integrated transport facilities	A.2.2.3
		Aviation information	A.2.2.4
		Parking information - external facilities	A.2.2.5
	Real-time vehicle display	Vehicle-mounted signal - guidance and supervision	A.3.2.1
		Vehicle-mounted signal - parking information	A.3.2.2
		Vehicle-mounted signal - speed and lane control	A.3.2.3
		Warning and consulting	A.3.2.4
		Public transport information	A.3.2.5
	Real-time path navigation information	Dynamic vehicle-mounted path navigation based on real-time information	A.4.2.1
		Personal path navigation based on real-time information	A.4.2.2
		Guidance of public transport travel	A.4.2.3
	Comprehensive travel plans	Comparative multimodal travel plans	A.5.2.1
		Concentrated travel plans based on real-time strategy input	A.5.2.2
	Travel service information	Travel service information - destination	A.6.2.1
		Travel service information - current position	A.6.2.2
Traffic management and operations	Traffic management and control	Traffic monitoring	B.2.2.1
		Ground road control (signal)	B.2.2.2
		Highway traffic control -Ramp control	B.2.2.3
		Trunk line speed and lane management	B.2.2.4

		Specific model priority (signal priority)	B.2.2.5
		Tidal lane management	B.2.2.6
		Coordinated control of ground road and highway	B.2.2.7
		Highway node management	B.2.2.8
		Parking management	B.2.2.9
		Traffic management in the working area	B.2.2.10
		Traffic warning information	B.2.2.11
		Accident monitoring	B.2.2.12
	Transport accident management	Driver rescue at the scene of accident	B.3.2.1
		Traveler rescue at the scene of accident	B.3.2.2
		Accident coordination and elimination	B.3.2.3
		Obstacle monitoring and management	B.3.2.4
		Other modes of transport for collecting accident details	B.3.2.5
	Demand management	Variable road pricing – special lanes	B.4.2.1
		Variable road charge - traffic facilities	B.4.2.2
		Regional congestion charge	B.4.2.3
		Access to the management	B.4.2.4
		Vehicle-sharing lane management	B.4.2.5
		Transport management based on air quality	B.4.2.6
	Road transport infrastructure maintenance and management	Road construction and maintenance management	B.5.2.1
		Winter maintenance	B.5.2.2
		Pavement management	B.5.2.3
		Automatic road management	B.5.2.4
		Safety management in the working area	B.5.2.5
	Compulsory traffic management	Access to management	B.6.2.1
		Use of vehicles for sharing	B.6.2.2
		Parking rules	B.6.2.3
		Speed limit	B.6.2.4
		Signal execution	B.6.2.5
Vehicle service	Road transport visual enhancement	The driver's visual management inside the vehicle	C.2.2.1
		The driver's visual management outside the vehicle	C.2.2.2
		Pedestrians and cyclists' visual management	C.2.2.3
	Automatic vehicle operation	High-speed automatic operation	C.3.2.1
		Low-speed automatic operation	C.3.2.2
		Automatic shutdown	C.3.2.3
		Adaptive cruise control	C.3.2.4

		Coordinated adaptive cruise control	C.3.2.5
		Accurate bus connection	C.3.2.6
	Collision mitigation/prevention	Longitudinal collision mitigation/prevention	C.4.2.1
		Side collision mitigation/ prevention	C.4.2.2
		Collision mitigation/ prevention at the intersection	C.4.2.3
	Safety preparation	Monitoring the vehicle-mounted system	C.5.2.1
		Outside-the-vehicle condition monitoring	C.5.2.2
	Anti-collision configuration	Anti-collision configuration	C.6.2.1
Cargo transportation	Commercial vehicle pre-check	Dynamic weighing	D.2.2.1
		Non-stop pre-check	D.2.2.2
		Vehicle safety recording and monitoring	D.2.2.3
	Commercial vehicle management process	Goods trans-information exchange	D.3.2.1
		Dangerous goods identification, monitoring and emergency response	D.3.2.2
		Automatic certificate application	D.3.2.3
		Automatic commercial vehicle management	D.3.2.4
		Automated border crossing	D.3.2.5
	Automatic roadside safety monitoring	Commercial vehicle safety data remote access	D.4.2.1
		Commercial vehicle driver data remote access	D.4.2.2
	Commercial vehicle on-board safety monitoring	Commercial vehicle internal system monitoring	D.5.2.1
		Commercial vehicle driver alertness monitoring	D.5.2.2
		Commercial vehicle cargo condition monitoring	D.5.2.3
	Intercity cargo transport fleet management	Intercity commercial vehicle fleet tracking	D.6.2.1
		Intercity commercial vehicle fleet dispatching	D.6.2.2
	Comprehensive information management	Arrival information exchange of vehicles and containers	D.7.2.1
		Freight information acquisition of consumers	D.7.2.2
		Cargo container tracking	D.7.2.3
	Management and control of multimodal transport center	Facility management of multimodal transport center	D.8.2.1
		Multimodal transport vehicle and container management	D.8.2.2
	Dangerous goods management	Dangerous goods transfer data collection and sharing	D.9.2.1

		Dangerous goods transferring data registry	D.9.2.2
		Dangerous goods transferring fleet coordination	D.9.2.3
		Dangerous goods transferring safety coordination	D.9.2.4
		Dangerous goods transferring located monitoring	D.9.2.5
	Heavy duty truck management	Heavy duty truck data collection and sharing	D.10.2.1
		Heavy duty truck registration	D.10.2.2
		Heavy duty truck positioning	D.10.2.3
	Local carrier vehicle management	Carrier vehicle fleet tracking	D.11.2.1
		Carrier vehicle fleet dispatching	D.11.2.2
		Carrier area and parking information service	D.11.2.3
	Application of conventional vehicle telemetries	Provisions of regular service provider	D.12.2.1
		Providing system security	D.12.2.2
		Providing vehicle information	D.12.2.3
		Providing vehicle access management	D.12.2.4
		Provide the speedometer remote monitoring	D.12.2.5
		Providing emergency messaging system	D.12.2.6
		Providing the driver’s on-duty records	D.12.2.7
		Providing vehicle assembling detection	D.12.2.8
		Providing vehicle position, velocity and transport data	D.12.2.9
		Providing vehicle parking facilities	D.12.2.10
	Cargo transport content identification and transfer	Collecting cargo transport identification data	D.13.2.1
		Transferring cargo transport identification data	D.13.2.2
Public transport	Public transport management	Public transport operation management	E.2.2.1
		Public transport fleet management	E.2.2.2
		Public transport vehicle and equipment monitoring	E.2.2.3
		Public transport service monitoring and arrangement	E.2.2.4
		Public transport operation strategy	E.2.2.5
		Public transport roadside status display	E.2.2.6
	Demand response and sharing	On-demand public transport fleet management	E.3.2.1

	transport	On-demand vehicle-sharing management	E.3.2.2
		On-demand cargo transport	E.3.2.3
Emergency services	Emergency notice and personal safety	A call for help of users	F.2.2.1
		Automatic emergency calls and rescue vehicle scheduling	F.2.2.2
		Automatic vehicle intrusion and pilferage warning	F.2.2.3
	Disposal after vehicle pilferage	Remote vehicle locking	F.3.2.1
		Missing vehicle tracking	F.3.2.2
	Emergency vehicle management	Emergency vehicle fleet tracking	F.4.2.1
		Emergency vehicle fleet management	F.4.2.2
		Emergency vehicle traffic management and coordination	F.4.2.3
	Dangerous goods and accident notification	Vehicle tracking and monitoring of dangerous goods	F.5.2.1
		Vehicle route management of dangerous goods	F.5.2.2
		Automatic vehicle emergency notification of dangerous goods	F.5.2.3
		Dangerous goods pre-check services	F.5.2.4
Payment concerning transport	Road use e-financial transactions	Interactive electronic toll collection	G.2.2.1
		Electronic toll collection	G.2.2.2
		Distance-based user pricing	G.2.2.3
		User pricing based on demand management	G.2.2.4
		User pricing based on vehicle models	G.2.2.5
		Parking payment system	G.2.2.6
	E-ticket price management services	Electronic toll collection	G.3.2.1
		Interoperable expense management system	G.3.2.2
	E-financial transactions concerning transport	Transport service e-payment	G.4.2.1
		E-payment system of integrated transport service	G.4.2.2
	Other road use toll collection modes	Road use non-cash payment	G.5.2.1
		Road use cash payment	G.5.2.2
Personal safety	Public travel security	Silent alarm	H.2.2.1
		Public transport emergency call	H.2.2.2
		Intrusion detection	H.2.2.3
		Public transport monitoring	H.2.2.4
	Measures to enhance the safety of vulnerable groups	Non-motor vehicle and pedestrian monitoring	H.3.2.1
		Specific vehicle monitoring system	H.3.2.2
	Measures to enhance the safety of the disabled	Special vehicle monitoring at the intersection	H.4.2.1
		Special vehicle’s driver warning	H.4.2.2
	Pedestrian safety	Sign display warning	H.5.2.1

	assurance at the intelligent intersection	Warning for approaching to the vehicle (applicable to the intersection without signal)	H.5.2.2
		Vehicle identification and warning system	H.5.2.3
Weather and environmental condition monitoring	Weather monitoring	Road weather information monitoring	I.2.2.1
		Road weather forecast	I.2.2.2
	Environmental condition monitoring	Water level/Torrent monitoring and forecast	I.3.2.1
		Earthquake monitoring	I.3.2.2
		Pollution monitoring	I.3.2.3
		Monitoring of avalanches, landslides, and descending rocks	I.3.2.4
Disaster response management and coordination	Disaster data management	Disaster and emergency data acquisition	J.2.2.1
		Disaster and emergency data sharing	J.2.2.2
	Disaster response management	Plan for transport network disaster response	J.3.2.1
		Implementation of disaster response	J.3.2.2
	Emergency strategy coordination	Disaster response coordination	J.4.2.1
National security	Suspicious vehicle monitoring and control	Vehicle detection of dangerous goods	K.2.2.1
		Suspicious vehicle identification	K.2.2.2
		Suspicious damaged vehicles	K.2.2.3
		Suspicious vehicle road traffic management	K.2.2.4
		Emergency notification of key institutions or suspicious vehicle	K.2.2.5
	Public facilities and pipeline monitoring	Dangerous goods/explosives monitoring	K.3.2.1
		Implementation of mitigation strategy	K.3.2.2
		Emergency notification of key institutions	K.3.2.3
ITS data management	Data registration	Reusable interactive data ITS registration	L.2.2.1
		Reusable interactive ITS subroutine registration	L.2.2.2
	Data dictionary	Registration of ITS terms and definitions	L.3.2.1
Performance management	Data storage	Data archiving (traveler information in the history)	M.2.2.1
		Data storage (traveler information in the history)	M.2.2.2
		Emission monitoring	M.2.2.3
	Simulation	Performance simulation system (online)	M.3.2.1
		Performance simulation system (offline)	M.3.2.2

5.1.4 Construction and Application Experience Reference of Domestic and Overseas Intelligent Public Transport Systems

At present, the United States, Japan, Europe and other developed countries or regions are in the stage of forming the industrialization and large-scale application. After analysis of their development patterns, the following characteristics are summarized:

(1) Pay attention to the preliminary planning and goal

The United States established ITS leadership and coordinating agency, formulated the *Surface Transportation Efficiency Act*, worked out the 20-year development planning, and published the *National ITS Project Planning*, specifying 7 fields of ITS and 28 functions of user service. Japan established the unified ITS development institution, i.e. VERTIS, and formulated the "Overall Conception of ITS Promotion", including partial application of intelligent public transport subsystem, infrastructure improvement as well as R&D of systems and product. Europe established the implementation institution of road transport information technology, i.e. TRICO to implement the R&D plan for intelligent road and vehicle equipment.

(2) Pay attention to setting norms and standards

The ISO (International Standardization Organization) founded TC-204 Technical Committee in 1992, which shall be responsible for formulating the "Standard for Traffic Information and Control System". The EU standardization organization started the work of CEN/TC278, and established the VIENNA. The United States established the ITS communication protocol.

(3) Large investment in R&D and engineering

In Japan, ITS fund mainly comes from taxes paid by the industries relevant to the automotive industry, in a total investment of 368.40 billion yen from 1995 to 1999. The U.S. government totally invested 1.3 billion dollars in the ITS projects from 1991 to 1997, and about 40 billion dollars as the budget of the 20-year development planning.

(4) ITS investment adopts the mode that the government takes the lead in it and enterprises participate in it.

The U.S. government requires that ITS development and construction should be incorporated in the basic investment scheme of the governments at all levels, and attaches importance to creating a new investment mechanism, for the sake of ITS deployment, support, development and construction. Japan also adopts the cooperative mode between the government and private enterprises. For instance, the mode of VICS operation has accelerated the Japanese ITS R&D, construction and application.

5.2 Relevant File Problems and Demands Analysis in China

5.2.1 Existing Standards and Problem Analysis

(1) "*Urban Public Transport Scheduling Vehicle Information Terminal*" (GB / T 26766-2011)

Many cities in China built intelligent public transport system, but there is a wide range of vehicle terminal equipment, different standards, no sharing and connecting information between devices, poor in reusability. China issued the "*Urban Public Transport Scheduling Vehicle Information Terminal*" (GB / T 26766-2011) in 2011, for vehicle positioning and functional requirements of the basic scheduling clear. In order to ensure the quality of urban intelligent transport construction, and promote the healthy construction, and promote the healthy development of the bus intelligent industry. It is mainly requirements for the composition, appearance, electrical components, electrical properties, the overall properties of the terminal (including the electromagnetic compatibility, climate adaptability and mechanical environment adaptability), terminal basic functions (including the self-checking, position, communication, auto-announcing station, manually stop, dispatching command prompt, volume adjustment, support multilingual stops, support multiple line operation, interfaces and upgrade maintenance), degrees of protection provided by terminal enclosure and reliability of the intelligent service terminal which is installed and used on the bus and trolley bus. On this basis, the standards put forward detection methods and detection rules for the intelligent service terminal.

However, the relevant requirements of existing standards have lagged far behind the mainstream products technology of the current market. It is mainly reflected in the following aspects:

First, with the development of technology, the current intelligent service terminal has not only had the requested basic functions of the standards, but also it has achieved the basic man-machine interaction. It can realize the vehicle state information, audio and video information, collection, storage and transmission of the interconnected expansion devices data, and possess the automatic alarm function for overspend line deviation, emergency, equipment malfunction, vehicle condition abnormity, coin box abnormity, etc. Seen from the standard content, the standard for the functional requirements of the intelligent service terminal can hardly satisfy the needs of today’s public transport intelligent.

Second, the standard only requests the intelligent service terminal possess the RS485 or RS232 interfaces to support the interconnection of the terminal and other peripherals. But nowadays, with the increase in the amount of the IC card reader equipments，passenger flow detection equipments, oil detection equipments, on-board information display, audio and video equipments, bus lane capture equipments and on-board WiFi and other peripherals application. The reserved interfaces of the terminal in the standard cannot meet demands, it also should be equipped with USB interfaces, audio and video interfaces, WiFi interfaces and other interfaces to come true other peripherals access and data processing.

Third, the standard only comes up with the demand of functions, properties and testing requirements for the intelligent service terminal. It to the IC card reader equipments, on-board information display, audio and video equipments, bus lane capture equipments, passenger flow collecting equipments and other peripherals functions, properties and interfaces, at this stage is still blank.

(2) Eleven standards for the urban public transport intelligent application demonstration project

In order to promote the rapid development of national public transport informatization, the *Promoting Program for the "Twelfth Five-Year Plan"Development Plan of Highway and Waterway Transport Informatization* released by the Ministry of Transport pointed out carrying out the "Urban Passenger Transport Intelligent Application Demonstration Project". In 2013, the Ministry of Transport issued the notice of the *Standard Construction Scheme for Urban Public Transport Intelligent Application Demonstration Project*, and formulated eleven project standards combined with the construction needs of the cities of "Urban Public Transport Intelligent Application Demonstration Project", in order to better establish the urban public transport intelligent system, providing reference for the cities which are not listed in the demonstration cities but are intended to construct the public transport intelligent system. These eleven standards are shown in the table below, and its draft for submitting for approval has been completed.

Table 5-2 Standards for Urban Public Transport Intelligent Application Demonstration Project

Serial Number	Standard Name	Type of Applied Standard
1	General technical requirements for urban public transport intelligent application demonstration project	——
2	Urban public transport management and service information system data elements	——
3	Standards for urban public transport management and service information system data exchange	Industrial standard
4	Urban public trolley bus on-board intelligence service terminal	National standard
5	Communication protocol between urban public trolley bus on-board intelligence service terminal and the dispatching center	National standard
6	Norms for data bus interface communication of urban public trolley bus intelligent service terminal	National standard
7	Technical requirements for urban public trolley bus electronic stop board and data communication protocol	Industrial standard
8	Norms for urban rail transit passenger flow data acquisition and transfer	Industrial standard

Serial Number	Standard Name	Type of Applied Standard
9	Technical requirements for urban public trolley bus intelligent dispatching system	Industrial standard
10	Technical requirements for urban public transit information service	Industrial standard
11	Technical requirements for urban public transport industry supervisory system	Industrial standard

Among the above 11 standards, standards such as the *Technical Requirements for Urban Public Transport Intelligent Dispatching System*, *Urban Public Trolley Bus Intelligent Service Terminal*, *Communication Protocol between Urban Public Trolley Bus Intelligent Service Terminal and the Dispatching Center*, *Urban Public Trolley Bus Equipment Data Bus Communication Interface Specification*, *Technical Requirements for Urban Public Trolley Bus Electronic Stop Board and Data Communication Protocol*, *Technical Requirements for Urban Public Trolley Bus* Intelligent Dispatching System and *Technical Requirements for Urban Public Transit Information Service* can be used as a reference for studying the guide.

5.2.2 Existing Files and Problems Analysis

In order to guide "Urban Public Transport Intelligent Application Demonstration Project" of the transit city, the Secretary for the Ministry of Transport road transport is being prepared, "Urban Public Transport Intelligent demonstration projects Guide", which mainly targeted for the first batch of 15 "transit city" model cities and the second batch of 22 "transit city" model cities' intelligence monitoring and dispatching, passengers travel information service, industry operation supervision and comprehensive analysis of the bus and trolley system. Overall consideration of bus rapid transit (BRT) operation detection, and consider with urban rail transit, taxi, public bicycle, urban ferry, comprehensive passenger transport terminal and information exchange between other urban passengers transport systems. The guideline clears the system architecture, function, information collection, integration and share, system supports conditions, related engineering standards formulation and construction and operation management of the urban public transport business intelligent dispatch platform, passengers travel information service platform, urban public transport industry supervision platform.

"*Construction guidance of the urban intelligent public transport demonstration project*" mainly clear the urban public transport business intelligent dispatch platform, passengers travel information service platform, urban public transport business supervision platform of the demonstration cities of "transit city". As well as it come up with the demands of collection, integration and share of related information, system support conditions, related engineering standards development and construction and operation management.

However, the guide has a certain limitation, which is mainly reflected in the following aspects:

First, the guide is mainly faced to large-scale demonstration cities of “transit city”, it cannot come up with the guidance for small and medium-sized city urban public transport intelligent system construction.

Second, the users of this guide mainly are business management department. The urgent needs of the application systems in the businesses operations, such as signal priority system, bus lane management system and so on have not mentioned. The needs of decision support in business are not mention either.

Third, the guide emphasize that functional planning of the urban public transport business intelligent dispatch platform, passengers travel information service platform, urban public transport business supervision platform. It is not mention the factors that affect the efficiency of the system which should consideration when the system planning and design, thus it cannot guide the project implementation.

Fourth, the technology used in this guide mainly are the mature technology has been large-scale application, it cannot reflect the application of new technologies for cloud networking, internet of things, TD-LTE, WiFi, etc..

6 APTS Framework

6.1 Application Value

（1）Importance of developing public transport

Important with public transport in cities is, that the creation of faster public transport will improve the situation for cars also. Since the speed of public transport does not change much when more passengers use this modality, the car drivers can change from car to public transport without making the public transport slow. On the contrary, when the number of passengers grows, the public transport operators has a reason to increase the frequency or to add new lines. The consequence is, that a faster public transport will reduce the volumes of car traffic. This will reduce the urban congestion.

On the other hand, if car traffic is improved in cities, passengers of public transport will be attracted to the car, which results in more car traffic and less public transport passengers. Frequencies of the service will be reduced for economic reasons, which will increase the travel times by public transport and push more travelers towards the car. The increasing traffic flows will create new congestion and the final situation will be worse than before the measures were taken.

Of course, the reality is more complicated, because many car drivers do not have the choice between car and public transport and an improvement of public transport will attract first of all cyclists and pedestrians. Still it is a valid statement that in cities it is better to improve the conditions for public transport than for private motorized vehicles.

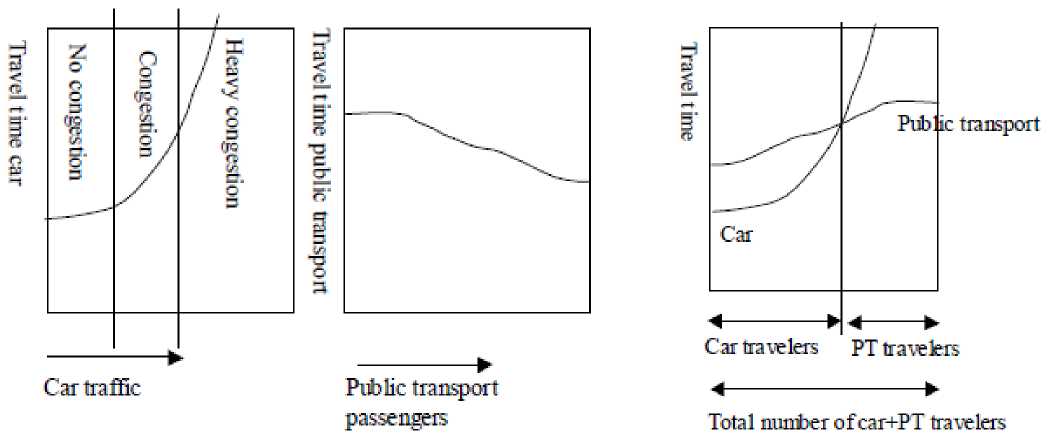


Figure 6-1 Travel Time by Car as Function of the Volume Car Traffic (left) and Travel Time by Public Transport as Function of the Number of Passengers (middle). The Equilibrium (right) is where Travel Time by Car and by Public Transport have Become the Same

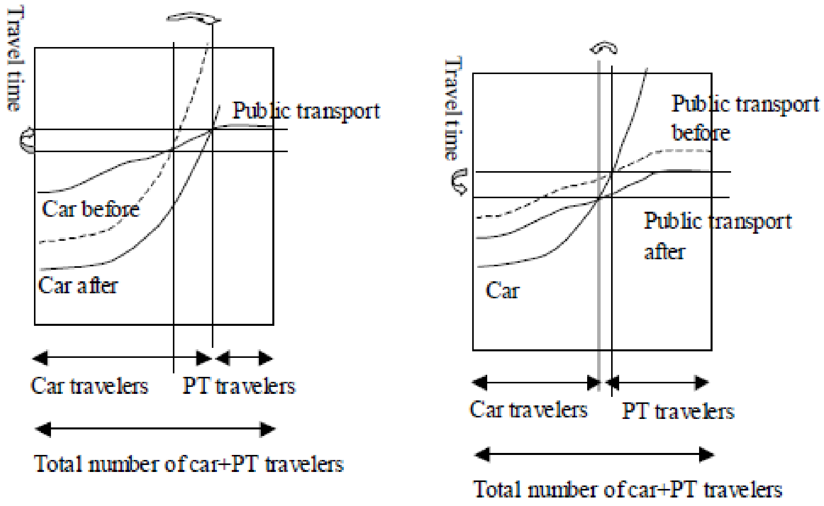


Figure 6-2 Change of Number of Car and Public Transport Travelers after an Improvement of Car Traffic (left) or Public Transport (right)

(2) Practical application of Intelligent Transport Services

Traffic signals have become a part of a more comprehensive set of Intelligent Transport Services (ITS). These services include also applications of Information Technology (IT) to public transport (computer assisted planning, vehicle monitoring, information system for public transport stations, fleet management, performance monitoring, passenger information systems). For road traffic ITS includes all dynamic control of roads infrastructure, traffic monitoring systems, traffic and travel information, control centers. It also includes all kind of intelligence integrated in modern cars such as positioning systems with GPS, cruise control, driver monitoring, intelligent speed adaptation, lane departure warning etc. In the future several new features will be added such that on the long term cars might become completely automated.

Figure 6-3 ITS for Public Transport: Information about the Next Arrival at the Tram Stop

In cities the possibilities to use a car are limited. The road space is not sufficient to make a smooth flow of cars possible on all roads. Other transport modes are more suited for urban accessibility: walking, cycling, and public transport: bus, tram, metro and taxi. Most forms of public transport are at this moment especially suited for transport along corridors, where the transport demand is concentrated along certain axis. Only demand responsive public transport, such as taxis, have possibilities to serve transport demand with diffuse origins and / or destinations. Newer forms of public transport are now in development which may bridge this gap between line oriented and surface oriented transport. For instance, Personal Rapid Transit (PRT) is a new transport mode of taxi-vehicles, automatically driving over a dedicated and partly elevated infrastructure. The vehicles drive along tracks to the destination/a station. These stations have a split track so that a stopped vehicle waits off-side of the main track and the other vehicles can proceed. Therefore the maximum cruise speed is equal to the average speed.

Figure 6-4 Route Plan for the PRT Network

A rather good way to improve the travel speeds and regularity of buses and trams is to give them priority at controlled intersections. The principle is that a green phase in which a bus/tram can pass is extended if such a vehicle approaches the intersection. If the signal is red, the conflicting green phases are terminated as quickly as possible or skipped, to give green to the bus or tram. Other ways to improve travel speeds for public transport are to give them dedicated lanes and even grade-separated crossings.

6.2 Present Survey Situation

(1) Construction guidance of the urban intelligent public transport demonstration project (simply "the Guide" for short)

The system framework proposed by the Guide was shown in Figure 6-5. Projects include urban public transport enterprise operating scheduling management, passenger travel information service and industry operation regulation and decision making. Framework also determines the project involves three aspects of the external business cooperative relationship and the business docking relationship between the engineering and the department in charge of transportation, bus enterprise and other departments.

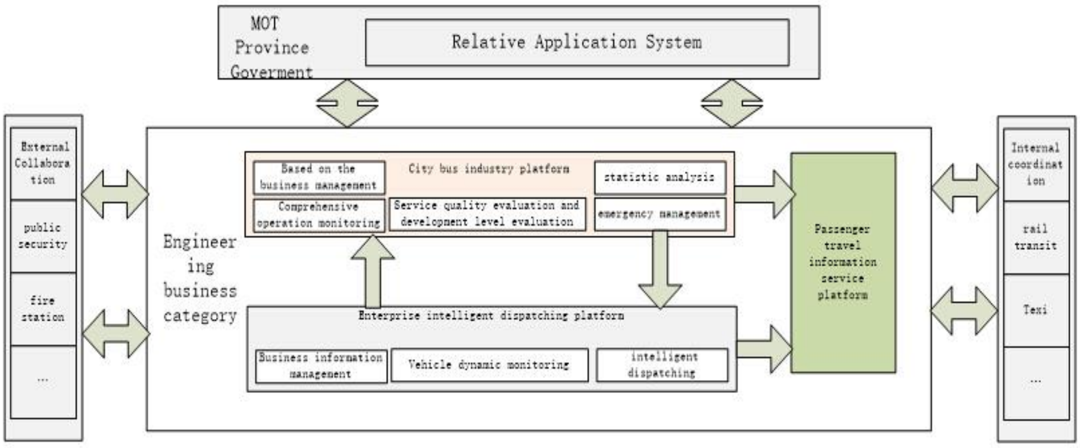


Figure 6-5 APTS Application Framework in the Guide

Industry – Enterprise data resources system was applied in the basic data of urban public transport, dynamic monitoring data, Comprehensive analysis of data and travel service information involved in the projects, as shown in Figure 6-6.

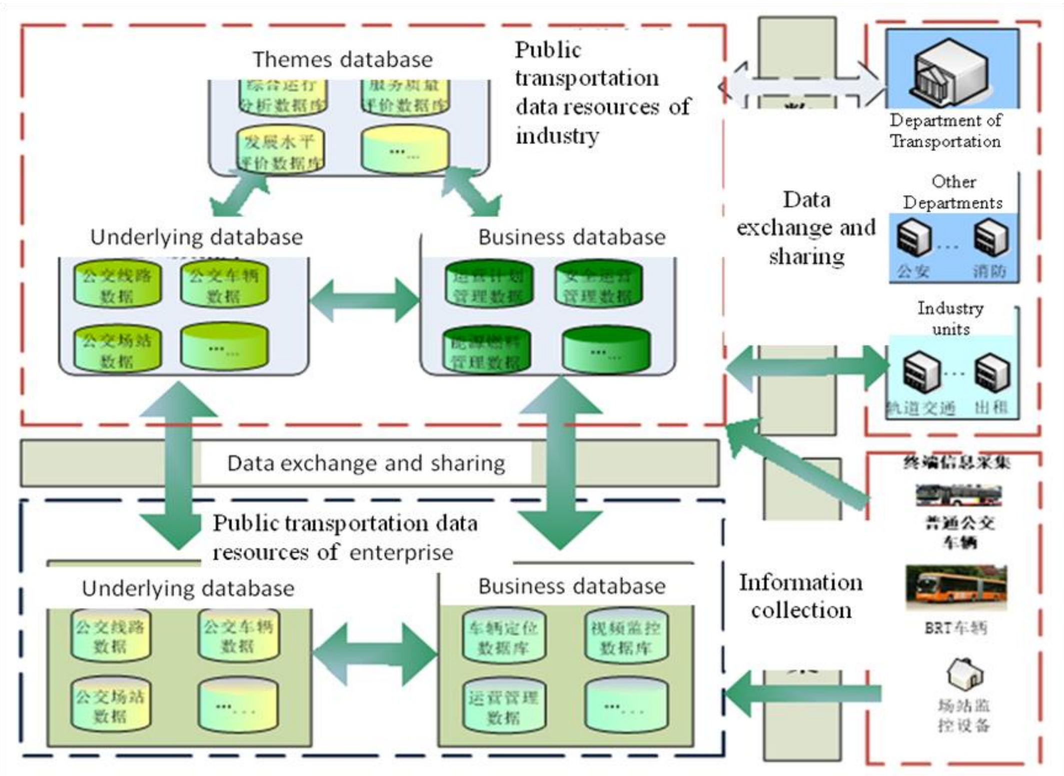


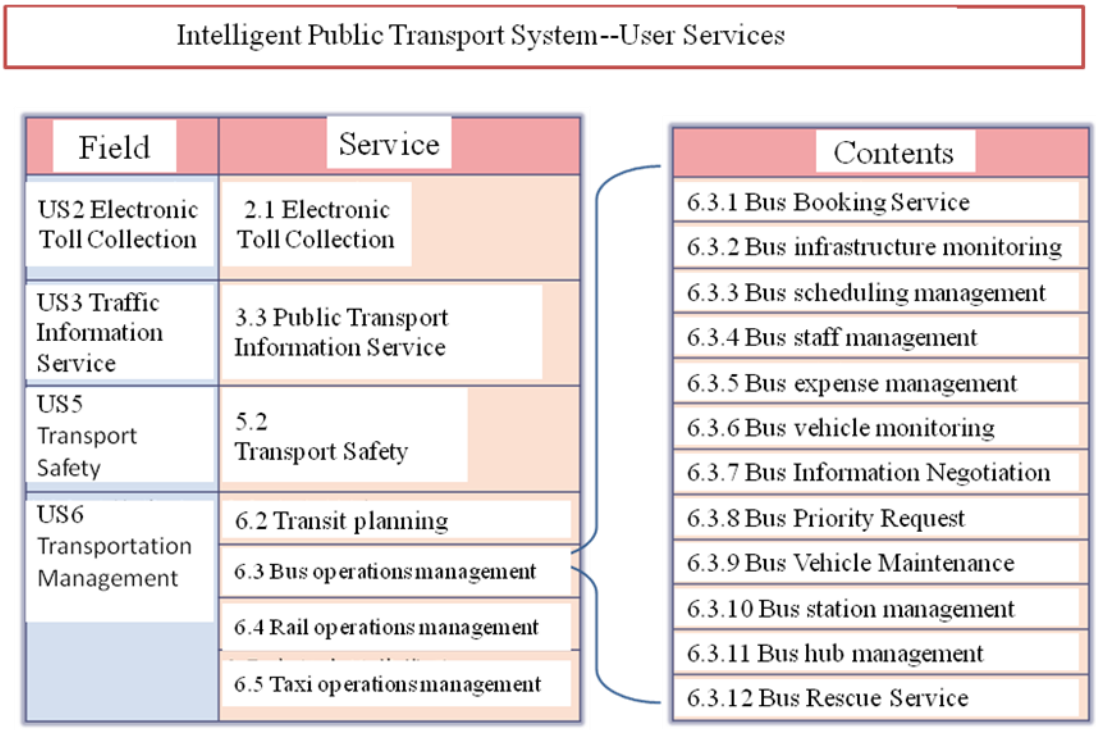
Figure 6-6 APTS Data Framework

The Guide has played a important role for country public intelligent system construction.

(2) China ITS Architecture public transport sector

Users' demands in the second edition of China ITS architecture public transport sector were listed in Table 6-1.

Table 6-1 Users' Demand in the Second Edition of China ITS Architecture Public Transport Sector



System components in the second edition of China ITS architecture public transport sector were listed in Table 6-2 and Table 6-3.

Table 6-2 System Components in the Second Edition of China ITS Architecture Public Transport Sector

System	Subsystem	System Module
PS7 Urban public transport system	7.1 Integrated Management Subsystem	7.1.1 Transit planning
		7.1.2 Fixed-line operations management
		7.1.3 Non-fixed line operations management
		7.1.4 Vehicle Positioning management
		7.1.5 Vehicle dispatching management
		7.1.6 Passenger Ticket Management

		7.1.7 Security Management
		7.1.8 Vehicle Rescue Management
		7.1.9 Vehicle maintenance Management
		7.1.10 Infrastructure Management
		7.1.11 Information Service Management
		7.1.12 Multi-way coordination and management
	7.2 Integrated Management Subsystem	7.2.1 Vehicle Positioning management
		7.2.2 Vehicle Information exchange management
		7.2.3 Passenger Ticket Management
		7.2.4 Security Management
		7.2.5 Information Service Management
	7.3 Outfield Management Subsystem	7.3.1 Vehicle Positioning management
		7.3.2 Passenger Ticket Management
		7.3.3 Information Service Management
		7.3.4 Infrastructure Management
	7.4 Passenger management Subsystem	7.4.1 Passenger information exchange Management
		7.4.2 Passenger electronic payment Management

Table 6-3 Systems in the Second Edition of China ITS Architecture Public Transport Sector

Urban public transport management	Security Management system of Urban public transport
	Station management system of Urban public transport
	Vehicle Rescue Management system of Urban public transport
	Information Service Management system of Urban public transport
	electronic payment Management system of Urban public transport
	Transit planning system of Urban public transport
	Operations Scheduling system of Urban public transport
	Operations Scheduling system of taxi
	Operations Scheduling system of rail
	BRT Operations Management system
	Digital Bus Station Management system

(3) Taking Shenzhen as an example, its public transport system was reformed based on the Guide. Two different frameworks of Shenzhen intelligent public transport system was shown in Figure 6-7 and Figure 6-8.

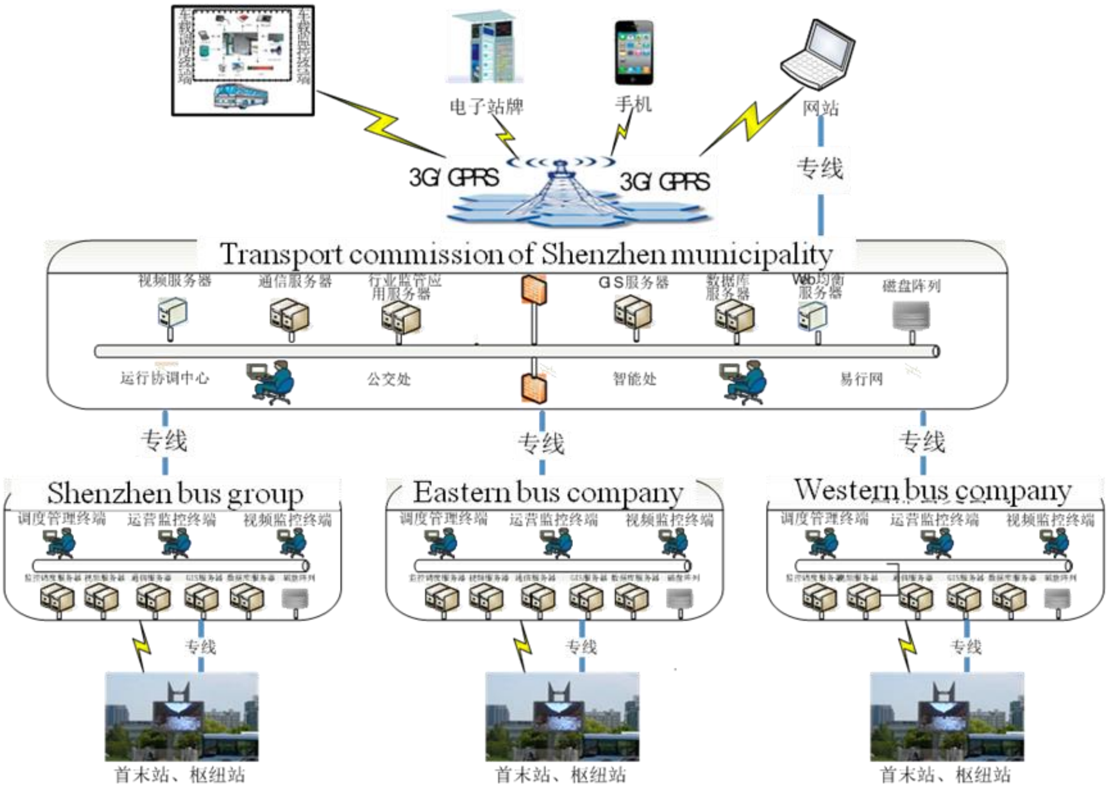


Figure 6-7 Framework 1 of Shenzhen Intelligent Public Transport System

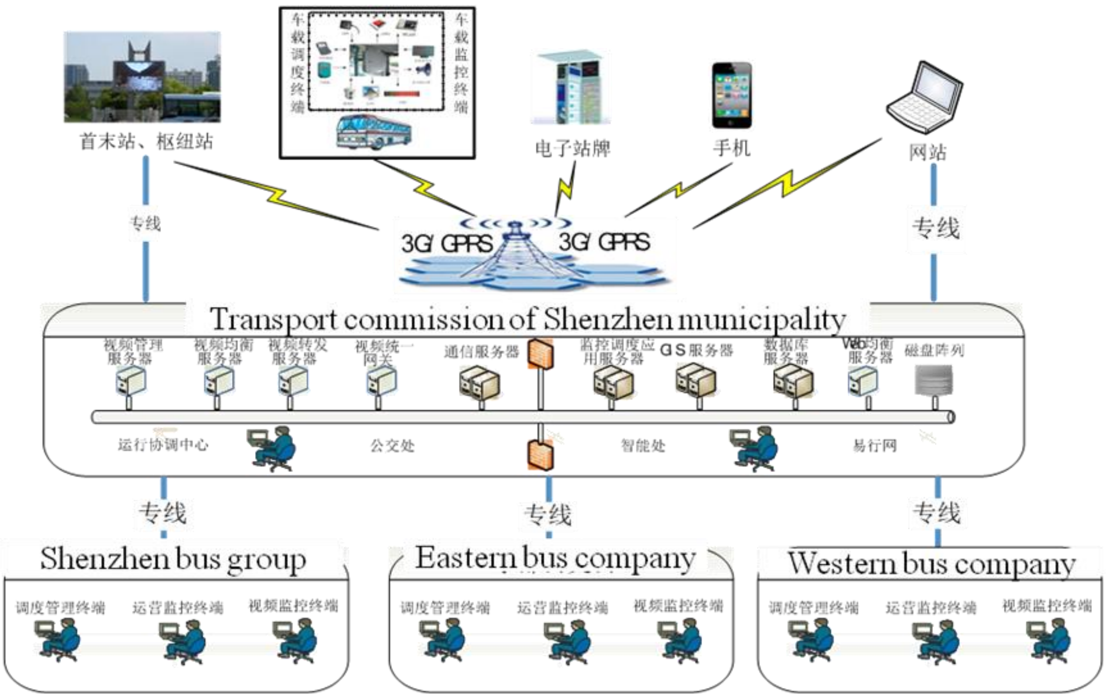


Figure 6-8 Framework 2 of Shenzhen Intelligent Public Transport System

Based on the figures above, the summary analysis of common modules and characteristics modules of several cities can integrate excellent framework designs and sum up the universal applicability of frame templates and the feature module that can be added depend on the situation.

Nowadays, the application of cloud, networking and some other new technologies brings the impact and change to the framework of intelligent urban public transport system.

The Internet of things technology, universal coverage data acquisition situation awareness and integration of the existing system of information resources were applied in Guangzhou. By data mining and intelligent analysis of dynamic data, the Information service platform can feedback the dynamic results to each business application system and data application terminal to impact system decision-making, the end user travel status at that time. In general, with the help of a powerful platform for computing power and efficient information communication mode and complex information processing algorithm, intelligent information collection, intelligent information processing and intelligent information show can be achieved.

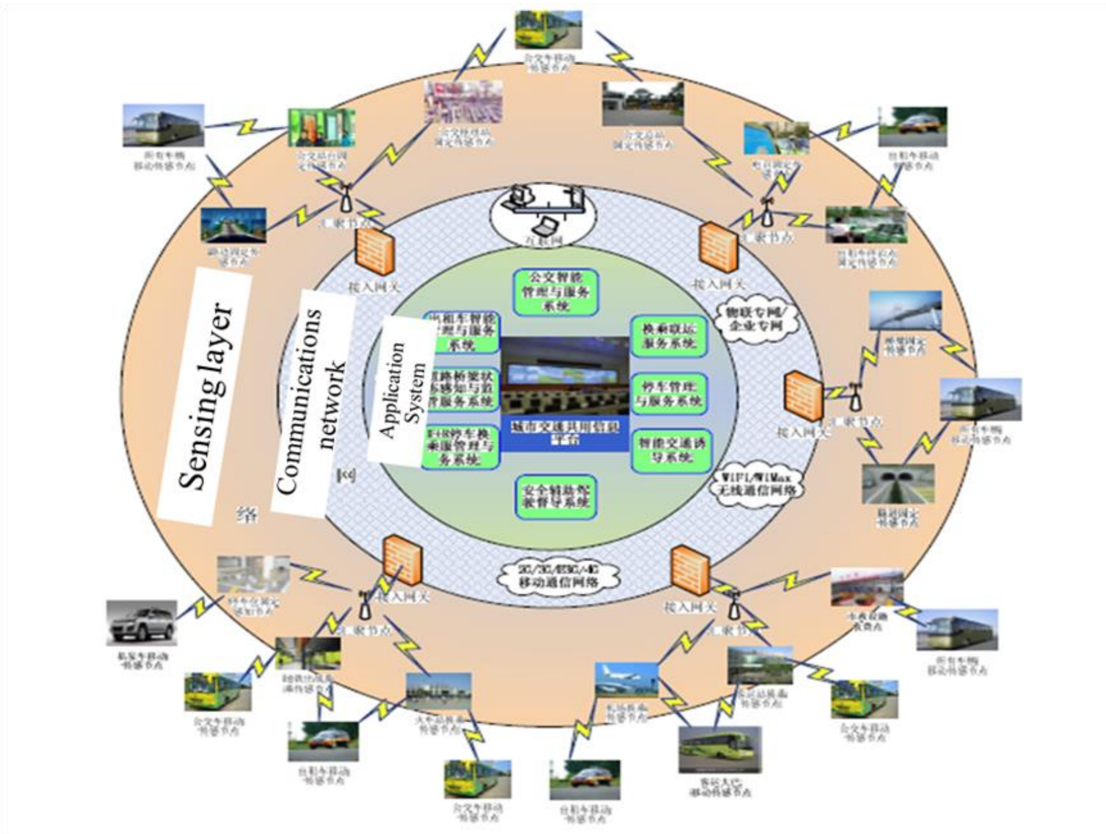


Figure 6-9 The Internet of Things Technology in Guangzhou

Traffic data of Fujian is large and disperse, which met the characteristic of could platform. Distribute cloud infrastructure was adopted in Fujian bus operation platform, which can solve the problem of existing data and system hardware. In the meantime, full consideration for the later performance extensions was given. Fujian cloud platform also provide bus companies and county departments related services.

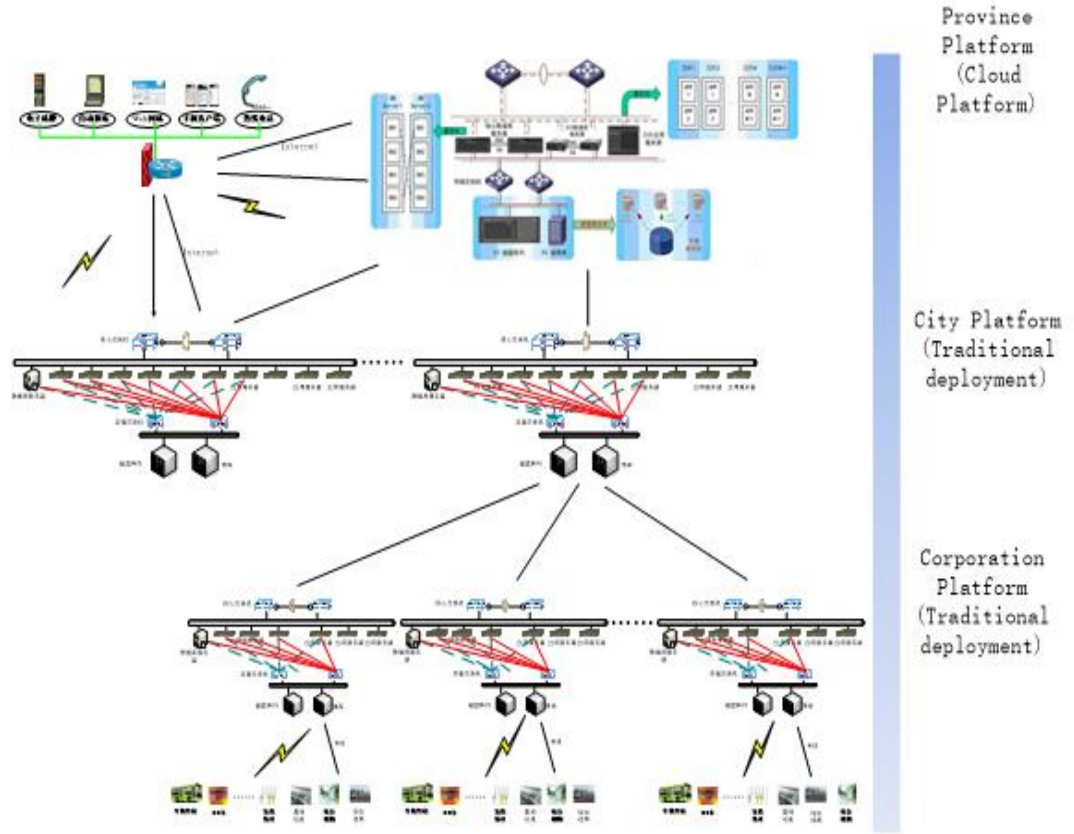


Figure 6-10 Fujian APTS Application Framework

6.3 Problem and Requirement Analysis

(1) The existing guidelines have different emphases, and a complete set of intelligent transport system framework has not yet established.

The *Construction Guidance of the Urban Public Transport Intelligent Demonstration Project* is aimed at the demands of government departments, enterprises and the public, setting up three basic business frameworks, namely, enterprise operation dispatching management, passenger travel information service and industrial operation supervision and decision. The Guidance does not show requirement analysis of user services at all levels and its corresponding system functions, system physical architecture as well as their interrelationship; therefore, it is of limited referential significance for the cities with lower or higher public transport informationization level. Through implementing the researches on a series of framework process such as user service requirements, logic functions, data flow as well as their interrelationship between the physical framework and the system, a set of intelligent public transport system architecture suitable for the cities at all levels is established.

(2) Due to different urban public transport market operational modes, the applicable intelligent bus system architectures are different.

In Shenzhen, data flow direction relationship of three public transport enterprises is on-board equipment -public transport enterprises -industry sectors, but in Guangzhou, that of several public transport enterprises is on-board equipment -industry sectors -public transport enterprises. Different cities have different public transport development levels, and there is a big difference in the informatization basic conditions of different cities. The research and analysis of advantages& disadvantages and applicable conditions of different system architectures is to provide guidance for construction and application of intelligent public transport systems in the cities.

(3) Small- and medium-sized enterprises have a demand for cloud architecture, which is not reflected in the existing files.

At the present stage, intelligent public transport systems in the cities are independently developed and established, and utilization rate of system computing resources is not high; meanwhile, restricted by their own scale, some public transport enterprises fail to establish the intelligent production scheduling system. Under such circumstances, lessons can be drawn from the construction mode for Fujian public transport operation supervisory platform. The distributed cloud architecture is adopted to give full play to its advantages of operation allocation, balanced performance and cost savings, to provide cloud service for industrial management departments at the county level as well as small and medium-sized enterprises and to provide favorable conditions for platform expansion at the late stage.

6.4 Application Scenario

By research and analysis on domestic and foreign cities, urban intelligent public transport system application scenarios are shown in Fig 6-11. Starting from industrial management, enterprise scheduling and serving the needs of the public, the overall framework faces competent units of urban public transport industry and public transport operation enterprises and provides them with superior guidance for intelligent public transport system construction and application in terms of public transport information sensing system, public transport information service, intelligent public transport dispatching, public transport decision support, transit signal priority and exclusive bus lane management, to comprehensively enhance the level of urban public transport monitoring, level of intelligent dispatching, level of travel information service, industry regulatory decision-making level, thus promoting the healthy and sustainable development of public transport industry, increasing its importance in the urban traffic system, making necessary contributions in the process of realizing green transport and reducing carbon emissions.

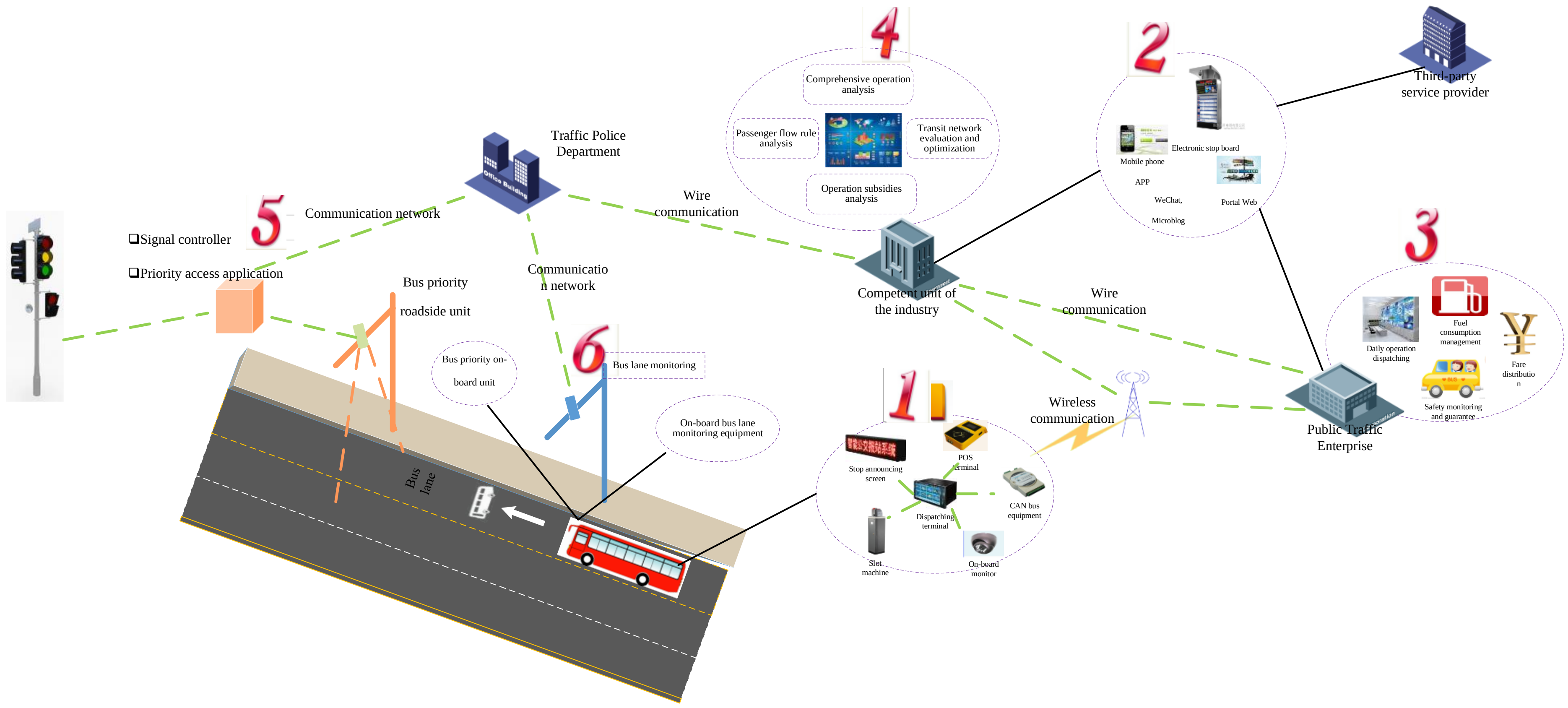


Figure 6-11 Typical Application Scenario of Urban Intelligent Public Transport System

(1) Public transport information sensing system. It is the basic support of the whole intelligent public transport system. Construction entities of public transport information sensing system for cities are different and application entities are public transport enterprises. Construction content shall be determined according to basic conditions and actual demands of cities.

(2) Public transport information service system. It mainly provides travelers with different modes of comprehensive information services. Users of the system are generally competent departments of public transport industry or public transport operation enterprises. The specific service mode can be determined according to actual conditions of cities. Information services are provided by management units of the public transport industry, public transport enterprises or third-party providers/Internet enterprises.

（3）Intelligent public transport dispatching system. It realizes real-time monitoring and dispatching for public transport vehicles. Users of the system are public transport operation enterprises. Business data generated by the system can be used in information service and industry decision support.

(4) Public transport decision support system. It mainly realizes monitoring on public transport operation, industry data statistics as well as analysis and decision on operation safety, travel characteristics and driving behaviors. The user of the system is the competent department of public transport industry. Functions of the system can be determined according to business demands of the competent department

(5) Transit signal priority system. Through real-time testing on public transport vehicles and dynamic control on intersection signals, transit priority will be given to public transport vehicles at intersections. User of the system is urban public transport management department. Urban traffic department, public security department and other departments shall cooperate with each other to complete system construction and operation after full consideration is given to influence and benefits of the system.

(6) Exclusive bus lane management system. Violation snapshot equipment is mounted on vehicle head or roadside for to ensure exclusive bus lane right. User of the system is urban traffic management department. Urban traffic department, public security department and other departments shall cooperate with each other to complete system construction and operation after full consideration is given to influence and benefits of the system.

6.5 Service Function Framework

Through literature review and survey analysis of major cities in China, based on six service domains, namely, public transport information service, public transport intelligent dispatching, public transport decision support, transit signal priority, exclusive bus lane management and data resource center, specific services and functional requirements are carefully sorted out to establish the list of the overall framework service functions of intelligent public transport system, as shown in Table 6-4.

Table 6-4 List of Service Functions

Service Domains	**Service**	**Functions**
Public transport information service	Basic information	Weather forecast
	Travel planning	Bus/subway line search
		Bus/subway stop search
		Bus/subway line demonstration
		Driving route search
		Driving route navigation
		Train line search
		Train line demonstration
		Online train ticket purchase
		Flight information search
		Flight information demonstration
	Transport hub information	Subway station information
		Railway station information
		Airport information
	Travel purpose	Neighboring area
		Tourist attractions
		Scenic transport information
		Introduction to scenic spots
	Personal travel	Travel information updating and pushing
		Travel information alert
		Travel schedule
		Public transport trip planning
		Self-drive trip planning
		Make an appointment to take a taxi
	News bulletin	News
		Notice
		News concerned by me
Public transport intelligent dispatching	Intelligent dispatching	Vehicle plan
		Vehicle allocation scheduling
		Automatic dispatching
		Dispatching management
	Operation monitoring	Line monitoring
		Vehicle monitoring
		Running chart monitoring
		GIS monitoring
		Video monitoring
		Card-swiping data monitoring
		Energy consumption data monitoring
	Statistical analysis and auxiliary decision-making	Statistics function
		Reporting function
		Analysis function
		Auxiliary decision-making function
	Basic information management	General requirements
		Information definition
		User role management
Public transport decision support	Statistical analysis and reporting support of the public transport industry	

	Public transport fiscal subsidies support
	Public transport development and service level evaluation
	Daily operation monitoring
	Road traffic operation index analysis
	Traffic survey data sharing and analysis
	Accident analysis and safety management decision support
	Public transport index analysis
	Personal trip chain and group trip behavior analysis
	Public Transport Energy Consumption and Emissions Monitoring and Analysis
	Public transport driver's driving behavior analysis
	Public transit network adjustment and optimization based on big data
	Transferring passenger flow monitoring and analysis of public transport supply capacity
Transit signal priority	Vehicle detection at the intersection
	Public transport vehicle positioning
	Application for signal priority
	Rule and strategy making
	Signal control
Exclusive bus lane management	Basic information management
	Snapshot management and analysis
	System operations management
	System management
Data resource center	Data access
	Data processing and integration
	Data storage
	Opening a shared interface

6.6 Technical Framework

Through analyzing each component and its function of the overall framework of urban intelligent public transport system, the technical framework is established as shown in Figure 6-12, including seven levels, namely, information sensing system, basic support, data resource center, application supporting platform, application system, information release terminal and system user, as well as related informationization security and standard system, government-enterprise cooperation and information sharing mechanism.

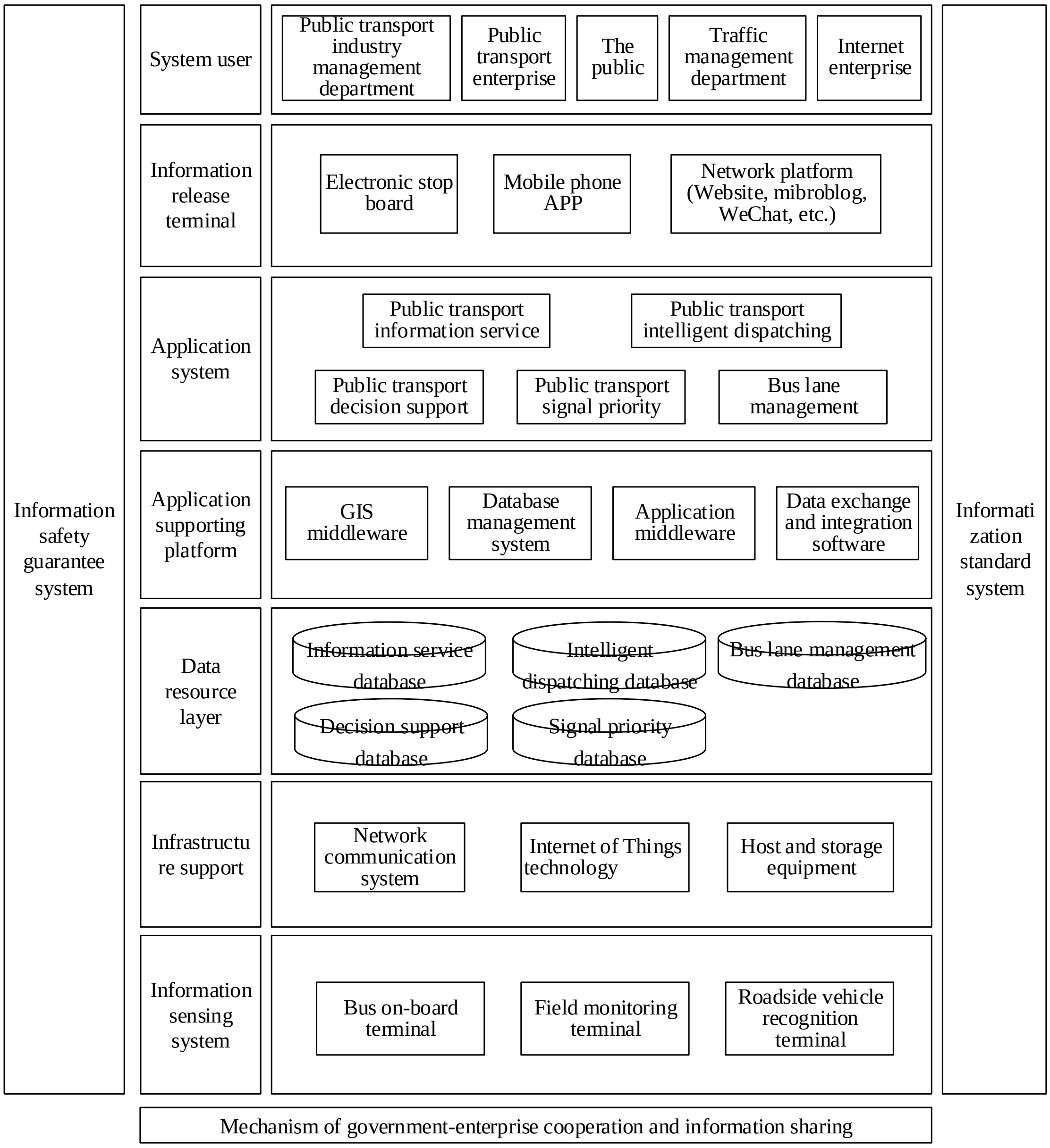


Figure 6-12 Technical Framework of Urban Intelligent Public Transport System

(1) Information sensing system: Obtain the dynamic data of public transport relying on on-board equipment (such as intelligent dispatch terminal), field monitoring terminal (such as imaging snapshot system of traffic violation in bus lane), roadside vehicle recognition terminal (such as roadside recognition equipment of vehicle electronic tag), providing data support to achieve different system applications.

(2) Foundation support: Provide network, technology and other foundation support conditions to achieve different system applications by applying network communication (such as optical fiber, 3G wireless), technology of Internet of Things (such as signal priority vehicle identification), host, storage equipment, etc.

（3）Data resource layer: Make format conversion and preprocessing for collected original data to form a basic database for 5 systems, namely information service system, intelligent dispatching system, decision support system, signal priority system and exclusive bus lane management system.

(4) Application support platform: Provide software support environment for achieving different system applications by relying on GIS middleware, database management system, application middleware, data exchange and integration software, etc.

(5) Application system: Select and get 5 typical application systems of public transport information service, public transport intelligent dispatching, public transport decision support, public transport signal priority and exclusive bus lane management by analyzing the typical needs of development in domestic public transport industry.

(6) Information distribution terminal: Distribute travel information services to the public relying on electronic stop board, mobile phone APP, network platform (website, microblog, WeChat, etc.).

(7) System user: The main users of urban intelligent public transport system include public industry management unit, public transport enterprise, general public and traffic management department.

(8) Government-enterprise cooperation and information sharing mechanism: Set up the government-enterprise cooperation and information sharing mechanism led by the government and prompted by mutually collaborative enterprises and scientific research institutions, form new information service modes under the Internet environment, and provide the public with more extensive and more reliable public transport information services.

(9) The building, application, operation and maintenance of urban intelligent public transport system shall meet the requirements of relevant domestic informatization safety and standardized system.

6.7 Physical Architecture

Intelligent public transport system mainly consists of four parts, namely, on-board equipment, field equipment, data center and application system. For more information, see Table 6-5 and Table 6-6. See Figure 6-13 for composition of each part and relations among them.

Table 6-5 Composition of Application System and Data Center

Application system	**Subsystem**
Public transport information service system	Basic information inquiry subsystem
	Travel route planning subsystem

	Transport hub information inquiry subsystem
	POI (Point of Interest) inquiry subsystem
	Personal travel customized service subsystem
	News bulletin promotion subsystem
Public transport intelligent dispatching system	Intelligent dispatching subsystem
	Operation monitoring subsystem
	Statistical analysis and auxiliary decision-making subsystem
	Basic information management subsystem
Public transport decision support system	Statistical analysis and reporting support subsystem of public transport industry
	Public transport fiscal subsidies support subsystem
	Public transport development and service level evaluation subsystem
	Daily operation monitoring subsystem
	Road traffic operation index analysis subsystem
	Traffic survey data sharing and analysis subsystem
	Accident analysis and safety management decision support subsystem
	Public transport index analysis subsystem
	Personal travel chain and group travel behavior analysis subsystem
	Public transport energy consumption and emissions monitoring and analysis subsystem
	Public transport driver's driving behavior analysis subsystem
	Public transit network adjustment and optimization subsystem based on big data
	Transferring passenger flow monitoring and public transport supply capacity analysis subsystem
Transit signal priority system	Vehicle detection subsystem at the intersection
	Public transport vehicle positioning subsystem
	Signal priority application subsystem
	Planning strategy making subsystem
	Signal control subsystem
Exclusive bus lane management system	Basic information management subsystem
	Snapshot management and analysis subsystem
	System operation and maintenance management subsystem
	System management subsystem
Data center	Data access
	Data processing and integration
	Data storage
	Opened sharing interface

Table 6-6 Composition of On-board Equipment and Field Equipment

<table>
<tr><td rowspan="11">Information sensing system</td><td colspan="3">On-board intelligent service terminal</td></tr>
<tr><td rowspan="6">Expanded equipment</td><td rowspan="2">Charging and settlement equipment</td><td>IC card equipment</td></tr>
<tr><td>Intelligent slot machine</td></tr>
<tr><td colspan="2">Video monitoring equipment</td></tr>
<tr><td colspan="2">Information distribution equipment</td></tr>
<tr><td colspan="2">Passenger counting equipment</td></tr>
<tr><td colspan="2">Public transport signal priority on-board equipment</td></tr>
<tr><td rowspan="2">Communication equipment</td><td colspan="2">Cellular mobile network communication equipment</td></tr>
<tr><td colspan="2">On-board wireless equipment</td></tr>
<tr><td colspan="3">Roadside sensing equipment</td></tr>
</table>

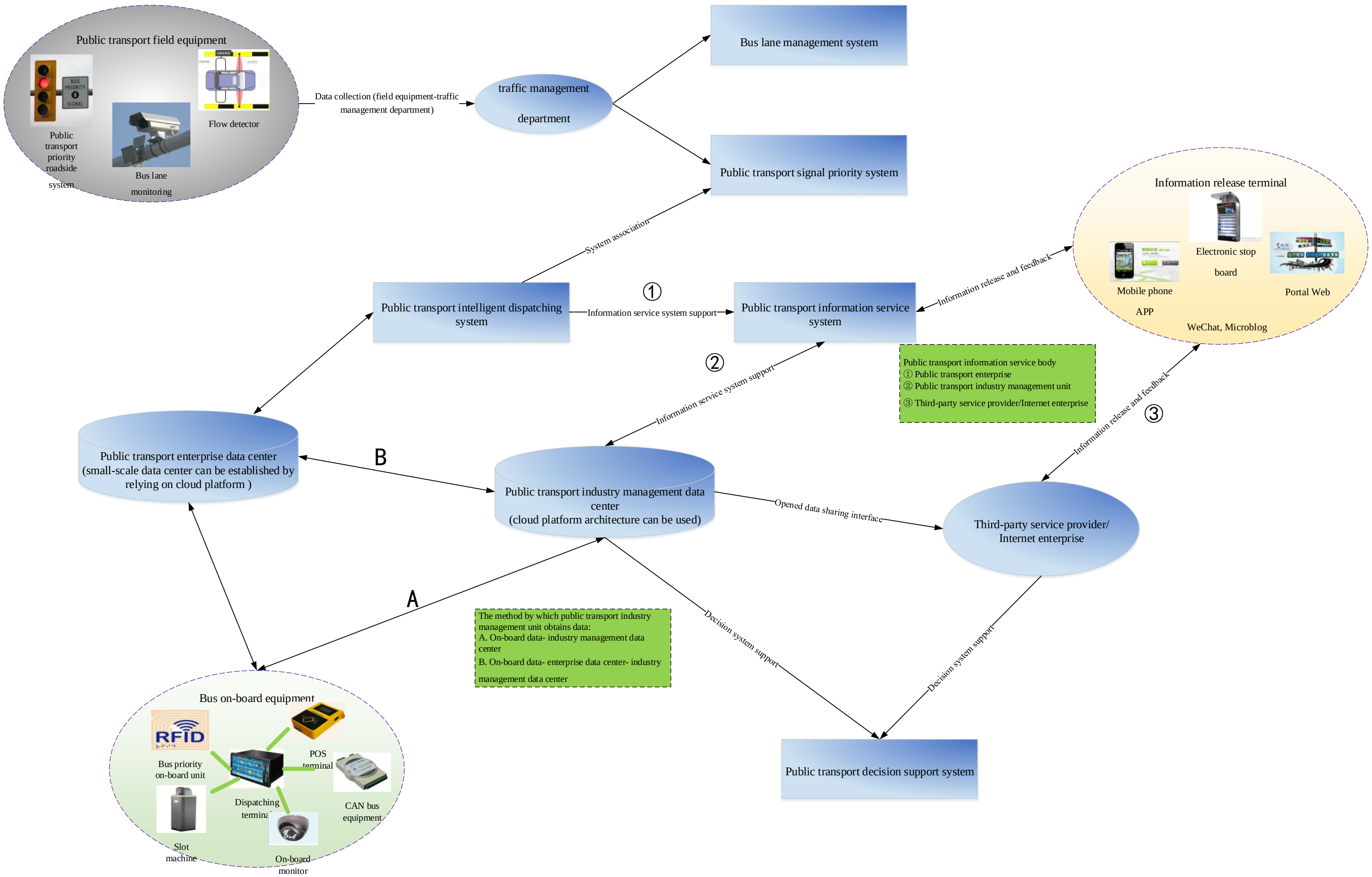


Figure 6-13 Physical Architecture of Intelligent Public Transport System

(1) On-board equipment

On-board equipment is the basis to realize functions of intelligent public transport system, specifically including obtaining the real-time position, card swiping passenger flow, monitoring video, vehicle running status and other data information of public transport by using on-board equipment.

According to the actual situation of different areas, the flow of data acquisition can be divided into two kinds:

1) The public transport enterprise acquires terminal data and then forwards it to industry management unit;

2) The data are directly distributed to the public transport enterprise and industry management unit from the terminal.

(2) Field equipment

Field equipment mainly refers to testing equipment that is installed to realize transit signal priority and exclusive bus lane management. Generally, real-time data communication is conducted between field equipment and traffic management department.

1) Roadside-installed equipment realizes transit signal priority service by using dedicated short-range communication technology (DSRC). Vehicles are equipped with electronic tags for identity recognition. Tag reader shall be arranged at the upstream section of intersection and flow detector shall be arranged at the approach of intersection;

2) Camera is usually installed at the head of bus or dedicated bus roadside to capture illegal social vehicles and guarantee the busway right.

(3) Data center

Data center mainly realizes collected data processing, integration, storage, sharing and exchanging, etc.

1) Industry management data center: It aggregates multi-source data of public transport industry and mainly provides support for industry decision. According to local actual conditions, traditional distributed architecture or cloud architecture can be adopted to construct the data center.

2) Enterprise data center: It mainly aggregates static and dynamic data needed for enterprise operation and mainly provides support for daily monitoring and dispatching. When an enterprise is small in scale and does not meet informatization construction conditions, it can

provide support for its own informatization system by relying on the industry cloud architecture data center.

(4) Application systems

Application systems include intelligent dispatching system, decision support system, information service system, signal priority system and exclusive bus lane management system. Among which:

1) If a city wants to develop the intelligent public transport, the intelligent dispatching system shall be first established. With this foundation, information service system and decision support system can be constantly improved and upgraded in functions according to specific demands at different development stages.

2) In order to further improve public transport priority level and service quality, bus lane management system and signal priority system can be selected for construction

3) Effectively associating intelligent dispatching system and signal priority system is beneficial to improve public transport operation efficiency.

4) Public transport enterprises, industry management units and third-party service organizations/ Internet enterprises can serve as information service bodies. When overall environment of urban information service becomes mature and open, third-party service organizations/ Internet enterprises can provide high-quality travel information service and decision support service via data opening and sharing.

6.8 Construction Suggestions

Combined with investigation and study, it can be known that due to the influence of urban scale, geographical features, recognition degree of local governments and other factors, the overall public transport development level among the domestic cities is discrete, and there is significant difference in the actual needs and development maturity of intelligent public transport system. If the construction of intelligent public transport system in different areas is required and restrained by the same standards, system application may be out of line with the actual needs of industry, thus resulting in the waste of human and financial resources as well as the decrease in management and operation efficiency. Therefore, it is the key for guaranteeing that urban intelligent public transport system can play its due role to take actual needs as the orientation of intelligent public transport, gradually promote information technology system construction by stages, as well as continuously explore and improve the system application results. By evaluating how the development level of urban public transport fits with the applicable conditions of intelligent public transport system, the overall suggestions on intelligent public system construction under the conditions of different public transport development stages are put forward as follows:

(1) Intelligent public transport dispatching system

When dispatching mode is selected for intelligent public transport dispatching system in different cities, it is difficult to determine whether traditional dispatching mode and centralized dispatching mode as a whole; specific analysis should be made in combination with its basic conditions, operation mechanism, mode transformation risks and other factors. For the cities with relatively mature traditional dispatching and corresponding management mode, it is suggested to first select dispatching mode, and gradually conduct the experiment and changes of centralized dispatching mode according to the development scale and the basis; for the cities with large scale, complex urban road network status and complex bus station management, it is suggested to select the mode of combining traditional dispatching and centralized dispatching.

For the functions of dispatching system, the functions that should be realized in the initial stage of construction include: travel plan, dispatching and scheduling, line monitoring, vehicle operation monitoring, statistical reporting, system management and other basic functions. Such application functions as automatic dispatching, video surveillance, swiping card data monitoring, energy consumption monitoring, ca analysis and aid decision making can be expanded gradually when conditions permit.

(2) Public transport information service system

Cities can select to construct public transport information service system using construction by government, construction by Internet enterprises and construction jointly by government and enterprises through cooperation according to their information service development ideas, travel demand scale, habits to obtain information services, open environment for marketization and other factors.

The government and enterprise cooperation mode is the preferred mode of sustainable development in public transport information service system. According to the basic conditions of urban data, suitable data sharing mode can be selected from three modes of resource exchange, free service input and purchase service, and the construction contents and operation mechanism can be determined based on this. Among them, free service input mode is suitable for the cities where travel service system has not be set up or travel information service function is weak, dominated by the one-way services of Internet enterprises, quickly filling in the blank of industry information services and improving urban transport travel information service capability; Being suitable for the cities with relatively good data source base, resource exchange mode encourages industry management department to conduct equivalent exchange of data, technology and service sources with Internet enterprises; as the mainstream development trend in the future, purchase service mode encourages all areas to selectively purchase the application services provided by Internet enterprises by means of government procurement, and conduct customized development according to local needs.

(3) Decision support system of public transport

The data collection and information base of different cities are different, and actual urgent management needs and specific function realization can also be divided into different stages.

For the cities with inadequate or weak foundation, priority selection and realization can be conducted for the following functions: industry statistics analysis and reporting support, financial subsidy support, daily operational monitoring, public transport service level evaluation and so on; for the cities with a certain foundation, the following functions can be gradually improved according to their actual construction status and development needs: transport operation index analysis of road, sharing analysis of various kinds of transport investigation data, accident analysis and safety management decision support, public transport indicator system; for the cities with relatively perfect system construction, they can actively explore the mode dominated by government with market-oriented operation, strengthen the cooperation with Internet enterprises, make full use of the data and sources of enterprises, build a more comprehensive and reliable decision support application system, and thus realize individual travel chain and group travel behavior analysis, public transport emission monitoring and analysis, analysis of bus driver's driving behaviors, public transport network adjustment and optimization based on big data, transferring passenger flow monitoring and public transport supply capacity analysis and other custom functions.

(4) Transit signal priority system

The effect of transit signal priority depends on urban road conditions, traffic flow conditions, intersection design and the data sharing degree of enterprise dispatching system. Actually considering the above factors, scientific and reasonable signal priority strategy and realization means should be determined according to the local conditions through evaluating the possible influence of signal priority on transport system.

Taking into account the accurate positioning signal control process required for uninterrupted buses, it recommended the establishment of real-time data exchange channel between the signal control system and public enterprise dispatching system.

Taking into account uninterrupted accurate positioning for public transport vehicles during signal control process, it is suggested to set up a real-time data exchange channel between signal control system and public transport enterprise dispatching system.

(5) Bus lane management system

According to the construction layout of bus lane and bus lane management system in different areas, two means of on-board capturing equipment and roadway capturing equipment are used to guarantee right of public transport roads. Bus lane management system is a cross-sectoral application system, involving public transport enterprises, transport industry management department and public security transport department; the background system dominated by roadway capturing is generally managed by transport management department in a unified way.

According to the principle of "adjusting measures to local conditions, making construction in steps as required", general construction suggestions are given for urban intelligent public transport system, as shown in Table 6-7 and Table 6-8. Among other things, basic type system/equipment refers to those system functions and information collection equipment that shall be first established for the urban intelligent public transport system; optional type system/equipment refers to those corresponding system functions and information collection equipment that are added for the city with basic type systems/equipment according to actual demands.

Table 6-7 Construction Suggestions on Application System and Data Center

Application system	**Subsystem**	**Construction Suggestion**
Public transport information service system	Basic information inquiry subsystem	Basic type
	Travel route planning subsystem	Basic type
	Transport hub information inquiry subsystem	Basic type
	POI (Point of Interest) inquiry subsystem	Optional type
	Personal travel customized service subsystem	Optional type
	News bulletin promotion subsystem	Basic type
Public transport intelligent dispatching system	Intelligent dispatching subsystem	Basic type
	Operation monitoring subsystem	Basic type
	Statistical analysis and auxiliary decision-making subsystem	Optional type
	Basic information management subsystem	Basic type
Public transport decision support system	Statistical analysis and reporting support subsystem of public transport industry	Basic type
	Public transport fiscal subsidies support subsystem	Basic type
	Public transport development and service level evaluation subsystem	Basic type
	Daily operation monitoring subsystem	Basic type
	Road traffic operation index analysis subsystem	Optional type
	Traffic survey data sharing and analysis subsystem	Optional type
	Accident analysis and safety management decision support subsystem	Optional type
	Public transport index analysis subsystem	Optional type
	Personal travel chain and group travel behavior analysis subsystem	Optional type
	Public transport energy consumption and emissions monitoring and analysis subsystem	Optional type
	Public transport driver's driving behavior analysis subsystem	Optional type
	Public transit network adjustment and	Optional type

	optimization subsystem based on big data	
	Transferring passenger flow monitoring and public transport supply capacity analysis subsystem	Optional type
Transit signal priority system	Vehicle detection subsystem at the intersection	Basic type
	Public transport vehicle positioning subsystem	Basic type
	Signal priority application subsystem	Optional type
	Planning strategy making subsystem	Optional type
	Signal control subsystem	Basic type
Exclusive bus lane management system	Basic information management subsystem	Basic type
	Snapshot management and analysis subsystem	Basic type
	System operation and maintenance management subsystem	Basic type
	System management subsystem	Basic type
Data center	Data access	Basic type
	Data processing and integration	Basic type
	Data storage	Basic type
	Opened sharing interface	Basic type

Table 6-8 Construction Suggestions on On-board Equipment and Field Equipment

Information sensing system	On-board intelligent service terminal			Basic type
	Expanded equipment	Charging and settlement equipment	IC card equipment	Basic type
			Intelligent slot machine	Optional type
		Video monitoring equipment		Basic type
		Information distribution equipment		Basic type
		Passenger counting equipment		Optional type
		Public transport signal priority on-board equipment		Optional type
	Communication equipment	Cellular mobile network communication equipment		Basic type
		On-board wireless equipment		Optional type
	Roadside sensing equipment			

After establishing the actual requirements, system users who have intelligent public transport system construction and application experiences generally face a problem, how to deal with the existing systems. The decision-tree approach is proposed to solve this problem. Main decision rules are as follows.

（1）If the existing system can both match the current demands and development needs in the foreseeable future.

（2）While the existing system can match system users' demands to a certain extent, if the cost of system upgrades is less than the cost of building a new system. The cost of system upgrades is as follows.

1）Cost of software development in order to extend thefunctions of existing system.

2）Hardware expense in order to maintain system performance

3）Necessary cost of developing data interfaces.

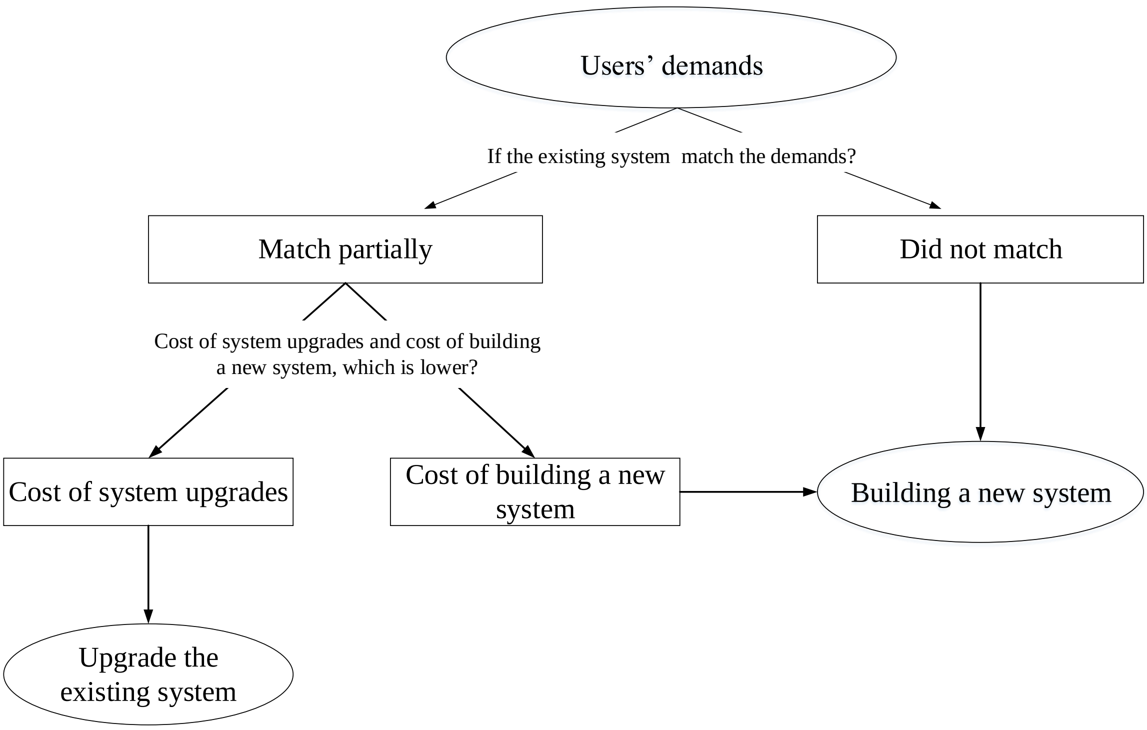


Figure 6-14 decision-tree approach

6.9 System Construction Mode

According to the status investigated in several cities, system construction modes are described as follows.

Table 6-9 system construction modes

System	Construction Modes	Explanations	Suggestions
Information Sensing System	● government investment mode	Government investment mode means all the cost of syst	According to the actual local co

	● government subsidy mode ● resource exchange mode	em construction is borne by the government; government subsidy mode means part of the cost is borne by the public transport enterprise, the rest is subsidized by the government; resource exchange mode means the public transport enterprise uses benefit of advertisement and data to exchange the cost of system construction from the third party.	nditions, choose the most appropriate mode.
Information Service System	● government investment mode ● Internet firm investment mode ● Government-enterprise Cooperative mode	Government investment mode is mentioned in information sensing system; Internet firm investment mode means Internet firm establishes the system to provide information service and earns profits; government-enterprise cooperative mode means government opens part of data resources to enterprise which can provide information services to public and customized services to departments in charge of transportation.	When conditions permit, government-enterprise Cooperative mode can be used to establish information service system.
Intelligent Dispatching System	● government investment mode ● government subsidy mode ● resource exchange mode ● purchasing service mode	Government investment mode, government subsidy mode and resource exchange mode are mentioned in information sensing system; purchasing service mode means system user can purchase customized services from the third party.	According to the actual local conditions, choose the most appropriate mode.
Decision Support System	● government investment mode ● government-enterprise cooperative mode ● purchasing service mode	Government investment mode and government-enterprise cooperative mode are mentioned in information service system; purchasing service mode is mentioned in intelligent dispatching system.	According to the actual local conditions, choose the most appropriate mode.

Signal Priority System	● government investment mode ● purchasing service mode	Government investment mode is mentioned in information sensing system; purchasing service mode is mentioned in intelligent dispatching system.	According to the actual local conditions, choose the most appropriate mode.
Bus Lane Management System	● government investment mode ● government subsidy mode ● purchasing service mode	Government investment mode and government subsidy mode are mentioned in information sensing system; purchasing service mode is mentioned in intelligent dispatching system.	According to the actual local conditions, choose the most appropriate mode.

6.10 Cost-benefit Analysis

For construction and application of the urban intelligent pubic transport system, interested parties include public transport enterprises, competent departments of industry, travelers and Internet enterprises. See Table 6-10 for cost-benefit analysis for each interested party.

Table 6-10 Cost-benefit Analysis for Intelligent Public Transport System

Interested party	Costs		Benefits	
Public transport enterprises	Direct	✧ Initial expenses ✧ Construction costs ✧ Operation and maintenance costs ✧ Other costs	Management cost savings	✧ Intelligent organization and dispatching, reduced transportation costs ✧ Reduced staff costs
			Management capacity improvement	✧ Enhanced dispatching capabilities ✧ Improved emergency response capabilities ✧ Increased resource utilization

	Indirect	✧ Time investment of enterprise in development stage ✧ Accumulation of technology and talents in enterprise accumulation	Employee satisfaction	✧ Reduced power of work, reduced repetitive work ✧ Improved working environment
Public transport passengers	Direct	✧ Waiting time ✧ Journey time	✧ More reliable in travel, securer in time ✧ More convenient in travel, securer in speed ✧ More comfortable in travel, more prefect in information service ✧ More environment-friendly in travel	
	Indirect	✧ Psychological feelings ✧ Riding experience		
Competent departments of industry	Direct	✧ Financial support to enterprises ✧ Costs for decision-making system model development ✧ Costs for decision-making system construction and maintenance ✧ Costs for purchasing Internet enterprise's service	Improved supervision and management capability	✧ Achieved dynamic supervision and management, more efficient management ✧ Making full use of data value, more scientific decision-making
	Indirect	✧ Policy support ✧ Data sharing	Relieving traffic congestion, Promoting energy conservation and emissions reduction	✧ Improved road resource utilization, relieved traffic congestion ✧ Improved public

				transport speed, reduced delay ✧ Effect of energy saving and emission reduction emerging, improved public satisfaction
Internet enterprises	Direct	✧ Initial investment ✧ Investment into cloud platform erection ✧ Costs for cloud platform operation and maintenance	✧ Obtaining more complete industry sharing data ✧ Developing more extensive industry market ✧ Creating more abundant derivative services and value	
		✧ Investment to propaganda		

(1) Cost of system construction

In major domestic cities, for example, construction costs of intelligent public transport system are listed in Table 6-10. For reference construction costs of specific system, see the related part.

Table 6-10 Construction Costs for Urban Intelligent Public Transport System in Major Domestic Cities

City size	**City No.**	**Construction content**	**Construction cost (10 thousand Yuan)**
Megacity	C1	Dual-mode on-board equipment updating for 7796 vehicles, upgrade of 12474 vehicle-mounted terminals, dispatching system	11000

	C2	4368 vehicle-mounted terminals, 275 electronic stop boards, dispatching system	5400
Supercity	C3	Reconstruction of 1856 vehicle-mounted terminals, 69 electronic stop boards, dispatching system	3000
	C4	15 sets of vehicle-mounted terminals, BRT camera equipment, dispatching system, BRT dispatching system	3000
	C5	1000 vehicle-mounted terminals, network system, dispatching system, video monitoring system, enterprise ERP system	3500
Type Ⅰ big city	C6	1200 vehicle-mounted terminals, 20 electronic stop boards, 628 sets of video monitoring equipment, dispatching system, network system	4800
	C7	3067 sets of on-board passenger flow data acquisition equipment, WIFI equipment, 300 electronic stop boards, dispatching system, comprehensive analysis system	4600
	C8	5232 vehicle-mounted terminals, dispatching system	5300
	C9	2290 on-board videos, 40 cameras, 30BRT vehicle-mounted terminals, dispatching system, BRT monitoring system, video monitoring system	4800
Type Ⅱ big city	C10	286 sets of vehicle-mounted terminals, 180 IC card swiping devices, 40 stop dispatching terminals, 200 BRT terminals, dispatching system, BRT system, enterprise ERP system	3500
	C11	1127 vehicle-mounted terminals, 50 sets of bus lane capture equipment, dispatching system, enterprise ERP management	3500
	C12	1130 vehicle-mounted terminals, 1130 sets of	5500

		passenger flow data acquisition equipment, card swiping device, 100 electronic stop boards, dispatching system, EPR system, etc.	

(2) Carbon Emissions

The construction of APTS can improve operational efficiency of public transportation system and reduce the energy consumption of public enterprises, promote energy-saving and emissions-reducing of the city and the public transportation enterprise.

1）The application of intelligent scheduling system can optimize the operation plan and improve the operation efficiency. Operation plan of public transport system affects the consumption of energy. Bus which travel in a reasonable full load rate and the economic speed can save energy and reduce emissions. According to the survey, the invalid mileage of bus accounted for more than 13% of the total mileage. Bus intelligent scheduling system, can develop operational plans and improve the bus load rate according to passenger flow, thus can reduce the invalid mileage of vehicles. Therefore, it can reduce the total energy consumption and total emissions of enterprises. Increasing of passenger flow can reduce energy consumption and emissions per kilometer. According to the operation efficiency of intelligent dispatching system, it can save the energy consumption of 10%-40%.

2）Public transportation information service system and bus lane management system can improve the operation condition and the service level of public transport, thus improve the sharing rate of public transport and reduce the proportion of car travel. Accordance to the data of the IFEU (2008D), the emission factors of load regional bus is 25 gCO2 / PKM (rated load 25 passengers). According to the ICCT (2011) , the factor of Chinese car emission is 226 gCO2 / PKM (gCO2 / passenger- km). For example, With 300 million populations in large cities, day public transportation passenger is about 180 million people, per capita travel distance is about 10km, assuming bus share rate is increased by 5% per year. Every day 9 million people used to by car travel change to take bus, annual CO2 emissions will reduce about 66 thousand tons.

3）Application of bus signal priority system can make public transit vehicle priority. Due to the impact of traffic signals at the intersection of the signal, the vehicle will experience deceleration - stop - idling - acceleration process, in those process, the vehicle fuel consumption and exhaust emissions will increase. Taking the data of 18 meters bus as an example[1], the average emission rate of CO2 is 2g/s in idle speed and deceleration mode, which is 1/12 of acceleration process. When the vehicle travel with a constant speed, the average quality of CO2 is 5g/s. Construction of the bus signal priority system, can give priority signal to transit vehicles. Take the big city with 2000 buses as an example, the

1 Li Jin, Li Mengliang. Research on 18-Meter-Long Bus Real-Road Emission. Journal of Shanghai University of Engineering Science. Vol.22 No .4.Dec.2008.

average running time of the bus per day are 5 times, assuming that each bus will reduce the process of the reduction - stop - acceleration process in 2 intersection, the annual CO_2 emissions decreased are about 690 tons. In intersection with no priority signal, the intelligent transportation system of traffic information and intersection signal prior can remind the driver began to slow down when the vehicle arrive a proper distance away from the intersection which can reduce bus of vehicle fuel consumption and exhaust emissions.

4）Application of energy-saving and new energy bus can effectively reduce energy consumption and emissions. Pure electric buses are no emissions. According to estimates, the annual reduction of emissions is about 16 tons per bus. According to the notification of Finance Ministry about accelerate the popularization and application of new energy bus, in key areas and key provinces of air pollution control, the new energy bus should reach 50% in 2016. Take the big city with 2000 buses as an example, when it has 1000 new energy buses, the annual CO_2 emissions will decrease about 16 thousand tons.

7 Information Sensing System

Information sensing system is the basis for construction and application of intelligent public transport system. On the basis of full investigation and research, this chapter will analyze existing problems and demands on construction and application of information sensing system, sum up application scenarios of information sensing system, highlight information sensing system architecture meeting requirements of intelligent public transport system application and functions and performance of on-board intelligent service terminal serving as the main part of information sensing system, as well as give construction suggestions for reference.

7.1 Present Survey Situation

This chapter will summarize the investigation and study of information sensing system from three angles of overall situation, individual demand and interconnection and interworking.

7.1.1 Overall

On-board terminal is the foundation of the public transport intelligent; it is the important precondition for determining the overall system intelligent.

By material study and field investigation, the following 28 cities which belonging to large, medium and small sizes, all cities installed intelligent service terminal. Among them, there are 15 cities whose intelligent service terminal installation rate reached 100%, accounting for about 54% of the investigated cities; 6 cities whose intelligent service terminal installation rate reached 80% to 100%, accounting for about 21% of the investigated cities; 5 cities whose intelligent service terminal installation rate are 50% to 80%, accounting for 18% of the investigated cities; 2 cities whose intelligent service terminal installation rate are less than 50%, accounting for 7% of the investigated cities, see Figure 7-1.

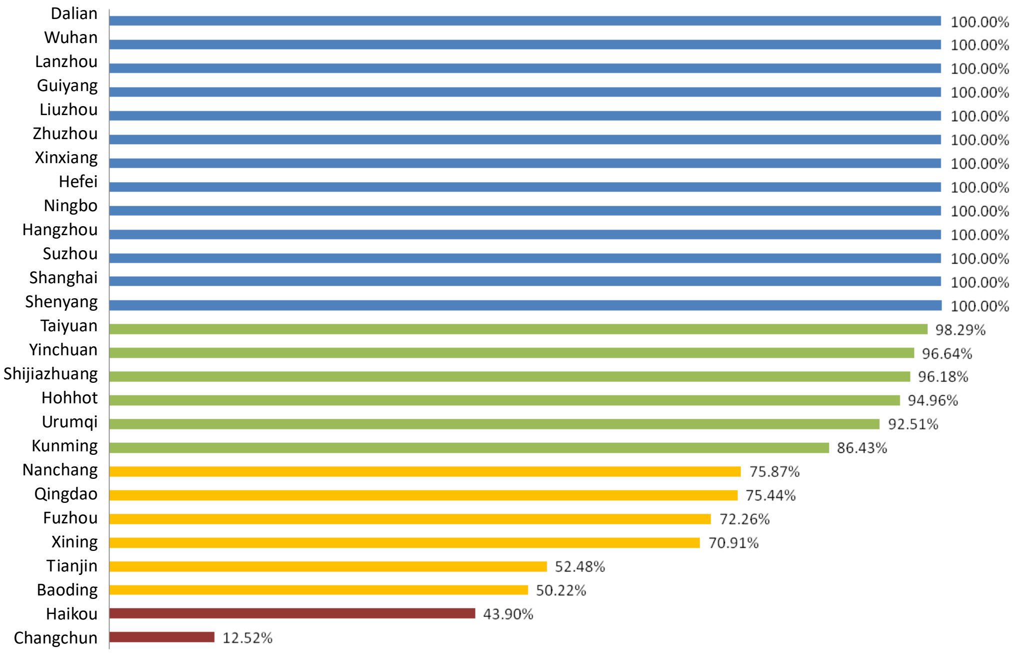


Figure 7-1 Intelligent Service Terminal Installation Rate

About video device, there are 65% of the 28 cities who installed video device, among which one-third installation rate up to 100%, see in Figure 7-2.

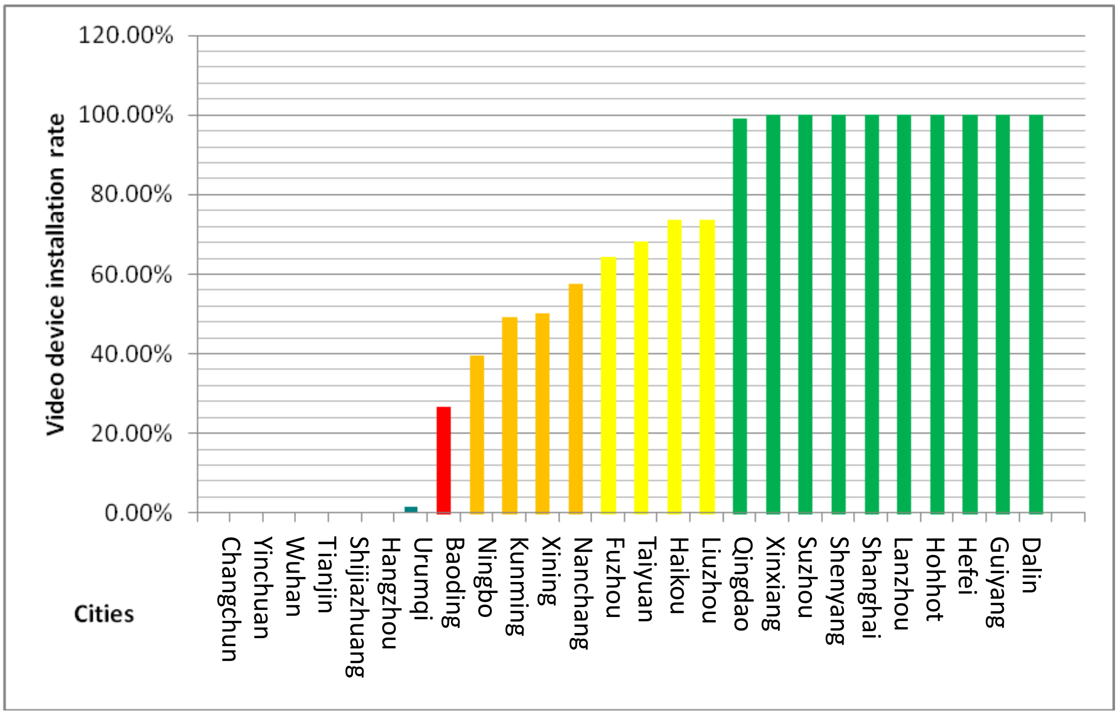


Figure 7-2 Video Device Installation Rate

About IC card swipe device, all cities installed IC card swipe device, among which the installation rate of 74% cities over 90%. In addition, 6 cities install smart corn machine, three cities installed integrated intelligent service terminal.

7.1.2 Individual Needs

Apart from intelligent on-board service terminal, video equipment, IC card equipment, intelligent slot machine, Media Player equipment, voice bus stop announcer, LED display in vehicle, electronic signs and other equipment has been installed in most cities. Other on-board equipment has also been installed in some of the urban public transport enterprises according to their needs.

1) Suzhou

To strengthen vehicle fuel management and driver assessment management, some of public transport enterprise in Suzhou have installed electronic fuel gauge to automatically collect the remaining fuel volume in the tank and upload it to server for fuel volume regulation and driver fuel saving assessment. After 2011, the public transport vehicles purchased by Suzhou City from Suzhou Jinlong Passenger Car Factory are equipped with G-BOS system, integrating the use of vehicle parts sensor, GPS, GPRS and GIS technologies and focusing on the real-time monitoring and analysis of vehicle maintenance performance and driver's driving behavior, with the monitoring and statistical analysis functions of fuel volume, vehicle location, speed of vehicle, rotation speed, brake, door opening and closing, mileage and other data.

In practical application process, some of public transport enterprises in Suzhou have installed radio frequency identification equipment in vehicles for supplement to solve data loss, poor accuracy and other problems due to instable GPS signal and signal shielding, and good results have been achieved at the beginning. However, the implementation effect has gradually decreased due to failure of radio frequency label battery. To make more accurate statistics of the passenger flow, use the slot machine with a counting function, and make statistics of getting-off passenger flow using video identification passenger flow counting equipment at the rear door. However, the real-time uploading of passenger flow has not been implemented.

2) Shenzhen

Landmark requirements have been proposed in Shenzhen City, its public transport enterprises can select to install vehicle condition monitoring devices (fuel sensor, temperature detector, smoke detector, tire temperature and tire pressure detector), wireless short-range communication devices, passenger flow acquisition devices after configuring necessary equipment, and support the collection, processing and transmission of its information.

7.1.3 Interconnection and Interworking

The vehicle terminal intelligentization of some cities has been promoted, and the kinds of collected information are no longer single. Vehicle running information and passenger information can be collected through on-board terminal and the interconnection with the outside can be achieved.

1）Guangzhou

In Guangzhou on-board terminal can obtain the vehicle electric data, and realize short-range auxiliary positioning and vehicle road (station) awareness through connection with CAN bus, can, Furthermore it can realize accurate positioning and passenger service based on the mobile Internet through connection with Wi-Fi and Bluetooth and so on.

2) Zhuzhou

The hardware equipment of intelligent public transport management system in Zhuzhou City adopt standard on-board CAN bus which has been internationally accepted, realizing online work with GPS on-board terminal, bus stop announcer, bus stop LED display, driving status monitor, rolling screen inside / outside the vehicle, LED display at the head of vehicle, IC card reader, on-board video and other on-board electronic equipment.

7.2 Summary of Experience

(1) The installation rate of information sensing equipment is high

Information sensing equipment is the core foundation of urban intelligent public transport system construction and the part accounting for a large amount of investment in system construction. It can be know through investigation and study that the installation ratio of intelligent public transport on-board equipment in large and medium-sized cities is relatively high, and intelligent on-board service terminals, video equipment, IC card equipment, media playback device, voice bus top announcer, on-board LED display, electronic road signs and other equipment have been basically installed in these cities, initially realizing the collection and services of public transport information.

(2) Personalized needs are high

Apart from intelligent on-board service terminal, video equipment and IC card equipment, Media Player equipment, voice bus stop announcer, LED display in vehicle, electronic signs and other equipment has been installed in most cities. Passenger flow collecting equipment, intelligent slot machine, electronic fuel gauge, CAN bus, assistant positioning equipment, WIFI and other communication equipment have been installed according to their own needs, achieving the collection of fuel volume, passenger flow and other information and providing wireless Internet access and other information services.

(3) The interconnection and interworking of products are being improved

The intelligent service terminal and expanded equipment purchased by urban public transport enterprises are from different equipment manufacturers. The interface protocols of the expanded equipment are not uniform due to different manufacturers, directly resulting in very heavy tasks of interconnection and interworking between on-board terminal and expanded equipment. Today, the application of CAN bus can effectively solve the data exchange problem between intelligent service terminal and expanded equipment.

7.3 Problem and Requirement Analysis

Due to lack of standard constraints and quality release and certification by authorities, products on vehicle-mounted equipment market are diversified and have different function parameters and specifications, no unified equipment interface and poor replicability, which leads to difficult engagement between equipment, difficult system upgrade and other problems. Therefore, sustainable development of the intelligent public transport system is seriously restricted.

(1) Low positioning accuracy

The positioning data of intelligent dispatching system is mainly from GPS. However, since bus is running on the urban roads, buildings such as tall buildings and viaduct interfere the GPS signal. The Signal reflects and generates noise, affecting the system positioning accuracy, leading to signal disappear, running track disorders and other phenomena, and then affect the system efficiency and the accuracy of statistical data.

(2) Assisted positioning device layout unclear

Laying the assisted positioning device, using the technologies such as AGPS、WIFI、Zigbee can realize the vehicle assisted positioning, which makes up the lack of instable GPS signal. But due to the influence from communication technology, communication network and some other factors, the layout of assisted positioning device greatly affected the stability and accuracy of positioning signal. Multi-point layout is sometimes necessary to determine the vehicle position, so the layout of the assisted positioning device still needs to be clarified.

(3) Low stability of intelligent service terminal

The current vehicle dispatch terminals use GPRS to communicate, limited by GPRS bandwidth, it often appears offline, as a result, dispatch center cannot grasp the real-time vehicle traffic condition, nor can it release dispatch instruction to vehicles. In addition, due to the lack of uniform standards for certification in line with business needs, there is a large gap in functionality and performance between different vehicle dispatch terminals, the failure rate of vehicle equipment is high, and the interconnectivity between vehicle dispatch terminals and other vehicle equipment from varied production enterprise remain to be improved.

(4) The strong needs of on-board system connectivity

The equipments need connect with each other with interface standards including intelligent service terminal, IC card swipe device, stop signs, electronic toll machine, coin machine, bus priority extension equipment, media player and so on.

(5) The model selection of passenger flow collecting equipment is not clear

The distribution of public transport passenger flow does not only affect the running organization of urban public transport vehicles, but also the planning and adjustment of urban public transport lines. In demonstration project pilot cities of urban public transport intelligent application, some cities hope to get public transport passenger flow running data to support real-time dispatching and decision analysis. Traditional passenger flow collecting methods include artificial investigation of passenger flow data and collection of IC card swiping passenger flow data, but the cycle of artificial investigation is long, the data is not accurate, and the collection of IC card passenger flow data is limited to the proportion of number of card swiping people, POS machine transformation and ticket system reform, so public transport passenger collecting equipment emerges as the times require. However, the public transport passenger flow collecting equipment is still at an initial stage currently, and there are some problems in equipment selection.

7.4 Overall Architecture

This chapter will introduce the application scenario of information sensing system, and then clarify the service functions that information sensing system should have, and finally give the overall architecture of information sensing system.

7.4.1 Application Scenario

- **Application scenario I: on-board information sensing system**

Install intelligent on-board service terminal, video equipment, IC card equipment, Media playback devices, voice announcer, on-board LED display, electronic road signs, passenger collecting devices, intelligent slot machines, electronic fuel gauge, CAN bus, WIFI and other communication equipment in buses and electric buses to collect driver status information, vehicle speed, mileage, vehicle condition, driver operation information, passenger flow information, charging and settlement information, image information, audio and video information; communicate with dispatching center through GPRS and other cellular mobile network or wireless LAN to realize real-time operation monitoring, dispatching and passenger information services.

- **Application scenario II: roadside information sensing system for assistant positioning**

Assistant positioning can be applied to the following two scenarios: one way is to install roadside sensing equipment in GPS signal blind areas below viaduct, building and tree, the roadside sensing equipment will communicate with on-board sensing node when vehicles enter the communication range of roadside sensing equipment, upload the vehicle information and the position information of the current roadside sensing equipment to dispatching center for assistant positioning. Another way is to rationally install assistant positioning equipment in bus station and halfway station platforms according to the site environment, communicate with the on-board nodes in the station platform, and achieve assistant positioning, accurate positioning, sensory information return and other functions.

- **Application scenario III: roadside information sensing system for signal priority**

Roadside sensing equipment is installed in front of the intersection of signal light and used for sensing whether the bus has entered the range of intersection. When the vehicle is approaching the intersection of signal light, roadside sensing equipment will communicate with on-board sensing node, and send vehicle information to intersection for public transport priority signal decision.

7.4.2 Service Functions

The project team has investigated and studied the intelligent service terminals of mainstream intelligent service terminal production enterprises such as Qingdao Hisense Group, Zhengzhou Tiamaes, Newcom Traffic Technology, Nanjing Putian Telecommunications, Anhui Fuhuang Hollysys Technology, Xiamen Information Port, Dalian Zhida Technology and Shenzhen Changtong Yida, summarized the functions of all intelligent service terminals, and it can be known that intelligent service terminal should include the following six functions in combination with the needs of intelligent public transport needs:

1) Basic functions: including self-check, terminal management, positioning, communications, information collection, human-computer interaction, monitoring, and calling;

2) Real-time operation monitoring functions: including warning alarm, remote inspection reply;

3) Public transport operation dispatching functions: including scheduling information reception, assistant dispatching, multi-line operation, operational region monitoring;

4) Bus stop announcing and passenger information service functions: including automatic and manual station announcing, voice services, information distribution;

5) Public transport signal priority response function;

6) Data management functions.

Roadside sensing equipment has communication function, roadside assistant positioning function, station video monitoring and signal priority vehicle sensing function

Mobile sensing equipment has positioning function, communication function, data acquisition function (including mobile terminal travel chain data, user search data, bus pass card-swiping data, etc.)

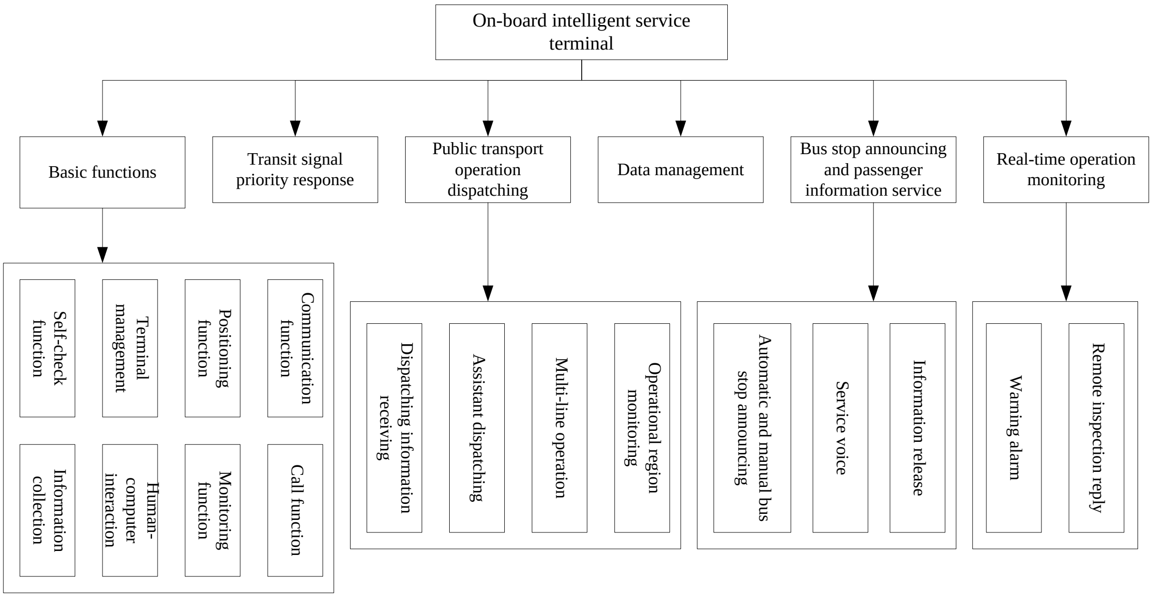


Figure 7-3 Function Requirements for Intelligent service terminal

Information collection can be used to collect the basic information including driver status information, vehicle speed, mileage, vehicle condition and driver operation information as well as passenger flow information, charging and settlement information, image information, audio and video information.

Specifically including:

(1) Equipment self-check

The intelligent service terminal has self-check function, monitoring the main modules of equipment and peripheral equipment in real time and reporting the software and hardware versions and equipment self-check status to the dispatching center in the case of abnormal case or failure.

(2) Terminal management

1) Parameter configuration

The parameters of intelligent service terminal can be modified and configured manually by dispatching center or the local part. When any parameter read by the equipment is illegal, the human-computer interface will give an error message and automatically restore the parameter to default value.

2) Terminal time checking

There are two time checking means for intelligent service terminal: check the time according to the standard time in satellite positioning data received or the time checking package issued by dispatching platform. The dispatching center will automatically issue time checking package to check terminal time after the terminal has been registered successfully; later, the terminal time checking will depend on the standard time of satellite positioning data.

3) Remote upgrading

Intelligent service terminal has hardware updating or remote updating function.

(3) Positioning

Intelligent service terminal is equipped with positioning module, supporting GPS positioning or BDS / GPS dual-mode positioning system:

1) These modules can provide real-time time, longitude, latitude, speed, elevation and direction and other positioning status information, and they can be stored to the internal of terminal and updated to operation dispatching center;

2) They can receive the positioning requests from one or more dispatching or monitoring centers, conduct or terminate the updating of positioning information;

3) When the communication is interrupted or after entering a blind area, the terminals should store at least 10,000 positioning information by means of first-in first-out, and reporting and updating should be made after restoring communication;

4) Support time, distance interval or uploading of positioning information by means of triggering external time. When the terminal is in a dormant state, positioning information should be uploaded at a certain time interval;

5) The positioning data of alarming vehicles or key vehicles can be uploaded according to the positioning way and interval set by the dispatching center.

The positioning information uploading ways of intelligent service terminal are divided into reporting at regular time, reporting at regular distance, reporting at regular time and distance and real-time positioning, the allowable error of cumulative time in recording time accuracy within 24 h should not be more than 5s.

In order to ensure positioning accuracy, differential positioning can be used to compensating the positioning errors. When the satellite positioning way fails, the roadside sensing equipment with assistant positioning recognition function can be used for assistant positioning.

(4) Communication

Intelligent service terminal can realize the communication of dispatching data and streaming media data. Dispatching data communication is used by dispatching center to set the operation, scheduling and line switching of vehicles. The terminal will upload the positioning data, driver attendance records and other data to the dispatching center, realizing the dispatching function of vehicles by the dispatching center. Streaming media data communication is used to connect the terminal with video server, realizing the remote preview and history data return of vehicle monitoring as well as hardware updating and voice regenerating of 3G or 4G equipment.

At the current stage, intelligent service terminal mainly uses 2G, 3G and 4G communication technologies. Of them, the intelligent service terminal using 2G communication technology can only achieve dispatching data communication, while the intelligent service terminal using 3G or 4G communication technology can achieve dispatching data and streaming media data communication. The terminal generally can support the connection of two access centers. When the communication is interrupted due to some reason, the equipment has automatic reconnection function; if the connection is not achieved successfully after the number connections has reached the set value, another access address will be automatically switched for reconnection.

Some of intelligent service terminals have realized data transmission through WIFI.

(5) Call

Intelligent service terminal realizes calls through human-computer interactive terminal, generally supporting two call modes of GSM call and IP call.

(6) Audio and video surveillance

Intelligent service terminal is connected with audio and video surveillance equipment, realizing the audio and video surveillance for the conditions in the vehicle. In the case of sudden power failure, video equipment can continue working for some time, and video data will be stored in the hard disk. Video data supports local storage, and cyclic covering will be used after full storage. The terminal supports video capturing through USB port or LAN port locally.

The driver can conduct real-time preview via human-computer interactive terminal, switch between single-screen and four-screen modes, and retrieve video for local playback. When triggering the alarm by pressing key or other forms, the active reporting of video can be triggered. The dispatching center can select vehicle and channel numbers via client software for remote preview of vehicle video, as well as capture and play back the historical video of vehicle.

BRT operation vehicles are equipped with monitoring equipment supporting image capturing function. Driver can operate human-computer interactive terminal to perform capturing command or automatic detection for capturing, and the captured image will be actively uploaded to the background. When the image cannot be uploaded due to the interruption of communication, it can be stored in image area; cyclic covering will be used after full storage, and supplementary transmission will be conducted automatically after recovering communication.

(7) Data acquisition and storage

Intelligent service terminal can collect the of current coordinate positions of vehicles, receive the passenger flow information and IC card data from peripheral equipment, support hard disk and SD card data storage, and conduct mileage statistics according to GPS.

(8) Human-computer interaction

Intelligent service terminal is equipped with LCD touch screen, achieving rich human-computer interactive functions.

(9) Warning alarm

When vehicle is too near or far from the vehicle in front of it, deviates from the running track, delays at station, rejects to stop at station, ahead of schedule or behind schedule during running, intelligent service terminal can give driver a hint or warning by voice or information. When the vehicle is over speeding, intelligent service terminal will alert driver to slow down by voice or information and report the over speed report to dispatching center. In addition, intelligent service terminal has video loss alarm, dynamic monitoring alarm, hard disk failure alarm, SD card failure alarm and other functions.

(10) Event reporting

Intelligent service terminal can report the entry, exit, door opening and closing of vehicle, and report door opening during running, door opening outside the station, deviation from running track, delaying at station, rejection to stop at station, running ahead of schedule or behind schedule and other illegal driving behaviors of driver. Meanwhile, driver can report failure, traffic jam, accidents, alarms, fuel filling and other event information via human-computer interactive terminal.

(11) Operation dispatching

Intelligent service terminal can receive the operation arrangement information of this day issued by the dispatching center, and driver can view via human-computer interactive terminal. Before departure, the dispatching center will send departure command to terminal according to the schedule. Departure command includes departure time, vehicle number, return time and other information; meanwhile, terminal can also receive the command of cancelling departure issued by the dispatching center. After receiving departure command, the terminal will alert the driver to depart according to set departure prompt interval, and driver can view the issued departure command via human-computer interactive terminal.

In the line of the vehicle, intelligent service terminal by positioning data in real time to obtain the line of travel of the vehicle location and upload it to the dispatch center, dispatch center on the electronic map in real-time remote monitoring of the operation of the vehicle. When the communication between the terminal and the dispatch center is interrupted for any reason, the terminal will be saved through the site, and the establishment of the site will make history information transmitted to the dispatch center in communication.

After completion of shift operation, the dispatch center for the complete operation of the vehicle to re-plan scheduling grid. In addition, the current intelligent service terminal on the market can support vehicle scheduling across multiple lines

(12) Bus stop announcing

Intelligent service terminal supports manual and automatic bus top announcing forms, and head sign, waist sign, tail sign and vehicle LED display screen will display the information synchronously when announcing bus stop. Intelligent service terminal can store the bus stop announcing voice and LED display data of multiple lines, and it can support 3 languages at most.

(13) Driver check-in or check-out

Intelligent service terminal provides driver with two kinds of check-in or check-out ways: when on-board terminal is connected with IC card machine, driver can swipe employee card at IC card machine for check-in, or swipe employee card at matching human-computer interactive terminal for check-in or check-out.

(14) Passenger flow statistics

Intelligent service terminal can realize the statistics of passenger flow data by stations via the connection with infrared slot machine, IC card swiping machine, video or infrared passenger detector and other passenger flow statistics devices.

7.4.3 System Architecture

(1) Equipment composition

It can be seen from investigation, research, comparison and conclusion that information sensing system of urban intelligent public transport system consists of on-board sensing equipment, roadside sensing equipment and mobile sensing equipment.

On-board equipment mainly includes vehicle-mounted service terminal of urban bus and electric bus as well as the following all or part of equipment:

1) Charging and settlement equipment, such as electronic toll collection equipment and slot machine for passenger;

2) Information distribution equipment, such as the bus stop information display equipment, line information and vehicle running position display equipment;

3) Passenger counting equipment;

4) Public transport signal priority on-board equipment, etc.

5) On-board bus lane snapshot equipment, etc.

Roadside sensing equipment mainly includes assistant positioning equipment, station video monitoring equipment and roadside bus lane snapshot equipment.

Mobile sensing equipment mainly includes mobile terminal like mobile phone.

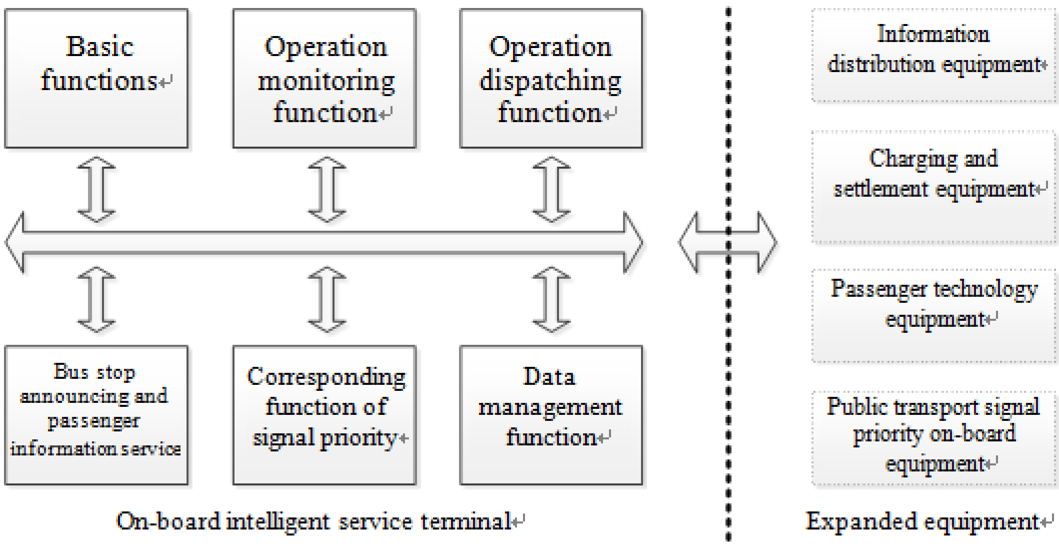


Figure 7-4 Schematic Diagram of Information Sensing System Construction

(2) Communication between equipment

Intelligent service terminal and expanded equipment adopt serial bus for communication, such as half-duplex RS485 bus or CAN bus. Intelligent service terminal communicates with on-board peripheral equipment via serial bus.

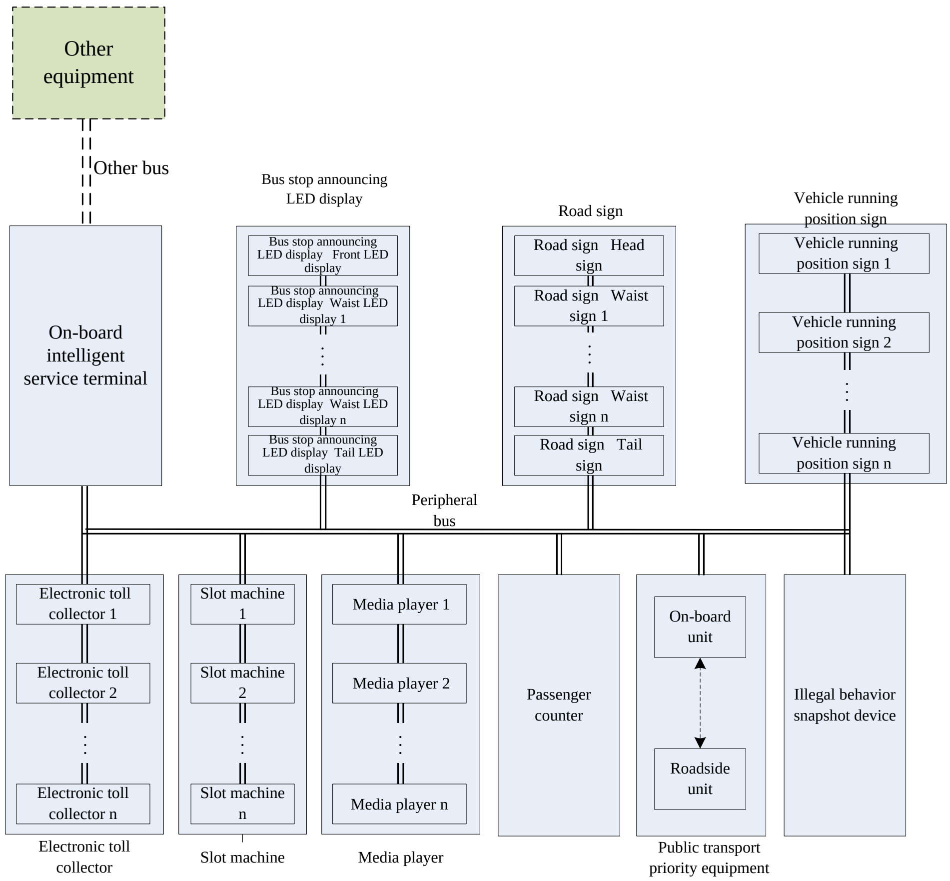


Figure 7-5 Communication Relationship between Intelligent Service Terminal and Peripheral Equipment

(3) External Interface

Considering the expanded peripherals that the public transport industry may connect with and usual maintenance requirements, the type and number of external interfaces of intelligent service terminals should be the most common. To reduce the number of wires, priority should be given to bus way, such as RS485 bus and CAN bus, etc. Taking into account that old expanded peripherals are not equipped with the interface of bus way, RS232 and other interfaces should be reserved to facilitate access of these peripherals, to make full use of existing equipment.

7.5 Suggestion for System Construction

This section will first present the basis and precondition for more effective system, and then give suggestions for the construction of information perception system from the views of configuration of intelligent service terminal, selection of expanded equipment, suggestion for selection of passenger flow collecting equipment and type of mobile perception data collection.

7.5.1 Basis of System Construction

The precondition of influencing the construction of information perception device and making the information perception system more effective is that interconnection is realized between intelligent service terminal and expanded equipment as well as dispatching center.

(1) Interconnection and interworking between vehicle service terminal and expanded equipment

Intelligent service terminal and expanded equipment adopt serial bus for communication, such as half-duplex RS485 bus or CAN bus. Intelligent service terminal communicates with on-board peripheral equipment via serial bus. Interactive data includes route name, stop name, slogans, time and other service information offered to passengers, and brightness control, volume control, speed control, version information and other basic information of terminal device and control information, and attendance data, passenger flow data, engine instrument data, photo-taking data and other business data that are used for background statistical analysis. It also includes the fuel consumption data used for carbon emission analysis and monitoring.

RS485 is more widely used while CAN bus is more stable and reliable with better application prospects (as shown in Table 7-1).

Table 7-1 Contrast between RS485 and CAN Bus

Feature	RS485	CAN bus
Single-point cost	Lower	Slightly higher
System cost	Higher	Lower
Utilization rate of bus	Low	High
Network feature	Single main network	Multiple main network
Data transfer rate	Low	High
Fault-tolerant mechanism	None	Reliable error handling and error detection mechanism
Rate of communication failure	High	Very low
Impact of node error	Paralysis of whole network	No impact
Communication distance	<1.5km	Reach 10km (5kbps)

Network debugging	Difficult	Very easy
Development difficult	Standard Modbus protocol	Standard CAN-bus protocol
Post-maintenance cost	High	Low

(2) Interconnection and interworking between Intelligent service terminal and dispatching center

The intelligent service terminal communicates with dispatching center via one wireless LAN or more in multiple cellular mobile networks such as GPRS, CDMA, TD-SCDMA, WCDMA, CDMA2000, TDD-LTE, FDD-LTE, wired network or WIFI, and can connect with two or more dispatching or monitoring centers simultaneously by the means of IP or domain name. When the local wireless network cannot be registered, data is stored on a first-in and first-out basis until the wireless network is registered and transmitted. If the stored data exceeds maximum capacity, the first stored data should be abandoned in chronological order. Moreover, the terminal should support the functions of receiving and sending data with batch, breakpoint resume and traffic counting and reporting.

7.5.2 Configuration of Intelligent service terminal

For the selection of vehicle perception device, first select the intelligent service terminal. The intelligent service terminal in the market today can be divided into split type and all-in-one type. The selected split machine or all-in-one machine should reach the functions required by the abovementioned business in 7.4.2, and have good extensibility.

To meet different requirements for enterprise purchase, the configuration of intelligent service terminal can be classified into A, B and C according to interface requirement, function requirement and performance requirement. A is the most basic configuration, and C is the top configuration. Enterprises should make purchase by reference to their own conditions and requirements and according to corresponding categories, as shown in Table 7-2.

Table 7-2 Configuration of Intelligent Service Terminal

No.	**Required item**		**Configuration category**		
			A	**B**	**C**
1	Interface requirement	RS485	√	√	√
2		RS232		√	√
3		USB HOST	√	√	√
4		CAN BUS		√	√
5		Audio input	√	√	√
6		Audio output	√	√	√
7		Video input		4	8
8		Digital input		√	√
9		Digital output		√	√

10		Wireless LAN interface					√
11		LAN interface					√
12	Function requirement	Basic function	Self-checking		√	√	√
13			Terminal management		√	√	√
14			Positioning		√	√	√
15			Communication		√	√	√
16			Information collection	Identity information of driver	√	√	√
17				Vehicle speed	√	√	√
18				Mileage	√	√	√
19				Vehicle state		√	√
20				Operating information of driver			√
21				Passenger flow information			√
22				Charging and settlement information		√	√
23				Image information		√	√
24				Audio information		√	√
25				Number of video information channel		4	8
26			Man-machine interaction		√	√	√
27			Monitoring function			√	√
28			Voice function		√	√	√
29		Operation and monitoring function	Warning alarm	Artificial alarm	√	√	√
30				Over speed alarm	√	√	√
31				Alarm for rejection to stop at station	√	√	√
32				Alarm for opening door outside of stops	√	√	√
33				Alarm for opening door during driving	√	√	√
34				Alarm for line deviation	√	√	√
35				Fast acceleration		√	√
36				Fast deceleration		√	√
37				Sharp turn		√	√
38			Remote inspection			√	√
39		Public transport operation dispatching function			√	√	√
40		Bus stop announcing and passenger information service function			√	√	√
41		Transit priority					O
42		Data management	Record		√	√	√
43			Covering		√	√	√

44		function	Inquiry			√	√
45			Playback			√	√
46			Export		√	√	√
47			Disaster delivery				O
48	Working performance	Overall performance			√	√	√
49		Positioning			√	√	√
50		Communication			①	②	③
51		Basic information			√	√	√
52		Image information				√	√
53		Video Information		Quality requirement for video playback		④	⑤
				Total resource requirement for video recording		√	√
54		Dispatching information reception			⑥	√	√
55		Multiline information storage				√	√
56		Stop report			√	√	√
57	Electrical performance				√	√	√
58	Electromagnetic compatibility				√	√	√
59	Environment adaptability				√	√	√

Notes: The item with "√" in the table means that the corresponding category needs to support it, with "O" means optional, and the number refers to the minimum quantity in which this item needs to be supported;

1) ① means that only GPRS is supported;

2) ② means that GPRS/WCDMA/TD-SCDMA/CDMA need to be supported;

3) ③ means that all the required networks are supported;

4) ④ means that the minimum resolution is 704*576 (D1);

5) ⑤means that the minimum resolution is 1280*720;

6) ⑥ means that audio report is not included.

In order to make sure the terminal has good extensibility, the quantity of terminal interface which businesses select should at least meet the requirements in Table 7-3.

Table 7-3 Quantity Requirements for Terminal Interface

No.	Interface type	Minimum quantity of interface	Interface specification
1	RS485	1	It is used for connecting and controlling the expanded

			equipment.
2	RS232	2	It is used for connecting and controlling the expanded equipment.
3	USB HOST	1	It is used for importing and exporting system maintenance and data.
4	CAN BUS	1	It is used for connecting the vehicle's own control computer, reading vehicle state information, or interconnecting information terminal and expanded equipment.
6	Audio input	4	It is used for connecting the pickup, and collecting audio information in the compartment.
7	Audio output	3	It is used for connecting the loudspeakers inside and outside of vehicle and the driver's loudspeaker, and reporting voice information.
8	Video input	4	It is used for connecting the camera, collecting video information in the compartment.
9	Digital input	8	It is used for collecting the vehicle ACC signal, reversing signal, emergency alarm signal, signal from passemger rescue button, signal from coin box state, etc.
10	Digital output	1	It is used for controlling the alarm turning on, etc.
11	Wireless LAN interface	1	It is used for connecting with the wireless device of computer.
12	Wired LAN interface	1	It is used for connecting with the computer network device.

For the bus company who started intelligent public transport system construction early, there are many differences in the intelligent service terminal function and performance, and the data interface does not meet the requirements. Update the terminals following the function, performance and interface requirements in the national standard "Urban Public Transport Scheduling Vehicle Information Terminal" (GB/T 26766-2011). Replace or phase out the terminals which cannot be updated.

7.5.3 Selection of Expanded Equipment

According to different vehicle models, refer to Table 7-4 in terms of the configuration quantity of expanded equipment:

Table 7-4 Configuration of Peripheral Equipment

Vehicle model	**Electronic toll collector**	**Coin machine**	**Bus-stop display screen**	**Guide board**	**Display sign of vehicle running position**
Vehicle with a	Not less than	Not less	Not less	Head sign and tail	No

length of 9m long and below	1	than 1	than 1	sign are required, and there must at least 1 waist sign	requirement
Vehicle with a length of 12m long	Not less than 1	Not less than 1	Not less than 1	Head sign and tail sign are required, and there must at least 1 waist sign	Not less than 1
Vehicle with a length of 18m long and above	Not less than 1	Not less than 1	Not less than 2	Head sign and tail sign are required, and the number of waist sign signs should not be less than 2 X-opening sides.	The number of waist sign signs should not be less than 2 X-opening sides.
Double-decker bus	Not less than 1	Not less than 1	Not less than 2	Head sign and tail sign are required, and there must at least 1 waist sign	Not less than 1 at either layer
Others	Not less than 1	Not less than 1	Not less than 1	Head sign and tail sign are required, and there must at least 1 waist sign	No requirement

7.5.4 Selection of Passenger Collecting Equipment

At the present stage, public transport passenger flow monitoring technologies mainly include IC card passenger flow collecting technology, pressure sensing monitoring technology, infrared sensing monitoring technology and video monitoring technology. Among which, IC card passenger flow collecting technology collects passenger service time, corresponding stops and other data. It has the advantages of large data size, high data accuracy, simple technology and low cost. For the enterprise in which the IC card devices are already installed, the IC cards can be used to collect passenger flow data instead of increasing new devices. These enterprises can transfer the IC card data to the dispatching center after connecting the intelligent vehicle-mounted service terminal with the IC card machine.

In order to define which kind of passenger flow collecting technology will be selected when IC card passenger flow collection technology cannot be used, the project team compares the technical working principle of passenger flow collecting device, applied environment and advantages and disadvantages, as shown in Table 7-5.

Table 7-5 Comparison of Passenger Flow Monitoring Technology

<table>
<tr><th colspan="2">Technical proposal</th><th>Working principle</th><th>Applicable environment</th><th>Disadvantage</th></tr>
<tr><td colspan="2">IC card passenger flow collecting technology</td><td>Connect with the card reader system interface of IC card, and collect bus dwell time, stops and other data.</td><td>Higher installation and utilization rate of IC card</td><td>Since the passengers who do not swipe the card on the bus are not included, it is not applicable to the cities with lower installation and utilization rate of IC card.</td></tr>
<tr><td colspan="2">Pressure sensing monitoring technology</td><td>Monitor the body weight, and perceive the existence of human.</td><td>The passenger flow is smaller; get on or off the bus in order.</td><td>Accuracy declines on the crowded bus.</td></tr>
<tr><td rowspan="2">Infrared sensing monitoring technology</td><td>Active</td><td rowspan="2">The sensor detects the human body’s infrared spectrum, gives a pulse signal, and then judges the number of passengers according to signal number.</td><td>It is applicable to the narrow and small channel.</td><td>Accuracy declines when many passengers go through the sensor.</td></tr>
<tr><td>Passive</td><td>There are greater differences between the temperature of counting environment and body temperature.</td><td>The statistical accuracy is no more than 80%, and it is more sensitive to fast-changing ambient temperature and strong sunlight.</td></tr>
<tr><td colspan="2">Video monitoring technology</td><td>Combine stereo-vision information and plane image information</td><td>It can better count large passenger flow information.</td><td>Huge calculation</td></tr>
</table>

According to Table 7-5, it can be known that the IC card passenger flow data acquisition technology is the optimal choice of passenger flow acquisition method at the present stage. Provided that the IC card passenger flow data acquisition technology cannot be used, the stress-sensing technology, infrared sensing technology and video detection technology can be adopted. However the stress-sensing technology and the infrared sensing technology cannot detect passenger flow correctly when there is huge passenger flow, whereas the video detection technology is appropriate to sense passenger flow data in such case.

The project team selected different lines to install the binocular video passenger flow data acquisition device, infrared video passenger flow data acquisition device, infrared weighing passenger flow detection equipment and 3D passenger flow monitoring system based on the stress sensing detection technology, infrared sensing technology and video detection technology. As for its multiple measurements and actual measurement analysis, see Table 7-6 as follows.

Table 7-6 Comparison of Passenger Flow Data Collection Equipment

Passenger flow data acquisition device	**Number of measurement station**	**Calibrated accuracy**	**Measured average accuracy**	**Minimum accuracy of every train**	**Average person number error of every station**	**Cost**	**Installation**	**Maintenance and repair frequency**
Binocular video passenger flow data acquisition device	4train-time, totally 204 stations	95%	98.27%	95.80%	0.07	High	Simple	Medium
Infrared video passenger flow data acquisition device	5train-time, totally 227 stations	Front door 99% Rear door 92%	87.15%	79.70%	0.58	Medium	Complicated	Medium
Infrared weighing passenger flow detection equipment	8train-time, totally 119 stations	92%-97%	86.06%	79.86%	1.29	Medium	Simple	High
3D passenger flow monitoring system	9 train-time, totally 180 stations	99%	94.23%	82.11%	0.33	High	Simple	Medium

According to the measured results, the average accuracy is ranked from top to bottom as follows: binocular video passenger flow data acquisition device, 3D passenger flow monitoring system, infrared video passenger flow data acquisition device, infrared weighing passenger flow detection equipment. However, device with the highest accuracy involves in high cost. When selecting the passenger flow data acquisition device, it is recommended to seek balance point between device cost and accuracy, and measure multiple aspects, such as device cost, data accuracy, device maintenance easiness, product application result. Under the acceptable accuracy, it is recommended to increase equipment layout density and compensate data accuracy shortcoming by acquiring more data.

7.5.5 Mobile Perception Data Acquisition Category

Table 7-7 Acquisition Category and Purpose of Mobile Perception Data

S/N	Acquisition category of mobile perception data	Analyzable	Purpose
1	Mobile phone's data time series Traffic zone division	Entry and exit of mobile phone user in every traffic zone	User travel chain analysis; user travel mode
2	Mobile phone map, APP and other position data Navigation data User search data	User travel frequency and travel time Arrival time estimate	User travel characteristics analysis Information service
3	Mobile travel chain data (time sequence, APP position data) Bus IC card data	User travel OD	Line network adjustment optimization, operation dispatching etc.
4	Position and travel information of mobile phone user of hot spot region Data of transport industry	Connection passenger flow analysis	Passenger flow thermodynamic diagram Operation organization and dispatching

(1) Judge the entry, exit, stay of mobile phone users in every transport analysis zone according to the mobile phone data time series and the matching relation between mobile phone network coverage and transport analysis zone, and analyze the travel modes of users;

(2) Collect mobile phone APP map and navigation user travel information, integrate with user's timetable law and regional land usage to identify the place of residence and working place of mobile phone user, analyze the travel frequency and travel time of user. Integrate with other internet-related behaviors (search etc.) of user to tap user interest preference, analyze user's travel characteristics and travel mode, learn the relationship between those factors, such as user track arrival time and space-time environment, and then estimate the arrival time of travelling user more accurately.

(3) Acquire the single-person travel chain information by analyzing the travel chain of mobile phone data and bus IC card data, and then analyze the travel characteristics of single traveler; conduct the technical research on the travel behaviors of citizens based on the transport

database to acquire the complete bus travel OD data, and then finally provide basis for line network optimization, adjustment, line dispatching, real-time dispatching etc.

(4) Incorporate the bus passenger flow hub, such as airport, railway station, passenger station, transport junction throughout the city into the hot bus passenger flow monitoring scope, and then integrate with the passenger flow data, video data, IC card data controlled by the transport industry, as well as the common people travel data controlled by the internet enterprises to generate the passenger flow thermodynamic diagram, analyze the passenger flow change characteristics of hot area in certain time, and finally supervise the connected passenger flow data.

7.6 System Evaluation & Appraisal Indicators

This part mainly proposes evaluation indicators for vehicle-mounted intelligent service terminals.

7.6.1 Main Work Performance

（1） Positioning accuracy

- Horizontal positioning accuracy not more than 15m;
- Elevation positioning accuracy not more than 30m;
- Speed positioning accuracy not more than 2m/s.

（2） Communication functions

- Support GPS and Beidou communication mode;
- Support one of wireless communication modes, such as GPRS, CDMA, TD-SCDMA, WCDMA, CDMA2000, TDD-LTE, FDD-LTE;
- Maintain at least 10,000 pieces of data when the network is unavailable.

（3） Basic information

- Vehicle speed data should comply with the requirements specified by Section 4.5.1.2 of GB/T 19056-2012.
- Mileage data should comply with the requirements specified by Section of GB/T 19056-2012.

（4） Image information

- Image resolution supports 704×576 minimally;
- Horizontal resolution: ≥400TVL
- Image storage size: ≥2,000 pieces

（5） Video information

- Supports 4-way video recording synchronously
- Video frame rate of every way should not be less than 10fps;
- The vehicle-mounted terminal should record 200hrs' video minimally when all video channels supported actually by the terminal are opened and recording video at the highest frame rate.

7.6.2 Electric Performance

（1）Withstand voltage adaptability

According to the nominal voltage of the device, all functions of the device are normal when the terminal is connected with the maximum and minimum power supply within the range of the fluctuation of voltage.

（2）Withstand power polarity reverse connection

According to the nominal voltage of the device, there is no other electric failure in 1 min when the terminal is connected with the power supply reversely (except for the fuse burnout).

（3）Withstand power source overvoltage

According to the nominal voltage of the equipment, there is no other electric failure in 1 min when the terminal is connected with the overvoltage (except for the fuse burnout). When the overvoltage increases, the short-time function of the terminal will be inactivated, and every function of the device becomes normal after the normal voltage recovers.

（4）Power-off protection performance

When the terminal power is off, the device will trigger its self-protection status; the information stored before power off should be maintained for 15 days at least. When the power failure occurs in the process of terminal line data updating, firmware updating, parameter modification, the processing can be recovered automatically, and the configuration information of the original line will be triggered to announce station or re-update and ensure the terminal to work normally when update fails.

（5） Low-voltage protection performance

When the voltage capacity of vehicle battery is lower than the threshold value, the terminal will stop getting power supply from vehicle battery so as to delay the service life of the vehicle battery and guarantee the vehicle to work normally. When the voltage capacity of vehicle battery exceeds the upper limit of the low voltage threshold valve, the terminal should switch the power supply from the backup battery to the vehicle battery so as to recover the power supply from the vehicle battery.

7.6.3 Electromagnetic Compatibility

（1）Electrostatic discharge interference rejection

The electrostatic discharge interference rejection should comply with the requirements of Category B of GB/T 19951-2005.

（2）Instantaneous disturbance rejection

The instantaneous disturbance rejection should comply with the requirements of Category B of GB/T 21437.2-2008.

（3）Vehicle ignition interference resistance

When the terminal is under the vehicle ignition interference, there is no any unexpectedness, and every function works normally.

7.6.4 Environmental Adaptability

The vehicle-mounted intelligent service terminal is suitable for an open application environment; therefore it should possess the following environmental suitability:

（1）Climatic environment adaptability

When using and storing at high temperature, low temperature or in the dump and hot condition, the terminal should be free of any electric failure, its every function works normally and every data stored in it is not lost.

（2）Mechanical environmental adaptability

When being collided, fallen off, inclined, vibrated or impacted, the terminal should be free of permanent deformation, its part is free of damage and there is no electric failure, all fasteners are not loosened, plugs and communication ports are free of serious deformation, all functions work normally and all data stored in it are not lost.

（3）Protective properties

The protective properties of the terminal should meet the requirements of IP 43 specified by GB/T 4208-2008, namely the terminal could prevent the object with the diameter more than 1mm from entering into the enclosure, and there is no electric failure after its every vertical surface is poured water in a range of 60°, all functions work normally and all data stored in it are not lost.

（4）Disaster recovery unit

- Height limit: 3m
- Temperature resistance: 1,100℃ for 30 minutes.
- Water resistance: IP66 of GB/T 4208-2008, namely it can prevent dirt from entering enclosure and withstand intense water spraying.

7.7 System Construction, Operation and Maintenance Cost

(1) According to market survey in 2014-2015, refer to Table 7-8 for information sensing system construction cost.

Table 7-8 Reference for System Construction Cost

Service field	Equipment			Function	Construction suggestion	Cost (10 thousand Yuan/set)
Informing sensing	Vehicle-mounted intelligent service terminal			Operation dispatching, monitoring, uploading data of expanded equipment to dispatching center	Basic equipment/ function	0.5~1
	Expanded equipment	Charging and settlement equipment	IC card equipment	Charging and settlement	Basic equipment/ function	0.1~0.2
			Intelligent slot equipment		Optional equipment/ function	0.3~0.5
		Information distribution equipment		Bus stop announcing and passenger information service function	Basic equipment/ function	0.2~0.4
		Passenger counting equipment		Passenger flow collection	Optional equipment/ function	0.3~0.5
		Public transport signal priority on-board equipment		Public transport priority response	Optional equipment/ function	0.5~0.6
		On-board WIFI		On-board Internet service	Basic equipment/ function	0.2~0.3
	Roadside sensing equipment			Assistant positioning, signal priority monitoring	Optional equipment/ function	0.2~0.3

(2) Operation and maintenance cost for information sensing system is about 5%-10% of its construction cost.

8 Information Service System

8.1 Present Survey Situation

After recent years of construction, the public transport information service in a lot of city has made more progress. Information service system converts traffic management from simple static management to intelligent dynamic management, which provides travelers real-time traffic information, enhances the public transport attraction and improves the public transport operation efficiency. And service mode converts from simplification to a variety of integrated information services. Information service website and hotline are the channels of traditional information service, most of cities have the basis.

The statistical analysis of the pilot cites of "transit city" show that about 12 cities have been equipped with electronic bus stops, and 17 cities can provide mobile phone APP services.

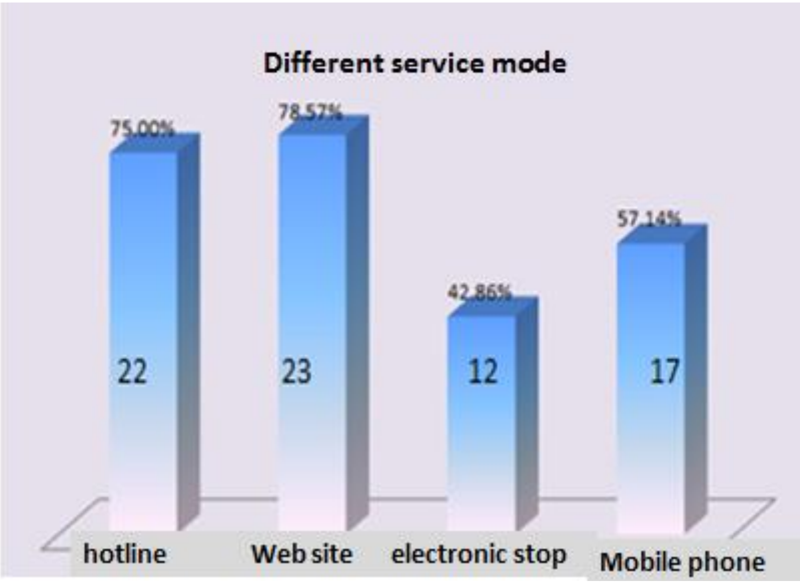


Figure 8-1 The Status of Information Service Mode

In Beijing, for example, during the Olympic Games, Beijing has completed the Olympic transportation service web, Olympic traffic service hotline, mobile phone and other mobile terminals of individual traffic information service system and so on. More effective results have been achieved. The Beijing Municipal Commission of Transport (BMCT) issued the "Beijing public transport" APP that realizes the dynamic information of bus lines, And the BMCT promotes the cooperation with Internet companies.

In Chengdu a certain number of electronic bus stops have been established. The bus companies have accumulated certain experience in operations. They solve problems of operations through the advertisement of auction or maintaining by themselves, In Suzhou, public information service mechanism has been built. It include bus information service website, intelligent terminal software, SMS, touch screen, electronic bus stop and others, Citizens can query the information about bus station and vehicle distribution on a line by different ways, Then they determine the travel plans through these information. In a word, it is convenient for citizens to arrange travel plans to build the multi-channel publishing platform of the bus information which can provide real-time bus travel information.

Furthermore in Shenzhen information service system mainly includes easy net, traffic radio, traffic in hand, transport live television program. A variety of functions have been realized which include bus information query, the traffic information query, path planning, traffic event notification, Travel service is relatively more perfect, and service terminal covers more widely.

A large number of social capital into travel information service market because of the social public increasingly strong demand for travel information service, Baidu, Sogou, Google and other companies provide travel information service for a large user, It plays an important role in convenient people travel. Baidu map service is now covers nearly 400 domestic cities and thousands of counties. It provides the function of query about transferring and most suitable route planning. In addition to the city bus information service, the Baidu maps have also developed the urban traffic basic information services, traffic situation information service, tourism information service, weather information service, complaint and advice service, also looking for service, etc. These make the bus information service more comprehensively.

At present, Baidu map has been increasingly recognized by users. A dominant position in the market shares in the same industry. As of June 2013, the number of daily visits in PC reach to more than 150 million, the number of mobile terminal installed capacity are more than 200 million, with 97 million monthly active users. In the service of ordinary Internet users, the Baidu map provides more than 250000 applications by being called at the same time. Visitors flow rate about external call has exceeded 2 times than the one about Baidu map product itself.

Sogou map is the first domestic public service map websites, data covering nearly 400 cities and 3000 counties, It mainly provides the self-driving route navigation, and the transit services of 130 urban. In addition to basic services such as search, bus, drive navigation, Sogou ma also provides long-distance station, multi-function book store, satellite image, mobile mapping and other characteristics, It can meet the needs of people to master travel information anytime and anywhere. According to the official Chinese Alexa web site statistics, not only the number of daily visits in PC but also the one of PV browsing reach about 7800.

Figure 8-2 Sogou Map Travel Information Service

8.2 Experience Summary

The general development of the Information Service System is introduced as follows:

(1) Unsatisfactory effect of the use of the information service system constructed under the leadership of the competent transport authorities

During the period of the 11th 5-year plan and the 12th 5-year plan, all provinces constructed two critical information projects, namely resource integration project and travel service project. Currently they have already been completed, and the travel information service platform based on the data resource integration has already been put into use. However because of multiple factors, such as the insufficient associated information resource, lagged data updating, unitary service mode, backward technical means, unimproved system functions and poor combination with demands, and even more travel service system provides services at the provincial level, and no travel service platform covering the whole country is available; the travel information service system is not used heavily and satisfactorily and recognized by the society.

(2) Rapid development of the travel information service system constructed by information service enterprise

As the masses' demands on travel information service are continuously increasing, some information technology enterprises march towards the information service fields and thence there are the travel information service products dominated by static-state electronic map search and navigation on the market. Represented by Baidu Map, Sogou Map, Google Map, the electronic map search service has owned plenty of visitors in its actual application, and even has formed the united platforms covering the whole country. For example, Baidu Map covers almost 400 cities and thousands of districts and counties of China. These enterprises are not only good at grasping the core demands of the public, but also own plenty of professional and powerful technical strength, follow closely the development of the information technology and provide new travel service modes, and thence preliminarily form their travel service platform covering the whole country. Besides, their sound foundation and flexible financing allow them to acquire economic benefits from the travel information service and guarantee the benign and sustainable development of the travel service system; certainly their services and products are easier to be recognized by the public.

(3) Popularizing mobile internet technology diversifies information service modes

At present, the development of mobile internet industry is certain to bring unprecedented leap for the public travel information service. In the cities of Beijing, Shanghai and Shenzhen, the mobile internet technology and the smart phone or terminal have already been used to construct the handheld portal so as to provide the special public transport map query, bus line planning, bus transportation status query function on the intelligent mobile terminal, and concurrently provide the real-time bus transportation information query, personalized information query and other information push services via SMS. Such handheld portal provides the convenience to the public, such as handling procedure query, telephone consulting, Microblog sharing, complaint and suggestions, and thence meets the diversified and personalized demands of the public on travel.

(4) The information service system develops towards the one with the user demand as the core

In the times of Internet, more and more transportation information service products are emerging, so travelers have increasing demands on product quality. At present, the development centered on user demands will thoroughly overturn the design mode of the existing transportation information service system. Aiming at providing safe, convenient, comfort and environmental friendly green travel services to citizens, Beijing, Xiamen, Suzhou, on the basis of conventional public transport, is expediting to popularizing the customized public transport. All local authorities improve their customized public transport platform to enhance their service level for passenger organization, seat reservation, online payment, and increase seasonal special route, city tour route according to travel demands to realize the diversified public transport service. In the context of mobile internet and with the new concept and technical guidance, the design of transportation information service system should more focus on user (consumer) demand and proceed from the demands of user, and let user demands affect every application systems of traffic management and transportation infrastructure construction conversely.

(5) Demonstration and application of operation & maintenance modes constructed under government-enterprise cooperation

Travel information service project is characterized by quick service function updating and high operation and maintenance costs. In the traditional sense, the travel information service projects of the transportation industry is constructed and operated by the management department of the transportation industry; however the system functions cannot catch up with the update speed of social services. With the lapse of the time, the operating speed of the system becomes increasingly slow, and user experience becomes worse and worse. Currently, more and more local governments (such as Beijing, Jiangsu, Jilin and Yunnan) realized that the travel information service cannot be constructed, operated and maintained according to the traditional engineering construction thinking, but the difficult projects in the transportation industry are transferred to the internet enterprise good at information operation and maintenance. The two characteristics aforesaid enable information service functions to closely follow up the social development trend, and flexibly adjust performance from time to time based on the system utilization, and thence guarantee the usability and smoothness of travel information service.

8.3 Problem and Demand Analysis

（1）Lack of dynamic information and poor information accuracy

Currently there are not many dynamic data of information service system, and data accuracy of data acquisition instruments could not completely adapt to the demands on travel information service. However there are not yet relevant policies or technical standards in China to limit information accuracy of information service system. Besides, information release not in time may lead to information inaccuracy relative to the road condition under real-time dynamic change.

（2）Difficulty in data acquisition and utilization, and low commercialization level of public transport data

The essential data of public transport travel information service come mainly from industry management department of the government at all levels. The travel service information controlled by the competent department of transport are not efficiently integrated, their standards are not consistent and the policy guidance for external release are still lack; enterprises face with many system and mechanism difficulties or need multipoint coordination when acquiring these information, and data acquisition cost is very high. Additionally, the system established by the competent department of transport focus mainly on industry management, but considers less on travel information service; data source is difficult to be directly used for travel information service. Meanwhile due to the restrictions of laws and systems, as well as the information confidentiality requirements, data release and utilization, especially data commercialization application has a long way to go.

（3）Insufficient guarantee for internal fund and talent of industry

Financial fund investment on information service system grows year after year, but it is difficult to meet the actual demands of information service development under new situations. Meanwhile in the actual operation, there is certain difficulty in raising transportation informatization fund via financial means, including approval procedures, approval time, actual fund scale etc., all of them would affect project progress.

Transportation informatization is not only driven by market, but also by technology. Transportation informatization has higher professional degree, but the technical strength of governmental departments is very limited; therefore it is needed to absorb widely high and new technology enterprise and talent through marketization mode so as to stabilize talent team and maintain technical advancement. Marketization model could let social capital participate in informatization project construction and operation under governmental guidance and benefit driving, and basically solve capital problems of informatization project construction and operation and maintenance problems during project operation period.

(4) Shortage of data sharing mechanism restricts the enhancement of information service system

In order to guarantee the long-acting development of information service system, it is needed to support enterprise’s leading construction and operation; however since the information service system established by enterprise is lack of reliable information source, hiring a huge sweeping-road-troop to acquire data and buying data from other ways as the essential data will cause high data acquisition cost, insufficient authority and unsecured authenticity; therefore it is a must to propose the public transport information service industry dominated by social forces to establish social sharing mechanism for transport welfare information resources as soon as possible, study and propose transport information service pricing mechanism, distribute rationally the utilization earnings of transport information resource, establish service quality supervision mechanism of transport information industry, maintain fair market competition environment, and guarantee transport information service industry to develop in a healthy and ordered way.

(5) Needing to enhance standardization works of urban transport information service

Currently the local urban public transport information service standardization needs to be strengthened, and standard and code are needed to be promulgated in order to standardize the public transport information service, especially the services of traditional public transport stop board, interior service mark, public transport guidance mark, and then finally realize standardized services and facilitate passengers for use.

8.4 Overall Architecture

8.4.1 Application Scenarios

Provide the social public with travel consulting, travel decision, travel reference and other traffic information at different levels via website, mobile APP and telephone hotline before traveling, in travel and before arrival, improve the travel efficiency of traveler.

Figure 8-3 Application Scenarios of Public Transport Information Service

Forecast for bus arrival time: people who are waiting for public transport vehicle can know about the distance of the target public transport vehicle to be taken and its estimated arrival time via mobile phone APP, electronic station board or others.

Query about bus travel route: people who travel by taking public transport vehicle can acquire the detailed travel route via bus information website, mobile phone APP, service hotline and SMS, which can also provide multiple optimized routes under the different modes for selection, such as the route needing minimum interchange, the route with minimum cost and the route requiring minimum walking.

Query about passenger ticket information of bus travel route: people can query about long-distance passenger ticket information, bus route transport information, public transport line information and multimode interchange information via bus information website, mobile phone APP, hotline telephone and SMS.

Rea-time travel navigation: people can acquire the navigation information of specific bus station, entrance, exit and other corresponding destination position via mobile phone APP so as to provide detailed reference for travel.

Revert bus travel problems: problems related to bus travel can be reverted to the relevant management department via telephone hotline, mobile phone APP, mail and in any other ways.

Information sharing of neighboring area: use the data opening and sharing function. The data to be shared between neighboring cities can be the original data, static-state data, and real-time data. Through authorization, the data exchange interface can be used for realizing data access.

8.4.2 Service Functions

The functions that can be realized by the information service system are summarized in Table 8-1 as follows, whichever it is the one established by government or by internet enterprise. These functions are classified according to the basic information services and the optional services.

Table 8-1 Information Service Content List

S/N	Service type	Service point	Service/template description	Service type
1	Basic information	Weather forecast	Weather condition may cause huge impact on the travel of user. In the weather forecast module, it displays the weather information of the city in future three days, thence it can provide convenience for user travel.	Basic service
2	Travel planning	Bus/metro line search	Bus/metro module: user can find the bus/metro line complying with the requirements by two ways according to the demands, namely route search and site search. In the line search module, user can search the list of all buses/metros of the station (which have already been recorded) by entering starting station, destination station etc, and then view the detailed information by clicking the desirous line on the list.	Basic service
3		Bus/metro station search	Bus/metro module: user can find the bus/metro line complying with the requirements by two ways according to the demands, namely route search and station search. In the station search module, user can search the list of the bus/metro line passing through the destination station or the bus/metro line nearby by entering destination station, and then view the	Basic service

			detailed information by clicking the desirous line on the list.	
4		Bus/metro line exhibition	It displays the detailed information of bus/metro line. For the bus line, it includes line number, start and end point, operation time, bus ticket price, real-time bus station information. For the metro line, it includes metro line number, start and end point, operation time, ticket price calculation and line map of the metro throughout the city.	Basic service
5		Driving route search	Driving route search module: user can search the driving route complying with multiple demands (such as the route with the shortest distance, the route without highway section etc.) by entering starting station and destination station, and then view the detailed information by clicking the desirous route on the list.	Basic service
6		Driving route navigation	It displays the detailed information of driving route, including estimated travel time, travel mileage, traffic light and other information of the travel. By calling the cloud platform SDK, user can realize route navigation function.	Basic service
7		Railway line search	Railway line search module: user can search the railway line complying with the demands by entering the corresponding contents according to the travel plan. The entry content includes: place of departure and destination, travel date, train type and seat number. User can acquire the information of the railway line complying with the demands by clicking the “Query” button.	Optional service
8		Railway line exhibition	On the webpage, the back office will list the detailed information complying with the railway line according to the relevant demands entered by user, which will assist user in making travel planning. The information includes: train number, time of departure and arrival, starting station, destination station, seat type and corresponding ticket price and other information.	Optional service

9		Online buy of railway ticket	By calling railway ticket buy interface of 12306.cn, Ctrip etc., user can buy railway ticket online from the China Travel Client Terminal. User selects the specific line, clicks the "Buy" button and enters the corresponding identity information, and thence user can realize the online ticket buy function.	Optional service
10		Flight information search	On the webpage, user can search the corresponding flight information according to the travel plan by entering the corresponding contents. User can change the flight type through the menu bar on the top, namely the domestic flight or the international flight. The entry content includes place of departure, destination, travel date, seat type. User clicks the "Query" button to acquire the information of the flight complying with the demands.	Optional service
11		Flight information exhibition	It displays the information of the flight complying with the requirements according to the flight information entered by user. The information includes departure city, arrival city, time, airport terminal information. It helps user to plan the travel better.	Optional service
12	Transportation junction information	Metro station information	It displays the relevant transport information of metro station, including metro line (showing the metro line map of the city), station exit (corresponding street of station exit and nearby mark POI lamp), plane view (internal plane view of metro station), nearby bus (information of bus station near to metro station). The specific functions are subject to the data capacity.	Basic service
13		Railway station information	It displays the relevant transport information of railway station, including railway line map of the city (the position should be specified in the map, and the specific address should be displayed), function (main service types of every railway station), plane view (internal plane view of railway station), nearby bus /metro	Basic service

14	Trip purpose		(information of bus /metro near to railway station). The specific functions are subject to the data capacity.	
14		Airport information	Airport information is used for displaying the relevant transport information of the airport. According to the current planning, the main functions are as follows: Basic information of airport: name, address, telephone of relevant service point. Internal plane view of airport: corresponding terminal building and every floor; it will help user to better understand the position layout of every function zone of the airport, reduce search time and facilitate indoor positioning. Airport transport: it provides the information related to the route of airport bus, airport public transport, and their service time.	Optional service
15	Trip purpose	Nearby	User can query the information of the nearby transport and living facility on this webpage, the contents include: Transport facility: including the position information of bus station, metro station, parking lot, gas station and other transport facilities. Living facility: including the position information of supermarket, drugstore, bank, toilet and other living facilities. User can trigger the route navigation for the searched facility by integrating with the travel functions. The module is correlated with the transport and travel sector.	Optional service
16		Tourist attractions	It displays the main scenic spot in the form of the picture; user can click the picture to browse the detailed information of the scenic spot.	Basic service
17		Scenic spot information & traffic information	It displays the information of the transport line of the scenic spots, including the information of tour station, station of departure, ticket fare, time, nearby traffic station etc.	Optional service

18		Scenic spot introduction	It displays the detailed information of the scenic spot, including the scenic spot introduction, picture of the relevant scenic spot and tour strategy.	Optional service
19	Personal journey	Travel information update and push	User can buy train ticket, airplane ticket for the third party platform (such as 12306.cn, Ctrip etc.) , then match through the reserved telephone of user. User who finishes matching operation successfully will receive the ticket information of China Travel. Besides, the travel record of user will be updated. Meanwhile, China Travel will push information to remind of the upcoming travel according to the travel record of user, and will assist user in managing his/her travel plan.	Optional service
20		Travel information reminding	It will push information to remind of the upcoming travel according to the travel record of user.	Optional service
21		Journey list	It will match the transport ticket record of user by the telephone number so as to acquire and display the relevant ticket information in the China Travel Client Terminal; which will facilitate user to view and manage. The exhibition data includes time, starting point, line, seat number, ticket status or check-in status. The overdue travel will have a weakened display.	Optional service
22		Bus travel planning	According to the detailed starting point, user can integrate with the cross-region travel information to plan the specific route of bus travel, record the complete travel and the corresponding route planning.	Optional service
23		Driving travel planning	User can plan the specific route of self-driving travel according to the starting point and the cross-region travel information, and record the complete travel and the corresponding route planning.	Optional service
24		Dated taxis	According to the starting point and the existing taxi business information, the starting point from which user takes a taxi will be recorded automatically. If there is no	Optional service

			special change, every click on the "Confirm" button will reserve a taxi. After reserving taxi successfully, the specific route and pick-up driver's information will be listed; in such case user can get in touch with the driver easily.	
25	Press release	News	User can select the local city from the personal setting. Except for exhibiting transport information, the news and announcement sector will add the corresponding news information according to the city selected by user. The news sector will display the relevant news about the transport of the city (traffic jam, transport accident information etc.).	Basic service
26		Announcement	It displays the relevant transport announcements of the city (such as changing route, road traffic control, oil price rising, free toll and other information).	Basic service
27		News concerned	User can define and concern the news of certain city; such information will display in the "My Concern" sector.	Optional service
28	Data opening & sharing	Data downloading	It displays the open data for the public, such as statistical bulletin data etc.	Optional service
29		Data exchange interface	Upon the authorization, user can access data through data exchange interface.	Optional service
30		Data service interface	It is for the data developed and used by internet enterprise. Through authorization, user can realize application by calling the data service interface.	Optional service

8.4.3 System Architecture

The technical architecture of the information service system is proposed according to three different construction modes.

(1) Technical architecture of the information service system established by government

The travel information service system, supported and based on the public transport data resource center, completes data acquisition, data processing and information release. The specific architecture diagram is shown by Figure 8-4 as follows.

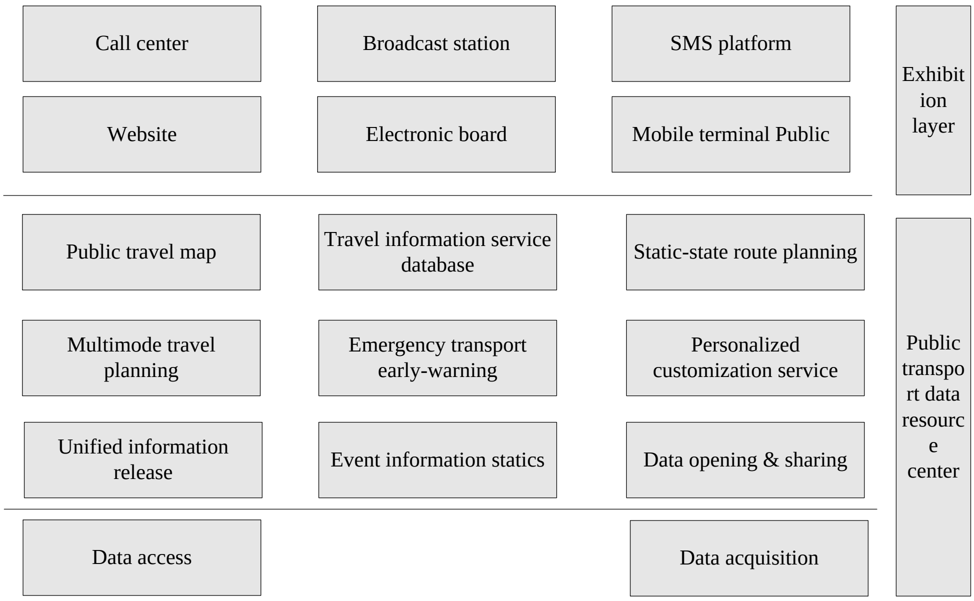


Figure 8-4 Technical Architecture of Information Service System

Data acquisition is responsible for collecting and integrating the data required by the travel information service system; it is the basis of information sharing and use. On the aspect of data acquisition, more real-time traffic information can be acquired by the mobile traffic information acquisition equipment. On the aspect of data integration and access, the existing traffic transport system should be improved, and three modes, namely active, passive and automatic mode, should be adopted to establish the subject database through data integration engine, multi-source information integration engine, massive data processing engine on the basis of two kinds of information (real-time information and periodic information), and then support the data analysis, calling, transfer, storage and exchange in the different application fields.

Data processing will mainly realize the data support for the application of all aspects. On the aspect of map construction, it will enhance system construction and improve search performance. On the public travel information database, it will improve the construction of every traffic subject database through data inspection, specification and processing. On the aspect of route planning, the route planning module based on real-time traffic status and probe vehicle data will be developed; which will integrate with the high-performance map matching algorithm to realize the real-time planning for route before travel and in trip. On the aspect of multimode travel planning, it will provide user with multiple travel guidance for seamless connection of multiple public transport modes. On the aspect of emergency traffic early-warning, it will coordinate the traffic authority, and release information and trigger early warning via multiple channels rapidly and automatically according to the early-warning flow in emergency. On the aspect of traffic incident's statistical analysis, it will conduct high-level analysis and tapping, depth processing and multidimensional analysis and association analysis, neural network analysis. On the aspect of personalized customization, it will provide the customized information for road emergency and highway construction. On the aspect of the release interface, it will establish the unified information release port to realize standardized management on information release. On the aspect of data sharing, it will set the data open interface to provide data sharing for the public, other organizations and internet enterprises. Information release uses gateway, communication interface and other ways to release information, including website, mobile terminal, call center, broadcast station, SMS system, variable message sign, vehicle-mounted terminal, bus electronic board etc.

(2) Technical architecture of the information service system constructed by third party information service provider

The bus information service system constructed by the third party information service provider realizes bus travel information service via mobile phone APP, including Android version, IOS version, wap version, WeChat number and microblog.

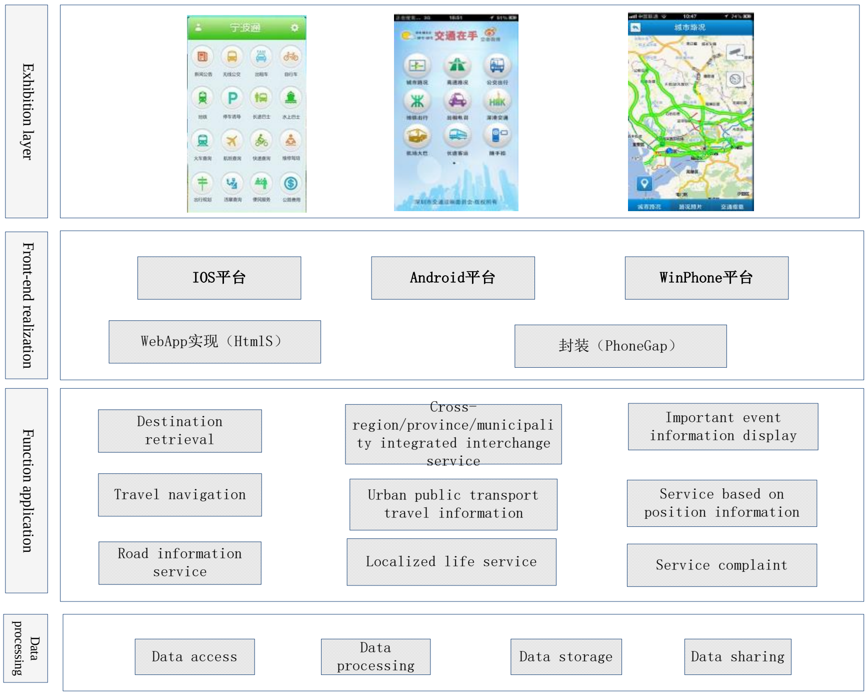


Figure8-5 Technical Architecture of Internet Enterprise Information Service

Where:

Data processing layer: it completes mainly the connection, processing and storage of the mobile APP application data supporting information service.

Function application layer: it supports mainly the realization of the mobile phone APP functions supporting information service; its specific function includes: destination retrieval, travel navigation, road condition information service, cross-region/province/municipality integrated transport & interchange service, rich bus travel information, localized life service, significant event information exhibition, position-based information service.

Front-end realization layer: it converts the data and function into the mobile phone APP software. The Web App is the application runs on the network and the standard browser to realize special functions based on the webpage technology development. Its encapsulation is to convert the webpage of various mobile phones for App software.

Exhibition layer: it is the APP software interface of the public transport travel information service.

(3) Technical architecture of the information service system under the cooperation of government and enterprise

The information service system under the cooperation of government and enterprise is based on the open-type integrated public transport travel information service cloud platform; its specific architecture is shown by Figure 8-6 as follows.

1) Cloud foundation platform: it is mainly used for providing the storage space, operation performance and other basic software and hardware environment required by data storage and service setup.

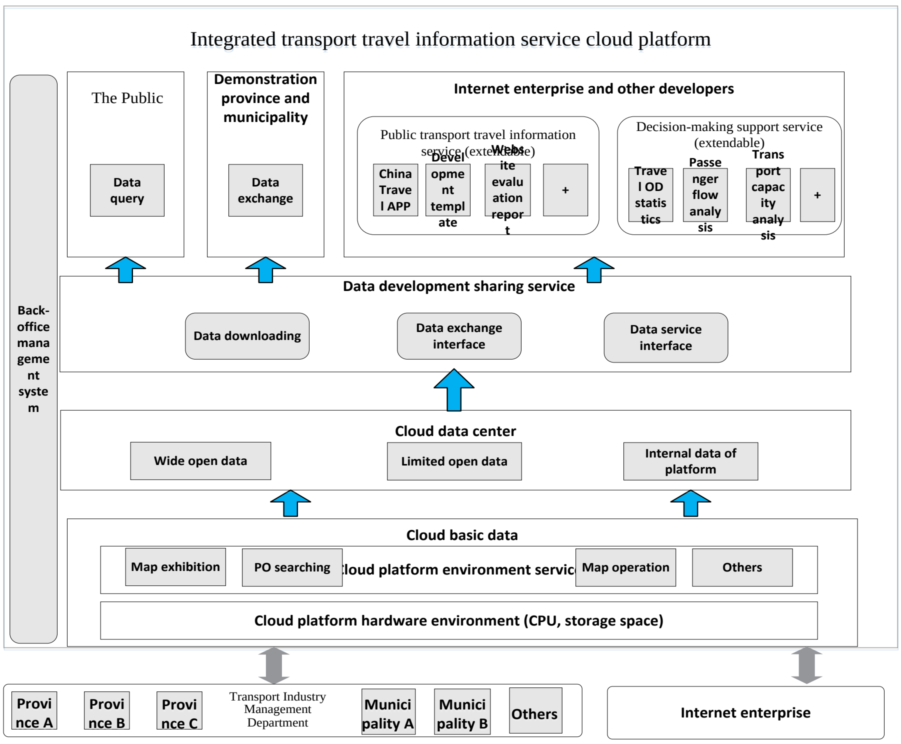


Figure8-6 Technical Architecture for Information Service System under Cooperation of Government and Enterprise

2）Cloud data center. It will access to the relevant data of the public transport travel service information system to realize the unified data management, integrate with the relevant data of internet enterprise, and provide data basis for data opening, sharing and data interface calling.

3）Two basic services, namely cloud platform environment service, data opening and sharing service. In which, the former includes cloud retrieval, cloud layer, cloud-side privatization management, data safety management; for the latter, it allows the data access service through data interface; the date to be opened and shared and their opening/sharing mode will be subject to the data owner.

4）Two basic application services, namely integrated travel information service, decision-making service. The two basic application services are the specific embodiment of the cooperation mode of enterprise and enterprise. In which, the former includes mobile phone software development, template call service, existing network evaluation service; the latter includes passenger flow analysis, operation capacity and carrying load analysis, travel OD analysis etc.

8.5 Influence Factors of System Construction and Suggestions

8.5.1 Influence Factor of System Construction

Currently, the influence factor restricting the service quality of the information service system includes:

(1) Quality of basic data

Bus travel service information content is based on the bus GPS station-arrival data of the bus intelligent dispatching management system; its accuracy and update frequency decide the information service accuracy directly. According to the researched cities, the bus GPS data are accompanying with the defects of non-uniform standard, poor accuracy and lost data.

In order to guarantee the accuracy of public transport information service system, it is needed to adjust from the following several aspects, i.e.:

1）Popularize the national vehicle-mounted equipments and data resource standardization, apply the unified standards to reduce information service data processing and improve hugely service information quality.

2) For the data drift of GPS data and in order to realize accurate station reporting service, the RFID collect technology can be adopted to supplement the accurate service of vehicle arrival information; such technology will have apparent application effect on public transport lane.

3) Significance of the information from statistical analysis of historical data for accuracy correction

4）In the time there are many uncertain factors on urban roads, it can provide vehicle arrival information. If the technology and data are available, it can provide the estimate service for vehicle arrival.

(2) Construction and operation mode of information service system

Public transport travel information service system's operation mechanism has important function for operation effect. As the main construction organization, local government has already developed many travel information service websites. However due to the reason the operation mechanism is not well guaranteed, the data on these networks are updated slowly and thence cause a less and less access and visit. For maintaining the sustainable application and development of the information service system, it is a must to establish a reliable construction operation mechanism and guarantee the open process during the whole period from data collection, data update to data release.

According to the different construction entities, the construction mode of the information service system will be divided into the types as follows:

1) Travel information service system established by government

Under this mode, the planning, design, construction, validation, operation and maintenance of the public transport travel information service are all under the control of the government. Since the associated funds are allocated by governmental finance, their ownership belongs to the government too. All processes thereof are dominated by the government, so the mode has low coordination cost, quick construction speed and governmental authority, and the government controls its future development. However since the construction expenditure, operation and maintenance cost are high, their operation efficiency and service quality are not better than the marketization operation. Most of public transport travel information service websites adopt such mode, so their operation efficiency and service quality are inferior.

2) Travel information service constructed by internet enterprise

Under such mode, enterprises undertake the informatization development planning, construction and operation works of the information service, but the government does not involve in the planning, investigation and construction process, and does not need to invest human resource and planning construction costs, and service quality is expecting to improve through marketization. High project risk, high coordination cost, inapparent government authority, less control for future development and the essence of going after commercial benefits may possible make the information service fairness come under question. Most of the public travel information service provided by Baidu, Gaode and other internet enterprises on the market adopt such mode, and the system itself is planned, operated and owned by enterprise itself.

3) Travel information service under cooperation construction of government and enterprise

Travel information service project has certain particularity and possesses the characteristics of quick service function update, high environment operation and maintenance cost. The functions of the system constructed by traffic industry management department cannot keep up with the updating speed of social service. With the lapse of the time, the operation speed of the system becomes slower and slower, and user experience becomes worse and worse. The practice has proved that the functions of the travel information service system under the cooperation mode of enterprise and government can follows the social development tendency closely, its performance can be adjusted flexibly according to the system utilization condition, and it can maintain the usability and availability of the travel information service for a long time.

Currently it is proposed to adopt the government-enterprise cooperation mode as the information system construction and operation mode. Such mode can integrate with the advantages of government and enterprises, give full play to the complementary action of advantages, and boost the sustainable development of the information service system.

(3) Essential data openness

Currently the information service system is constructed on the basis of data resources. However the essential data resources of public transport belong to the governmental resources, therefore they are not yet opened this moment. The realization of the core value of these public transport data lies in the data liquidity and their cross use with other living data. If the data cannot be vitalized and are only used for government for reference, these data will lose their value. Therefore opening of essential data and information sharing between government and internet enterprise are the important factors of boosting information service system to get a sustainable development.

8.5.2 Essential Data Resource Catalogue Reference

Data resources are the basis of the travel information service system. In this section, the travel service information resource catalogue was studied, and the essential data catalogue reference was proposed, which can lay a basis for the construction of the information service system. See Table 8-2 as follows.

Table 8-2 Data Resource Catalogue

Information classification		**Information resource**	**Update cycle**
Basic information	Bus line information	City name, route name, route type, route number, longitude and latitude series, time of first and last bus, total line length, self-service ticketing (or not), ring line (or not), the company to which the bus belongs.	Quarterly
	Bus station information	City name, station name, longitude, latitude, road on which the bus is driving, correlation	Quarterly

		relationship of line and stations.	
	Ticket fare information	Line, full fare, starting fare, distance-based incremental price, station-based incremental price, monthly ticket (supporting or not), charging mode, cross-province/city consumption (supporting or not).	Quarterly
Dynamic information	IC card information	Recharging place of card, card withdrawal place, card cost, etc.	Yearly
	Vehicle positioning data	Time, vehicle plate number, line number, ascending/descending mark; longitude, latitude, instantaneous speed, azimuth angle, sequence number of next station.	Real-time acquisition
	Vehicle arrival and departure data	Vehicle number, line name, time, station, driving direction, station arrival identification.	Real-time acquisition
	Vehicle shift data	Shift number, line name, operation data, vehicle, driver, driving direction, operation frequency, steward and plan time.	Everyday
	Video snapshot	Video place name, address, time, GPS information, picture.	Real-time update
	Passenger flow data	Swiping card: single charging bus: card number, swiping time for getting on bus, line number; charging bus by section: card number, swiping time for getting on/off bus, number of station for getting on/off bus, line number. Passenger flow data to be collected by other ways: statistical number of passenger flow, time for getting on/off bus, station, line number.	Real-time update

8.5.3 Government-enterprise Cooperative Construction & Operation Mode

Government-enterprise cooperative construction & operation mode is an important measure to forge a new type of ecological travel information service. For the city which has already had the information service system that can not meet demands of the public and the city which does not have the information service system, appropriate data sharing and government-enterprise service mode can be selected according to local conditions to improve the information service level.

Operation mechanism of government- enterprise cooperative travel information service system at the present stage is still in a policy-driven exogenous innovation and growth mode. It cannot develop without power from government, enterprises and various intermediate organizations. First, the government controls macroscopic development direction and leading-edge industry of technology development and proposes development task requirements. Second, realization of the objective relies on technical innovation entities (enterprises) and knowledge innovation entities (scientific research organizations); long-term, stable and efficient collaborative innovation mechanism between enterprises and scientific research organizations is a key link to development of the information service mode under government-enterprise cooperation mode. Third, information service development can not be realized without travelers' demands; thence, it is a must to insist on taking innovation demands of travelers as the basic direction for development of internet enterprises.

(1) Government is the first driving force

The government's promotion plays a vital role in not only macroscopic planning but also microcosmic guidance, which is mainly manifested by four aspects:

Governmental planning function: Government-enterprise cooperative information service features strategic, fundamental and non-profit; its development direction must closely follow needs of the government and the government makes an overall planning on the strategic level.

Policy guidance function: The government shall attach importance to demand orientation and task guiding, consider more development of government and enterprise cooperation and study relevant policies for public travel information service, and formulate Travel Service Information Resource Opening & Sharing Catalogue of Traffic Transport Industry Authority (interim) (including opening/sharing attribute, classification and leveling, data review, information safety, update mechanism).

Coordination mechanism function: In the early cooperation, the government not only creates sound innovation environment through its relevant policies, but also acts as a go-between for cooperation of enterprises and scientific research institutes by using its own status and reputation, to lay a solid basis for collaborative innovation.

Data resource sharing: data resource is the base of travel information service system. However the data resources are under the control of the government currently, so data resource sharing is one of the main tasks of the government. Its specific contents include:

- Improving the system related to data acquisition and update management, clarifying the responsible department of data acquisition and business flow, enhancing data quality control and ensuring data quality according to the specified acquisition frequency and acquisition mode.

- Establishing a perfect information exchange and sharing mechanism; clarifying the responsibility and obligations of both parties for information exchange sharing between different departments and between different businesses, as well as making clear regulations on sharing contents, sharing mode, sharing time effectiveness, sharing range etc.

- Establishing a perfect information release mechanism; clarifying the responsibility of relevant departments, as well as standardizing information release content, mode, scope and information review procedure by following the principle of "Those who carry out data acquisition will take the corresponding responsibility".

- Supervising information service quality, following up and evaluating service quality in the information service development process, and proposing modification, improvement, localization and other demand contents.

(2) Scientific research institutions are the ties of mode innovation application

From resource contribution, policy support, undertaken task and other respects of every involving mainstay, scientific research institutions can conduct researches and establish efficient collaborative innovation mechanism, promote cross integration and development between industry disciplines, make every endeavor to break internal and external barriers of every mainstay, and then boost every elements to converge, integrate and run through between upstream and downstream reaches.

(3) The market-based operation of internet enterprises is the guarantee of sustainable development.

Internet enterprises are the mainstay to realize information service and their main tasks include:

- Constructing information service system according to requirements and regulations of the government; conducting operation, maintenance and daily management for the system.

- Receiving data according to requirements of the data sharing catalogue and distributing the information according to the release requirements.

- Making mining and analysis based on the massive traffic data and Internet data, to provide decision support for the industry management department.

- The enterprise independently establishes a perfect mode to maintain system operation.

8.5.4 Selection of Data Sharing Mode

Currently, data sharing mode under the government-enterprise cooperation is still in a continuous exploration and innovation stage; references can be made to following modes (but are not only limited to them):

(1) Resource exchange mode

This mode embodies the reciprocity principle and applies to the city possessing good data resource base. Governmental departments, Internet enterprises and other demand parties consult with each other, which is beneficial to establish sustainable government-enterprise cooperation.

It is mainly manifested by the following contents: Departments of traffic transport industry swap their data resources for data, technology and service resource from Internet enterprises. Among which, urban data resource shall be sustainable and guaranteed on the aspect of content, quality and update. Internet enterprise should provide services, according to urban demands, such as data feedback after integration, traffic travel information service improvement scheme and development template, as well as urban traffic travel decision support and analysis integrating with Internet behavior data characteristics.

(2) Free service input mode

This mode embodies the mutual assistance principle and applies to the city in which the travel service system is not yet established or the travel information service function is weaker. It is dominated by the one-way service input. This mode can quickly improve the traffic travel information service functions of these cities.

It is mainly manifested by the following contents: Existing traffic travel information service output of Internet enterprises is used to fill in the gap in local traffic travel information service; basic service provided by the cloud platform can be used according to local data integration. As relevant data integration of the city develops, it will gradually convert into the resource exchange mode.

(3) Service purchasing mode

This mode meets the national mainstream development tendency. It encourages every region to selectively purchase application services provided by internet enterprise in the form of government procurement, and allows making customized development according to the regional demands. The mode has the advantages on the aspect of sustainable service, meeting personalized demands and easy operation. Meanwhile, it also supports various internet enterprises to adopt the bought data, joint investment or other ways to legally use opened and shared data resource of government and enterprise and thus to develop high-quality integrated traffic travel information service.

8.6 System Evaluation Appraisal Indicators

（1）Performance requirements

- The system update cycle should not exceed 60 seconds;

- (From the one data starts computation to the one data completes computation) every computation speed: <5 seconds.

- The time from the one data computation completes to the one data is pushed to the terminal and displays on the terminal: <3 seconds.

（2）Demands on stability and robustness

- Meeting the system to run for 18 hrs minimally everyday (stop working from 11:00pm to 5:00am).

- Annual fault rate: <98.8%

（3） Information accuracy requirements

- The arrival station number forecast error should not be more than 1 station.

- Station arrival time estimate accuracy: >78%

- Accuracy for degree of congestion of passengers in bus: >75%

（4）Interface requirements

- The interface is simple, generous, understandable, readable, and has good user experience.

The service classification is clear, and the service navigation is quick and convenient.

8.7 System Construction, Operation and Maintenance Cost

(1) System construction cost

According to market survey in 2014-2015: When information service system established the government is adopted, which includes public travel information service websites, mobile terminal information service system, electronic stop board release system, etc., 400-800 thousand Yuan is needed for construction of public travel information service websites, 300-600 thousand Yuan is needed for construction of mobile terminal information service system, electronic stop board release system has functions including static information display, dynamic information display on LED screen, monitoring video uploading and state uploading, etc. and about 50 thousand Yuan is needed for each set of equipment.

Information service system for government-enterprise cooperation project dominantly uses the mode of swapping data for service. Expense needed is mainly the cost for cloud platform for data uploading, including expense for front-end processor and network, about 100 thousand Yuan.

(2) System operation and maintenance cost

According to market survey in 2015, operation and maintenance cost of information service system is about 5%-10% of its construction cost.

9 Intelligent Dispatching System

9.1 Present Survey Situation

Intelligent dispatching system realizes the functions of intelligent scheduling management, operation dispatching, and data statistics and so on. Its system efficiency plays a major role on the efficiency of public transport operation.

The dispatch system in the operation dispatch center has the function of basic information management, work schedule plan management, real-time dispatch management, operation monitoring management, inquiry and statistics management, ticket management, decision support management, operation support management, system management.

Intelligent dispatching system has been established in many cities in China. Take Guangzhou as example, the intelligent public transport monitoring and dispatching system has been established in 2007, which covers all the public transport vehicles in the city. Based on GIS platform, it realizes real-time monitoring of vehicle dynamic location and operating state by making use of the vehicle dynamic satellite positioning, wireless communication and electronic map display technology. In the area without GPS signal, the system set up a beacon in a certain range to realize the short distance positioning to make up the shortfall. This system realizes a closed-loop management including passenger flow statistics, passenger flow analysis, planning and scheduling, operation state monitoring, operation and dispatch effect analysis, which fundamentally improves the real-time management and control of dispatch system. It also realizes the multi-line centralized dispatch, cancels the current “driving record” manual and publishes the real-time public transport information through electronic stop board and LED, LCD information display board in vehicle.

In order to enhance the level of intelligent dispatching system, some cities like Shenzhen, Chengdu have issued local standards. In Shenzhen the "*Intelligent public transport dispatch system platform specification*" has been clear about ten main functions:

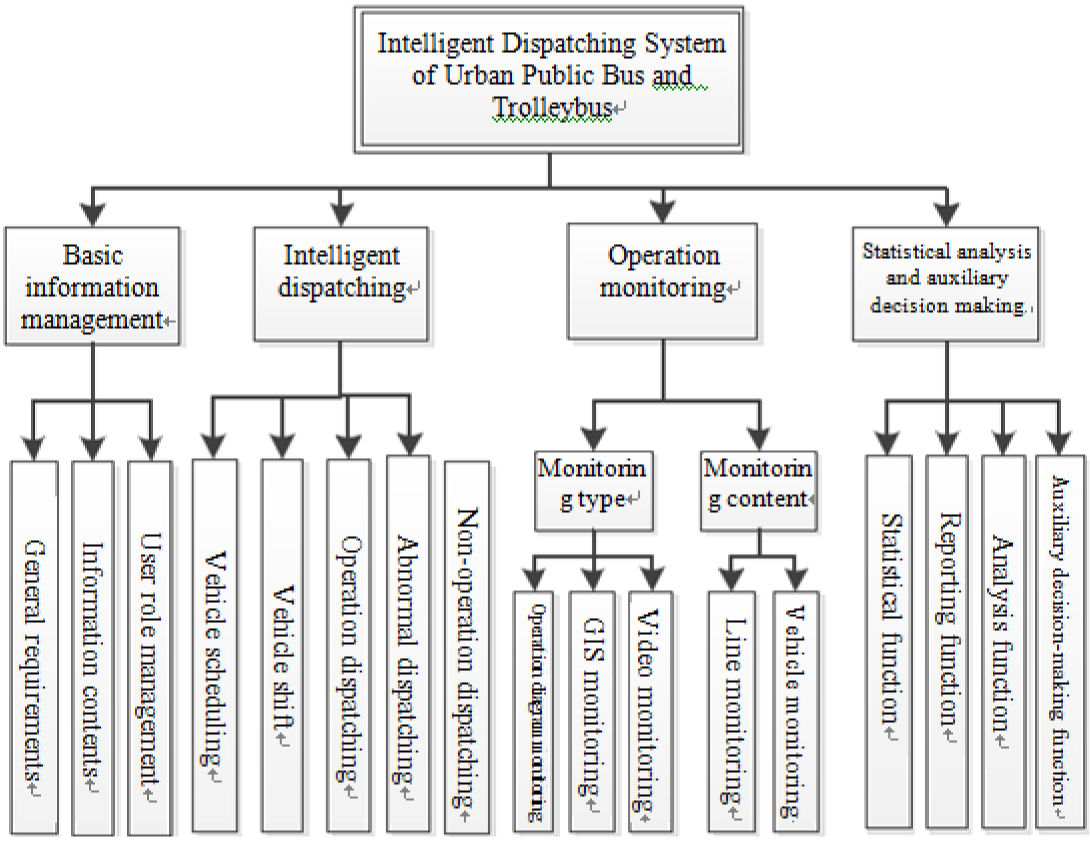


Figure 9-1 10 Main Functions of Intelligent Dispatching System Platform

In the dispatching model, in order to realize the unified management, improve the efficiency of the dispatching, a lot of urban bus group adopts three-level dispatching model. Such as Chengdu bus group dispatching center, branch dispatch center and the team. Bus group dispatching center is responsible for the planning. Every day the branch dispatch center plan team execution plan according to the scheduling. The team's operator according to the execution plan dispatch vehicles.

Liuzhou City: the sole public transport operation entity in Liuzhou City is Liuzhou Hengda Bus Co.,Ltd. In August 2007, the Intelligent Safety Monitoring & Operation Dispatching Center was established. By adopting the “Centralized dispatching, united monitoring and level-to-level management” mode, the center is fully responsible for the safety monitoring, operation dispatching and other management works of operating vehicles. By the beginning of 2013, there were about 105 lines, more than 1,030 vehicles, 29 terminal stations and almost 4,000 employees in the company, and the company transported over 600,000 person-times every day. In the dispatching center, there were 10 seats and about 27 dispatchers; every dispatcher was responsible for dispatching 80~100 vehicles and 10 lines approximately (or 15 lines maximally). The dispatching center controls and dispatches all operating vehicles and drivers in the centralized way, conducts the real-time monitoring on the on-schedule operation and the safety operation of every line, records and reverts the nonconformity to every branch company. The branch company is responsible for implementing the operation support and the field management of every terminal station under its justification, and carries out the dispatching instructions of the dispatching center.

Guiyang started its intelligent information engineering construction as of 2005. The public transport lines of the city are exclusively operated by Guiyang Public Transport (Group) Co., Ltd. By the beginning of 2013, there were more than 2,200 vehicles, almost 9,000 in-service employees and 164 lines in the company, and it transported 1,700,000 person-time every day. The dispatching center of the company tested the public transport lines since March 2005, and implemented the GPS remote intelligent dispatching for all public transport lines by 2007. Currently there are totally 35 dispatching seats and 107 dispatchers in the dispatching command center, and every dispatcher dispatches almost 60 vehicles and 4~8 lines. Following, for the purpose of mobilizing the initiative of operating branches, the company is intended to release the HO-based centralized dispatching to the branch company, and let the branch company to dispatch, whereas the HO will only be responsible for the supervision, coordination and command for the centralizing dispatching.

9.2 Experience and Summarization

(1) Government's attention and standard first

In view of the intelligent development of the existing urban public transport in China, the attention, policy and financial support of the government of every place on the intelligent public transport directly affects the local public transport intelligence level. Additionally, in order to improve the intelligent dispatching level more normatively, the standards are indispensable and very necessary. As long as the standards are available, workflows and construction processes will be standardized, for instance in Shenzhen and Chengdu, the relevant local standards for intelligent dispatching have already been promulgated, which will drive the development of the intelligent public transport dispatching hugely.

(2) Driving by enterprise production and integrating with advanced technology

The intelligent dispatching system must integrate with the GIS electronic map, vehicle positioning, mobile communication and other advanced technologies. By combining the automatic preparation and implementation of vehicle operation plan in the public transport enterprise and by collecting the information related to the position and status of operating vehicle in the real-time way, the intelligent dispatching system can realize the real-time visual monitoring on the operating status of vehicles and the real-time dispatching command of vehicles in the operating lines, and thence the intelligent dispatching can be realized authentically. Moreover, by integrating with the personnel performance appraisal, governmental financial incentive and appraisal measures, the accurate digitalized management and appraisal means can be provided for the operation management of the public transport enterprises, and thence the operation efficiency and service level of the public transport enterprises can only be improved.

(3) Advanced and flexible process, timely emergency disposal

The actual operation of public transport vehicle is a huge and open dynamic system; the road conditions vary with the time, and many random factors may cause influence on operating vehicles, such as traffic jam, intersection signal delay, station parking, traffic accident, weather condition etc., therefore the phenomena of non-uniform vehicle distribution, bunching etc. may occur, and the public transport resource cannot be sufficiently used; in such case the waiting time of passengers will have to increase or the different buses on the same line may become crowded.

The dynamic public transport dispatching is to maximally relieve the influences caused by emergency on line operation by adopting some real-time dispatching measures so as to recover the normal operation level when the service vehicle operation is disturbed. Therefore the intelligent dispatching system should have flexibility and the quick reaction for the emergency.

（4）Suitable dispatching mode and rational process and flow

The dispatching management and organization modes of the different public transport enterprises have the different requirements on the establishment of the intelligent dispatching systems, such as the on-site dispatching mode is very popular to these public transport enterprises with small scale, however the centralized dispatching mode is the preference of the public transport enterprise with large scale. The advantages and disadvantages of the different dispatching modes are different, and thence are not all same at the different development stages of the public transport enterprise; therefore a rationally adapting dispatching mode will optimize the intelligent bus dispatching procedure and improve enterprise’s operation efficiency. Certainly, it is recommended to select the appropriate public transport dispatching management and operation mode, as well as the public transport industry supervision mode to boost the public transport intelligence development in accordance with the different urban characteristics and the characteristics of urban public transport enterprises.

9.3 Problem and Requirement Analysis

(1) Analyzing the relationship between dispatching mode choose and the system efficiency

In the centralized dispatching mode, the dispatch center can directly access the information such vehicle position, headway, running in and out of the stop, etc., and dispatch the vehicles directly according to the on-schedule rate and the passenger flow. However, in this mode, the dispatch instruction might not match with the real situation, and the hardware of the system might be able to support the needs of centralized dispatch, which will affect the operation efficiency.

In the hierarchical dispatching mode, the dispatch system is divided into the general dispatch system as well as several parallel sub dispatch system. The dispatch is operated by the subsystem, which avoid the inconsistent between the dispatch instruction and the real situation. Nevertheless, the cross-line dispatch between subsystems cannot be realized in the hierarchical dispatching mode, and the overall transport capacity is not well made use of.

(2) Large gap to the true intelligent dispatching

In most of the cities the electric road bill is parallel with the paper. The assessment of driver, vehicle still rely on a single paper road bill, which show that there are flaws in the vehicle positioning mileage calculation precision, production scheduling execution, production process, no discontinuity of system using and so on.

(3) The using regulations is not perfect and the operation and maintenance are not in place

Enterprises have issued use system for related systems with the construction of intelligent dispatching system, but the use system is imperfect and execution does not reach the designated position such as system update, vehicle terminal operation and maintenances, etc.

9.4 Overall Architecture

9.4.1 Application Scenarios

1）Traditional dispatching mode

The traditional dispatching mode is dominated by the mode as follows: headquarters/branch/dispatching center - vehicle fleet dispatching - bus dispatching. Under such mode, enterprise’s operation dispatching focuses mainly on the experience of management staff and the control on some simple service indicators, but the plan cannot be adjusted dynamically according to the change in passenger flow. For the entire public transport enterprise, there is the dead zone for the supervision and monitoring of the whole route. In such case, a dispatching room is needed to set for every route or every station, and every dispatching room must be assigned three dispatchers at least for being on duty by turns. In most of areas of China, dispatchers are required to fill in the dispatching report manually.

2）Centralized dispatching mode

Centralized dispatching mode is the mode under which the “Headquarters/dispatching center – bus vehicle” dispatching mode is dominated, all bus vehicles are connected with the monitoring & dispatching center through vehicle-mounted terminals, and receive the dispatching instructions of the dispatching center; dispatcher can monitor and dispatch the buses on every line in a convenient and centralized way through the monitor server in the dispatching center, but no more dispatching rooms are needed to set in the starting station and the destination station of every bus. Besides, the on-site support personnel will be appointed to every site for making supervision.

9.4.2 Service Functions

According to the early investigation, by referring to the Smart Urban Public Transport Demonstration Project Construction Program Standards: Technical Requirements for Intelligent Dispatching System of Urban Public Bus and Trolleybus (hereinafter referred to as "Demonstration Project Standard"), and upon the informatization development and local demands, the swiping card data monitoring function module will be increased. As for the preliminary service function framework of dispatching system, see Figure 9-2 as follows.

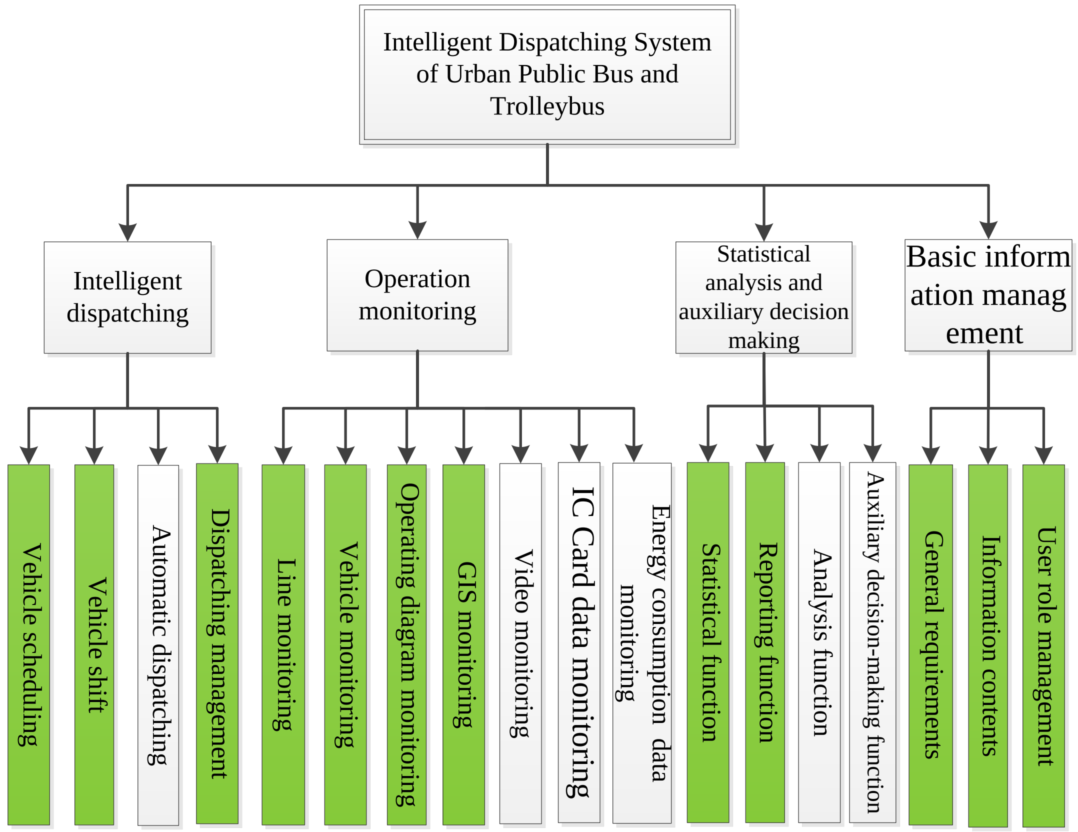


Figure 9-2 Service Function Framework of Intelligent Dispatching System

Note: In the figure above, vehicle scheduling, vehicle shift, dispatching management, line monitoring, vehicle monitoring, operation diagram monitoring, GIS monitoring, statistical function, reporting function, general requirements, information definition and user role management are typical dispatching system requirements. Automatic dispatching, video monitoring, IC card data monitoring, energy consumption data monitoring, analysis function and auxiliary decision-making function are customized or planned according to development needs and construction requirements under the condition of sufficient construction funds.

For specific description on functions, see Table 9-1. For part of functions involved, refer to Standard on Urban Intelligent Public Transport Application Demonstration Project: Technical Requirements on Intelligent Dispatching System of Urban Public Bus and Trolleybus (demonstration project standard)

Among which, in the intelligent dispatching, full consideration shall be given to relevant emergency dispatching and coordination dispatching of hub information and rail transit information.

Table 9-1 Service Content List of Intelligent Dispatching System

S/N	Service type	Service point	Service/template description	Remarks
1	Essential information management	General requirement	Manage routine station, vehicle, line, personnel information.	Combining with the Demonstration Project Standard.
2		Information definition	Define, number and mange relevant information.	Combining with the Demonstration Project Standard.
3		User role management	Manage the access user at the different levels, including username, use privilege etc.	Combining with the Demonstration Project Standard.
4	Operation monitoring and control	Line monitoring and control	Monitor driving lines of bus.	Combining with the Demonstration Project Standard.
5		Vehicle monitoring and control	Real-time or historical playback for vehicle track, conduct electronic fence and other monitoring operations	Combining with the Demonstration Project Standard.
6		Operation chart monitoring	Realize the bamboo joint chart monitoring for the service vehicles on the designated line, and the departure interval monitoring.	Combining with the Demonstration Project Standard.
7		GIS monitoring	Realize the whole-network monitoring on the basis of the whole GIS diagram.	Combining with the Demonstration Project Standard.
8		Video monitoring	Monitor video data, and record immediately if finding unexpectedness.	Combining with the Demonstration Project Standard.
9		Swiping card data monitoring	Monitor the abnormal IC card data and passenger flow.	
10		Energy consumption	Monitoring vehicle energy consumption	

		data monitoring		
11	Statistical analysis and auxiliary decision	Statistics	Make statistics by day, line and vehicle.	Combining with the Demonstration Project Standard.
12		Report form	Generate the report form with the format required by the management department on the daily or monthly basis.	Combining with the Demonstration Project Standard.
13		Analysis	Use the relevant models to make the relevant analysis and tapping.	Combining with the Demonstration Project Standard.
14		Auxiliary decision making	According to the analysis contents and the relevant information feedback, propose the auxiliary decision-making scheme for the decision maker and the dispatcher for making change for the dispatching strategy or implementing emergency measures	Combining with the Demonstration Project Standard.
15	Intelligent dispatching	Vehicle scheduling	Prepare the vehicle timetable etc.	Combining with the Demonstration Project Standard.
16		Vehicle shift	Configure and allocate vehicle according to vehicle maintenance plan and operation plan.	Combining with the Demonstration Project Standard.
17		Automatic dispatching	Realize automatic vehicle scheduling and shift arrangement according to the relevant experience and rules, release dispatching instructions according to the system feedback.	Combining with the Demonstration Project Standard.
18		Dispatching management	Make real-time recording and log management for actual dispatching, compare the record with the planned dispatching scheme to obtain the appraisal indicator list.	See the Demonstration Project Standard for details; pay attention to the sharing of the information related to hub and rail transit

9.4.3 System Architecture

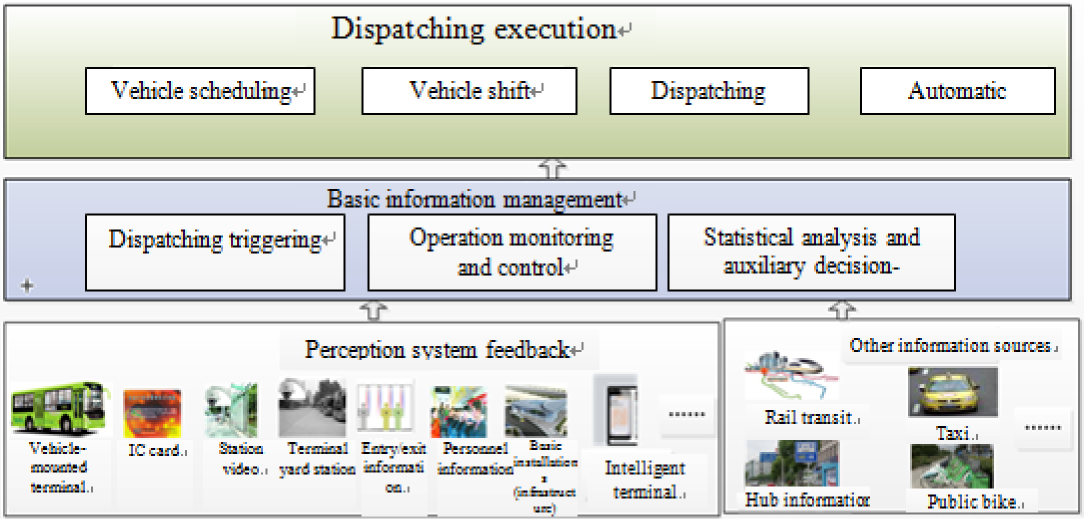


Figure 9-3 Architecture of Intelligent Dispatching System

As shown by Figure 9-3, the intelligent dispatching system reverts the relevant information to the dispatching center by detecting the system information, information of rail transit operation dispatching and hub monitoring information. Afterwards, the relevant base information management and operation monitoring & statistical analysis module will generate the relevant dispatching scheme, which will be transferred to the implementation terminal by relevant devices and communication technology; afterwards, dispatcher will adjust and manage the corresponding vehicle plan, vehicle schedule and dispatching need, release dispatching instructions, and finally complete the dispatching flow.

9.5 System Construction Recommendations

9.5.1 System Construction Base

There are many factors affecting the base of the intelligent public transport system. By investigating the relevant systems of the relevant enterprises in every place, 5 dominating factors are selected, *i.e.*:

1) Organization and management: the factors on such aspect involve mainly in the establishment, management and support mechanism of intelligent dispatching system; among which, the establishment of an efficient and professional project team is key to the construction efficiency of the whole intelligent dispatching system, and which directly affects the recognition degree at all levels, the system construction progress, and the adaptability for the system application in future. A good support mechanism can guarantee an unimpeded access to information and an efficient system implementation of the intelligent dispatching system.

2) Hardware construction of dispatching system, namely the technology of vehicle-mounted equipment, communication equipment, network and operation environment is an important factor to guarantee an unimpeded access to the information between dispatching management personnel and vehicle, let the dispatching management personnel acquire enough real-time information, and keep the system run normally and steadily.

3) Adopting rational method and selecting flexible dispatching and scheduling strategy are the important means to improve the dispatching efficiency and the supply and demand level of transport capacity. Besides if necessary, the integration with the change in passenger flow will hugely improve the operation and dispatching level.

4) Selection of dispatching mode: according to the different enterprise scale management system and actual demands, allocation of appropriate personnel and appropriate dispatching can support and improve dispatching efficiency comprehensively.

5) Development and application of dispatching software: a good software process is the key to guarantee dispatching efficiency; it is very important to select the software development partner with good reputation. As you know, a good software developer will affect the later software operation, maintenance, upgrading and improvement.

6) Evaluation on dispatching system: many places have launched the dispatching systems blindly; however the lessons and experience analysis on the application results and use of the dispatching system are very important; they are one of the key factors directly affecting the construction efficiency of the entire system.

7) For the comprehensive utilization of existing equipment, it should be to combine with the new needs and system construction needs, to upgrade the existing system with a reasonable and comprehensive utilization, to avoid duplication of equipment and the waste of resources.

9.5.2 Dispatching Mode Selection Recommendations

The dispatching management and organization modes of the different public transport enterprises have the different requirements on the establishment of the intelligent dispatching systems, such as the on-site dispatching mode is very popular to these public transport enterprises with small scale, however the centralized dispatching mode is the preference of the public transport enterprise with large scale. The advantages and disadvantages of the different dispatching modes are different, and thence are not all same at the different development stages of the public transport enterprise; therefore a rationally adapting dispatching mode will optimize the intelligent bus dispatching procedure and improve enterprise's operation efficiency. However, the selection and application of the centralized operation & dispatching mode and the traditional decentralized dispatching mode makes enterprise and industry management personnel feel uncertain. In the actual applications, it is difficult to determine which dispatching mode is better, but each enterprise has to select their appropriate mode according to their own demands. This paper, on the basis of summarizing and analyzing existing researches and investigation results, made an preliminary research on the advantages and disadvantages of the different dispatching modes, and the different demands of the different dispatching modes on the organization structure, software function, hardware configuration and system management of the intelligent bus system, which provides the reference for the management personnel selecting the dispatching mode.

（1）Comparison and analysis of advantages and disadvantages

Table 9-2 Comparison on Advantages and Disadvantages of Different Dispatching Modes

Item	Traditional dispersed dispatching	Centralized dispatching
Advantages	● Complying with traditional operation mode, all personnel are familiar with and are used to the operation mode. ● For the driver, there is lack of the full-process monitoring management or there is the incomplete monitoring, and driver prefer the free work and have less psychological inversion. ● It is suitable for the city in which the public transport enterprise has a small scale, weak informatization degree and relatively low labor cost. ● The field dispatching and the management are centralized and integrated, and thence it is easy to realize communication.	● Introducing the operating vehicle monitoring and centralized dispatching system is the mean to adapt to the modern management concept and use the informatization measures to boost public transport management innovation. ● The centralized dispatching system records and collects massive data related to the line operation, which can provide the basis for the operation management department for exploring passenger flow law and operation dispatching law, formulating scientific and rational vehicle operation plan. ● It provides better technical means for the monitoring and management on the full process of vehicles. ● Improve economic benefits: for example Liuzhou: after carrying out the real-time centralized dispatching, the traffic accident reduced by 43% approximately, the safe interval mileage rose by 50% approximately. A single computer dispatches 15 lines or more; 8 dispatchers of a shift replaced the original 86 dispatchers who were dispersed in every station. The overall operation and dispatching efficiency was improved by 300% approximately, the turnover efficiency of operating vehicle improved by 15%, the realization ratio improved by 97%, and the operating on-schedule rate was 95%.
Existing problems and	● Lack of public transport process monitoring, not beneficial for resource optimization.	● Some management personnel and employees were not adapted to the new management mode, and thence did not

disadvantages	● Not suitable for modern delicacy management requirements, operation efficiency remains to improve. ● Not beneficial for the balanced development of demands and transport capacity. ● Imperfect personnel appraisal means, overall enterprise efficiency cannot be maximized. ● Incapable of coping with and meeting sharp increase or changing demands of passenger flow. ● Incapable of adapting to informatization development and lack of efficient data acquisition.	dispose and solve the in-coordination problem of operation supports in the field. ● Some drivers felt unsatisfied with the systematic monitoring and were meant to damage the vehicle-mounted device. ● Since the operation dispatching is separated from the field operation support, the dispatching and the field could not communicate each other smoothly, the dispatching instruction and the executive force of the field operation organization cannot be coordinated properly, causing the coordination between the dispatching center and the field support fail to adapt to the changing demand on passenger flow, or even arouse the conflict between the dispatching center and the operation field. ● Higher requirements on the reliability of operating vehicle are proposed, but the coordination capacity of the operation field for the management, use and repair of vehicle is rather inferior, causing the maneuverability and reliability of operating vehicle fail to meet the requirements on new dispatching modes. ● High requirements on the accuracy of vehicle-mounted device, driver attendance machine and real-time communication. ● High requirement on system safety grade and maintenance level, needing the hardware maintenance of larger scope. ● Requiring higher personnel quality.

（2）Mode selection recommendations

1）As for the mature traditional dispatching modes and the mature management modes, it is recommended to give priority to the traditional mode. Meanwhile upon the development scale, the experiment on the centralized dispatching mode can be conducted gradually. Although the selective experiment can be conducted in the early time, the dispatching mode can be gradually converted as the concept and the management system become mature and adaptive.

2) For the place with huge urban size, complicated urban road network and complicated bus station management, it is recommended to select the integrated mode of traditional dispatching mode and the centralized dispatching mode.

3) For the bus dispatching under regionalization or within large hub facility, it is recommended to select the centralized dispatching mode.

4) For directly turning traditional dispatching mode or directly constructing the centralized dispatching mode, the recommends are made as follows:

On the technical layer:

- Centralized dispatching center
  - Operation commanding & dispatching system of centralized dispatching center;
  - Operation data report generation & analysis system of centralized dispatching center;
  - Dynamic operation data release system of centralized dispatching center; Information interaction platform software;
  - Video monitoring platform software (including the connecting platform with the monitoring system of public security bureau).
- Enterprise side
  - Connecting platform for basic information maintenance system of enterprise's personnel and bus;
  - Connecting platform for scheduling system of enterprise's personnel and bus;
  - Enterprise's dispatching monitoring & supervision client side, driver attendance machine etc.
  - Connecting platform for enterprise's vehicle repair, accident handling, passenger service center system;
  - Enterprise's parking lot management system (including entry, exit, field patrol inspection, vehicle parking information acquisition function)
- Hardware
  - Vehicle-mounted terminal (satellite positioning equipment, 3G video monitoring, POS terminal, intelligent pay machine, CAN bus equipment etc.)
  - Mobile terminal of driver, station management personnel etc. (PDA, mobile phone, Tablet PC);
  - Vehicle entry, exit and station information acquisition terminal (RFID, card access gate, ETC);
  - Site video monitoring equipment;
  - Information release screen in dispatching center, first/last station, station in transit, repair workshop, parking lot etc. ;
  - Site vehicle information acquisition, night watch equipment;

- Seat, network communication, voice intercom, multimedia supporting facility of the centralized dispatching center.

Consistency requirements on management:

- Attention of enterprise leaders has the direct bearing on the one if the centralized dispatching system can run normally or not; it is recommended to improve the recognition of all people on the system, mobilize the initiatives of all people and solve the initial in-adaptation.

- Under the centralized dispatching mode, the operation field is required to enhance the application system theory, stress the uniform coordination for personnel, vehicle, repair, logistics and transport capacity reserves, especially the daily maintenance and repair timeliness of vehicle; moreover it is recommended to conduct management by encircling the comprehensive execution of the instructions of the dispatching center; if not, the operation support capacity of the branch company will be seriously affected.

- Field management personnel and the front-line drivers should comprehensively adapt to the centralized dispatching system and receive the training thereof.

- It is recommended to establish the operation management system for vehicle monitoring and centralized dispatching system, strengthen appraisal, implement responsibility systems; all of them are the supporting conditions for the normal operation of new dispatching mode.

- It is recommended to implement flexibly and efficiently by stages, drive the initiatives of all concerned parties, allocate the dispatching privilege varying with the passenger flow to the field station personnel, in the beginning, make them realize standardization slowly, and then finally centralize at the center side.

- It is recommended to enhance the efficient utilization capacity of the machinery management department for the management, use and repair, and the efficient utilization capacity of motor-driven vehicles, and then finally meet the transport capacity requirements.

- It is recommended to enhance the industry informatization talent reserve of enterprise and support them system to make a continuous improvement.

9.5.3 Organization Management Recommendations

It is recommended to establish the project team or the special technical department led by the leader, especially by the top leader. According to the experience in the intelligent construction of the existing urban public transport in China, the attention of the leaders of every place for the intelligent bus reflects directly the support of policy and finance; the organization and construction conducted by the professional organization led by the top leader affects directly the development of the bus intelligence level of every place. Additionally the dispatching management department at all levels should appoint the full-time IT personnel to support the whole dispatching system.

The project team should seriously organize and analyze enterprise personnel, especially the business flow and dispatching demands of dispatching management personnel so as to form the first-hand project construction data and facilitate the project construction.

In addition to set up the construction system, the project team should concurrently study to formulate the intelligent dispatching system operation and management method so as to integrate with the personnel performance appraisal system, form the performance appraisal mechanism and motivate personnel's initiative for application and work.

Project team should formulate the emergency plan and the alternative plan. When the system goes wrong or is disturbed, or the system cannot be used normally, it is required to start the real-time dispatching measures, such as the manual telephone etc., to relieve the influences of the emergency on the line operation maximally, and finally restore to the system according to the management flow after emergency problem is solved.

The project team should establish the continuous and efficient follow-up evaluation system for the intelligent dispatching system, keep the focus on the system application, such as operating efficiency of bus system (shortening time, reducing travel delay etc.), customer satisfaction, bus safety improvement, energy reduction, economic cost reduction, and then improve the modes and functions of the intelligent dispatching system continuously.

Workflow and appraisal system revision. When the intelligent dispatching system is constructed, the existing rules and systems will not suit for it anymore; therefore they must be modified, including the aspects as follows:

- Vehicle fleet: duty flow of line dispatcher, vehicle fleet dispatching team leader, driver and operation captain;
- Branch center: position duty flow.
- Dispatching commanding center: position duty flow
- Employee position appraisal management flow
- Line emergency disposal measures
- Vehicle plan management regulations

■ Operation disciplines

Pay attention to the coordination with the relevant intelligent dispatching information source departments and the construction of the sharing mechanism. The bus dispatching system cannot work without the actual bus passenger flow demands, especially the passenger flow monitoring of large hub station, rail transit passenger flow arrival and dispatching information connection. All concerned departments are required to establish a good information communication mechanism to guarantee the real-time and efficient transfer of information. Meanwhile, it is recommended to formulate the communication collaboration mechanism at all levels. Especially, the support system for the emergency is very important.

9.5.4 Product Selection Recommendations

（1）Requirements on the accuracy of vehicle-mounted equipment

- When selecting the vehicle-mounted equipment, it is required to select the equipment with the positioning accuracy passed the test of the authoritative department, the positioning accuracy not more than 7 m in the static condition and the positioning accuracy not more than 10m in the dynamic condition.

（2）Communication requirements of vehicle-mounted equipment

- The functions should comply with the requirements specified by Section 5.3 of JT/T 794－2013 and Section 6.1.4 of Smart Urban Public Transport Demonstration Project Construction Program Standards: Vehicle-mounted Intelligent Service Terminal of Urban Public Bus and Trolleybus.

- Stability requirement: it should comply with the requirements specified by Section 7.1.1 and 7.1.3 of Smart Urban Public Transport Demonstration Project Construction Program Standards: Vehicle-mounted Intelligent Service Terminal of Urban Public Bus and Trolleybus.

（3） Requirements on operation and network environment

- It should comply with the requirements specified by Section 7.6 and 7.7 of Smart Urban Public Transport Demonstration Project Construction Program Standards: Technical Requirements for Intelligent Dispatching System of Urban Public Bus and Trolleybus.

（4）Requirements on other information acquisition equipments

- All other information acquisition equipments involving in intelligent dispatching system are required to have an equipment stability not less than the stability of the vehicle-mounted equipment.

（5）Recommendations for selection of small and medium-sized enterprises for dispatching software and dispatching platform

- Currently there are the public transport dispatching software and dispatching platforms based on the cloud technology on the market for the small and medium-sized public transport enterprises for selection, all of them can realize the small investment, quick effect and easy use. Therefore small and medium-sized enterprises can use their construction modes as the reference when selecting system construction mode.

9.5.5 Construction Implementation Recommendations

(1) Focusing on the collection of dispatching system construction demands

- Business flow control, data specification, network security (3A certification), popularization and implementation (demands, development, implementation and training) of operation and maintenance system.

- Dispatching system demands: prepare vehicle scheduling and verification demand more scientifically, dispatch the commanding demands more efficiently (existing passive dispatching, data lagging).

- Operate follow-up and emergency event demands more intelligently.

- More accurate statistical analysis demand.

- More channel's information interaction demand (originally it was the real-time intercom; the new vehicle-mounted equipment realizes the voice communication);

- More personalized passenger information service demands (vehicle departure information are available at the hub station and the starting station).

- The needs of comprehensive utilization and upgrading of the existing software and hardware.

(2) Software flow requirements

- The functional requirements of the dispatching system should be subject to the requirements specified by Section 6 of Smart Urban Public Transport Demonstration Project Construction Program Standards: Technical Requirements for Intelligent Dispatching System of Urban Public Bus and Trolleybus.

- There is good business flow connection and flow optimization function for the dispatching user, and there is good user interface.

- The flow should be advanced and flexible, and can cope with emergency, such as traffic jam, intersectional signal delay, station parking, traffic accident, weather conditions etc.

- The dispatching system should have a good expansibility; it is recommended to construct along with the works of the government together, plan the data connection with the relevant specialty departments, as well as the interaction of business data in advance; it is recommended to conduct based on the SOA data platform so as to avoid frequent change in the later time.

- Data query: the data query interface must be opened in 5 seconds, and the query result must be reverted in 15 seconds.

- Conduct the emergency command from top to bottom automatically in emergency [sudden change in passenger flow, weather, control, road collapse, supporting rail transit (linked with rail transit command center)], passenger evacuation in large hub, level-to-level automatic release of dispatching instruction, implementation of instruction, and improvement of efficient management for emergency.

Table 9-3 Examples of Emergency Dispatching Means

<table>
<tr><th>Factors</th><th>Specific situations</th><th>Real-time scheduling</th></tr>
<tr><td>Driver</td><td>Sick leave, casual leave
Schedule missed, late
Accident</td><td rowspan="4">Short line
Express
Inter-zone
One-way
Add vehicles
Reduce vehicles
Adjust departure plan</td></tr>
<tr><td>Vehicle</td><td>Vehicle breakdown
Vehicle maintenance
Rental
Transferred vehicles
Repaired vehicles
Delay due to gas refilling</td></tr>
<tr><td>Road</td><td>Traffic accidents
Municipal construction
Detour for any reason
Traffic jam</td></tr>
<tr><td>Passenger flow</td><td>Interruption due to large passenger flow
Fast single trip due to small passenger flow
Passenger flow affected by unexpected events
Passenger flow affected by weather changes</td></tr>
</table>

(3) Requirements on dispatching &scheduling policy and scheduling method:

- Planned and scrolling scheduling and dispatching are combined in most cities of China. The public transport companies are suggested to take effective dispatching policy in time according to passenger flow statistics and actual situation of the intelligent dispatching system, avoid bunching and large interval, and ensure intelligent, real-time and scientific dispatching of vehicles, in order to improve service quality and efficiency of public transport.

- The shift arrangement of buses and trolley buses should guarantee the implementation of scheduling plan. On this basis, each of the bus lines should guarantee substitution rate not lower than 1.4and an alternation rate not lower than 0.08.

- The accuracy of automatic generation of electronic waybillis not lower than 90%, and data analysis means should be provided to ensure that the data accuracy is not lower than 98% after data analysis and processing.

- Operation dispatching shall ensure the service provision. If large interval is caused by traffic jam, bad weather or other reasons, dispatchers should take appropriate dispatching measures according to the actual situation, and adjust the travelling time reasonably to restore normal running order as soon as possible.

(4) Establishing standard of data structure

- Intelligent public transport dispatching system should be established in standard data structure together with various business systems and related industry sectors to facilitate future system expansion and upgrade as well as related data analysis and decision.

- Construction matters are synchronized with governmental supervision system. Planning shall be made in advance for data connection and business data interaction with other departments of relevant specialties. Expansion demand shall be reserved based on SOA data interaction platform.

(5) Pay attention to security issues: as of information systems and other new technologies, pay attention to privacy, communication protocol and cloud issues.

(6) Examples of construction scale and costs

Through research on major cities of China, the construction costs of public transport dispatching system are shown in Table 9-4.

Table 9-4 Construction Costs of Dispatching Systems in Major Domestic Cities

No.	**City**	**System composition**	**Construction costs (million RMB)**	**Remark**

1	Beijing	Dual-mode vehicle equipment configuration for 7,796 vehicles, upgrade of 12,474 vehicle terminals, 20,000 onboard controllers, upgrade business database of bus passes. Real-time acquisition and transmission, traffic planning and passenger flow matching, real-time monitoring, vehicle terminals dispatching instructions, position with front and rear vehicles, and deviation from dispatching instructions.	11000	Under constructi on
2	Chongqing	4368 vehicle terminals, 275 electronic stop boards, dispatching system	5400	Under constructi on
3	Zhuzhou	1127 vehicle terminals, 50 bus lane capture equipment, dispatching systems, ERP management	3500	Under constructi on
4	Suzhou	Full sets of equipment for 4066 buses, 210 stop information collection terminals, as well as data sharing and exchange platform, four types of application systems, and public transport operation and dispatching system of the city	8000	Under constructi on
5	Tianjin	3621 vehicle terminals, dispatching system	3000	Materials approved for the project
6	Chengdu	Over 4000 vehicle terminals, dispatching system function - monitoring, dispatching, and data collection and analysis	2000	Data of 2008
7	Dalian	Renovation of 1856 vehicle terminals, 69 electronic stop boards, dispatching system	3000	Materials approved for the project
9	Shenzhen	1000 vehicle terminals, dispatching system	3000	Under constructi on
10	Wuhan	15 sets of vehicle terminals, BRT camera equipment, dispatching system, BRT dispatching system	3000	Materials approved for the project
11	Urumchi	2 sets of passenger flow capture devices for BRT stops, 100 sets of onboard passenger flow capture equipment, dispatching system, communication system, room supporting	2000	Materials approved for the project
12	Baoding	286 sets of vehicle terminals, 180IC card	3500	Materials

		tapping devices, 40 stop dispatching terminals, 200BRT terminals, dispatching system, BRT system, ERP system		approved for the project
13	Hangzhou	1000 vehicle terminals, network system, dispatching system, video surveillance system, ERP system	3500	Materials approved for the project
14	Hohhot	400 vehicle terminals, 1583 card tapping devices, dispatching system, analysis and decision	2800	Materials approved for the project
15	Shijiazhuang	900 vehicle terminals, 40 stop management, 208BRT sites, 52 stop management terminals, dispatching system, BRT monitoring system, ERP	6500	Materials approved for the project
16	Taiyuan	1200 vehicle terminals, 20 electronic stop boards, 628 video monitoring, dispatching system, network system	4800	Materials approved for the project
17	Yiwu	1130 vehicle terminals, 1130 passenger flow capture equipment, card tapping device, 100 electronic stop boards, dispatching system, ERP systems, etc.	5500	Materials approved for the project
18	Hefei	3067 onboard passenger flow capture equipment, WIFI equipment, 300 electronic stop boards, dispatching system, integrated analysis system	4600	Materials approved for the project
19	Shenyang	5232 vehicle terminals, dispatching system	5300	Materials approved for the project
20	Guiyang	2290 vehicle-mounted video, 40 cameras, 30BRT vehicle terminals, dispatching system, BRT monitoring system, video surveillance system	4800	Materials approved for the project

9.5.6 Suggestions on the Operation and Maintenance Mode of System Construction

Good business model assure the enterprise succeed. As the development of technology and economy, the operation and maintenance modes of the intelligent dispatching system have changed from the traditional way to some new ways, The following several ways for enterprises reference:

(1) Traditional operation and maintenance modes

1）Construction based on government investment

For some bus companies, which belong to the government, the operation and maintenance are directly managed by the government. So, the traditional operation and maintenance mode is based on government. And the company can choose it according to its characters.

2）Construction based on enterprise investment, and apply for the government fiscal subsidy

For advancing the public transport development, in our country, bus companies will apply fiscal subsidy from local government in general. Now, there are some cities, which want to improve their manga and service abilities, support bus companies to build the information sensing system in the vehicle and the intelligent dispatching system. And after construction of system, the company sends data to the government, in the same time the government take the initiative to give money to the company.

(2) New operation and maintenance modes

1） Cooperate with in changing resources

With the influence of the internet companies and some hardware service companies, more and more governments and companies can cooperate with in changing resources for operation and maintenance. Such as , the bus company can use there GPS data to change the internet company's services, which include the hardware and software building. And the internet company will use the data to do some use, for example, traffic information for people.

2）Buy a third-party service

With the cloud technology development, there are some mature intelligent transportation dispatching platform companies. Some small and medium-sized enterprises can choose this model by buying a third-party service. They can put the whole system's operation and maintenance. to the third-party, and pay for it every year. They only need to do is to give their request, then use and supervise it.

9.6 System Assessment and Evaluation Indicators

(1) Cost-effectiveness Analysis

In the process of building intelligent public transport dispatching system, the decisions of public transport companies and management departments will have different effects of input and output, so that these effects also should be analyzed according to qualitative or quantitative indicators in the process of building and implementation in order to facilitate decision-making.

In a certain time frame, the investment cost of the public transport companies is the most specific, including the fixed costs of initial construction, variable costs of annual operation and maintenance and implicit costs in time and technology of the companies to improve service levels. These costs include:

- Construction costs of information collection facilities for vehicles, dispatching centers or stops, i.e. vehicle terminals, communication networks and other one-time construction costs.

- If repeat construction or not, and the Initial costs of repetitive constructions (software and hardware development, operation and management mode and algorithm research, etc.)

- Operation and maintenance costs, routine operation and maintenance costs (including HR expenditures, commercial expenses, etc.);

- Time investment and costs in enterprise development stage;

- Costs of technology accumulation for enterprise development.

The costs of industry management department include industry policy and fiscal subsidies, and the public costs are the public transport cost.

The benefits of intelligent public transport dispatching system can be analyzed in aspects of public transport companies, passengers and industry management department as follows:

- Passengers: time savings and satisfaction are the main benefits;

- Public transport companies: operational efficiency, vehicle operating costs, energy consumption data etc.;

- Industry management department: dynamic regulation, improvement in social benefits, etc.

Through the above analysis, the cost-benefit analysis indicators of intelligent dispatching system are created as shown in Table 9-5.

Table 9-5 Cost-benefit Analysis Indicators of Intelligent Dispatching System

Interested parties	**Costs**		**Benefits**	
Public transport companies	Direct	✧ Construction costs: ✧ Initial expenses of the project ✧ Project implementation, construction and installation costs ✧ Other expenses of the project ✧ Operation and maintenance costs: ✧ Update and maintenance of equipment and system	Management cost savings	✧ Transport costs reduced by % ✧ Operation and maintenance costs reduced
			Management capacity improvement	✧ Dispatching capabilities enhanced ✧ Emergency response capabilities improved ✧ Resource utilization increased
	Indirect	✧ Time investment of enterprises in development stage ✧ Technology accumulation of enterprise development	Operational efficiency improvement	✧ Line capacity control ✧ Dispatching time ✧ Departure capability
			Employee satisfaction	✧ Job content (mainly working mode and intensity). ✧ Working environment;
Passengers	Direct	✧ Time	✧ Travel time saved ✧ Convenient travel, improved accessibility ✧ Travel safety improved	
	Indirect	✧ Psychological feelings ✧ Security risk		
Government and society	Direct	✧ Currency support	✧ Dynamic regulation achieved ✧ Road resource utilization increased ✧ Public transport delay reduced by % ✧ Fuel consumption reduced by % ✧ Emissions reduced by %	
	Indirect	✧ Policy support		

(2) Main evaluation indicators

The evaluation should be carried out mainly from the following aspects:

(1) Match degree of the system and business process exceeds 90%; sampling survey shall be carried out after 3 months from formal operation of project.

(2) Employee satisfaction increased by not less than 10%; sampling survey shall be carried out after 6 months from formal operation of project..

(3) Working environment improved significantly; sampling survey shall be carried out after 6 months from formal operation of project.

(4) System response time less than 5 seconds; continuous monitoring shall be made through system after formal operation of project.

(5) System reliability exceeds 90%; continuous monitoring shall be made through system after formal operation of project..

(6) Response time to system failure less than 10 minutes; continuous monitoring shall be made by system management personnel after formal operation of project.

(7) Obtained benefit reference values are as below:

Making comprehensive statistics and analysis after 1 year of formal operation of project

- Transport costs reduced by not less than 10%
- Operation and maintenance costs reduced by not less than5%
- Resource utilization increased by over 10%
- Single line dispatching time saved by not less than 20%
- Departure capacity increased by not lower than 10%
- Emergency response capacity increased by not lower than 15%

9.7 System Construction, Operation and Maintenance Cost

(1) System construction cost

Table 9-6 Construction Cost of Urban Public Transport Intelligent Dispatching System

System	**Sub-system**	**Module**	**Construction suggestions**	**Expected cost (10 thousand Yuan)**

Public transport intelligent dispatching	Intelligent dispatching	vehicle scheduling	Basic type module	30~50
		Vehicle shift	Basic type module	30~50
		Automatic dispatching	Optional type module	30~50
		Dispatching management	Basic type module	20~30
	Operation monitoring	Line monitoring	Basic type module	50~60
		Vehicle monitoring	Basic type module	30~40
		Operation diagram monitoring	Basic type module	30~50
		GIS monitoring	Basic type module	30~40
		Video monitoring	Optional type module	50~100
		IC card data monitoring	Optional type module	50~80
		Energy consumption monitoring	Basic type module	30~80
	Statistical analysis and auxiliary decision-making	Statistical function	Basic type module	15~30
		Reporting function	Optional type module	10~15
		Analysis function	Optional type module	40~60
		auxiliary decision-making function	Basic type module	50~100
	Basic information management	General requirements	Basic type module	10~20
		Information definition	Basic type module	10~20
		User role management	Basic type module	15~25

Note: As shown in Table 9-6, for meanings of basic type module and optional module refer to sections 6.8 Table 6-7. Among which, expected cost excludes expense for hardware configuration and is only used as reference for software development expense. Also, relevant functions involved shall be subject to list of functions in *Standard on Urban Intelligent Public*

Among which, expected cost excludes expense for hardware configuration and is only used as reference for software development expense. Prices in the table are calculated based on 2014-2015 market survey and must be updated and evaluated according to market survey in actual construction.

(2) System operation and maintenance cost

Operation and maintenance cost of intelligent dispatching system is about 5%-10% of its construction cost.

10 Decision Support System

10.1 Present Survey Situation

10.1.1 Requirements on Decision Support in Construction Guide of Public Transport Intelligent Application and Demonstration Project

In the Construction guidance of the urban intelligent public transport demonstration project, decision support system is an important part of urban public transport regulatory platform, decision support system included Basic business management, integrated operation monitoring, security management, service quality and level of development assessment, Statistics and analysis, and other functions. Based on analysis of Traffic data, transport network and capacity configuration can be optimized. Statistics and analysis of urban public transport capacity, operation safety and efficiency can be shown in the form of figures. Public transport network optimization and adjustment can be achieved in some cities.

The content related to decision support shown in Table 10-1.

Table 10-1 Public Transport Decision Support in the Guide

Decision support content	**Specific functions**
Emergency security management	➢ Emergency resource management ➢ Emergency response management
Assessment of service quality and evaluation of development level	➢ Service quality assessment: establish evaluation index system and model for the assessment according to the standard ➢ Evaluation of development level: achieve statistics, analysis, calculation, overall evaluation and analysis of each index ➢ Development and monitoring of transit-oriented cities: achieve statistics, analysis, calculation, overall evaluation and analysis of each index according to the "Evaluation System for Transit-oriented Cities" issued by the Ministry of Transport
Statistics and analysis of transport capacity	➢ Departure frequency of each line ➢ Fulfillment rate of dispatching ➢ Completion of operation plan ➢ Operation mileage
Statistics and analysis of passenger flow	➢ Passenger capacity ➢ Transfer volume ➢ Fitness analysis of capacity and volume
Statistics and analysis of operating efficiency	➢ Punctuality rate ➢ Punctuality rate of first and last departure ➢ Average running speed
Statistics and analysis	➢ Speeding, crossing line, overtaking stop, illegal door opening

of operational safety	and closing and other illegal driving conditions of buses and trolley buses ➢ Accidents statistics ➢ Interval mileage of safe running ➢ Frequency of fatal accidents
Energy consumption statistics	➢ Detailed inquiry of energy consumption of buses and trolley buses ➢ Integrated inquiry ➢ Various types of statistical analysis and trend change analysis
Lines, network and sites optimization and adjustment	

10.1.2 Construction Status of Decision Support System in Different Cities

10.1.2.1 Construction Status of Decision Support System in Guangzhou

In the aspect of decision support, Guangzhou has built the public transit network adjustment system, public transport industry regulatory system, urban road traffic analysis system and public transport passenger flow analysis system.

(1)Public transit network adjustment system

Currently, Guangzhou has constructed public transit network basic data management information system that meets the business needs of transit network management and public transit network resource management database that covers the city, which can achieve the process management of core businesses for public transport lines and stops within the city, provide timely, accurate and comprehensive information about the public transport lines to public transport administrations, provide intuitive graphical and data support for the setup and adjustment of public transport lines, and provide basis for decision making of public transit lines through the index calculation, analysis and assessment of network architecture. The decision-making basis currently offered by the system is only in the aspect of network structure, while passenger flow analysis and evaluation will be added in the future, and the feedback when the system has been launched is combined to improve the system, and provide decision making basis for better planning of the public transit network.

(2) Public transport regulation system

Achieve list inquiry of public transport lines, inquiry of passing stops, inquiry of first and last departure time and other basic data; basing on GIS platform, display vehicle location on the monitoring map, traveling direction and other information in real-time, support vehicle location inquiry and track playback; supervise the public transport service quality through punctuality rate of first and last departure, violation rate of non-normal departure, violation rate of departure interval, route following rate of drivers and other indicators. Monitor speeding behaviors and alarm information; through summary and analysis of operation data, users can monitor, query, summarize and analyze daily vehicle dispatching information of dispatchers and vehicle feedback of public transport companies.

(3) Urban traffic operation analysis system

The system collects urban road traffic flow, speed and other basic traffic data accurately in real-time in accordance with the function orientation of "real-time analysis, trend analysis, early warning analysis and measures analysis" through floating car, video detection, microwave detection and other collection means of basic traffic data; basing on the integration and sharing of resources, reflect the status of urban road traffic comprehensively, accurately and stably with the evaluation index and system, fully grasp the status of all roads of Guangzhou, strengthen in-depth analysis of macro and micro urban traffic, achieve real-time status analysis of 635 trunk roads and secondary roads (over 1100km), automatic warning of congested roads and forecasting of road congestion, and provide decision support for urban traffic organization and management.

(4) Public transport passenger flow analysis system

The system bases on the departure data of intelligent public transport system of all public transport vehicles and all-in-one pass data of the entire city. Through this system, the users can obtain the passenger flow demand of all roads, designated areas, lines and stops of different date and time periods. Analyze departure of relevant lines according to passenger flow, optimize and adjust, forewarn and monitor the service quality. Collect and analyze in depth the passenger flow of all public transport lines, stops and vehicles of the city, and play the "actuary" role of public transport management.

Initially, public transport information system didn’t achieve real-time monitoring of passenger flow, and thus it is difficult to adjust the departure plan in time according to the passenger flow. As the rule of passenger flow is unknown, the operation and dispatching of public transport vehicles mostly rely on experience, and can’t be adjusted according to the changes of passenger flow; particularly during peak hours, the passenger satisfaction of certain routes is low due to congestion. Therefore, the public transport passenger flow analysis system had been the established in 2013 to obtain passenger flow data in real-time and carry out multi-dimensional analysis to provide decision support for government regulation and operation and dispatching of public transport companies.

10.1.2.2 Construction Status of Decision Support System in Shenzhen

Shenzhen has initially built the transportation management online service platform, and it is establishing decision support system for public transport industry by virtue of the opportunity of "Shenzhen Urban Public Transport Intelligent Application Demonstration Project". By establishing Shenzhen Municipal Public Transport Industry Decision Support System, it provides analysis and decision-making window for Shenzhen traffic administration. In the specific analysis process, carry out multi-dimension and multi-layer analysis of different themes, different time and different space for the basic data collected by the data acquisition system, and provide decision support for the development of plan and management programs; provide basis for decision making for the implementation, adjustment and improvement of public transit network and operation services.

(1)Passenger flow analysis subsystem

Passenger flow analysis subsystem mainly includes passenger flow scale statistics and analysis, spatial distribution statistics and analysis, time distribution statistics and analysis, and characteristic attributes statistics and analysis. It achieves statistics and analysis of public transport passenger flow, subdivision passenger flow, custom region passenger flow, section passenger flow, specific line passenger flow, and boarding/alighting amount of specific stop (daily average); passenger flow attraction statistics among large districts, medium districts, small districts, and specific stops (OD matrix); statistical period is year, month (months), or day (days); achieves statistics of passenger travel intensity (trip rate), travel time, travel distance, travel costs and other characteristic values.

(2)Network assessment subsystem

Network assessment subsystem includes plan and construction indicators assessment, current supply and demand assessment, public transport integration assessment, and assessment of impact of transit network planning. It reflects the health level of transit network shape; reflects the health level of capacity supply in macro, meso and micro aspect; reflects transfer activity, and assesses the collaboration degree of urban public transport resources integration and network integration of different types and different levels; analyzes the positive impact (attracting feeder passenger flow) and negative impact (splitting passenger flow of same route)of planned transit network (providing network rendering capabilities) on existing regular public transport, predicts the impacted degree of regular public transport lines in advance, and provides decision making information for the adjustment of regular public transport lines when the planned tracks are built and opened to traffic.

(3) Operation evaluation subsystem

The main purposes of public transport service quality evaluation: first, objectively describe and grasp the status of public transport service quality in details and analyze the causes of problems, in order to provide basis for decision making in terms of policies, measures and strategies to improve the service quality of public transport; second, keep the public transport travel utility ahead of other modes of transport according to local conditions, and thus enhance the attractiveness and sharing of public transport travel, to achieve sustainable, environment-friendly and energy-saving development of transport in large cities. Operation evaluation subsystem mainly includes periodic reporting of enterprise operational data and operation service assessment.

(4)Alert monitoring subsystem

Reflects the abnormal changes of public transport environment within a certain period (one month or season) through monitoring, predicts problems in advance, and provides decision support to respond to and solve conflicts before exposed, including passenger flow monitoring, stop monitoring, lane monitoring, and terminal monitoring module.

10.1.2.3 Construction Status of Decision Support System in Foshan

Foshan has established and launched the transport decision support system that covers the status of public transport and rental. On public transport, excavates and analyzes the static and dynamic data of public transport vehicles to get the data that reflects the status of public transport operations in Foshan, and provides support in daily operating conditions and related decision-making for industry department.

Transport decision support system includes transport decision management subsystem, transport decision data access subsystem and public transport operating status display subsystem.

(1) Foshan transport decision-making data management subsystem

Data filtering, data preprocessing, data loading, storage and management of urban fundamental geographic vector data, image data, transit network data, basic information point data, and urban transport infrastructure; urban transit network data, public transport stop data and dynamic data, and provide basic business data for road traffic operation evaluation, public transport evaluation and traffic simulation. Establish transit network evaluation database, public transport database, and geographic information system database.

(2) Foshan transport decision-making data access subsystem

Access to GPS data and IC card data of existing intelligent public transport system of Foshan through standard data sharing interface, develop data receiving program, transform and expand existing database table structure fields, which are compatible with existing or new device data access . Allow viewing data access status and data access details (transit network, base maps and other static data, GPS data, and real-time traffic data).

(3) Foshan public transport vehicle status display subsystem

Public transport vehicle status display subsystem includes operation monitoring and evaluation of public transport operation. Reflect the status of public transport through the analysis of routes, terminals and other static information and the level of construction and development, service levels and the overall efficiency and other dynamic indicators.

(4) Foshan road traffic operation evaluation subsystem

Make real-time quantitative evaluation for traffic status of Foshan, analyze and display traffic status of core areas in Foshan on-line in real-time Foshan through scientific and rational evaluation index of traffic congestion basing on GPS real-time monitoring data of existing passenger vehicles on roads in Foshan (including: public transport vehicles, rental vehicles and other vehicles of enterprises) and traffic flow data of detectors in fixed sections.

Monitor and assess roads of different grades in real-time, describe the dynamic changes of traffic congestion from congestion intensity, scope, time, frequency and operation reliability, screen out congested sections and hours of the transit network, and analyze the traffic congestion situation objectively. Forecast the road traffic status within a certain time through statistics, excavation and analysis of relevant history data.

10.1.3 Status of Traffic Decision Support Construction under Internet

Currently, some Internet companies and research institutes gradually explore the traffic data analysis results decision support and information services under Internet support basing on mass traffic data and Internet data, relying on own technologies and resources. For example, Urban Data Party builds non-profit online traffic innovation and service platform through cooperation with scientific research institutions, universities and R&D enterprises to explore and exploit the value of city data and support government decision-making and public information services; Baidu Map provides nationwide integrated travel solutions, real-time traffic, event information service and driving navigation services, and provides users with personalized travel proposals; meanwhile, Baidu Map LBS open platform enables Baidu Map location visualization big data, displays nationwide population migrations in real-time, and shows population migration trajectory and characteristics; Baidu Huiyan provides passenger flow analysis through massive population behavior technology and big data engine and provides support for refined management; the future traffic laboratory initiated by Shenzhen Traffic Information and Traffic Engineering Laboratory integrates taxi/bus GPS, all-in-one pass, parking lots, mobile signaling, carbon emissions, residents travel survey, passenger flow and other information in depth, excavates data application value, and achieves Internet-oriented open data sharing services.

10.1.4 Research Summary

In the guide of urban public transport intelligent application demonstration project, decision support is mainly statistics and analysis data and provides initial support for the transit network adjustment.

In recent years, with the construction and promotion of transit-oriented cities of the Ministry of Transport, some cities such as Beijing, Shanghai, Guangzhou, Shenzhen, Suzhou and Foshan have gradually built the transport decision support systems, which are being optimized in the aspects of initial basic business management, daily operation monitoring, transit network optimization, service level evaluation, and data mining and analysis. Different regions have different construction and development levels, and different problems in construction and applications, such as incomplete data collection and inadequate support for decision support; there is also experience such as accurate grasp of the needs of city level decision support and gradual construction promotion, which can provide practical experience and reference value for the construction of decision support systems in other cities.

In the context of the Internet, decision support is not only the work of government departments, more and more Internet companies and research institutions rely on advanced technology and massive resources, mine big data value through multilateral open sharing platform, and provide richer data analysis results and decision support.

This topic studies the jobs that public transport industry decision support can really do in the Internet context. Analyzes user group travel behaviors basing on massive traffic data, Internet and mobile network user data, mines traffic information valuable for industry management departments, plays an auxiliary role in decision support, and provides services to government departments.

10.2 Experience Summary

(1)Combine, mine and analyze data that can be collected from the actual business and specific needs in city level, and provide decision support at different levels and dimensions.

In Guangzhou for example, integrate and mine card tapping data and video capture data through the construction, and provide users with timely and accurate passenger flow and departure rules through multi-dimensional analysis and report output; access and analyze mileage, speed, punctuality rate, passing frequency and other vehicle operation data, and assist government in operational performance regulation of enterprises; provide data support for transport capacity by analyzing the vehicle number, traffic flow and speed distribution; provide verification functions of data related to public transport subsidies according to all-in-one pass tapping data and public transport operation data, and calculate the subsidies to provide an objective basis for the subsidies; create an index system suitable for the assessment of Guangzhou public transport energy consumption and emissions by combining relevant requirements of the "Road Transport Energy Consumption Monitoring Data Acquisition Program" issued by the Ministry of Transport, "Major Pollutant Emission Reduction Plan of Guangzhou for the12thFive-Year Plan" and "Energy Conservation Program of Guangzhou for the12th Five-Year Plan" and local public transport industry of Guangzhou.

(2) Strengthen top-level design, normalize and guide intelligent public transport construction of various departments, refine actual decision-support needs, integrate information resources of various departments, and provide better decision support services.

Urban intelligent transport has a good development foundation in Shenzhen. The implementation of urban intelligent public transport pilot and demonstration project will further standardize the construction of public transport information engineering in Shenzhen. On the one hand, the construction of Shenzhen urban intelligent public transport has been arranged and planned from the top-level design level to avoid repeated construction and investment as much as possible; on the other hand, the construction of decision support systems has improved the management and work efficiency of public transport administrations, improved scientific decision-making ability, optimized and adjusted transport capacity resources, stop and terminal layout, improved the utilization of public transport resources and thus improved urban management and operational efficiency.

In the ongoing construction of transit-oriented cities intelligent demonstration projects, many cities have strengthened the top-level design, have designed more comprehensive decision support system functions, including daily monitoring, service assessment, financial subsidies and emergency response, and have fully considered the current status of information resources to provide more complete and compliant decision support services.

(3)From the level of overall traffic development and urban transport operation, establish inter-departmental data sharing and collaborative response mechanism and improve the operation and safeguard mechanism, and ensure that the appropriate decision-making can respond and implement promptly when the decision support system has been completed.

Shenzhen has formed a large integrated transport system, the Shenzhen Municipal Transport Commission and the Traffic Police Bureau communicate smoothly, and passenger flow assessment, network operations, alert monitoring and other decision support system run properly under data sharing support and collaborative handling mechanism. After constructing the decision support system, perfect operation and safeguard mechanism should be provided to ensure that all departments perform their duties, and appropriate decisions can be implemented timely and appropriately.

(4) Explore the construction and operation mode of decision support system according to local practice.

Guangzhou, Shenzhen and Foshan have built decision support systems, which only cover business management, routine operation monitoring and other basic functions in initial stage. With the continuous improvement of infrastructure and urban development, the decision support systems are more perfect, and gradually cover transit network optimization, service assessment, fuel subsidies, energy consumption monitoring, integrated data mining and analysis, road congestion index release, route guidance and other aspects.

As of how to promote the system construction and implementation in initial stage, and how to ensure the effective functioning of the system with the improvement and upgrading of system functions, refer to the construction experience of the cities, and explore gradually according to the actual situation.

(5)Under Internet support, explore richer applications of decision support, and provide support for users such as government, enterprises and research institutions.

Baidu Huiyan provides passenger flow analysis through the massive population behavior technology and big data engine, and provides references for different users to grasp passenger flow data; the future traffic laboratory integrates basic data including license plate recognition and vehicle inspection of traffic police, environmental protection and other department, obtains model constitution and traffic information of different areas and sections, builds fleet constitution model, calculates transport energy consumption and emissions, publishes traffic emissions accounting result once every hour, generates carbon emission maps, and provides support for industry departments to develop carbon emissions monitoring and energy conservation policy. Therefore, richer applications should be explored for decision-making under Internet support to provide support for different users.

10.3 Problems and Demand Analysis

10.3.1 Problems

(1) Nationwide, the decision support systems are deficient in general, and the built decision support systems in some cities are insufficient in data acquisition, application and analysis.

Decision support system bases on good information collection. The current information level of urban public transport companies is not unified in China, the understanding and development of decision support system vary in different cities, resulting in lack of industry decision support system in most cities of China. Decision support systems that have been built mainly have statistics, analysis and other basic functions in initial stage, dynamic data and data mining and analysis are insufficient, and can’t provide effective support for transport decision; every region is designing and building relatively complete decision support system gradually.

(2) Core functions still need determination to provide support for different services and decisions.

Decision support system includes transit network optimization and adjustment system, passenger flow statistics and analysis system, infrastructure service capability assessment system, line status assessment and early warning system. Currently, due to the lack of a unified core function requirement suitable for all cities, each city has different priorities in the construction of decision support system according to own characteristics, resulting in imperfect system functions; during overall construction of decision support system, appropriate decision support capabilities should be constructed according to local situation and different business needs, and the core functions and available decision support should be determined.

(3) Pay attention to the top-level design, and further strengthen collaboration in different business departments.

The transport decision support of the city level needs support of different business data. Pay attention to the top-level design, system arrangement, planning and construction, further strengthen collaboration in different business departments, and integrate information resources of various departments to provide better decision support services.

(4)The data requirements should be determined, and the algorithms about comprehensive data application and how to use various data for decision support should be further studied.

Data information can be divided into basic data, dynamic data, statistical data, change data, alarm data, image data, and released data. In the construction process of decision support system, application system construction plan should be combined to analyze data requirements that support these applications, and determine the main contents of information resources needed for application system construction.

Facing diverse and closed operating environment, the algorithms about how to collect and manage traffic data, how to ensure the data quality and how to use various data to provide support for transport decision need further study.

10.3.2 Public Transport Decision Support Needs of Current Stage in Different Regions

Public transport decision support content in the guide is mainly demand of city level. In addition, it also includes decision support in joint coordination, feeder passenger flow analysis, financial subsidies and other aspects; at the provincial level, the demands for decision support are mainly reflected in operation monitoring, safety monitoring, quality of service, financial subsidies, industry statistics and analysis; at ministerial level, it focuses on the statistics and analysis data of public transport across China and related policy development.

User travel data from mobile APP maps and navigation are counted by hundreds of millions bytes every day. With the support of Internet data, the massive transport data of traffic departments can provide wider public transport decision support and more deepened applications for all levels of industry management departments and relevant enterprises. These include: personal trip-chain analysis based on mobile phone data and credit card data, group travel behavior analysis based on map requested data, public transit network adjustment and optimization based on large data, emission monitoring, feeder passenger flow monitoring, accident analysis, and public transport index analysis. The decision support needs of ministerial, provincial and municipal users are shown in Table 10-2.

Table 10-2 Summary of Decision Support Needs

Users	Decision support functions under traditional conditions	New decision support applications under Internet support
Ministerial users	✓ Financial subsidies ✓ Industry statistics and analysis ✓ Analysis of public transport development in different regions	✓ Traffic migration ✓ National passenger capacity distribution ✓ National public transport survey data ✓ National bus emission monitoring and analysis ✓ Analysis of the spatial distribution of accidents over the years
Provincial users	✓ Operation monitoring ✓ Safety supervision and collaborative interaction ✓ Evaluation of service quality ✓ Financial subsidies ✓ Industry statistics and analysis ✓ Report support	✓ Analysis of public transport index ✓ Analysis of group travel behaviors of intercity users(between different regions of the province, intercity) ✓ Analysis of road traffic operation index of the province ✓ Bus emission monitoring and comparison of the province ✓ Sharing and analysis of all kinds of traffic survey data ✓ Analysis of the spatial distribution of accidents over the years
Municipal users	✓ Daily operation monitoring ✓ Traffic operation and jam analysis ✓ Urban passenger flow monitoring and analysis (public transport and feeder) ✓ Public transit network adjustment and optimization ✓ Evaluation of public transport service level ✓ Industry statistics and analysis system (running statistics, monthly and annual report support) ✓ Financial subsidies and compensation accounting ✓ Safety management decision	✓ Road traffic operation index analysis ✓ Feeder passenger flow monitoring and analysis of public transport supply capacity ✓ Public transit network adjustment and optimization based on big data ✓ Public transport index analysis ✓ Analysis of the spatial distribution of accidents over the years ✓ Analysis of personal trip chain information ✓ Analysis of group travel behaviors of users ✓ Bus emissions monitoring and analysis ✓ Sharing and analysis of all kinds of traffic survey data ✓ Analysis of driving behaviors of bus drivers

10.3.3 Design and Construction Plan

Through research and analysis, decision support has different basis and different construction status in different cities, and has different construction foundations in terms of capacity statistics and road operation analysis. There are some problems, mostly in static data statistics, insufficient analysis and mining of dynamic data, and insufficient support to integrated decision of industry departments. In addition, hundreds of millions bytes of Internet data will produce impact on decision support of transport industry. In the specific construction, local condition and problems should be combined to analyze the needs of decision support construction, assess the construction phase objectively, choose the appropriate decision support capabilities according to the recommendations, customize personalized functions, implement and construct by phases, as shown in Figure 10-1.

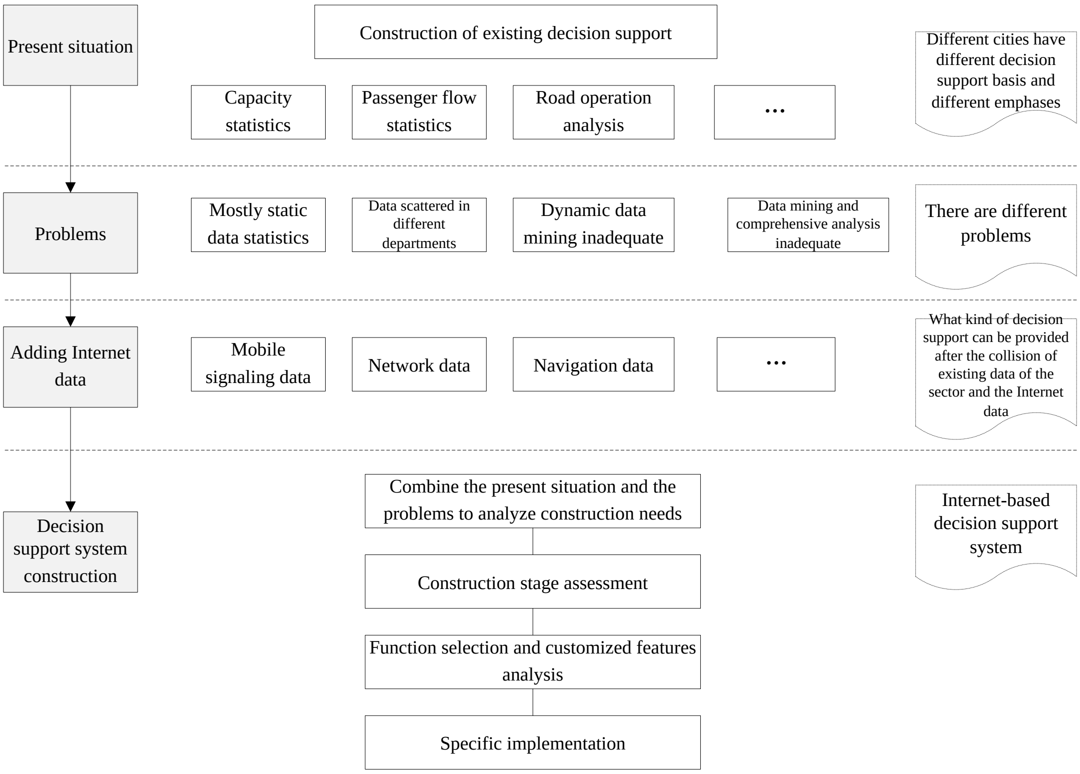


Figure 10-1 Design and Construction Ideas of Decision Support System

10.4 Overall Architecture

10.4.1 Application Scenarios

Summarize the dynamic and static public transport data of the industry to provide decision support for industry statistics and analysis; analyze the service level data and daily monitoring data, and provide decision support in service quality assessment and operation services. Under Internet support, decision support has broader scope and application scenarios.

Scenarios example 1: daily business personnel of TOCC or industry management personnel at all levels can view the dynamic operation of public transport and passenger flow thermodynamic diagram of all major passenger distributing centers on the big screen in the monitor hall, and provide decision support for the holidays and large passenger flow organization. Specific implementations: include major public transport passenger distributing centers of the city, such as airports, railway stations, bus terminals and hubs, in the scope of passenger flow hot spot monitoring, and generate passenger flow thermodynamic diagram by integrating passenger flow data, video data and credit card data of the transport sector; match and analyze the feeder passenger flow data and the load of public transport infrastructure, as well as public transport supply capacity of operating vehicles in passenger distributing centers, find out the supply weakness, and thus provide support for such decisions.

Scenarios example 2: daily business personnel provide basis for decision making for transit network optimization and adjustment, line deployment and real-time dispatching according to the passenger flow OD data. Specific implementations: by analyzing trip chain of mobile data and all-in-one pass tapping data, obtain single trip chain information, analyze the trip characteristics of single traveler, analyze and study resident population travel behaviors basing on traffic database and obtain complete public transport trip OD data.

Scenarios example 3: industry management department releases intercity traffic forecast to the public according to acquired and analyzed data, and develop public transport organization and evacuation plans in advance. Specific implementations: use the user travel data from mobile APP maps and navigation to predict the rough population of a city in advance, combine the mature prediction algorithm with massive traffic data, analyze group user travel behaviors according to the research results of traffic data analysis of travel information service, and forecast group travel behaviors to obtain travel trends in different cities and travel forecast data of different modes of transportation.

10.4.2 Service Functions

The framework of decision support system services is shown in Figure 10-2.

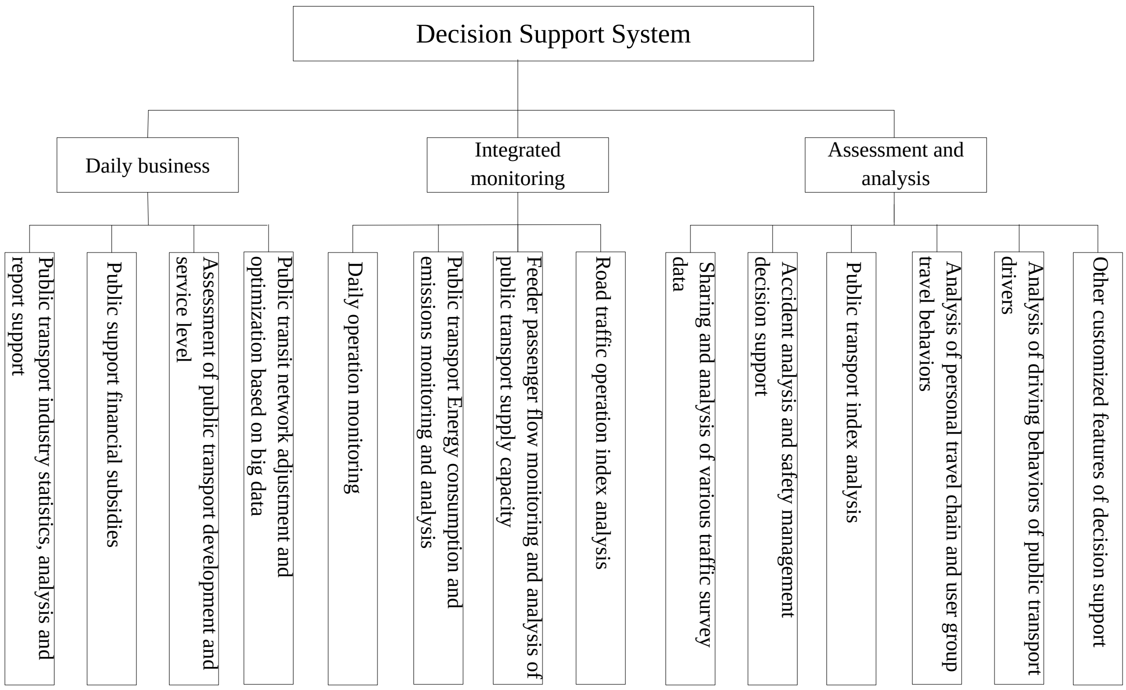


Figure 10-2 Service Functions of Decision Support System

Service functions of decision support system can be divided into three parts: daily business available for daily business personnel of the departments such as statistics and analysis, public transport service assessment, and transit network adjustment; integrated monitoring that allows real-time display and monitoring, and available for the users to master the operation, passenger flow and traffic operation index; assessment and analysis functions to analyze various data comprehensively and provide support for decision-making of different purposes.

(1) Daily business

- **Public transport industry statistics, analysis and report support**

Intended for ministerial, provincial and municipal users: carry out statistics, analysis, display and query for existing public transport data and concerned service level data, daily monitoring data and financial subsidies data; meanwhile, meet the requirements of the "Urban (Rural) Passenger Transport Statistical Reporting System" issued by the Ministry of Transport, and automatically generate relevant data; municipal users classify the collected data and count automatically to generate relevant reports and submit to the province; provincial users summarize the municipal data and submit to the ministry. On the basis of industry statistics and analysis, it also supports automatic generation of different monthly and annual reports of the public transport industry and provides support for all types of reports.

- **Public support financial subsidies**

Intended for ministerial, provincial and municipal users: support display and query of subsidies data, and display of basis for various subsidies and related details. On the one hand, fuel subsidies module is consistent with the requirements of the fuel subsidy system of the Ministry of Transport, through public transport operation mileage, actual fuel consumption and fuel subsidies by models and fuel types, provide support for ministerial users and provincial users to develop rational fuel subsidies distribution programs for provincial users and municipal users respectively; on the other hand, calculate ticket system and price subsidies and vehicle purchase subsidies automatically according to the IC card type, vehicle information and other detailed data as well as relevant local subsidies, and provide objective basis for such public welfare subsidies in different regions.

For the subsidies issued by the ministry, such as fuel subsidies, obtain provincial and municipal subsidies data and details, and provide basis for scientific and rational allocation of subsidies.

- **Assessment of public transport development and service level**

Intended for ministerial, provincial and municipal users: on the one hand, for provincial and municipal users, support the existing operation and service standards, and achieve sorting of operation and service level and the analysis of indicators for enterprises, lines and vehicles; on the other hand, support the "Evaluation System for Transit-oriented Cities "issued by the Ministry of Transport, display its 30related indicators, and achieve vertical comparison of different cities. For ministerial users, evaluate and analyze the public transport development in different cities, and provide basis for relevant policies.

- **Public transit network adjustment and optimization based on big data**

Intended for municipal users; as for public transit network planning, traditional approaches require a lot of manpower for OD survey and data collection, and data comparison and effects before and after transit network adjustment can't be accurately grasped. Assist the adjustment and optimization of public transit network with big data, obtain personal travel chain information and group user travel information basing on credit card data and mobile phone data, thereby accurately grasp passenger flow distribution and movement of public transit network, provide scientific support for public transit network adjustment and optimization, and track the operation of public transit network in real-time after adjustment.

(2)Integrated monitoring

- **Daily operation monitoring**

Intended for municipal users; by docking enterprise intelligent dispatching management platform, and accessing to the vehicle and terminal video data, realize daily monitoring of the vehicle running state; on the one hand, comprehend the public transport supply and overall situation of the day and important periods; on the other hand, focus on the daily work of industry management, monitor the operation status of the entire or local public transit network from routes, sections, regions, transit network and other dimensions, and display concerned indicators in real-time, such as the number of current operating vehicles, vehicle speed and position, and implementation of vehicle trips.

- **Public Transport Energy Consumption and Emissions Monitoring and Analysis**

Intended for ministerial, gathering energy consumption data about vehicles with different models and different fuel types, provincial and municipal users: according to online operating data, real-time speed and acquired CAN data of public transport, estimate the energy consumption and emissions of public transport vehicles, present the changes in emissions of public transport within different space and time scope, generate real-time thermodynamic diagram of public transport carbon emissions, and comprehend the provincial and municipal public transport carbon emissions. Basing on the data acquisition of public transport rentals, freight and bayonet flow, combine Internet data, access to data of motor vehicles of different types, calculate the energy consumption and emissions data throughout the region, and generate dynamic emissions monitoring figure by time periods.

For municipal users, provide decision support for vehicle update selection and public transit network optimization; for provincial users, show the public transport energy consumption and emissions of the province intuitively by thermodynamic diagram, summarize, analyze and compare the energy consumption data of public transport in different regions, and provide basis for vehicle selection, subsidy allocation and development of energy conservation policies. For ministerial users, display the national public transport energy consumption and emissions intuitively, provide basis for fuel subsidies and the development of energy conservation policies, and evaluate the effect of energy saving and emission reduction.

- **Feeder passenger flow monitoring and analysis of public transport supply capacity**

Intended for municipal users; include major public transport passenger distributing centers of the city, such as airports, railway stations, bus terminals and hubs, in the scope of passenger flow hot spot monitoring, and generate passenger flow thermodynamic diagram by integrating passenger flow data, video data and credit card data of the transport sector, analyze the changes in passenger flow in certain period of time, and monitor the feeder passenger flow data.

Meanwhile, match and analyze the feeder passenger flow data and the load of public transport infrastructure, as well as public transport supply capacity of operating vehicles in passenger distributing centers, find out the supply weakness, and thus provide support for such decisions.

- **Road traffic operation index analysis**

Intended for ministerial, provincial and municipal users; road traffic operation index is a comprehensive indicator for quantitative assessment of the overall operation of the transit network. Combine the GPS data and FCD data reported by rental vehicles of the city, and the obtained traffic detector data, mine and analyze the vehicle location and speed information of floating car data as well as vehicle operation information detected by the traffic detector, combine cities reported, and access to roads and other traffic detector data mining analysis, integrate heterologous data, obtain more accurate real-time traffic information, and provide support for real-time traffic service, route planning and other services. Mine traffic data of traffic detector and GPS, analyze traffic congestion and other events, integrate crowd sourcing model to get the information of accidents, congestion and other events uploaded by users, improve data quality and accuracy of event information, and provide support for real-time traffic and LBS service.

For municipal users, present thereal-time congestion index and analysis of congestion causes of various sections and hotspot areas of the city through the collection and analysis of real-time traffic and event information, and provide support for government decision-making and public travel.

For provincial users, combine the Internet data and massive traffic data, analyze intercity user travel behaviors within the province basing on the user group travel behaviors within the city, comprehend the flow of passengers at the provincial level, and provide support to enhance the level of public transport development of the province.

For ministerial users, display and analyze road traffic operation index of China.

(3)Assessment and analysis

- **Sharing and analysis of various traffic survey data**

Intended for ministerial, provincial and municipal users: the government departments, public transport companies and different mobile public transport service development companies and Internet companies conduct various traffic surveys through artificial, system and network mode, including passenger flow survey and public transport satisfaction survey; share various types of traffic survey data, query and analyze the reports, and provide decision support for different users.

- **Accident analysis and safety management decision support**

Intended for ministerial, provincial and municipal users: presents spatial distribution of national, provincial and municipal public transport accidents on years, combine with traffic police data, show the statistics and analysis data of accidents of China, analyze accident type, cause and handling, and compare with historical data to reflect changes in accident management level and provide support to improve safety management level and emergency response capacities.

- **Public transport index analysis**

Intended for ministerial, provincial and municipal users; analyze the multi-source data from industry sectors, enterprises, the public and the Internet, use "crowd sourcing" philosophy to build an open and interactive public transport index platform, and then build transport sector index platform to meet the instant needs of different users on data.

Public transport indicators cover operations, security, services and management, which are classified into the major categories and breakdown, including various types of statistical analysis indicators and dynamic analysis indicators.

- **Analysis of personal travel chain and user group travel behaviors**

Intended for ministerial, provincial and municipal users

- **Personal travel chain analysis**

Use the matching relation between mobile data time series and mobile network coverage and the traffic analysis region to determine entering, exiting and stay of mobile users in each traffic analysis region, identify dwell points and permanent points by a large number of user track points, restore the true trajectory through sparse track points, analyze user's travel patterns and obtain the travel chain information of each mobile user. Basing on historical data of user travel, integrate the continuous travel information of travelers, construct complicated trip chain of single traveler, and build user trip chain database.

Basing on the history trip chain information of mobile users, combine user schedule regularity and the land properties, and identify the place of residence and work area of mobile users. According to the user's travel frequency and travel time, combine the search information of user travel service client to determine the commuting trip and other travel behaviors of users to analyze the trip characteristics, for example: mine user interests and preferences through travel, stay and other information of massive users and other Internet behaviors (e.g. search); estimate the arrival time of user travel more accurately by learning the relationship between arrival time of tracks of large number of users and space-time environment.

Obtain single trip chain information by analyzing trip chain of mobile data and public transport card tapping data, and analyze the trip characteristics of individual traveler; analyze and study resident population travel behaviors basing on traffic database, obtain complete public transport trip OD data, and then provide basis for transit network optimization and adjustment, route deployment and real-time dispatching.

- **Analysis of user group travel behaviors**

At present, some Internet companies use user travel data from mobile APP maps and navigation to predict the rough population of a city in advance, combine the mature prediction algorithm with massive traffic data, analyze group user travel behaviors according to the research results of traffic data analysis of travel information service, and forecast group travel behaviors. It is applied in public transport, and can provide a powerful decision support for urban traffic management, passenger evacuation and intelligent dispatching combining with public transport operation data.

At provincial level, analyze the Internet data to obtain travel trends between cities, combine the transport supply capacities of each city, and provide the basis for public transport infrastructure load of the destination and organization of public transport. Analyze the traffic flow, congestion periods and sections of tourist attractions along the highways according to the travel tracks of massive resident group and historical data, analyze the aggregation of attractions and other hot spots, distinguish and analyze the traffic situation, congestion periods and sections of urban roads on important festivals and holidays, provide forecast data and provide the basis for public transport organizations.

At ministerial level, display the traffic travel between different regions of the country, generate dynamic traffic migration map, and compare with historical data.

- **Analysis of driving behaviors of public transport drivers**

Intended for municipal users; track travel habits of public transport drivers through big data from routes to behaviors, combine the driving behavior analysis method of traffic engineering, analyze acceleration and deceleration, speeding, fatigue driving and other behaviors of drivers through real-time speed of vehicles received by business operation dispatching platform, vehicle acceleration and deceleration data in CAN data, and road grade, traffic information and traffic signals, provide public transport drivers driving behavior analysis report, and provide employment, scheduling and security management support for industry management department and transport enterprises.

- **Other customized features of decision support**

Intended for ministerial, provincial and municipal users; with the system construction and technology development, customize other decision support functions according to the actual needs of different users.

10.4.3 System Architecture

Transport decision support system mainly provides services for transport departments. According to the needs of municipal, provincial and ministerial users, the architecture of decision support system is shown in Figure 10-3.

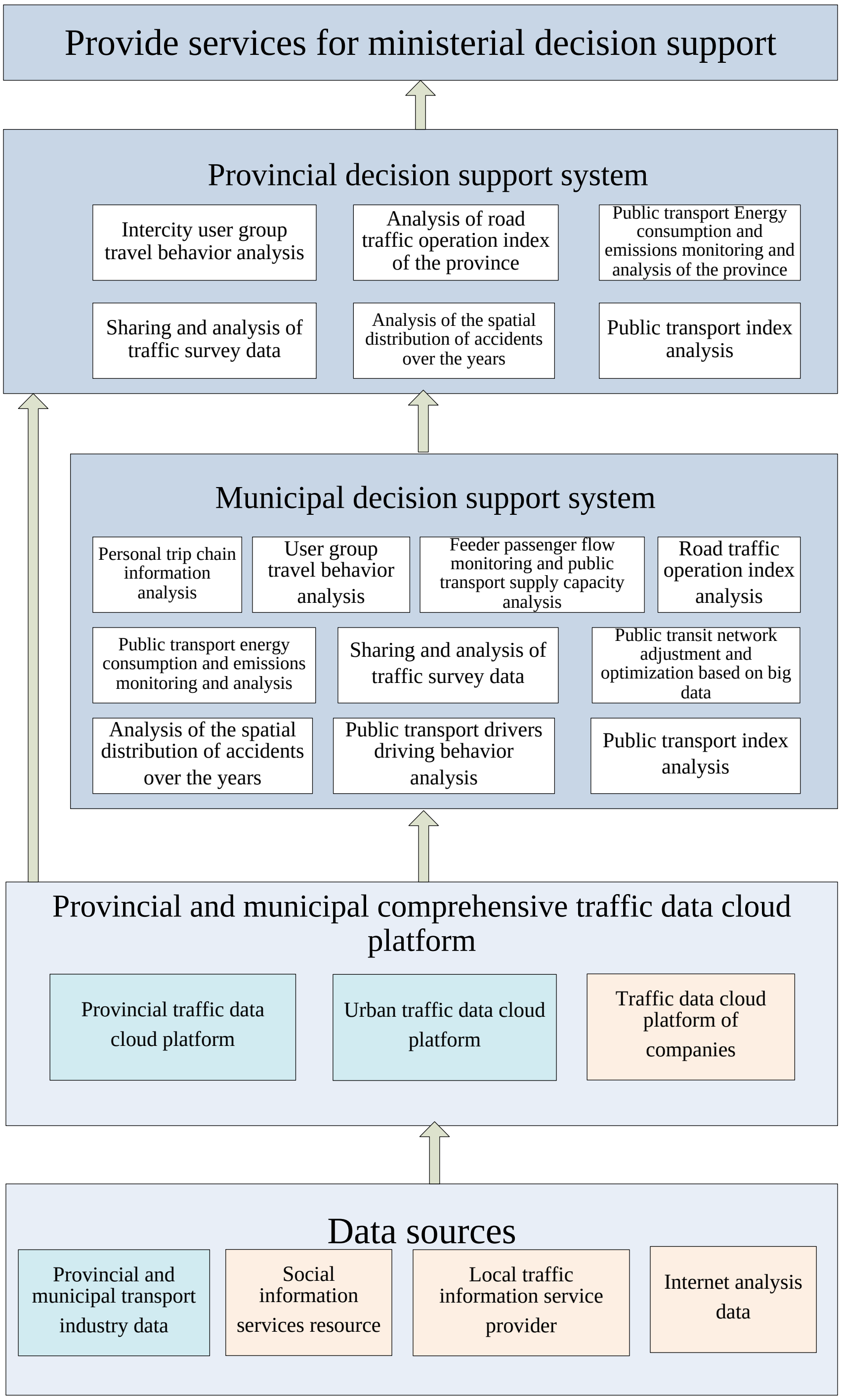


Figure 10-3 Service Framework of Public Transport Decision Support System

Decision support is a comprehensive system. The data source is not limited to public areas. It provides support for public transport decision support together with a variety of other traffic information and Internet data. Industry data from the transport departments and diversified data from local traffic information service providers and the Internet are integrated into the transport data cloud platform, and provide appropriate decision support applications according to the actual business needs of municipal, provincial and ministerial users.

10.5 Suggestions on System Construction

10.5.1 System Construction Basis

The factors affecting the construction of the decision support system include:

(1)Data type and data validity

The decision support system covers a wide range. Specific decision support generally requires multiple data support. The factors of data type, data acquisition, data acquisition in automatic mode or by manual entry, data continuous update and validity will affect the specific function and availability of the decision support system.

(2) Construction of other information systems

Different decision support requires different data support. The data is usually derived from the constructed information system. For example, the dynamic data of the industry statistical analysis system is from the enterprise intelligent dispatching system whose construction will have an impact on the analysis of the dynamic data in the industry statistical analysis system.

(3) Understanding of the demand for the construction of decision support

The ministerial, provincial and municipal industry sectors and different industry management users have different requirements for specific decision support. The accurate understanding of the construction demand to ensure the availability and effectiveness of the constructed system is also the factor affecting the construction of the decision support system.

(4) Data application and algorithm support

To support the application of the decision support system at all levels, appropriate data algorithms are required to provide support, such as travel behavior correlation algorithm to provide the analysis results of personal travel and group travel, continuous travel integration algorithm. The rationality and validity of the data algorithms will directly affect the result data of the decision analysis.

As can be known from the above analysis, the data requirements and the construction basis of the decision support system are shown in the following table.

Table 10-3 Data Requirements and Construction Basis of Decision Support System

Decision Support System	**Data Requirements /Data Type**	**Construction Basis (not limited to)**
Public Transport	Data of bus personnel, vehicles,	

Industry Statistical Analysis and Reporting Support System	enterprises and lines Dynamic data of bus transit (GPS data, bus scheduling and departure data, etc.) Report data requirements, etc.	Enterprise dispatching system construction；Report statistical system, etc.
Public Transport Financial Subsidy Support System	Related data of fuel subsidies Ticket fare subsidy and compensation data Data of vehicle subsidies Data of other subsidies	Enterprise dispatching system construction；IC card swiping system, etc.
Public Transport Development and Service Level Evaluation System	Basic line data Related data of bus service quality Related data of bus operational efficiency Related data of public transport economic and social benefits	Enterprise dispatching system construction
Daily Operation Monitoring System	Bus dynamic operation data Bus and station video data IC card swiping data, etc.	Terminal construction of bus GPS and video; Enterprise dispatching system construction, etc.
Road Traffic Operation Index Analysis System	Vehicle running speed Probe vehicle data Junction traffic flow data Basic road network data	Data acquisition equipment of external traffic flow and speed; Probe vehicle data acquisition
Traffic Survey Data Sharing Analysis System	Related data of traffic survey (class, object, purpose , etc.) Related indexes of traffic survey	Various traffic survey systems and historical data
Accident Analysis and Safety Management Decision Support System	Traffic accident information Basic vehicle information Driver behavior information Road information Accident analysis data, etc.	Vehicle CAN equipment and historical accident information
Public Transport Index Analysis System	Safety data Operation data Service data Management data, etc.	Enterprise dispatching system ; Service assessment data, etc.
Personal Travel Link and Group Travel Behavior Analysis System	Mobile phone signaling data Map access data Bus card swiping data Personal location data (mobile phone applications) Other transport data of taxi, railway, passenger transport , etc.	Acquisition and analysis of mobile phone location data; Time sequence information of mobile phone applications ; Data access of other transport modes, etc.
Public Transport	Basic bus information(vehicle age,	Vehicle CAN equipment;

Energy Consumption and Emissions Monitoring and Analysis System	energy type, emission standards, etc.)	Bus PS equipment, etc.
	CAN data	
	Consumption data about vehicles with different models and different fuel types	
	Vehicle operation data (time, speed, etc.)	
Bus Driver Driving Behavior Analysis System	Vehicle running speed	Vehicle CAN equipment; Bus GPS equipment; Vehicle video equipment, etc.
	CAN data	
	Vehicle warning information	
	Person travel link data	
	Vehicle video data	
	Credit data	
Public Transport Network Adjustment and Optimization System Based on Big Data	Basic bus network data	Urban GIS system construction ; Basic bus network data; IC card swiping data, etc.
	Bus operation data	
	Passenger flow data	
	Poll data	
	Internet data	
Passenger Flow Connection Monitoring and Bus Supply Capacity Analysis System	Bus infrastructure data	Video surveillance equipment at stations and hubs; Acquisition and analysis of mobile phone data, etc.
	Bus passenger distribution data	
	Passenger arrival data of hot spots such as railway stations , passenger stations and hubs	
	Bus operation data	
	Mobile phone signaling data	
	Person travel link data	

10.5.2 Emphasis on Key Technology Research

In the process of the construction, the study of the key technologies of data management and data algorithm shall be emphasized. Their rationality and validity will directly affect the data analysis of the decision support system thus to have an impact on the construction and application of the decision support system at all levels. The data management technologies and data algorithms of the decision support mainly include: data processing and data quality assessment technologies; travel behavior correlation algorithm to provide the analysis results of personal travel and group travel, continuous travel integration algorithm, big-data-based user interest and preference discovery algorithm required for tapping the Internet data applications and traffic industry.

In the support of the Internet and big data, various data algorithms and applications are emerging endlessly. To ensure the validity and sustainability of the system, the key technologies of data management and data algorithms shall be processed with a rolling optimization and continuous improvement to adapt to the demand for the construction and application of the constantly updated and expanded decision support system. The example of data management and data algorithm research is shown in Figure 10-4.

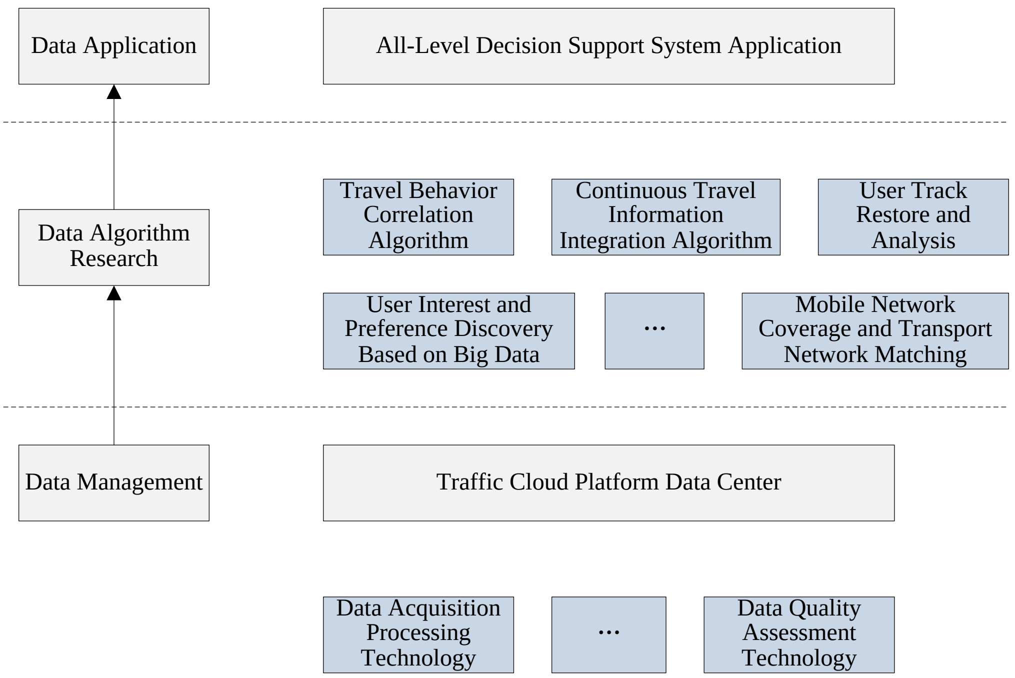


Figure 10-4 Example of Data Management and Data Algorithm Research of Decision Support System

10.5.3 Suggestions on the Implementation at Different Stages

Table 10-4 Suggestions on the Implementation for Different Users at Different Stages

No.	**User**	**System Name**	**Construction Stage**		
			A	**B**	**C**
1	Ministerial Users	Public Transport Industry Statistical Analysis System	√		
		Financial Subsidy Support System	√		
		Local Public Transport Development Analysis System	√		
		National Road Traffic Operation Index Analysis System		√	
		National Bus Traffic Survey Data System		√	
		Accident Analysis and Safety Management Decision Support System		√	
		Public Transport Index Analysis System		√	
		Traffic Transfer System			√
		Public Transport Energy Consumption and Emissions Monitoring and Analysis System			√
		Other custom systems			√
2	Provincial Users	Public Transport Industry Statistical Analysis and Reporting Support System	√		
		Financial Subsidy Support System	√		

		Public Transport Development and Service Level Evaluation System	√		
		Provincial Road Traffic Operation Index Analysis System		√	
		Traffic Survey Data Sharing Analysis Systems		√	
		Accident Analysis and Safety Management Decision Support System		√	
		Public Transport Index Analysis System		√	
		Intercity User Group Travel Behavior Analysis System			√
		Provincial Public Transport Energy Consumption and Emissions Monitoring and Contrast System			√
		Other custom systems			√
3	Municipal Users	Public Transport Industry Statistical Analysis and Reporting Support System	√		
		Financial Subsidy Support System	√		
		Public Transport Service Level Evaluation System	√		
		Daily Operation Monitoring System	√		
		Road Traffic Operation Index Analysis System		√	
		Traffic Survey Data Sharing Analysis Systems		√	
		Accident Analysis and Safety Management Decision Support System		√	
		Public Transport Index Analysis System		√	
		Personal Travel Link and Group Travel Behavior Analysis System			√
		Public Transport Energy Consumption and Emissions Monitoring and Analysis System			√
		Bus Driver Driving Behavior Analysis System			√
		Public Transport Network Adjustment and Optimization System Based on Big Data			√
		Passenger Flow Connection Monitoring and Bus Supply Capacity Analysis System			√
		Other custom systems			√

As shown in Table 10-4, according to the construction basis and the user requirements, the construction can be divided into three stages, i.e. Stage A, Stage B and Stage C. Stage A is the stage for the construction of base systems, Stage B is the stage for the construction of integrated systems, and Stage C is the stage for the construction of custom systems for different users in the support of the Internet and big data. Different users can select appropriate construction according to the actual demand and the local construction situation and with reference to the specific implementation at different stages.

Stage A is the stage to achieve the functions of the decision support system at its initial construction. In the cities where relevant decision support systems of bus industry management have not been established, it is alternative to construct the Public Transport

Industry Statistical Analysis and Reporting Support System, Financial Subsidy Support System, Daily Operation Monitoring System, Public Transport Service Level Evaluation System, etc. For the provincial users, corresponding systems can be constructed based on the data imported from various cities in the province. For the ministerial users, the data reported by various regions can be received based on the construction of the existing decision support.

Stage B is the stage to construct the integrated systems which can be gradually developed and implemented based on the data analysis and information construction. The provinces and cities with data base and part of decision support systems can gradually develop and improve the Road Traffic Operation Index Analysis System, Traffic Survey Data Sharing Analysis Systems, Accident Analysis and Safety Management Decision Support System as well as Public Transport Index Analysis System according to their own construction situation and development demand and report relevant data to ministerial systems.

Stage C is the stage to construct the custom systems. The decision support systems which are more comprehensive and meet the local demand can be developed based on the actual situation and needs in various regions. The cooperation between government and enterprises should be strengthened in government-led and market-based operation mode and the cooperation with the third-party companies like the Internet companies should be strengthened. The enterprise data and resources should be taken full advantage to combine the massive transport industry data with rich Internet data thus to construct more comprehensive and reliable decision support systems, including the Personal Travel Link and Group Travel Behavior Analysis System, Bus Emissions Monitoring and Analysis System, Bus Driver Driving Behavior Analysis System, Public Transport Network Adjustment and Optimization System Based on Big Data, Passenger Flow Connection Monitoring and Bus Supply Capacity Analysis System and other custom systems, and to provide services to public transport industry management and decision support.

10.5.4 Suggestions on the Operation and Maintenance Mode of System Construction

In the Internet era, with the increasing of data and application value resulting from the decision support systems, the construction of the systems is gradually changed from traditional government-based investment to open multi-participation and cooperation thus the responsibilities and divisions of each government and enterprise are also changed.

(1) Construction based on government investment

The users of the decision support system are government departments and its applications mainly serve the industry sectors at all levels, so the basic data of it is mainly from the traffic industry database. Therefore, the construction, operation and maintenance of the existing decision support systems in most cities are based on the government investment. The construction can be carried out in the cities separately and also carried out in the province which provides data for the applications in the cities.

(2) Government-enterprise cooperation model (government-led, market-based operation)

With the influence of the Internet traffic data on the decision support and the increasing of the benefits resulting from the decision support systems, the governments can cooperate with the enterprises to construct, operate and maintain the decision support systems. The operation model can be a "government-led and market-based operation”. The government investment shall be dominated in the project construction and the late maintenance costs of the systems can be settled through the service of value-added data.

The data packets can be put into the data market to provide value-added services in the market-based operation mode. After the operation is successful, the benefits can be distributed and shared according to the data quality and data volume to nurture local traffic information resource integration and acquisition investment. In addition, the governments can cooperate with third-party companies to provide them with data resources while the third-party companies provide mass data processing technologies and related internet data tot pinto the traffic information valuable for industry management departments. Meanwhile, the benefits generated from the decision support API service can be used for system operation and maintenance.

10.6 System Assessment Index

（1）System assessment index

Table 10-5 Assessment Index of the Evaluation on Decision Support System

Decision Support System	Assessment Index
Public Transport Industry Statistical Analysis and Reporting Support System	All data sources are clear. Automatic generation and manual entry can be distinguished; The proportion of data items which can be automatically generated is greater than 60%. Reports can be automatically generated.
Public Transport Financial Subsidy Support System	Various financial subsidy data can be classified for display; Subsidy data can be automatically calculated ; The accuracy of data is greater than 90%.
Public Transport Development and Service Level Evaluation System	Assessment indexes can be in line with local service quality assessment methods ; Assessment results of vehicles, lines, enterprise service level can be queried. The data supporting urban public transport assessment index can be displayed
Daily Operation Monitoring System	Related indexes of daily operation can be displayed online in real time. Data update frequency is less than 10min;

	Index data can be automatically calculated ; The accuracy of data is greater than 90%.
Road Traffic Operation Index Analysis System	Road traffic operation indexes can be in a visual display ; The update and accuracy of data meet the requirements.
Traffic Survey Data Sharing Analysis System	Traffic survey data can be classified; Different dimensions (time, purpose, etc.) and keyword query can be supported; The authenticity and accuracy of data meet the requirements.
Accident Analysis and Safety Management Decision Support System	Data is real and valid ; Accidents can be classified for display and query ; Case base and data analysis are available.
Public Transport Index Analysis System	Indexes are correctly classified in compliance with related definitions and requirements of traffic engineering; Indexes are classified for display in large and small items and dynamic data is classified for setting update frequency; Data source is clear.
Personal Travel Link and Group Travel Behavior Analysis System	Travel data is collected; The accuracy and validity of data collection meet the requirements ;
Public Transport Energy Consumption and Emissions Monitoring and Analysis System	Emissions data can be automatically collected with a frequency of less than 1h; Emissions monitoring data can be updated and displayed in accordance with the period; The accuracy and coverage of data meet the requirements ;
Bus Driver Driving Behavior Analysis System	Driving behavior data can be automatically collected ; Behavior analysis, etc.
Public Transport Network Adjustment and Optimization System Based on Big Data	Basic network data is available; The item of network assessment index which can be automatically calculated is greater than 10 ; Indexes before and after network adjustment can be contrasted; Operations like modification, update and index contrast can be performed;
Passenger Flow Connection Monitoring	Monitorable passenger flow data and data sources are

and Bus Supply Capacity Analysis System	clear; Passenger flow connection data can be collected or accessed; The analysis of supply capacity evaluation is effective; The accuracy and validity of data meet the requirements.

（2）Method for carbon footprint calculation

The emission factors of CO_2 for the different transport modalities are obtained by consulting a wide range of sources, and are based on factors such as transport modality, region of the world, average load factor and number of kilometers travelled. The emission factors are indexed per average km travelled by a passenger, or gCO_2/pkm. The availability of sources that can represent these emissions is usually variable for different transport modalities or countries. Due to this fact diverse approaches have to be followed to obtain the emission factors. The regions are not only chosen on a pure division based on continents but also by analyzing the specific reality of some countries, which may be different from other countries inside the same continent. The transport modalities are defined according to the specificities of each of the modalities, such as capacity, operation range or speed, as well as the approach followed by the generality of the sources consulted.

The emission factors obtained will be used as input to compare travel modalities which, in combination with information about modalities, locations and distances travelled, will return to the user the CO_2 emission values for each trip alternative.

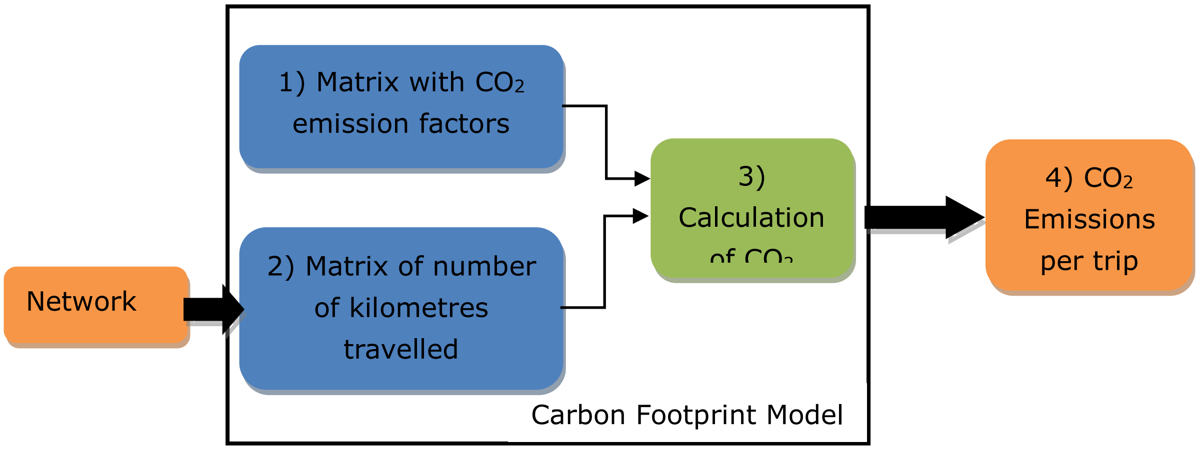


Figure 10-1 The Carbon Footprint Model

The selection of the regions to be used for the calculation of CO_2 emission factors has to consider in a first level the existing differences on a global scale regarding the use and efficiency of the distinct transport modalities. The results does not always provide complete homogenous regions but provides a differentiating factor for an increased assertiveness of the results. The existing differences inside some continents make it necessary to separate regions inside a same continent and in other cases consider countries of different continents as belonging to the same group of emission factors. The main factors considered for this division are the following:

- Historic evolution of the vehicle park (for the different modalities);
- Dimension of the vehicle park;
- Mobility habits;
- Regional context and similarities;
- Previous approach from consulted sources.

The transport modalities used as base for the calculation of the emission factors were derived from the consultation of publications and from the analysis of the modal share for different regions of the world. Moreover, specific usage patterns, occupancy capacity and emission intensity factors were taken into account to establish the different modalities and include further decision options for some modalities. The modalities considered are the following:

- Car;
- Taxi;
- Minibus;
- Buses
    - Urban;
    - Regional;
- Coach;
- Trams;
- Metro;
- Trains
    - Commuter/Regional;
    - Long Distance;
    - High-speed;
- Two-wheelers;
- Ferries;
- Aircraft
    - Short distance;
    - Medium distance;
    - Long distance;
    - Extra-long distance.

The emission factors of CO_2 are calculated considering the transport mode and are presented on a gCO_2/passenger.km basis. Different approaches can be used to obtain these emission factors:

- Continuous emission monitoring or direct data from transport companies or institutional organizations, associated with occupancy data;
- Estimation of the amount emitted by multiplying activity data (fuel/energy consumption and occupancy) by relevant emissions conversion factors.

The procedure followed to obtain the emission factors for the different regions is described in the following sections. Here an example is given to show how to calculate the CO_2 for Chinese situation.

1）Car

The calculation of the emission factors for cars was performed using, like for the European and North American regions, the antiquity of the car park as basis. It was assumed that the vehicle age of these countries is the same category and has the following division.

Table 10-6 Distribution of the Vehicle Park for China

Year of the vehicle	Share of Vehicles
Pre-2001	60%
2002 - 2005	15%
2006-2007	10%
2008 - 2010	10%

In ICCT (2011) the NEDC gCO_2/km emissions of the vehicle park of China is presented for the years 2002, 2006 and 2008. These emissions are correlated with the vehicle distribution indicated in the table. With this approach, the emission factor for the car fleet of China is

$$EF_{Car\ China\ India} = 226\ gCO_2/pkm$$

2）Taxi

The approach followed for the calculation of the emission factors for the taxi is the same as the one used for the previous regions. So, the emission factor is

$$EF_{Taxi\ India} = 258.3\ gCO_2/pkm$$

3）Minibus

The model of the urban minibus considered for this region is a van-type vehicle with a maximum occupancy of 13 passengers. The study of Iea (2009) indicates the same average occupancy of minibus for China and Africa (among other world regions), which is 95%. This occupation factor was applied to a vehicle-km emission value based on a large vehicle, providing an emission factor of 20,93 gCO_2/pkm.

4）Buses

- Urban

The emissions of the Urban Buses of the type 15 – 18t are provided in Ifeu (2008d). The emission factor for this type of buses is 66 gCO_2/pkm.

- Regional

In Ifeu (2008e) the full capacity emission factor is presented: 25 gCO_2/pkm (maximum capacity of 25 passengers). Considering the average occupancy of 70% referred in the same source for the coaches one can obtain an emission factor of 35,71 gCO_2/pkm.

- Coach

Like for the regional bus, in Ifeu (2008e) the emission factor for a full occupancy coach of 44 people is presented. Considering the average occupancy of 70% an emission factor of 29 gCO_2/pkm was obtained.

5）Trams

The tramway/light rail systems is a modality with a minimal existence in China and India. A multiplying factor, representing the difference between tram and metro in Europe, was applied to the emission values for the metro in China. From this, the emission factor for the trams in China is

$$EF_{Tram\ China\ India} = 53{,}59 \cdot 41{,}02/42{,}37 = 51.89\ gCO_2/pkm$$

6）Metro

The emission factor for the metro is indicated in Ifeu (2008f) for a full capacity utilization (216 persons): 20,9 gCO_2/pkm. For a capacity of 39%, indicated in the same source, the emission factor is

$$EF_{Metro\ China\ India} = 53{,}59\ gCO_2/pkm$$

7）Trains

- Commuter/Regional

In Ifeu (2008d) an emission factor of 54 gCO_2/pkm is indicated for the rail transit in the region of Shangai. This value is considered for the present report.

- Long Distance

A full capacity long distance train has an emission factor of 15 gCO_2/pkm, following Ifeu (2008g). In this same source an occupation factor of 70% is indicated, which leads to an emission factor of 21,43 gCO_2/pkm.

- High-speed

The emission factor of a high-speed train in China is indicated in Ifeu (2008f) with a value of 16,9 gCO_2/pkm. This source indicates an occupancy factor of 70%, from where an emission factor of 24,14 gCO_2/pkm is obtained.

8）Two-wheelers

The approach used before regarding this transport modality is applied with the following Euro class division:

- Euro 0: 70%
- Euro 1: 30%

The different types of motorcycles are divided according to their stroke and motor volume, resulting in the following market share

- 2 stroke: 50%
- strokes up to 250 cm3: 30%
- 4 strokes 250 – 750 cm3: 20%

From this approach an emission factor of 93,88 gCO_2/pkm was obtained.

9）Ferries

The value obtained for the ferries in Europe is used as reference for this region. For the calculation of the emission factor an improvement of 30% in load factor and a reduction of 20% in the energetic efficiency were considered. From this an emission factor of 184,80 gCO_2/pkm was obtained.

10）Aircraft

The emissions for the aircraft are obtained using the method applied for the previous regions. The specific occupancy factors are obtained from IATA (2012). From this approach, the emission factors presented in Table 10-7 were obtained:

Table 10-7 Emission Factors for the Aviation in the Region China

Flight Type	**gCO_2/pkm**
Domestic	132,38
Short Haul	117,87
Long Haul	87,45

Very Long Haul	96,87

With increasing interest for the environment and carbon footprints in particular, there is a need to implement a method and tool that can return the CO_2 emission per trip. The CO_2 matrix which is described in the previous section can be a tool in achieving this. Each cell of this matrix describes the amount of CO_2 emitted per kilometer per passenger for a certain modality of transport and in a certain region in the world.

10.7 System Construction, Operation and Maintenance Cost

(1) System construction cost

Expected cost for the decision support system excludes hardware configuration expense and is only used for reference of software development expense. Also, prices in the table are reference values which are calculated based on 2013-2015 market survey on decision support system construction costs of part of large and medium sized cities as well as development cost for software with new functions. These prices can fluctuate to a certain extend according to different local infrastructure and conditions. Attention shall be given to the following problems:

1) Algorithm and model are difficult points and key problems occurring in the development of decision development system. Specific local infrastructure leads to different research and reservation on model and algorithm, which cause fluctuation of software development cost in a larger range. Investment can be given according to actual conditions. Expected cost listed in the table is reference value;

2) For the same province, software modules at municipal level can be reused in different cities of the province. Also, local adjustment or customized development can be made according to characteristics of different cities, to avoid overlapping investment and wasting of resources and to save development cost.

3) If part of decision support functions are available at municipal/provincial level or there is a certain infrastructure for some one part, upgrading and improvement will be made on the basis of existing infrastructure and construction costs will be adjusted accordingly.

Table 10-6 Implementation Content and Construction Cost for Specific User at Different Stages

No.	**User**	**System Name**	**Expected cost (million)**
1	Ministerial Users	Public Transport Industry Statistical Analysis System	1.2~1.5
		Financial Subsidy Support System	2.5~3.0
		Local Public Transport Development Analysis System	1.8~2.2

		National Road Traffic Operation Index Analysis System	1.8~2.2
		National Bus Traffic Survey Data System	1.2~1.6
		Accident Analysis and Safety Management Decision Support System	1.6~2.0
		Public Transport Index Analysis System	2.4~2.8
		Traffic Transfer System	1.8~2.2
		Public Transport Energy Consumption and Emissions Monitoring and Analysis System	2.6~3.0
		Other custom systems	
2	Provincial Users	Public Transport Industry Statistical Analysis and Reporting Support System	1.0~1.4
		Financial Subsidy Support System	1.8~2.2
		Public Transport Development and Service Level Evaluation System	1.6~2.0
		Provincial Road Traffic Operation Index Analysis System	1.2~1.6
		Traffic Survey Data Sharing Analysis Systems	0.7~0.9
		Accident Analysis and Safety Management Decision Support System	1.2~1.5
		Public Transport Index Analysis System	1.0~1.4
		Intercity User Group Travel Behavior Analysis System	1.2~1.6
		Provincial Public Transport Energy Consumption and Emissions Monitoring and Contrast System	1.4~1.8
		Other custom systems	
3	Municipal Users	Public Transport Industry Statistical Analysis and Reporting Support System	1.0~1.4
		Financial Subsidy Support System	1.0~1.4
		Public Transport Service Level Evaluation System	1.2~1.6
		Daily Operation Monitoring System	1.8~2.4
		Road Traffic Operation Index Analysis System	1.1~1.5
		Traffic Survey Data Sharing Analysis Systems	0.5~0.8
		Accident Analysis and Safety Management Decision Support System	1.0~1.4
		Public Transport Index Analysis System	1.0~1.4
		Personal Travel Link and Group Travel Behavior Analysis System	1.6~2.0
		Public Transport Energy Consumption and Emissions Monitoring and Analysis System	1.4~1.8
		Bus Driver Driving Behavior Analysis System	1.6~2.0
		Public Transport Network Adjustment and Optimization System Based on Big Data	2.5~3.0
		Passenger Flow Connection Monitoring and Bus Supply Capacity Analysis System	1.8~2.2
		Other custom systems	

(2) System operation and maintenance cost

Operation and maintenance cost of decision support system is 5%-10% of its construction cost.

11 Signal Priority System

11.1 Present Survey Situation

Signal priority system is an intelligent system which uses advanced communication technology, control technology and computer technology to realize public transport priority through intelligent signal controller. The functions of bus signal priority are as follows: the signal control machine at the signalized intersection determines whether the arriving bus should get the signal priority through receiving the arrival situation of the bus, the bus lane occupancy and the current operating situation of signal cycle. There are only a few cities that have built the BRT system using the bus signal priority system in China. In addition, the construction scale and function of the signal priority system is different.

(1) Jianye is the only one pilot area in Nanjing for using bus signal priority system. There are “intelligent signal lights” in 269 intersections and corresponding equipments in 725 buses among 15 bus lines. In the next, signal priority control modules will be installed at 687 intersections in six zones of Jiangnan, Nanjing(from Weiyi Road in the North, to Software Avenue in the south and to Muxuyuan Street in the East, and closing to the Yangtze River Avenue in the West). Meanwhile, the corresponding equipments will be installed in 950 buses. The whole Nanjing city will promote the bus signal priority system by the end of 2014.

(2) Yantai has achieved the “red-green timing” of the signal lights at the 25 signal priority intersections of NO. 1 and NO. 5 lines. The green light can delay and advance for 3-5 seconds. As a result, the equipments of the intersections can sense the bus when it is 30m away from the intersection.

(3) The signal priority system in Changzhou mainly includes vehicle detection system, priority requests generator and priority requests server. Because of the size of buses is much larger than that of social vehicles, when setting detectors, multiple layout and synchronous detection are adopted to confirm vehicles to avoid confused test results from social vehicles. The principle of signal priority system in Changzhou is not only realizing public transport signal priority but also taking the overall traffic intersection benefits into consideration, and it balances wire control priority and point control priority to realize public transport signal priority.

(4) Suzhou has built the bus rapid transit network combining local specialties. There are 5 bus express lines, 113 buses and the total length of the 5 lines is 141 km. Suzhou has built bus lanes in more than 20 sections and the total length (two directions) is 115.92 km which accounts for 14.7% of the length of artery. In addition, there are 121 intersections that have bus signal lights.

(5) Shanghai has started building the bus lanes from 2005 and has built bus signal priority control system now. The functions of the system include signal control status collection, vehicles perception at the intersection, bus route collaborative priority control, single bus signal priority control and bus pre-signal setting function, etc. Furthermore, Shanghai achieved active bus signal priority in 7 intersections and bus pre-signal in 2 intersections along the Xizang Road, bus velocity control at Beijing Road - Quxi Road and publishing dynamic bus information at 4 pilot stations.

(6) In 2011, Beijing started the bus priority expansion project of traffic information control system at 14 lines and 300 intersections in three stages. Currently, the project has been completed at 202 intersections in the first and second stages. The project of the third stage comes into effect. Based on the existing traffic signal control system, through the installation of wireless bus inquiry and monitoring equipment on the buses of the lines and annunciators on the road sections, the annunciators can identify the vehicles on the road. Through the determination of the demand for public transport vehicles, the traffic signal control system can selectively perform the bus priority control in the state of system optimization and the local bus priority control under the system surveillance.

11.1.1 Bus Priority Strategies of Urban Traffic Signal Control System

At present, the following control systems are adopted in large and medium-sized cities in China. Due to the influence of closed systems, the options of signal strategies are limited. The cities should choose the appropriate strategies based on the current signal control systems in the construction of bus priority.

(1) Bus priority in the TRANSYT system

As early as 1967, D.I. Robertson, a researcher of the British Transport and Road Research Laboratory (TRRL) proposed the TRANSYT system. The bus priority in the system simulated the operation of public transport vehicles based on the method of "combined stop line" meanwhile an exclusive dispersion coefficient algorithm of buses was constructed to calculate the bus priority weight and determine the signal timing distribution based on the minimum delay per passenger. The Glasgow Experience proved that compared with the traditional timing plan based on the optimization objective of the minimum delay of vehicles, the timing plan based on the minimum delay per passenger for optimization had a higher operation efficiency, around 8 % more than the former and had less impact on the operation of other non-priority vehicles.

(2) Bus priority in the SCOOT system

Based on the TRANSYT system, the British Transport and Road Research Laboratory (TRRL) improved it in 1981 and developed the SCOOT (Split Cycle Offset Optimization Technique) system, which was a center-based adaptive control system. The bus signal priority control strategy of the system focused on the active priority strategy. The active priority means that a recovery strategy was performed after the bus signal priority service to restore the signal to the normal SCOOT optimal state through two control modes of early green and green extension provided by the central controller or area controller. The number of buses with priority service was limited by the intersection saturation, that is, only when the current intersection saturation was below the saturation set before, the bus priority strategy was able to be performed. In the SCOOT system, different levels of priority were set for different vehicles. For example, priority service was not provided for the buses which did not arrive according to the running schedule while the buses which arrived late were provided with some priority. The later the bus arrives, the higher the priority. The survey data during 07: 00-12: 00 and 14: 00-19: 00 at Camden Town showed that the average delay of buses was decreased by 17%~20%; at low saturation, the average delay of buses was more seriously reduced by 44% -71%.

（3）Bus priority in the SCATS system

Similar to the bus priority control strategy of the SCOOT system, in the SCATS (Sydney Coordinated Adaptive Traffic System) system developed by the Road Transport Bureau of New South Wales in Australia, the bus signal priority control was achieved through the two control modes of passive priority and active priority. In the system, the bus priority was achieved through the passive priority control which was based on the analysis of a lot of historical public transport vehicles to determine the main direction of public transport vehicles as a priority service phase to achieve the minimum delay of the phase buses for optimization. The active priority service was also achieved on the single buses through the two control modes of early green and green extension. The Head report in 1997 showed that the bus signal priority strategy could be achieved in the SCATS system with some benefits. The implementation of bus priority in the SCATS system could significantly improve the transit time of public transport vehicles and the transit time was decreased by 6 % -10 % than that of vehicles in the direction of maximum traffic congestion.

The current researches on bus signal priority attach increasingly more attention to self-adaptive implementation priority strategy that can be applied to independent intersections and regionally linked intersections. Most of recent research findings are directed at independent intersections. The typical control system serving intersections in application of self-adaptive bus signal priority control strategy is the SPPORT system; the noted signal control system in service of regions is the RHODES system.

(4) Bus priority in the SPPORT system

The SPPORT (Signal Priority Procedure for Optimization in Real-Time) system is a real-time signal priority control system based on the decision-making condition of total passenger delay. With the core of a non-loop priority model and on the basis of regular optimization procedure, the SPPORT system realizes signal control plans of different priority levels, and calculates the current delays and future delays of all phases of the intersections. Current delays are the sum of delays of phases to be optimized and adjusted, while future delays refer to the combination of all priority requests of remaining phases. Phase sequence is obtained by optimization with the optimization goal of minimum total passenger delay. While providing buses with priority service, the SPPORT system has exerted little impact on other public vehicles. However, this method is not applied in reality. That's because the waiting time of the vehicles in different phases in the delay calculation equation is equal by default, which is not the case in reality. Delay is, in fact, to multiply the ratio of queuing vehicles by interval time. Furthermore, the system fails to take into consideration priority requests in overtaking. The lower of degree of fitting between buses and timetable, a greater weighted value should be given. Therefore, a delay model shall consider all factors involved to acquire the optimum signal timing plan.

(5) Bus priority in the RHODES system

The RHODES (Real-time, Hierarchical, Optimized, Distributed, Effective System) is a traffic signal control system researched and developed by the Arizona State University, the United States. The RHODES system adopts advanced smart vehicle detection system to realize real-time collection of bus operation information (positioning, load factor, etc.), and then calculate the weight function of buses to get the weighted value. The weighted value is mainly determined by load factor and delay time of the buses. The higher the load factor and the longer the delay time, the greater of weighted value should be given. The optimum signal timing plan is achieved by optimization with the optimization goals of minimum average vehicle delay, minimum stops and minimum vehicle queuing length. This system can effectively lower bus delay, but has an effect on the traffic flow of other branches. In 1992, Head et al. utilized CORSIM simulation model to simulate a regional road network including several intersections. It's found that in comparison to the semi-actuated traffic control system, the RHODES system with bus signal priority can reduce the average vehicle delay time in main roads by 8.5% and that in secondary main roads by 21.2%.

（6）Bus priority of Hicon system

HiConis a high-end product of Qingdao Hisense TransTech Co., Ltd. used in the traffic control of ITS industry. It provides real-time control software and software-compatible annunciator for urban traffic. The basic strategies include green-extension passing through the intersection, red-shortening passing through the intersection and phase insertion (rarely used). In case of the contradiction between coordination and priority, the recovery of the coordination effect as a result of bus priority to non-priority status needs to be considered with the support of signal algorithm. Currently, our products support the recovery of the coordination.

11.1.2 Bus Monitoring Technology and Layout Design

Currently, the bus signal detection is divided into the following categories according to the working principle and characteristics of detector:

(1) Loop coil

Loop detector is a detector most used on the current road. It is composed of coil inductor, transmission line and detection processing unit buried under the pavement. The basic working principle of the loop coil is as follows: A tuning circuit is formed by an inductance element (loop coil) and the detection processing unit. When a current flows through the loop coil, an electromagnetic field may be formed in the vicinity. When there is an iron material such as automobile running into the electromagnetic field, eddy currents will be generated to reduce the inductance volume in the tuning circuit. As the circuit frequency is increased, a response is generated resulting in an output signal thus to detect the vehicle passing through the coil. The induction coil is generally embedded under the pavement characterized by adjustable sensitivity, high cost performance, easy installation and application so widely used in engineering. However, the traffic would be interrupted with great interference when installing an induction coil. Meanwhile, such installation would damage the road to a certain extent. The detection with induction coil has the advantages of mature and precision technology, easy installation, high cost performance and stable performance, but it also has the following disadvantages during use:

①Due to the limitation of the detection principle, when there is a large traffic and the vehicle spacing is less than 3m, its detection accuracy would be greatly reduced, so it is difficult to identify continuous traffic and detect every vehicle.

②Road must be excavated when installing or maintaining the coil, which would affect the life of the coil and the road, hinder the normal operation of the traffic resulting in traffic jam.

③The induction coil is easily affected in the environment of freezing, roadbed sink, saline and alkaline. A large workload is required for the coil maintenance in such places.

（2）Microwave detector

Microwave detector completes the detection through the transmission and reception of microwaves. It mainly consists of two parts, namely antenna and receiver. The antenna transmits microwaves to the area to be detected. When a vehicle passes, the Doppler Effect will be generated to reflect the waves of different frequencies back. By detecting the reflected waves, we can determine whether a vehicle passes. The basic working principle of the microwave detector is as follows: The transmitter continuously transmits modulated microwaves with low power in a fan-shaped area and leaves a very long shadow on the pavement to be detected. The microwave vehicle detector divides the shadow into 32 layers as one "layer" is two meters. Users can define the detected area to be one or more layers. The receiver receives the microwave reflecting from the detected object and calculates its traffic information according to some changes in the characteristics of the microwave. The traffic information will be sent to the control center via RS-232 every once in a while.

Practical applications showed that the microwave vehicle detector generally has higher detection accuracy on the road with stable traffic flow, single models and uniformly distributed speed while lower detection accuracy on the road with traffic jam, more large vehicles and unevenly distributed models. The reason is that small vehicles cannot be detected by the microwave as there are more vehicles so the large vehicles are prone to block the small vehicles at their side. A large number of experiments showed that the microwave detector has the following advantages of all-weather operations, stationary vehicle detection, direct vehicle speed detection, multi-lane vehicle detection in lateral mode in addition to easy installation and maintenance. It also has some disadvantages: only long and short vehicles can be distinguished when it is installed at the side. The number of vehicles may be lost while the vehicles on the adjacent lanes are passing at the same time. The installation is demanding, difficult and expensive.

(3) Video detection technology

Video detection technology is an advanced detection technology through which we can obtain the required traffic information after analyzing the traffic video with graphic processing. It has a higher requirement for video quality and image processing technology. The basic working principle of the video detection technology is as follows: Through the technology of computer and video camera simulating human vision and the analysis of the traffic image taken by the video camera, a virtual coil is defined as a detection area within the video range. When a moving object runs into the detection area, the gray level on the background of the image would have some change, so the moving object can be perceived. By using this method, the detection, identification, positioning and tracking of the traffic object like pedestrian and vehicle can be achieved and the analysis and determination of the traffic behavior of the moving object can be performed so as to complete the collection of required traffic data information. The working schematic of the video detection technology shows that the video detection system consists of electronic camera, video detector, image processor, display and communication module. The video detection system has the advantages of multi-point layout and unlimited detection. Important traffic information like vehicle queue length, traffic density, stops and vehicle size can be achieved by using this technology. In addition, the video detector has the advantages of easy installation and maintenance, much available traffic management information and multi-lane detection.

The video detection system is greatly influenced by light. The processing of image background is complex, so the compensation of multiple disturbing factors must be considered in the image processing. Therefore, the video detection technology also has the disadvantages of low accuracy, easy affection by environment and interferent. In addition, it is somewhat difficult to detect and capture fast-moving vehicles with the video detection technology due to the calculation in the video detection.

By using the video detection technology, buses and other social vehicles can be clearly distinguished for easy detection.

（4）RF tag

RF tag can also be referred to as electronic tag, smart tag or RF card, generally composed of controller, code generator, modulator, memory and antenna with the capacity of intelligent read and write and encryption. It is an electronic device storing identifiable data in the radio frequency identification system. The reader is a device reading or writing the tag information, generally composed of RF module, read-write module and antenna. The vehicle identification system based on RFID technology is mainly composed of vehicle tag, reader, antenna and data processing system. The data processing system is composed of database, central processor and PC terminal. The basic working principle of this detection system is: The antenna of the detector transmits radio carrier waves. When a vehicle equipped with a RF tag enters the magnetic field, the RF tag is activated. The relevant information stored in the chip is transmitted by the antenna, read and decoded by the reader and then sent to the central information system for data processing.

（5）RFID technology

RFID technology is a non-contact automatic identification technology characterized by fast-moving object identification, adverse environment resistance and simultaneous identification of multiple objects. RFID is less interfered by external environment with a higher capacity than traditional image processing technology in the identification of moving objects. Currently, the RFID technology has been used in the intelligent transport system to some extent.

（6）GPS technology

Global Positioning System (GPS) is an advanced mobile traffic detection technology. It consists of three separate parts: space (21 working satellites, three spare satellites); ground support system(1 master control station, 3 injection stations, 5 monitoring stations) ; user equipment (receiving the signals from GPS satellites to obtain the necessary navigation and positioning information which is used for data processing to complete the navigation and positioning).In the detection of road traffic information, the ground segment of the system is composed of vehicle equipment, central monitoring equipment, annunciator and communication system. The mobile vehicle equipment is a user terminal and can provide real-time and latest information of positioning data, operational status and alarm of every moving object for the command control center with automatic recording for late query and analysis. It consists of the following four parts:

①GPS receiver, receiving antenna ;
②Radio communication transmitting and receiving device;
③ Vehicle controller and data processor;
④DGPS differential correction signal receiving antenna.

Combined with the GIS electronic map, the command and monitoring center can display the current location of the monitored and commanded vehicles in real time. Itconsists of the following four parts:

①Central server;
②Data storage device, database;
③ Data analysis control system;
④ GIS and radio communication transceiver.

The annunciator is mainly used for generating signal timing plan in real time;

The communication system is used for controlling the data transmission and the interconnection between hardware devices of subsystem.

GPS equipment has the advantages of high-accuracy signal and powerful system software. The system can be in an efficient and safe operation with strong openness for easy maintenance and management. However, GPS has the disadvantage of unstable performance. GPS has a good signal reception and accurate measurement in the construction of new area with wide vision and few obstacles as well as field exploration positioning. However, the accuracy of its measurement would be affected to some degree in big cities or mountains due to the effect of high-rise buildings and trees on the signals which would transmit in a non-linear manner resulting in some errors in calculation. At the time, GPS cannot present its advantages in the measurement. Meanwhile, if the GPS equipment models do not match or different types of GPS are used for the measurement, there would be a difference between the measurement results, and sometimes the difference is relatively large, which would be inconvenient for the mutual communication between different equipment as well as the maintenance and update of equipment. Due to such disadvantages, there are some limitations for GPS measurement.

To sum up, buses have certain regularity in their operation and are different from other vehicles. Therefore, the detection of buses shall be based on their special nature and different from that of other social vehicles. In practical detection, it is necessary to select appropriate detector according to its characteristics and properties to improve the detection accuracy of the vehicles with appropriate detection methods.

Suggestion: GPS shall be adopted for bus signal acquisition to save costs; RFID or DSRC shall be adopted if a closed signal control system is concerned.

11.1.3 Transit Signal Priority Strategy Classification and Selection

The control strategies of transit signal priority are passive priority control, active priority control and real-time priority control based on active priority.

（1）Passive priority

Passive priority involves the optimization for off-line plan through which the bus priority signal timing at the intersection is performed in advance based on historical data without setting a vehicle detector. The main data on which the signal control system is based under the condition of passive priority includes bus lines, departure frequency and vehicle speed of each bus line. The specific methods of the passive priority strategy include network timing, signal period adjustment, phase time increase, phase division and turning prohibition.

1）Network timing

Network timing is a plan designed on the signal timing at the intersection based on the passage of buses through the road network. The network signal timing plan is generally divided into two kinds. The first plan is that green ratio is allocated based on the passenger travel volume through the road network; the second plan is that the signal timing plan within the transit network is coordinated based on the running speed or travel time of buses which would encounter least red light in the road network.

2）Signal period adjustment

If there are more bus lines through the intersection, the length of the signal period can be reduced to reduce the time of buses waiting at the intersection thus to improve the traffic efficiency of the buses. However, for an independent intersection, this method of controlling optimization results in the increasing of traffic efficiency of all vehicles, which does not reflect the priority of buses. Meanwhile, with the decrease of the signal period length, the traffic capacity at the intersection is reduced accordingly.

3）Phase time increase

The effective green time can be increased at the phase of intensive bus lines through the adjustment of green ratio to increase the possibility of buses passing through the signal intersection thus to reduce the waiting time of buses. However, for the case that there are more phases of bus lines at the intersection, if the green time is increased for each phase, the period length at the intersection is greatly increased, the impact on the traffic capacity at the intersection would also be increased.

4）Phase division and turning prohibition

Phase division means that the phase of bus priority is divided into multiple phases in a given period when the signal service frequency is increased. However, with the increasing of phases, the signal loss time would be gradually increased and the traffic capacity at the intersection would be affected to some degree.

（2）Active priority

Active priority means that when the vehicle detector detects the arrival of a bus at the approach of an intersection, the measures of green time extension or advance and phase increase or decrease should be taken to provide corresponding priority service for the bus according to the bus information, traffic status and signal control logic. Active priority can be divided into unconditional priority and conditional priority. Unconditional priority is similar to vehicle actuated control, i.e. once the vehicle detector detects the arrival of a bus, a signal priority plan will be immediately performed on it. Practice showed that the unconditional priority has a significant effect on the delay increase while the conditional priority has little effect on the delay increase at the intersection. The specific methods of active priority control include green extension, green advance and phase insertion.

1）Green extension

Green extension refers to the extension of green time at the end of the green phase. The extension of green time can ensure that there is plenty of time for buses to pass through the intersection. The original timing of signals will be restored after the buses pass through the intersection. It is currently the most common method to implement the bus signal priority. This method is also applicable to the case when there is a parking station for buses at the approach.

2）Green advance

Green advance means that the time of a red-phase bus waiting for a green signal is shortened. When a bus arrives at the approach of an intersection and the phase of the running bus is red light, the green time of non-bus priority phase at the intersection can be shortened to activate the bus phase signal light in advance, so that the bus can pass through the intersection at a green light when it reaches the intersection. This method is often combined with green extension to implement the bus signal priority when the bus arrives in case of different signals. But the two methods are usually applied to the situation of more concentrated arrival time of bus at the same approach. Meanwhile, in order to reduce the impact on the traffic capacity of the intersection, the green time of other phases should be correspondingly reduced to ensure the fixed length of the signal period.

3）Phase insertion

Phase insertion means that a special phase is added into the current phase sequence for buses. When a bus arrives at the approach of an intersection, the bus phase is red light and the next phase is still red light. To achieve the bus priority, an exclusive phase for buses can be inserted between the current phase and the next phase. However, for the case of dispersed arrival time of buses, if there are frequently-inserted phases, the passage of social vehicles at other phases would be severely disturbed resulting in a disorder at the intersection and even a serious threat to traffic safety.

4）Phase jump

Phase jump means that a green phase is temporarily removed. When a bus arrives at the approach of an intersection, the bus phase is red light and the next phase at the intersection is still not the bus phase, so the bus cannot pass until the end of the phase. Due to fewer waiting vehicles at the next phase of the intersection and based on the overall efficiency, the next phase is skipped then the bus phase is switched to green phase to ensure that buses can pass through the intersection.

5）Phase reverse

Phase reverse refers to the change of the phase position and sequence of signal period. When a bus arrives at the approach of an intersection, the phase to be switched at the intersection still does not allow the passage of buses. Then the phase of bus passage can be switched to green phase through the adjustment of the signal phase sequence, and the green phase to be performed according to normal phase sequence is placed behind the phase of bus passage, so that the bus can pass through the intersection at the green phase. Different from the jump phase, the phase is postponed for performance for phase reverse while it is not performed for jump phase.

6）Exclusive phase

Exclusive phase is the phase especially providing signal priority for buses. Only when a bus is detected, the exclusive phase will be enabled. If a bus is detected entering the left-turn lane at the intersection, as there is no special signal for left turn in the normal signal timing, the exclusive left-turn phase will be enabled automatically to ensure the safe and smooth passage of buses through the intersection. The difference between the control strategy and the phase insertion is that only buses are allowed to pass when enabling such a phase.

Compared with the active priority strategy, the adjusted timing signal control mode as a result of the implementation of the passive priority strategy is mainly applicable to the cities or regions with regular changes in road network traffic status and fixed bus departure frequency, such as some small and medium cities in our country. The active priority strategy is very flexible and applicable to the areas with large road network traffic and frequent changes in traffic status of bus lines, such as Beijing, Shanghai and Guangzhou in our country.

11.2 Experience Summary

(1) Signal priority in line with local conditions and comprehensive application of multiple strategies

According to the engineering practice in Beijing:

1）The control method of phase difference signal priority is suitable for some sections (e.g. the distance between the intersections is short and the vehicle travel time between the intersections is regular).

Active priority control method is only used in some special intersections (such as separate intersections far from upstream and downstream intersections). The specific indicators are as follows:

◆ The requirements for the sections are those when there is a phase difference signal priority control: the intersections with a spacing of less than 100m (based on the speed of 10m/s and travel time of10s) can be in a coordinated control by keeping the clock synchronization of two intersections with the same period and zero phase difference. The bus priority detection equipment is only installed at both ends of the intersection in one direction to detect the bus travel time; when the spacing is greater than 100m and less than a certain distance (such as 500m), the phase difference can be set in a coordinated manner based on the bus travel time and stop time, and the buses can be released in the next period (disadvantages: some cars would lose their speed advantage when the intersections are not far from each other).

◆ The requirements for certain special intersections only in the active priority control are: when the spacing is greater than a certain distance (such as 500m), the bus signal priority is requested so the bus signal priority has less impact on the normal social traffic flow.

In the implementation of the project, the local conditions of bus priority should be attached great importance with emphasis on the hybrid application of multiple strategies, i.e. the combination of point control, line control and network control can be achieved.

(2) Emphasis on the application of traffic simulation in signal priority

In the implementation of transit signal priority, the application of traffic simulation should be emphasized. The transit signal priority of Changzhou has been conducted with adequate simulation and verification during the project construction to guarantee the effectiveness and feasibility of the system construction.

（3）Implement the bus signal priority with combination of the bus transit lane to enhance the bus running efficiency and reduce carbon emission.

After the bus transit lane from the urban area of Beijing to Tongzhou District is operated, the bus running speed is increased significantly, with the running speed in the bus transit lane increased to 45km/h from 25km/h. The time taken from Beiyuan, Tongzhou District to Bawangfen is shortened to 12 min from 36 min before the bus transit lane and signal priority are implemented, the bus carrying capacity at the peak time is enhanced by 35% and the daily passenger transport capacity is increased by 24.5%. After the bus transit lane and bus signal priority are implemented for the route from 3rd West Ring to 3rd East Ring of Chang'an Street, the average delay time when the bus passes this intersection was reduced by 18s, with a passing efficiency increase by 29%. The above-mentioned data sufficiently show that the implementation of bus signal priority with combination of the bus transit lane may greatly enhance the bus running speed, enhance the transport capacity and reduce the average delay time, fuel consumption per person/bus/ road and carbon emission.

11.3 Problem and Requirement Analysis

(1) Technical implementation mode

At present, passive priority, active priority and real-time priority are three common signal priority technical implementation modes. Passive priority mode presets intersection signal priority scheme based on historical data, but it can't realize signal priority strategy due to poor punctuality rate in actual operation. Active priority mode adjusts the signal phase by the induction coil used to detect vehicles at the entrance of intersection, but it has a problem of poor accuracy when distinguishing between bus and social vehicle. It is only suitable for point control, not apply to wire control and unable to cope with the complex traffic conditions. Real-time priority mode collects real-time vehicle information by GPS and other methods, then establishes analysis model for signal control, but it usually has a problem of inaccuracy in positioning as GPS signal affected by urban construction.

(2) The layout is general

Research emphasis in China is qualitative analysis. There is insufficient research in functional performance, setting location, setting methods, use condition and effect evaluation of bus testing equipment, also lacks pertinence and applicability to varied road and traffic conditions.

(3) Priority rules remains to be further defined

Signal priority rules can be divided into unconditional and conditional priority. Unconditional priority provides priority for all buses detected at the signal intersection and is the most common rules adopted at present, but it causes great influence to social vehicles. Conditional priority provides priority for buses delayed but not for buses in advance, it improves punctuality rate of public transport vehicles and minimize influence to social vehicles while it needs complex priority algorithm and system supported.

(4) The cost of construction, operation and maintenance is high

Signal priority system adopts information collection technology such as video detection, induction coil, infrared sensors thus raise a high requirement for hardware and system platform, that leads to high cost of construction, operation and maintenance.

11.4 Overall Architecture

11.4.1 Application Scenarios

The transit signal priority system is used to ensure that buses have priority over other vehicles in terms of transit time. It can shorten the travel time of bus routes, cut down the delay at intersections, reduce the number of bus stoppages and improve the level of bus services. The specific application scenarios are as follows:

During the course when a bus is travelling on an urban road, the bus's real-time position information is collected by the vehicle-mounted positioning equipment. When approaching an intersection, the bus will obtain its real-time dispatching status interactively with the intelligent dispatching system, including whether there is any lateness, whether any early arrival dispatch is needed, and what the full load rate is. A transit priority request will be generated based on the bus's real-time status. At the same time, the vehicle detection system will catch the vehicle passing information and then the signal priority system will send the priority request to the traffic control department. Based on the original scheduling information and the real-time dispatching information, the system of the traffic control department will process the request according to the priority control strategy and finally give a priority result. After the bus leaves the positioning area, the signal control system will enter the status of signal status restoration until the signal status restores. The signal priority dispatching process is thus completed.

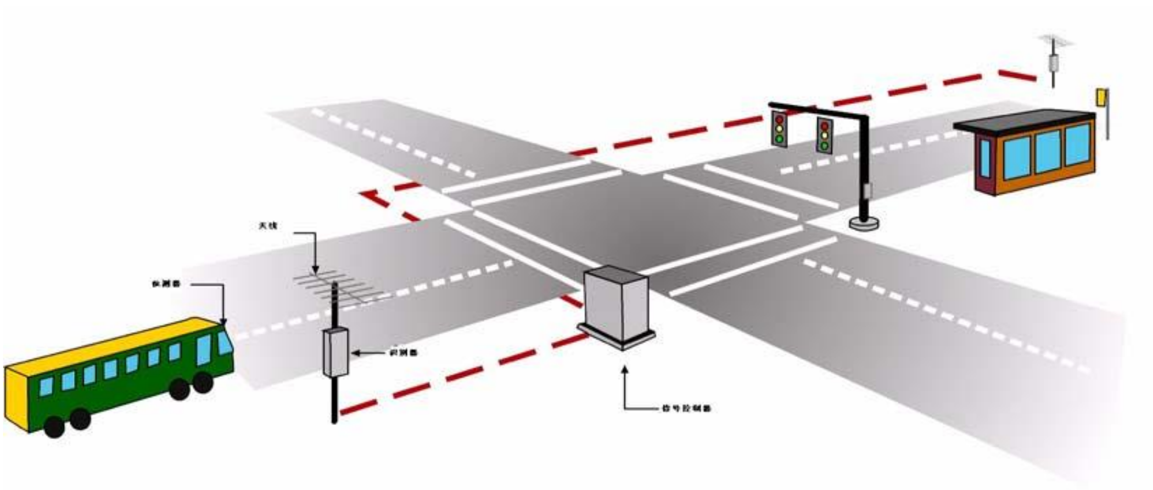


Figure 11-1 Application Scenarios of Transit Signal Priority System

11.4.2 Service Function

The bus priority signal control system mainly consists of the vehicle-mounted positioning system, vehicle detection system, signal priority request system, background rule and strategy formulation system, and the response part of the signal control system.

◆ Vehicle-Mounted Positioning System

The System determines the exact position of a vehicle mainly through processing the accurate information obtained from the vehicle dispatching system or with the help of the positioning equipment such as RFID road detection devices.

◆ Vehicle Detection System

When a bus approaches a bus priority signal intersection, the exact position of the bus is detected through the arranged road surface or road detection equipment to provide a basis for the background to form a priority control strategy.

◆ Signal Priority Request System

After the data are collected and processed, the decision on whether to send the signal request and what contents to send will be formed based on the designated different rules before the signal request is transmitted to the signal control system through the signal request system.

◆ Rule and Strategy Formulation System

Formulate reasonable bus priority signal request strategies. The data model should be built according to the different characteristics of each city, for example, if five buses are gathering on a road section during a city's morning rush hours, the system will immediately send the bus priority signal request or formulate a priority strategy based on the full load ratio of a bus and on whether there is any lateness against the bus schedule, as well as on whether any big interval has occurred, etc.

◆ Signal Control System

The signal control system judges whether to respond to a bus priority information request based on the actual situations of signal control.

By taking into account the conditions of relevant traffic facilities existing now and to be developed in the future, the whole system should generally meet the following scope of functions:

(I) reduce the adverse influence on social vehicles to the minimum on condition that the transit control requirements of bus priority signals are met:

(II) optimize and combine the detection areas by considering the control requirements of bus priority signals;

(III) accord with the coordination and control strategy as to bus priority signals;

(IV) provide the real-time information as to the abnormal operation of equipment to maintain the normal operation of bus priority signal control; and

(V) after the automatic feedback center performs bus priority signal transit control, the early ending seconds of the green or red light will be actually extended to provide reference data for traffic management.

11.4.3 Priority Mode of Bus Signals

The intelligent bus priority signal control system closely interrelates with the urban traffic signal control system. It achieves interaction between mutual information and realizes transit signal priority via the communication system.

According to different bus positioning information technologies, the physical framework of the transit signal priority system can be divided into the following two types:

(1) **Architecture I**: Physical Framework of Beacon-Based Bus Positioning Technology

The beacon-based bus positioning technology is to realize bus positioning using microwave short-range communication technologies such as RFID. The beacon-based transit signal priority system consists of the following parts: vehicle detection sub-system, bus detection and positioning sub-system, intelligent signal controller and communication sub-system. It connects with the urban traffic signal system via optical fiber and other communication sub-systems to realize transit signal priority. Its physical framework is as shown in Figure 11-2.

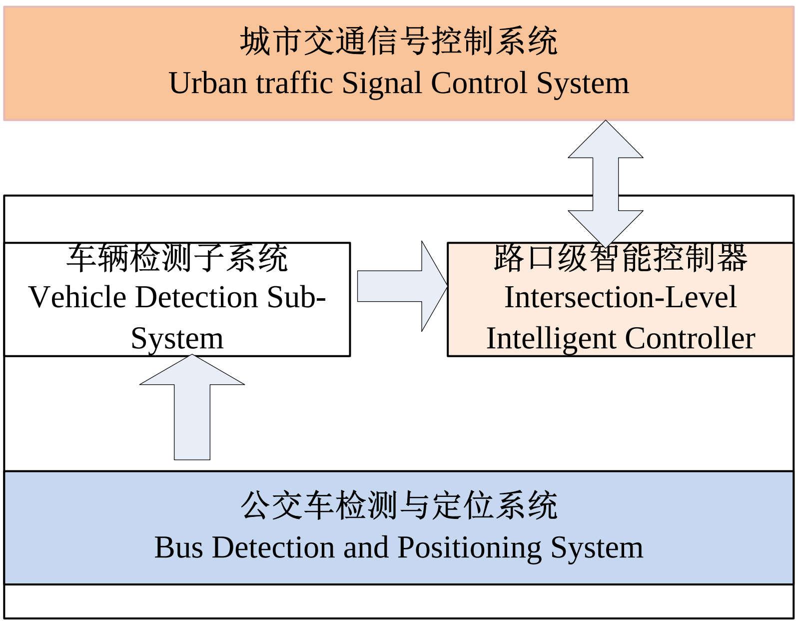


Figure 11-2 Physical Framework of Beacon-Based Bus Positioning Technology

Characteristics of the architecture: accurate positioning without being affected by signals; can be further extended in the existing urban traffic signal control system although the cost is high.

(2) **Architecture II**: Physical Framework of Transit Signal Priority System Based on Intelligent Public Transport System

The public transport systems in some cities have been completed gradually. The intelligent public transport system can match with the urban traffic signal system and directly send the bus positioning information to the city's traffic signal control center to realize transit signal priority through system coordination.

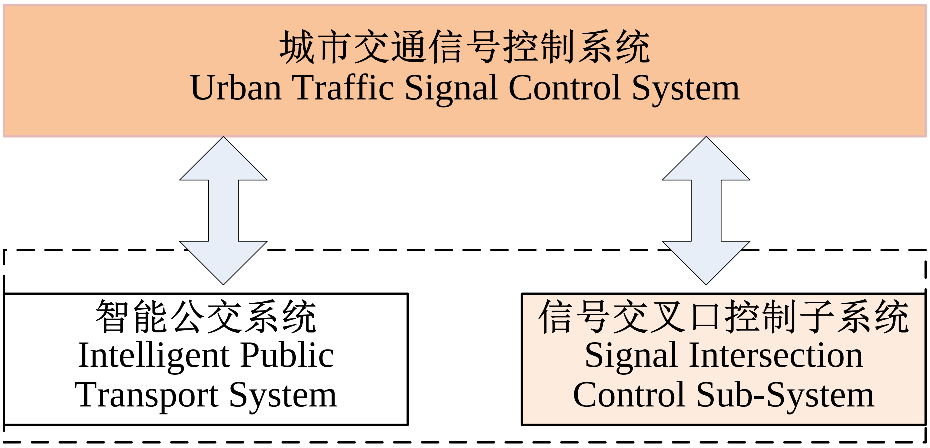


Figure 11-3 Physical Framework of Transit Signal Priority System Based on Intelligent Public Transport System

Characteristics of the architecture: the positioning accuracy is greatly affected by environment; the construction cost is low.

11.4.4 System Architecture

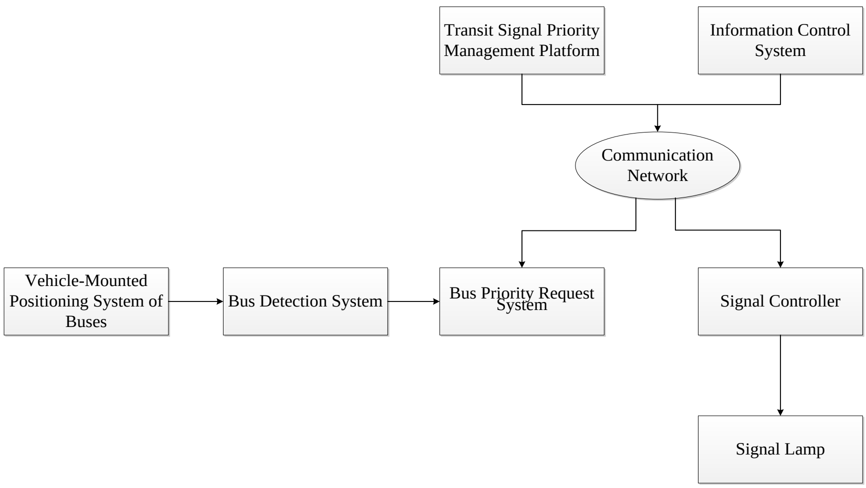


Figure 11-4 Overall Logistic Architecture Chart of Transit Signal Priority System

A general intelligent bus priority signal control system, viz., the transit signal priority system in overall architecture I consists of the following parts: vehicle detection sub-system, bus detection and positioning sub-system, intelligent signal controller, communication sub-system and control center.

(1) Vehicle Detection Sub-System

In the bus priority intelligent signal control system, the first step to finish is the detection of the flow of all vehicles and the detection and positioning of buses. The vehicle detection sub-system completes the detection of the flow of all vehicles. Many types of vehicle detectors have been put into use by now, including magnetic induction detectors, wave frequency vehicle detectors and video detectors, etc.; if classified according to the installation method, vehicle detectors can also be divided into buried and suspension detectors. Among the three types of vehicle detection, the annular coil vehicle detection method is of the matures technology, widest application and lowest cost, which can completely meet the requirements as to detection of all vehicle flow information. The detection effect of the video detection technology will fail to meet the requirements of the system during morning and evening time periods because light rays have a big influence on the technology. It can be considered for use in the future as the image recognition technology develops. Therefore, in the bus priority intelligent signal control system, annular coil vehicle detectors are used to complete the detection of the flow of all vehicles.

(2) Bus Positioning Sub-System

1) Global Satellite Positioning System

The vehicle positioning technologies are classified into two type: one type is to determine the coordinate position of a vehicle in a space using the global satellite positioning system, dead reckoning and other methods; the other is to determine the position of a vehicle in a large area relative to roads and intersections, which method needs the map for realization. Presently, the global satellite positioning system has the widest application. The signal benchmark positioning system is also applied to the positioning of public transport vehicles.

GPS navigation and positioning are that the GPS receiver catches the signals sent from over three GPS satellites and obtains the 3D position, 3D speed and time information of the point through calculation. The GPS system provides a positioning accuracy less than 10m at present. To have higher positioning accuracy, the differential GPS technology is usually adopted: install a GPS receiver on the benchmark station for observation. The correction figure of the distance from the benchmark station to the satellite is calculated based on the precise coordinates known for the benchmark station and then the station sends the data out in real time. While the user’s receiver performing GPS observation, it also catches the correction figure sent from the benchmark station and makes correction to its positioning result thus increasing the positioning accuracy.

The GPS technology is used in the traffic field mainly for vehicle positioning to realize the functions such as navigation, tracking, monitoring and anti-theft alarm for vehicles. With the research on advanced public transport system in the TIS, the GPS is finding increasing applications in the public transport system: in the public transport intelligent dispatching and direction system of Beijing City, bus positioning is performed using the high-accuracy differential GPS and then dispatching is performed using the analogue cluster communication system by combining with wireless data transmission, and on the terminal, the advanced geographic information system is used for display .

2) Signal Benchmark Positioning System

Theoretically, the benchmark positioning technology is very simple: just need to install a detection equipment on the location from which the data need to be obtained; when a vehicle runs to the location, the detection equipment can catch the position and transit time of the vehicle. There are no time and position errors theoretically.

The microwave short-rang communication system, which has been widely used internationally over recent years, is the most effective and convenient system among benchmark positioning. The intelligent card (CI card) and the resonant circuit (antenna) are used together through the radio frequency identification card (RFID), with which the objects can be identified wirelessly without contact; and it can be installed in a vehicle very conveniently thanks to the small size. After we install a short-range communicator in a location where positioning is needed, we can read the ID codes in the RFID cards installed in the passing vehicles as well as other additional information. The effective data as to bus travel are obtained thus.

When the GPS is in areas such as an urban high-rise area, tree-lined street, culvert, tunnel, overpass, it may temporarily fail. Meanwhile, its cost is relatively high. The signal benchmark positioning technology is to complete vehicle positioning by catching the passing vehicles through signal benchmarks. Signal benchmarks can be arranged on different roads according to positioning requirements and the positioning accuracy depends upon the density of arrangement of signal benchmarks. Compared with GPS positioning, it can realize the monitoring and positioning of the buses in a city at a lower price and meet the application requirements of buses.

Considering that each type of navigation and positioning technology has its own advantages and disadvantages, combination of different navigation methods is usually used to increase the positioning accuracy. The common practice is to combine the GPS with the dead reckoning positioning technology and with the map matching technology. Among the bus positioning systems, it can be considered to combine the GPS with the benchmark positioning system to realize more accurate real-time positioning if the GPS cost becomes lower in the future.

The positioning of buses has its own particularity. Firstly, bus routes are relatively fixed and bus stops are distributed at a relatively even interval. In the real-time information as to bus operation, the information about the relative position between a bus and a bus stop is especially important. Moreover, considering the requirements for detection and differentiation of buses, the signal benchmark positioning system is adopted to realize bus detection, differentiation and positioning.

In the bus priority intelligent signal control system, the signal benchmark positioning technology is adopted for the detection and positioning system of buses. In the positioning system, buses are equipped with a vehicle-mounted movement unit, viz., the signal transmitting device. The fixed unit (viz., the signal benchmark) is installed at each bus stop as well as near a signal control intersection and at the even interval among other longer road sections.

The positioning accuracy of the signal benchmark technology is dependent upon the density of arrangement of fixed units. Although the positioning technology cannot achieve continuous accurate positioning, it can set different distribution densities of signal benchmarks in response to different positioning requirements, viz., arranging more signal benchmarks on the road sections requiring a higher positioning accuracy. Therefore, the technology can completely meet the positioning requirements of buses. What is most important is that the differentiation and detection of buses are realized through the fixed units arranged near the intersections and thus the signal controller can perform bus priority intelligent control based thereupon.

(3) Intelligent Signal Controller

The intelligent signal controller completes real-time decision-making and determines the signal status at the next moment according to the information as to the traffic flow at different moments and the information as to the bus priority level: either by making a change to the phase or by prolonging the duration of the current green light. The controller finally outputs the intelligent decision in the form of a signal light.

(4) Communication Sub-System

The communication system completes the communication between various sub-systems and that between the sub-systems and the control center. Many forms of communication can be adopted according to different needs:

1) The communication between the bus detection sub-system and the intelligent signal controller;

2) The communication between the bus detection and positioning sub-system and the intelligent signal controller;

3) The communication between the bus detection and positioning sub-system and the control

center;

4) The communication between the intelligent signal controller and the control center.

The communication between the bus detection sub-system and the intelligent signal controller is simple. Method of communication: the annular coil detector sends the information to the intelligent signal controller, which is a one-way communication; the information conveyed: the information as to the flow of all vehicles; communication medium: wired link and serial interface.

The bus detection and positioning sub-system consists of the vehicle-mounted movement unit and the fixed unit. The radio frequency or infrared radio frequency communication technology can be used between the vehicle-mounted movement unit and the fixed unit; method of communication: the vehicle-mounted movement unit sends the data packet to the fixed unit, which is a one-way communication; the information conveyed: the information about a bus, including the plate number, route number, departure starting point, travel time, travel speed and passenger load, etc.

The communication between the fixed unit of a signal benchmark and the intelligent signal controller: method of communication: the fixed unit sends the information to the intelligent signal controller, which is a one-way communication; the information conveyed: the information related to a bus and the identification information of the fixed unit; communication medium: wired or wireless link, in which the wired link connects all stops and the control center together through the laid electric cable or the optical fiber cable, while the wireless communication link performs information transmission through the dedicated or public wireless communication network.

In the communication between the signal fixed unit and the control center, a wired or wireless link can be used for two-way communication.

1) the information conveyed when the fixed unit sends the information to the control center: the information as to a bus and the identification information of the fixed unit;

2) the control center sends the processed bus positioning information to the signal fixed unit at each bus stop and the function of electronic route board is realized after display processing.

In the communication between the signal controller and the control center, a wired or wireless link can be used for two-way communication.

1) the intelligent signal controller sends to the control center such information as the information about the traffic flow at an intersection and the real-time information as to signal phase control;

2) the control center can perform data update of the signal controller; in case of

malfunctioning of the controller, the control center can achieve remote control over it.

(5) Control Center

The control center is the commanding post of the whole system. On the one hand, it completes the integration among various sub-systems and on the other hand, it realizes the connection and organic integration with other public transport systems.

The control center performs relatively complicated information processing of the collected data packets: the specific position of a vehicle at a certain moment can be obtained through referring to the identification information of the fixed unit; the latest data packet can be identified through comparing the information as to the receiving time of different data packets of a vehicle in order to update the position of the vehicle constantly; the control center can estimate the travelling position of the vehicle based on the information about the vehicle's travel speed of and thus know its rough position on a road section without signal benchmarks.

The control center displays the positioning information on the electronic map by combining with the geographic information system to realize real-time monitoring of vehicles. The public transport operation and dispatching system can obtain the relevant positioning information of each bus through the control center to realize real-tine operation dispatching.

With the public transport information service system, the electronic route board can provide a bus's real-time information very conveniently. Through configuring a voice announcer triggering device on the signal fixed unit at a bus stop, the automatic stop announcing function of buses is realized very simply. This can both avoid wrong stop announcement and reduce the burden of bus drivers.

11.5 Suggestions Concerning System Construction

11.5.1 Basis of System Construction

The construction of the transit signal priority system is influenced by such factors as road conditions, traffic flow status and the construction of the exclusive bus lane system. Besides, many basic environment factors also have an influence on whether the control effect can be achieved.

(1) Road Conditions

Road conditions need to be studied before taking bus priority. Not all roads are suitable for bus priority. If only the priority of buses is considered in the road system and the benefit of other social vehicles is ignored, the jam of the social vehicles will in turn affect the priority of the buses, which will then hinder the target to realize bus priority. Therefore, before implementing public transport priority control strategy in a road system, it is extremely necessary to study the conditions of the road on which bus priority is to be taken. In a trunk line system, the roads suitable for taking bus priority should meet the following conditions.

1) Pulse Arrival of Vehicles

If the vehicle flow in a linear control system reaches in an even arrival manner, the effect is un-ideal. Only when the vehicle flow arrives in a pulse manner will the control effect be relatively ideal

2) Distance between Two Intersections

If the distance between two intersections is big, the vehicle flow will exhibit a discrete feature after the vehicles pass the intersections, to which trunk line coordination and control are not suitable. Practice has proven that the distance between two intersections using linear control should be within 800 meters.

3) Time Dependent Fluctuation of Traffic Flow

The traffic flow on a road keeps varying with time. It is big during rush hours and vehicles arrive in the form of vehicle fleet. When coordination control is used, the effect is obvious. However, considering the feature of arrival of vehicles during non-rush hours, it is not suitable to adopt coordination control.

4) Signal Phase Setting Conditions

The trunk line system will form a biggest passage belt when trunk line coordination control is adopted; while there are more signal phases at an intersection, the constant changeover of the signal phases will have a big effect on the passage belt. Therefore, the simpler the phases at an intersection are, the better the trunk line coordination works.

(2) Traffic Flow Conditions

A road system in which bus priority is adopted has certain restrictions on the flow of the buses on a trunk line. The effect of bus priority is not obvious when the flow of buses is small. It is even possible to cause an increase in the delay of the vehicles at other phases. In order to obtain the trunk line traffic flow conditions meeting bus priority, the conditions for bus priority can be assessed through person-total delay. This is because the average passenger load of a bus is far more than that of a social vehicle. Assuming that the average passenger load of a bus is 40 persons and that of a social vehicle is 2 persons, under the standard that person-total delay serves as the assessment index, the jam of one bus equals to that of 20 social vehicles. This method increases the weighting of buses rather than viewing buses and social vehicles equally. However, the purpose of transportation is to realize the movement of both human beings and objects. Using person-total delay as the assessment criteria accords with the people oriented thinking and therefore has social fairness.

(3) Optimal Design of Public Transport Signal Intersections

The optimal design of a transit signal priority intersection will also influence the effect of realization of transit signal priority. The optimal processing of an exclusive bus lane intersection includes the processing of both the entrance and exit lanes. As the entrance lane has a major effect upon the transit capacity at an intersection, the optimal processing of intersections mainly focuses on entrance lanes. In summary, the method for the optimal processing of exclusive bus lane intersections includes: exclusive bus entrance lanes, setting of feedback lines, widening of intersections and setting of zigzag entrance lanes, etc.

1) Exclusive Bus Lanes

An exclusive bus entrance lane means extending the exclusive bus lane to the intersection. This method can ensure that buses will separate from social vehicles at the entrance lane of an intersection, which can reduce their mutual interference and lessen the transit time loss and delay of buses at intersections; however, since exclusive bus lanes are generally arranged in the middle or on a side of a road, at the entrance lane, the so arranged exclusive bus entrance lanes will certainly conflict with the vehicle flow which is turning left or right.

In China, an exclusive bus entrance lane was generally arranged in the following two manners in the past:

a) exclusive lanes were arranged along the most outside motor lane, and in order to avoid or reduce conflicts with the motor vehicles making a right turn, the road section was required to have less vehicle flow which turns right at the entrance lane, or a lane and arrows dedicated for the right-turn vehicles were provided separately.

b) exclusive lanes were arranged on the inside of a road, and in order to avoid or reduce conflicts between motor vehicles and buses when the former makes a left turn, exclusive bus entrance lanes had to forbid social vehicles from making a left turn at intersections, and entrance lanes would not be used only when there were enough vehicle lanes for use by other vehicles. Or alternatively, vehicle lane lights and the left-turn and right-turn dedicated phases were installed to eliminate the conflicts between buses and social vehicles when the former travels straightforwardly.

Although the two traditional methods above provided exclusive lanes for buses and reduced the conflict with social vehicles when buses entered an intersection, they still failed to avoid conflicts with social vehicles when buses passed through an intersection. The two methods even caused traffic chaos and many other demerits were found during practical application.

2) Setting of Feedback Line

If an exclusive bus lane is extended to the stop line at an intersection (viz., set a dedicated entrance lane), it may lead to the following problems: at the signal control intersection, there are less buses waiting on the exclusive bus entrance lane but there are more social vehicles queuing at other entrance lanes; if the exclusive lane is arranged along the most outside motor vehicle lane and extends through to the road exit, another problem will be caused: the right-turn vehicle flow will interweave with the buses on the exclusive lane (unless a right-turn dedicated phase is set). To solve the said two problems, foreign countries first come up with the method of setting a feedback line, viz., the exclusive bus lane ends at certain distance ahead of the stop line, which distance is called a “feedback distance” or “feedback line”. The conditions for setting a “feedback line” are that when there are less entrance lanes and each entrance lane is already close to its full load, or the exclusive lane is arranged along the most outside motor vehicle lane, and there is a big flow of vehicles making a right turn, then a right-turn dedicated lane and arrow lights should be configured unconditionally.

3) Widen the Passageway at an Intersection

Traffic jams are the key factor affecting the road network traffic flow of the entire city. To promptly evacuate the vehicle flow coming from the up-stream of a road section and keep the intersection clear and smooth, the best solution is to make the number of the entrance lanes at the intersection bigger than that of the vehicle lanes on the road section in order that vehicles can be diverted towards more lanes at the intersection thus to increase the transit capacity there. However, this method is greatly restricted by geographic conditions and it is difficult for practical application.

4) Zigzag Exclusive Bus Lanes

Zigzag exclusive bus entrance lanes serve as one of the measures for bus priority at an intersection. It means more exclusive lanes are provided for buses at the intersection. Meanwhile, corresponding pre-signal lane lights are provided for exclusive bus lanes to ensure the full utilization of resources and smooth implementation thus giving more transit priority to buses in terms of both time and space.

(4) Sharing of Public Transport Dispatching Information

To realize the function of bus signal priority, the information accessed to the system should be able to meet the requirements of various public transport control strategies. The signal priority control system must interact with the public transport dispatching system to obtain relevant required information, which mainly consists of:

1) Basic Information as to Public Transport Dispatch

The information as to a bus route and to the position of a bus stop, vehicle running schedule (bus schedule), departure frequency of a route, and information as to the running speed, etc.

2) Information as to Dynamic Operation of Buses

The information as to the running position of a bus, the information as to bus entry, departure and stoppage, the information as to the rate of full load of a bus, the information as to the time-distance of the vehicle fronts of two adjacent buses, the information as to the value of deviation of the bus running time from the bus schedule, and real-time dispatching commands, etc.

11.5.2 Flowchart of Selection of Transit Signal Priority System Schemes

It is suggested that a transit signal priority construction scheme should be chosen through: the selection of bus priority strategy - selection of bus optimization targets - selection of signal processing and collection technologies - single-point intersection signal priority and network signal priority. The scheme can be selected by reference to Figure 11-5.

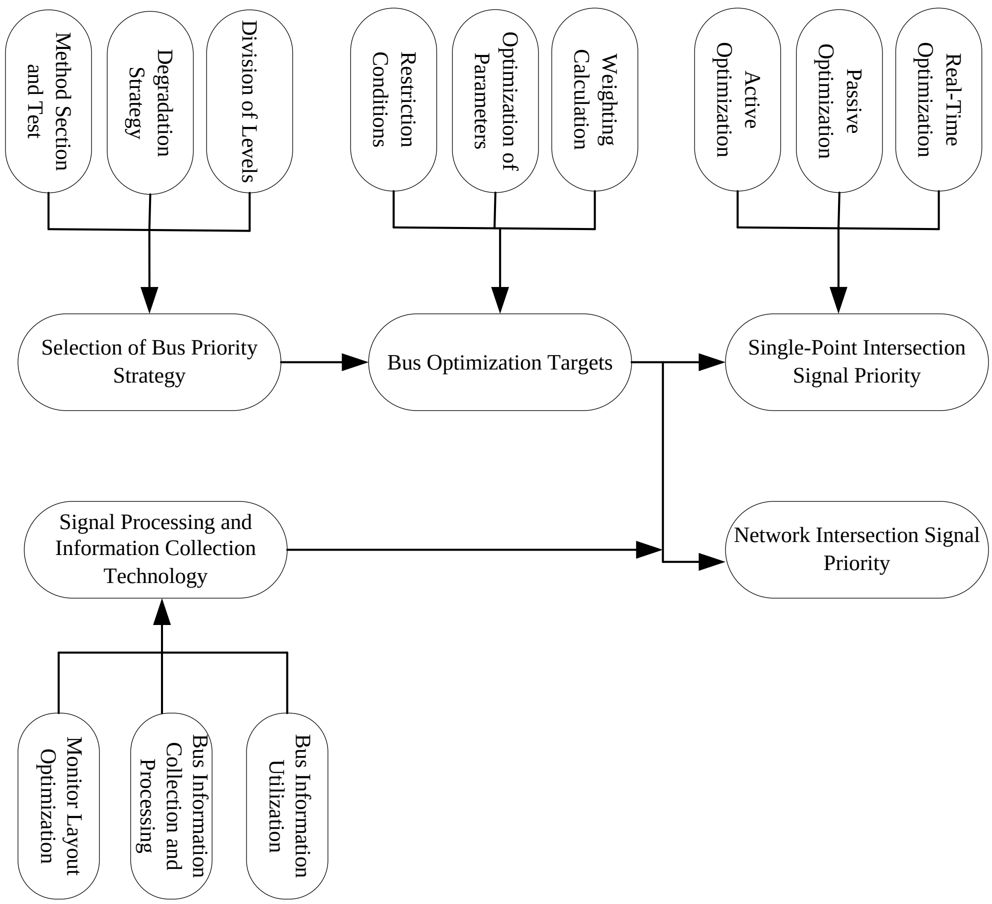


Figure 11-5 Flowchart of Selection of Transit Signal Priority System Schemes

(1) **The selection of bus strategies** mainly include method selection, degradation strategy, and division of levels.

1) Method selection. Bus priority signal control methods are classified into such three types as networked bus priority control, trunk line bus priority control and single-point bus priority

control.

2) Degradation strategy. Make timely dynamic adjustment to the regional scale as the status of road network traffic changes. When the 2D region is adjusted to a 1D trunk line region or an isolated intersection, the scope of bus priority degrades from networked priority to trunk line priority or single-point priority.

3) Division of levels. The levels of the bus routes arriving at an intersection can be divided according to the following two indexes:

◆ Flow of Route Buses

Give higher priority to the bus routes with larger vehicle and passenger flows in order that the buses can pass the intersections quickly.

◆ Degree of Lateness of Route Buses

Increasing the degree of punctuality of buses is one of the important purposes for which transit signal priority is given. The buses arriving at an intersection are given different levels of priority according to their degree of lateness obtained by the signaler at the intersection. The longer the lateness time is, the higher the corresponding level of priority becomes.

(2) **The target of transit signal priority** mainly covers restriction conditions, optimization of parameters, and weighting calculation.

1) The restriction conditions for transit signal priority control is divided into the types below:

◆ Road Condition Restrictions

Road condition restrictions mainly refer to whether any exclusive bus lane is arranged at an intersection. Compared with an intersection where no exclusive entrance lane is arranged, on condition that an exclusive entrance lane has been arranged, buses will not meet with the interference from social vehicles and will have a higher transit priority. Thus the estimation as to the accuracy of the bus travel time as well as to the signal priority benefit and transit smoothness can all be improved. Whereas on condition that no exclusive bus entrance lane is provided, due to the interference from social vehicles, buses cannot correctly estimate the travel time accuracy, the transit smoothness becomes lower, and the signal priority benefit becomes less.

◆ Signal Matchtime Restrictions

Signal matchtime restrictions mainly refer to the restrictions of such key matchtime parameters in signal control as the cycle, green light duration and phase difference upon the transit signal priority algorithm.

2) Bus Priority Optimization Parameters

The optimization parameters involved in bus priority matchtime include the following two:

Macro matchtime parameters, which refer to such parameters as the signal cycle, green signal ratio and phase difference;

Micro matchtime parameters, which refer to the green light parameter adjustment made for the purposes of increasing the bus operation benefit and realizing the transit smoothness during the course of bus priority, which includes maximum green light prolonging duration, unit green light prolonging duration, maximum advanced activation time of green lights, basic green light duration and inserted phase duration.

3) Methods for Vehicle Weighting Calculation

According to the requirements for the information as to the active and passive bus priority modes, the methods for bus weighting calculation are divided into the following two:

◆ Method of Bus Weighting Calculation under Active Priority

The priority object of active bus priority is a single bus arriving at an intersection, which weighting is divided into two type in this section: (a) same weighting, viz., taking bus delay as the optimization target: treat the arrived buses equally, give them equal weighting, and provide them with transit priority as much as possible; (b) lateness time based weighting calculation: treat buses differently according to their lateness time against the running schedule; the longer the lateness time of a bus is, the higher the priority and the bigger the weighting become; while for the buses arriving punctually or early, the lowest priority is given and even no priority will be given.

◆ Method for Bus Weighting Calculation under Passive Priority

The priority object of passive bus priority is the overall bus flow arriving at an intersection. According to different optimization targets, the bus weighting calculation under passive priority is also divided into the following two types: (a) bus flow based weighting calculation, viz., take statistics of the bus flow in each phase; higher priority weighting will be given to the phases with large bus flow and lower weighting to the phases with small flow; (b) lateness time based weighting calculation: take statistics of the lateness time of all buses in each phase and then calculate the priority weighting based on the accumulative lateness time; higher priority will be given to the phases with a longer accumulative lateness time and lower priority to the phases with shorter lateness time.

(3) Bus Priority Targets

1) Per Capita Delay Based Control Target

It refers to the matchtime parameter optimization carried out through making statistics of the average delay of all passengers by comprehensively considering the social vehicles and the passenger delay of the buses arriving at each entrance, in each time period, in each phase and on each lane and by taking the reduction of the average delay of all passengers in a studied road network as the control target.

2) Bus Delay Based Control Target

During the course of signal matchtime optimization, focus on the transit benefit of the buses arriving on each lane at an intersection in order to shorten the red light waiting time for buses. Lessen the delay of buses through adjusting the signal matchtime parameters to ensure the priority transit of buses. The inspiration of this thinking is that buses have a higher load of passengers, which passengers represent a large percent of the total passengers arriving at an intersection. Therefore, while the delay of buses is reduced, the per capita delay at the intersection is also significantly diminished.

11.5.3 Relation with the Existing System

At present, the bus signal priority system has not been widely applied in China. Most of the existing bus signal priority systems are used for the BRT routes. For cities with certain informationalization basis, the consideration to provide the environmental support such as basic data (including bus No., bus model, real-time location, speed and load rate) and communication services for the bus signal priority by using the existing system should be given for constructing the bus signal priority system. The RFID label equipment of the intelligent public transport system with RFID auxiliary locating system may be used as the basic equipment of the bus signal priority and it is OK to access its data to the bus signal priority system.

In addition, the coordinative handling with the traffic management system is also one of key problems to handle the existing system. At present, most of traffic management departments have established the signal control system and coordination control platform and the construction of the bus signal priority system should be sufficiently and timely connected with the data of the existing signal control system (including signal timing information, priority strategy information and bus transit lane drawing information).

Table 11-1 Information Table to be Accessed by Bus Signal Priority System

User	Information type	Information item
Traffic control department	Signal control information	The length of the road for which the bus signal priority is implemented, number of lanes, space between different intersections, intersection signal cycle and split.

	Bus priority information	Location of intersection for which the bus signal priority is implemented, priority strategy and priority mode.
	Bus transit lane information	Mileage, location and name of the bus transit lane.
Bus management department	Bus information	Bus No., bus type, number of passengers approved and information about the driver.
	Bus route information	Route No., station location, route length and road information.
	Bus monitoring information	Real-time location, driving speed, passenger carrying capacity and load factor.
	Bus dispatching information	Timetable, information about on schedule, whether behind schedule and scheduling table.

11.6 System Assessment and Examination Indexes

The effect of implementation of the transit signal priority system is represented mainly by the improvement of the bus operation efficiency. The following indexes can serve as references for the assessment of the specific implementation effect.

(1) Number of Stoppages

The number of stoppages is a very important index for assessing the signal control effect. As a matter of fact, the number of stoppages of the vehicles travelling on a smooth and well-controlled road is small; whereas on a crowded and badly-controlled road, the number becomes bigger. The increase in the number of stoppages indirectly reflects the increase in delay. With the signal priority system, the number of stoppages at an intersection lowers in a great extent and the optimized effect is better.

(2) Per Capita Delay

The per capita delay at an intersection reflects the average waiting time of bus passengers. The purpose of public transport is the movement of people. Measuring the benefit of the signal priority system based on per capita delay has certain scientificalness. After transit signal priority is implemented, the per capita delay at an intersection should be reduced by 10%~20%.

(3) Interval Running Speed

The interval running speed is an import index to reflect the operation efficiency of buses. The interval running speed of the route buses to which transit signal priority is given can be increased by 10%~15%.

11.7 System Construction, Operation and Maintenance Cost

According to market survey in 2015, cost for public transport signal priority system is mainly related to annunciator type, numbers of signal priority intersections and other factors. It covers intelligent annunciators, development fee for docking with intelligent annunciators, electronic tags, reading devices, etc. Average fee for each intersection is about 100 thousand Yuan, which slightly fluctuates according to construction scale and infrastructure conditions.

Operation and maintenance cost of signal priority system is about 5%-10% of its construction cost.

12 Bus Lane Management System

12.1 Present Survey Situation

12.1.1 Relevant Domestic Policies

On special lane specified according to the Road Traffic Safety Law, only vehicles allowed to use the lane can drive and other vehicles must not drive; police car, fire vehicle, ambulance and engineering rescue vehicle in emergency, on the premise of ensuring safety, can be free from limitation of driving line, direction and speed and signal lamp.

In Oct. 2012, a standing conference of the State Council studied and arranged priority to development of urban public transport. The conference clarifies: to guarantee priority to bus road right, increase arrangement of lanes with priority to urban buses and expand scope of signal priority; allow airport buses, school vehicles and regular buses to use priority lanes for public transport; enhance monitoring and management of lanes with priority to public transport.

12.1.2 Situation of Domestic City

The bus lane management system is to ensure the bus lane right and improve the bus operating efficiency. However, there are only a few cities that have built the BRT system using the bus lane management system in China. In addition, the construction scale and function of the signal priority system is different.

(1)Shanghai

Shanghai is promoting the construction of bus lane network steadily year by year from 1999 when Shanghai put the first bus lane – Yanan Road bus lane into effect. It has 31 bus lanes and the total length is 161.8km by the year of 2010. The main road of the Puxi outer ring has been laid and has basically formed the bus lane backbone network. And the backbone network, which consists of the main transit corridor, such as Zhangyang Road, Longyang Road, Chengshan Road, Pudong South Road, Dongfang Road and Pujian Road in Pudong, is initially formed. The type of the bus lane in Fuzhou Road, Pudian Road and Weifang Road is unidirectional bus lane. The type of other bus lanes is roadside routine bus lane that is set up on the road which has 6 lanes or more than. There are two using types of the bus lane: full time lane and rush hour lane. And most of the bus lane is used in rush hour.

Shanghai plans to add bus lane management system on the Xizang Road on the basis of original system. The new system includes: vehicle information system, lane detection system, station information system, bus signal priority system, isomorphism vehicle to vehicle homogeneous communication system, isomerism network communication system, the central subsystem design and hardware. The sensor network function of the bus lane includes collecting and monitoring bus lane information through lane detection equipment and lane video monitor. The lane detection equipment determines whether the bus lane is used by private vehicles. The lane video monitors supervise the illegal use of the bus lane.

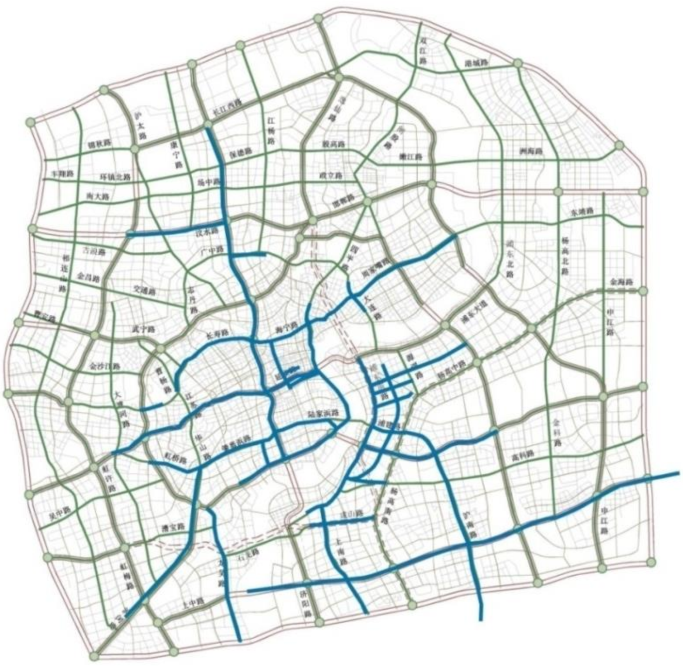


Figure 12-1 The Current Layout Figure of Shanghai Bus Lane

(2)Beijing

Since the first bus lane in 1997, mileage of bus lane in Beijing has increased by annual average of 30km. By the end of 2014, Beijing’s total bus lane mileage was 394.6km. According to Beijing’s experience in arrangement of Beijing-Tongzhou express bus lane, it can be found that bus driving speed improves remarkably, passenger flow goes higher obviously and corridor structure tend to be optimized. On the bus lane, bus driving speed improves from 25km/h to 45km/h, making bus travel time shorter clearly, and the time from Tongzhou Beiyuan to Bawangfen is shortened to 12 minutes from 36 minutes before availability of the bus lane; one year after the bus lane, bus transport capacity in rush hour improves by 35%, and passenger transport capacity of bus lines on Beijing-Tongzhou main road increases by 24.5% in a day, and by 57% and 37% in morning and evening rush hours respectively. Meanwhile, with eastward extension of the lane, congestion in crossings under Guomao Bridge and Dawang Bridge has been improved. With help of bus lane, 61 regular commercial bus lines have been development nearby, with 60% of passenger flow through transfer to regular commercial buses from cars according to relevant information.

Beijing constructed bus lane violation snapshot system. The system is constructed by the public security traffic administration bureau and has 1410 buses from the bus group mounted with front-end equipment by bus enterprises, for mobile snapshot, front-end analysis, real-time 3D transmission of the results to the bureau’s database and local storage of images.

System operation and maintenance is executed as entrusted by the bureau. The bus lane snapshot system keeps monitoring driving situations of the lane to collect information on bus driving state, operation and lane occupation against regulations, etc, effectively enhancing regulation of use of bus lane and providing supports to crossing signal control, optimized control of bus lane line and bus dispatch management.

Beijing mapped out the *Code for Arrangement of Bus Lane* and began to implement the Code from May1, 2015. The standard breaks limitation on arrangement of bus lane on expressway for the first time, firstly proposes conditions for arrangement of bus lane on low-grade roads, and clarifies that bus lane can be arranged on two-way dual-lane roads. The standard also puts forward arrangement of bypass area and guiding line special for bus to solve the problem of insufficient continuity of bus lane at crossings.

The standard involves three kinds of lanes, including those for rush hour, long time span and all time spans. Social vehicles' illegal occupation of bus lane not only influences traffic efficiency of the lane bus also means serious hidden trouble against safety. Therefore, the standard proposes addition of an electronic eye every 400-500m on bus lane and of electronic eyes in buses, and connects the electronic eyes with the testing platform to safeguard "unshakable position" of bus lane. In addition, bus-first signal control equipment should be mounted at crossings to improve bus traffic efficiency and reduce delay.

(3) Shenzhen

Shenzhen is building the vehicle violation snapshot system for bus lane. It plans to select 100 snapshot equipments and install them in the buses. The system consists of four modules: the bus lane snapshot video analysis module, snapshot communication module, snapshot management module and system interface to the traffic police department. The system can ensure the bus lane right to avoid being used by private vehicles in order to effectively develop the function of the bus lane.

(4)Hangzhou

Hangzhou formally put the BRT 1 into practice in Apr.,2006 and creatively built bus express network with free transfer for the same station and direction. It has BRT 1, 2, 4 , 3 (first-stage) and 7 (first-stage). The BRT network consists of 5 trunk lines, 12branch lines, 9 feeder lines, 17 free transfer lines and 3 lines that share the bus lane. There are 0.46 million people enjoying the convenience and benefits brought by the BRT and free transfer network every day. The length of the bus lane in the central zone of Hangzhou is 152.4km and the length of the full time bus lane is 74.97km by the end of 2012. The ratio of bus lane in Hangzhou accounts for 7.6% and bus signal priority at the intersection is 33.3%.

(5)Guangzhou

By the end of 2014, total mileage of Guangzhou's bus lanes had reached 370km, covering more than 70 main roads in Guangzhou City and forming a large-sized road ring, and many stages of bus lane informationization construction had been carried out. On the basis of the above-mentioned construction, bus driving speed in Guangzhou is lifted by 8%, bus platform order is maintained effectively, and more than 7 million people/times are benefited per day, winning unanimous good remarks from the broad citizens.

Guangzhou's bus lane system is centrally constructed by Guangzhou Road Maintenance Center. For bus lane related law enforcement, an E-police system has been established in the traffic police department of the public security system (transfer to the traffic police department for law enforcement after construction, with construction cost covering 5-year operation maintenance service), to mainly connect fixed E-police along bus lanes (for punishment of illegal occupation of bus lane) and execute road video monitoring; for operation management of bus lanes, a bus lane management system has been established with the Commission of Transport's Commanding Center, to mainly connect E-police road situation data, road video monitoring, platform video monitoring, HiFi car flow testing and vehicle video monitoring units. In addition, more than 100 sets of bus-mounted equipment have been installed to buses, mainly for monitoring but not for punishment at present, to play a warning role.

(6) Chengdu

Chengdu started construction of the vehicle violation snapshot system for bus lane from 2010. At present, the violation snapshot system has been installed in 1,115 buses. Terminal equipment system is constructed by bus enterprises according to technical requirements of the traffic administration bureau of the public security system, and then connected into the bureau's system, but under maintenance of bus enterprises. Working sections of the snapshot system are mainly those with bus lanes but do not include intersections.

According system construction experience, driving speed of buses on bus lanes is lifted by 9% after the construction, while penalty is executed by the traffic administration bureau on the basis of E-police information.

(7) Harbin

Harbin started construction of bus lane from 1999, mainly in manner of road-side bus lane and planned with one-way lane only for buses and taxis.

As for the snapshot system for bus lane, Harbin City plans to add more than 400 electronic monitoring units in August this year, especially for monitoring bus lanes, to realize snapshot through artificial identification and mobile snapshot through patrol cars. Considering road-side bus lanes as main target and needs of full violation evidence, the system focuses on snapshot of bus lanes but less on area near intersection where social vehicles turn right.

(8) Suzhou

By the end of 2012, the City had owned 5 BRT lines with total length of 141km, average line length of 28.2km and average station distance of 1561m, initially forming a BRT network to serve the Industrial Park, New District, Wuzhong and Xiangcheng. On the basis of which Suzhou will open three new BRT lines, to further perfect BRT network, improve bus travel efficiency and complement rail transport of Suzhou.

Currently Suzhou City is working to construct bus lanes, with details shown as the table below. In addition, Suzhou City is executing urban intelligent public transport system application project, and will construct BRT operation monitoring subsystem including bus lane snapshot video monitoring, and establish an interface into the traffic police department's system, so as to realize connection with traffic police department's special video network through network gate, for directly calling platform video, road video and vehicle video in the violation snapshot system for bus lane through video platform interface.

Table 12-1 Current Situations of Bus Lane Construction in Urban Area of Suzhou

No.	**Bus Lane Position**	**Area**	**Mileage (KM)**	**Nature of Construction**	**Years of Construction**
1	Tongjing Road(South Ring Road - W. Jiefang Road	Gusu District	5.2	Newly built	2013-2015
2	Xinshi Road (Changxu Road-Renmin Road)	Gusu District	1.2	Newly built	2011-2015
3	Panxu Road(Xinshi Road-South Ring Road)	Gusu District	1.3	Newly built	2013-2015
4	Fenghuang Street(Gangjiang Road - Shiquan Street)	Gusu District	1	Newly built	2013-2015
5	Guangji Road(Jinmeng Road-Ganjiang Road)	Gusu District	0.7	Newly built	2013-2015
6	Jinmen Road(West Ring Road-Changxu Road)	Gusu District	2.7	Newly built	2013-2015
7	Xingming Street (W. Suhong Road- Suxiu Road)	Industrial Park	1	Newly built	2013-2015
8	Xinghai Street (W.Suhong Road - Jinjihu Ave.)	Industrial Park	2.4	Newly built	2013-2015
9	Suzhan Road(Pingquan Road - Shanggao Road)	Gusu District	4	Newly built	2013-2015
10	Shishan Road(Changjiang Road- Shishanqiao)	Hi-tech Zone	2.5	Newly built	2013-2015
11	Sanxiang Road(Shishan Bridge-Tongjing Road)	Gusu District	1.6	Newly built	2013-2015

12	W. Jiefang Road (Lingtian Road - South Ring Interchange)	Wuzhong District	9.1	Newly built	2013-2015
13	N. Dongwu Road-S. Dongwu Road (South Ring Road-Yuehu Road)	Hi-tech Zone	5.4	Newly built	2013-2015
14	Changjiang Road(Huashan Road-Sufu Road)	Hi-tech Zone	9.1	Newly built	2013-2015
15	Jinshan Road(Zhuyuan Road-Zhongshan Road)	Wuzhong District	2.2	Newly built	2013-2015
16	Xiangcheng Ave.(North Ring Road-Taidong Road)	Xiangcheng District	12.1	Newly built	2015
17	Yuehu Road(S. Dongwu Road-Longxiang Road)	Wuzhong District	6.1	Newly built	2014
18	Zhuyuan Road(Tongjing Road-Yunhe Road)	Hi-tech Zone	2	Newly built	2013-2015
Matching construction of signal lamp special for bus and color asphalt pavement					2013-2015

(9) Hefei

The ratio of bus lane in Hefei accounts for 4.3% by the end of 2012. It has 4 BRT lines and the bus speed can achieve to higher than 18 km/h on the bus lane of the central zone in rush hour. Hefei has initially formed the network consisting of BRT, the trunk lines and the branch lines. It will build bus lane video monitoring system this year.

(10)Kunming

Kunming put the first bus lane into practice in 1999 and the length of the bus lane in the central zone of Kunming is 113.5km by the end of 2012. Furthermore, it is the first city to use BRT system in China.

12.2 Experience Summarization

(1) Many cities have recognized importance of bus lane management

Bus lane is of significance to guarantee bus operation road right. Many cities in China such as Beijing, Shanghai, Guangzhou, Shenzhen, Chengdu, Harbin, Hefei and Hangzhou, etc have constructed bus lane management system for snapshot of social vehicles entering bus lane, so as to guarantee bus driving road right, and some other cities such as Suzhou have also planned to construct bus lane management system. Bus lane, featuring less investment, quick effect and low technical requirements, is an important measure to embody bus priority. Particularly in morning and evening rush hours of working days, congestion always exists in many sections of urban main roads, but buses on bus lanes drive more smoothly. Bus lane can guarantee road right for bus driving and effectively lift attractiveness of buses.

(2) Bus lane management system offers on-board snapshot and roadside snapshot functions, with position and density of snapshot devices different from region to region

Bus lane management system generally consists of front-end equipment, communication module and backstage system. At present, front-end equipment include on-board equipment and roadside equipment. Front-end equipment mainly means bus on-board violation snapshot equipment, namely bus lane snapshot terminal mounted in front end of buses. Roadside equipment means E-police installed by traffic police department of the public security system.

Usually many cities first choose experimental sections and vehicles for a period of effect test before popularization. Number of terminal equipment used differs from region to region.

Beijing combines roadside special shot and on-board snapshot units, Guangzhou mainly uses roadside equipment for snapshot, while Chengdu, etc mainly adopts bus on-board terminal for snapshot.

(3) Bus lane management system is based on cooperation with bus enterprises, transport department and public security traffic police department

Bus lane management needs cross-department cooperation and involves bus enterprise, transportation department and public security traffic management department. In driving bus lane related works, transportation department and public security traffic management department need to establish coordinated work mechanism and enhance sharing of bus lane management information.

(4) System maintenance state has high influence on whether or not the system can give play to its role

Currently, most bus lane management systems are based on bus on-board snapshot equipment. As the equipment is mounted in bus, system maintenance is usually conducted by bus enterprises but mainly used by public security traffic police department. Relevant maintenance involves source of system maintenance funds on the one hand and timely communication between bus companies and traffic police department on the other hand. For example, in Hefei, operation and maintenance of the system is carried out by bus enterprises, as such enterprises have systematic agency management platform (mainly of operation and maintenance functions), but enjoy fiscal funds as system maintenance funds source, realizing good use effect of system. But in some other cities, relevant systems, due to poor operation and maintenance, fail to give full play to role of snapshot.

(5) Cities differ from each other in provisions for bus lane management and penalty

All cities with bus lane management system constructed have clarified provisions for bus lane use management, bus lane use time and provisions for penalty of social vehicles entering bus lane, providing policy support for bus lane snapshot.

For penalty of social vehicles occupying bus lane, cities are different from each other in criterion. For example, the penalty per violation is 100 yuan in Hefei, 200yuan in Guangzhou and 200 yuan in Beijing.

In terms of use, penalty is mainly managed by traffic police department.

12.3 Problem and Requirement Analysis

(1) More research about capture device placement choice is needed

Bus lane illegal capture means that through installing the monitoring device, capture device realize the bus lane bus lanes video surveillance, video and image post back, monitor the front road in real time. The installing placement should be hidden, open-sided, and not easy to be damaged and disturbed by human factors. For ensuring the device safety and vehicle drivers view clear, more research of placement about inside vehicle equipment is needed. Due to the road bumps, abrupt stop of the vehicle will seriously affect the quality of the image, the function of the equipment and performance requirements also need to be further defined.

(2) System operation and maintenance need to be enhanced

Bus lane management system involves bus enterprise, transportation department and public security traffic management department. Particularly in manner of bus on-board snapshot, equipment terminal is run by bus enterprises, but the system is used by public security traffic police department. For the cross-department-application system, relevant operation and maintenance make very high influence on continuous operation of the system and need to be further enhanced.

(3) Law enforcement management is difficult, legal system is imperfect

The traffic administrative departments are facing with some problems like off-site penalty evidence obtainment is difficult, avoid duplication of punishment management is difficult. So perfect system and strict law to clear rules of law enforcement is needed.

(4) Using method of penalty is not clear

Accordance with the Road Traffic Safety Law stipulating, the violation about entering bus lane will be fined 200 Yuan. However there is no explicit stipulation to explain how to handle the penalty.

12.4 Overall Architecture

12.4.1 Application Scenarios

Scenario 1: Bus on-board equipment snapshot scenario: Use bus on-board violation snapshot equipment to take snapshot of vehicles illegally occupying bus lane and transmit snapshot information such as video and image to bus enterprises, then to bus industry administration department and public security traffic police department for the latter to carry out violation examination and punishment enforcement.

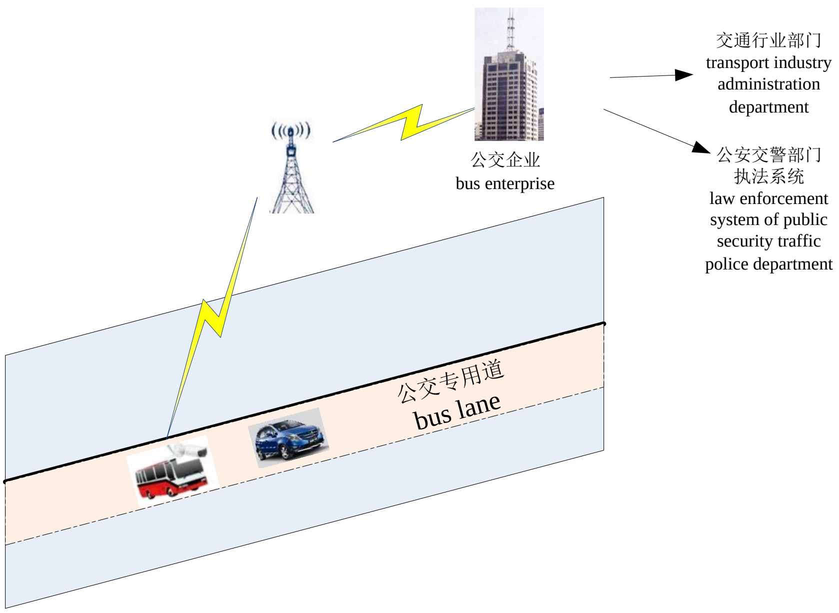


Figure 12-2 Scenario 1 of Bus Lane Violation Snapshot

Scenario 2: Roadside equipment (E-police) snapshot scenario: Use the violation snapshot equipment (E-police) fixed on the road with bus lane to identify vehicles illegally driving on bus lane, and transmit relevant information to public security traffic police department's law enforcement system for it to carry out examination and punishment enforcement.

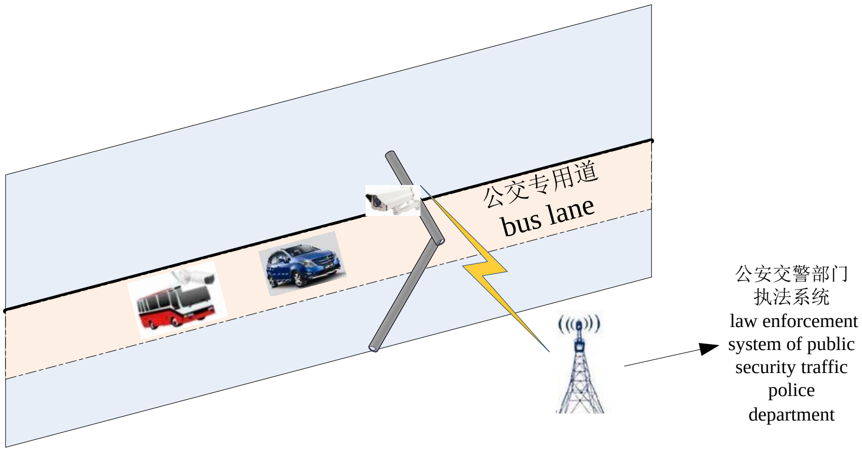


Figure 12-3 Scenario 2 of Bus Lane Violation Snapshot

Scenario 3: Combination of on-board equipment and roadside equipment for snapshot. On the one hand, install violation snapshot equipment in buses driving on the lane, on the other hand, add violation snapshot equipment (E-police) to the road with bus lane, for joint snapshot and punishment of vehicles illegally entering bus lane.

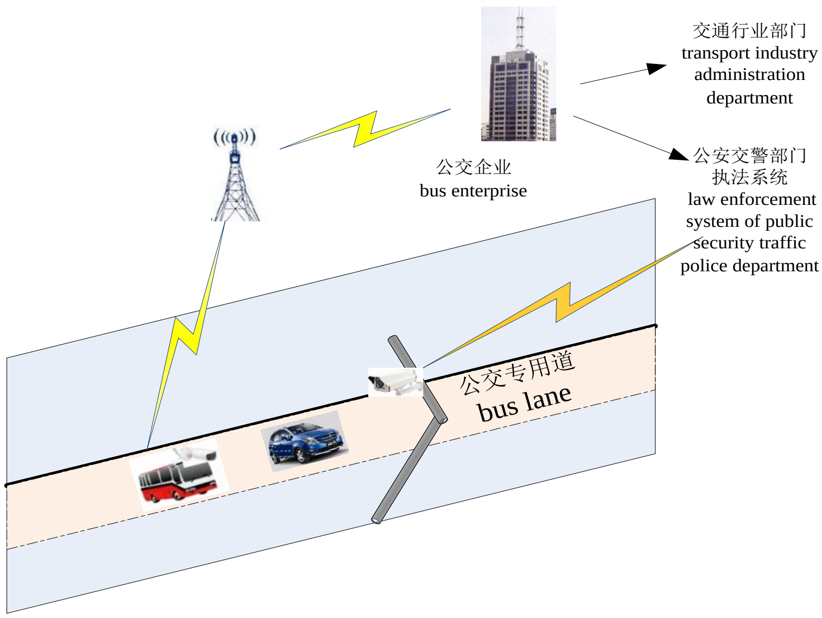


Figure 12-4 Scenario 3 of Bus Lane Violation Snapshot

12.4.2 Service Functions

By using vehicle identification technology based on video image, users of bus lane management system mainly include bus industry managerial personnel, public security traffic police enforcers and bus enterprises. Specific functions of the system are as follows:

(1) Basic information management

Bus line information management. Able to demonstrate bus lines and stops based on GIS map, to show information on bus lane and to realize editing.

Information on violation snapshot equipment. If it is bus on-board violation snapshot equipment, the function can show equipment model, manufacturer, and date of use, and information and position of the vehicle in which the equipment is mounted.

(2) Snapshot management and analysis

Video and snapshot management: traffic flow parameter testing; automatic recording bus lane violation snapshot image (including video and image); make identification; real-time video and video replay, video and pictures uploading and remote downloading.

Inquiry management: able to make statistics of result inquiry by lane, bus line and area.

(3) System operation and maintenance management

Storage resources management: Through centralized console, monitoring system should be able to monitor information on capacity, performance, resources positioning, availability and save time, etc of various storage products.

Maintenance management: to carry out real-time test and fault alarm of all violation snapshot points and on-board violation snapshot equipment constructed with bus lanes, and with function of dispatch list release and management.

(4) System management

To distribute different user authority to bus industry managerial personnel, public security traffic police enforcer and different users of bus enterprises.

12.4.3 System Architecture

(1) Technical architecture

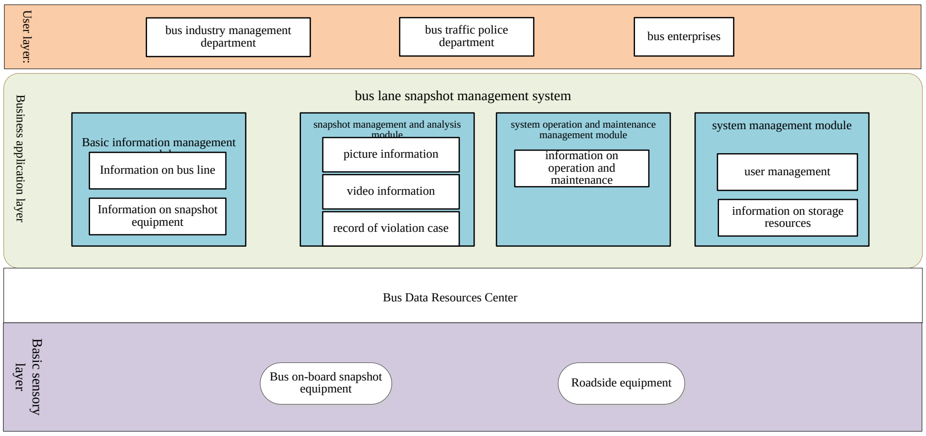


Figure 12-5 Technical Architecture for Bus Lane Management System

1) Basic sensory layer

Basic sensory layer consists of bus on-board snapshot equipment and roadside violation snapshot equipment (E-police) to acquire information on vehicles illegally entering bus lane.

2) Communication network layer

Communication network layer mainly consists of optical fiber and 3G/4G wireless network to realize communication transmission with backstage system.

3) Application support layer

Application support layer mainly consists of server equipment, network equipment, storage equipment, and basic software environment, etc, and is centrally considered with bus data resource center.

4) Data resource layer

Data resource layer is mainly used to form bus lane management database through data cleaning, extraction, conversion and summarization on the basis of data acquisition, and to centrally consider data storage together with bus data resource center, etc.

5) Business application layer

Main functions of business application layer include: basic information management module, snapshot management and analysis module, system operation and maintenance module and system management module.

6) User layer

System users mainly include bus industry managerial personnel, public security traffic police enforcers and bus enterprises.

7) System security system

System security system mainly consists of information safety and standard code security system, and is considered together with bus data resource center.

(2) Physical framework

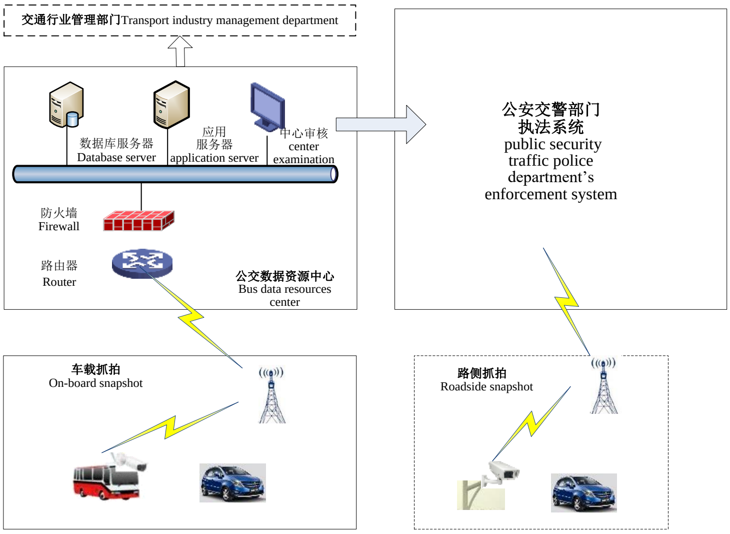


Figure 12-6 Physical Framework of Bus Lane Management System

Physical framework of bus lane management system consists of front-end external field equipment, communication network and backstage system.

Front-end external field equipment consists of bus on-board violation snapshot terminal and roadside violation snapshot equipment (E-police); communication network mainly consists of optical fiber and 3G/4G network; backstage system mainly consists of database server, application server, firewall and user terminal, etc.

Particularly, data server and firewall, etc can be considered centrally with bus data resources center. The system should give full consideration to interface for transport industry administration department and public security traffic police department to conveniently receive or call or inquire snapshot video and image.

12.5 Suggestions on System Construction

12.5.1 System Foundation Construction

(1) Advanced bus lane network

Bus lane construction situation is an important precondition for bus lane to give play to strong points. At the beginning, bus lane may consist of some scattered special lines and needs to be planned overall to build them into network-type, complete and continuous bus lane network system, so as to provide better bus lane facilities foundation for better use effect of the lanes and better guarantee of bus driving road right.

(2) Serious road traffic congestion

In construction of bus lane management system, the road with the lane usually presents road traffic congestion, particularly in morning and evening rush hours, when congestion is serious and social vehicles occupy bus lane frequently.

(3) Cross-department cooperation consensus of transportation department and public security traffic management department

Bus lane management system needs to be based on cross-department cooperation. Transportation department and public security traffic management department have reached consensus of bus lane snapshot and communicated about system construction, operation and maintenance and penalty.

12.5.2 Requirements for Snapshot Equipment

For bus on-board snapshot equipment：

- Pay attention to influence of power supply management (as buses often meet frequent, high-current and full-load startup and power-off);
- On-board host equipment should be mounted in hidden place generally to keep it free from artificial interference or damage and make it easy for disassembly, assembly and maintenance.
- On-board equipment host upgrade should be realized through remote wireless operation, so as to avoid frequent disassembly and assembly of equipment on board.
- Efforts should be made to choose equipment with function of snapshot by road section identification and time span division as far as possible.

- Make identification should be realized from front end as far as possible, so as to avoid transmission of a large number of invalid pictures to the center.

Roadside snapshot equipment needs to meet relevant standard technical specifications for E-police of the Ministry of Public Security.

12.5.3 Suggestions on Snapshot Equipment Arrangement Density

For bus lane system, major external field equipment consists of bus on-board snapshot equipment and roadside snapshot equipment. Equipment arrangement density has important influence on system use effect. In addition, combination of roadside equipment (E-police) and on-board equipment can enhance application effect.

1) Bus lane snapshot equipment.

Fixed bus lane snapshot equipment should be arranged on bus lane by certain proportion of interval. If snapshot equipment distance interval is too long, snapshot will be hard to cover all range of bus lane; if the interval is too short, repetitive snapshot will occur. Too-short interval will add backstage load on the one hand and increase input of equipment on the other hand. According to Beijing's local standard of the Code for Arrangement of Bus Lane, an interval of 400-500m between electronic snapshot devices is proposed. Such device should meet relevant standard technical specifications for E-police of the Ministry of Public Security.

2) Bus on-board snapshot equipment

In principle, it is allowed to add bus on-board snapshot equipment to all buses using bus lanes, but the addition can be achieved stage by stage. On-board snapshot terminal can be mounted first to certain proportion of buses and then to all buses. Such terminal should meet relevant standard technical specifications for E-police of the Ministry of Public Security.

12.5.4 Suggestions on System Development Stage

Bus lane management system is closely tied with urban public transport development level and traffic congestion situation. According to surveys, bus population and bus lane mileage have important influence on bus lane management system in all regions.

Table 12-2 Data of Bus Population and Bus Lane Construction Situation in Major Cities in Survey

City	Bus Population (Set)	Number of Bus Lines(Line)	Special Mileage for Bus （km）	Number of Bus Lane Snapshot Equipment (Set)	Number of Violation According to Bus Snapshot/2014	Mode of Bus Lane Snapshot
Beijing	25300	877	394.6	1410	30,000	On-board snapshot
Guangzhou	12028	918	370			Roadside

						snapshot
Chengdu	8915	269	387	1115		On-board snapshot

In construction of the system, should enhance reused the existing system, use the compatible terminal equipment in accordance with the relevant standards, stage by stage development is proposed:

Stage 1: carry out test with some buses driving on bus lane and give publicity to embody warning role of bus lane snapshot.

Stage 2: expand use of snapshot equipment according to test situation and add roadside snapshot terminal (E-police) to guarantee bus driving road right in all-round manner.

12.5.5 System Construction, Operation and Maintenance Mode

(1) For roadside violation snapshot, investment and construction are generally made by the public security traffic police department. Like the traffic police enforcement system, it will be under integrated operation and maintenance by traffic police; however, its construction can also be conducted by the transportation department according to actual conditions of the city. After construction, information will be transmitted to public security traffic police platform;

(2) For on-board violation snapshot, the following two methods can be adopted:

- Investment and construction by the traffic police department: On-board violation snapshot equipment can be installed on public transport vehicles of the public transport enterprise. The traffic police department entrust the third-party company with operation and maintenance. After snapshotting, the system will directly upload relevant information to the traffic police platform.

- Investment and construction by the transportation department or the public transport company: On-board violation snapshot equipment can be installed on public transport vehicles of the public transport company. The public transport company is responsible for integrated operation and maintenance. After snapshotting, relevant information will first uploaded to the platform of public transport company and then uploaded to the public security traffic police department where punishment is made due to violation. Also, data can be uploaded to the platform of the transportation department at the same time.

12.5.6 Law Enforcement Intensity and Use of Penalty

According to experiences of the cities in survey, law enforcement intensify of social vehicles illegally occupying bus lane, such as penalty rate, punishment of multiple occupation in a day and timely disclosure to the public after construction of bus lane all make warning influence on social vehicles.

In addition, use of penalty also makes influence on continuous operation of bus lane system. As for penalty rate, according to provisions of the Road Traffic Safety Law, vehicles entering bus lane against relevant regulations will be fined 200yuan. If part of the penalty can be used as the funds for maintenance of bus lane system, it will play active role in high-efficient operation of bus lane. According to experiences of cities in survey, penalty is arranged overall by public security traffic police departments.

12.6 System Evaluation and Appraisal Index

For cities with bus lane management system, main attentions should be paid to the following aspects in system evaluation and appraisal after construction:

(1) Scale of bus snapshot equipment

Scale of bus snapshot equipment should be considered centrally on the basis of bus lane mileage and bus line mileage. For example, Beijing has 394km bus lane, the on-board snapshot equipment scale is of 1410 sets; Chengdu has 387km bus lane, the on-board snapshot equipment scale is of 1115 sets, both better guaranteeing bus driving road right.

(2) Driving speed of buses on bus lane

Driving speed of buses on bus lane can better embody effect of system construction. For example, in Beijing urban area - Tongzhou bus corridor, bus driving speed improves obviously, and travel time by bus becomes shorter clearly; in Chengdu, after construction of the system, buses on bus lane meet driving speed higher by 9%.

(3) Number of violation according to bus snapshot and penalty

Evaluation on effect of bus lane can be reflected by number of violation according to snapshot after construction of bus lane and by penalty. For example, number of violation by snapshot in Beijing in 2014 stood at about 30,000.

12.7 System Construction, Operation and Maintenance Cost

According to survey on public transport snapshot equipment manufacturers in 2015, when the scale for bus lane snapshot equipment is large, average cost is 20 thousand Yuan/set (including system); when scale for equipment is small, average cost for each set (including system) is slightly increased.

Operation and maintenance cost of bus lane management system is about 5%-10% of its construction cost.

13 Further work and suggestions

13.1 Future research work

The future of intelligent public transportation system is not only to more application of new technologies, but also to try to promote the construction of a new model of operation and maintenance.

With the popularization and application of new technology of Internet of things, cloud computing and big data, we should also consider more about the new technology application in planning and design of the intelligent public traffic system. This will also be a key work of the future study of the guidelines.

Intelligent transportation system construction needs close cooperation with the government and the private sector, at present China has many applications in the bus mobile applications, including "Che-lai-le", " DiDi Taxi ", " Uber "," Baidu Map " and etc. They have huge user group and mass travel data, the government needs to share part of the government industry data, cooperation with the private sector, both work together to solve some problems faced by urban public transport.

In addition, on the operation of the intelligent bus system, Wuhan and Shenzhen have been the first attempt. Wuhan cooperated with Alibaba, Shenzhen relying on Tencent, both take the first step to take the service outsourcing, a new way of government procurement of services. It is worth to continue to study in our subsequent work. Although these patterns of cooperation is in the stage of exploration, and the subsequent impact of these patterns has yet to be assessed, but the future of intelligent public traffic system construction mode undoubtedly will gradually shift to the development pattern of the cooperation between the government and the private sector a public-private partnership (PPP), this model is we will focus on research direction.

13.2 Application and promotion of the guidelines

According to China's administrative management system and transportation management system, we will positively suggest the related departments of Ministry of Transport to issue the guidelines to the provincial Department of Transportation for guidance related to the implementation of the project. If possible, we will further promote the related to the city level demonstration projects, so that the guide subsequent implementation of criterion and demonstration project to obtain the popularization and application in the central, provincial and city level.

- Guidelines for the promotion.

This guide will be unified release by the Ministry of transport, and the provincial department of transportation formulate the detailed rules for the implementation, and in accordance with the provinces of intelligent transportation construction based screening out suitable city as a demonstration project for the popularization and application of this guide.

◆ The demonstration project

This guide applies not only in big cities, are equally applicable to small and medium-sized cities. Based on this guide we can select those cities which are not included in "the urban public transport intelligent demonstration project "as demonstration project, avoiding repetition of different demonstration project construction.
In addition, we also hope that this guide can be recognized by the world bank and the global environmental fund, and thus be able to promote the use of this guide to the worldwide in the similar population and city scale areas. If it is possible, we hope the global environmental fund can choose China's intelligent bus project as a typical case in the implementation of relevant international projects as a reference.

◆ The relevant standards

There are 11 intelligent public transportation demonstration project standards at present which were issued as engineering standards on 11 December 2015. The next step work will promote three criteria to rise to national standards, the other eight will be rised as the industry standard. "Urban public trolley bus on-board intelligence service terminal " has been completed and the draft program, forming the manuscript, preparing to convene a manuscript review, will serve as a revised edition of the standard of GB/T 26766. "Communication protocol between urban public trolley bus on-board intelligence service terminal and the dispatching center " will be the revised edition of GB/T 28787, the amend plan will be reported this year; "Norms for data bus interface communication of urban public trolley bus intelligent service terminal "has formed a draft for approval.