eISBN: 978-1-60805-138-0

# The Theory and Method of Design and Optimization For Railway Intelligent Transportation Systems (RITS)


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# THE THEORY AND METHOD OF DESIGN AND OPTIMIZATION FOR RAILWAY INTELLIGENT TRANSPORTATION SYSTEMS (RITS)

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# FOREWORD

With the rapid development of research on Intelligent Transportation Systems (ITS) in worldwide scope, the relevant research on ITS technology applying to railway transportation began in about 2000; subsequently the Railway Intelligent Transportation System (RITS) construction became the focus of railway transportation improvement. Much remarkable progress, such as the ERTMS system in Europe and the CyberRail system in Japan etc., has been obtained in recent 5 years. The research on RITS in China is on going. RITS related framework, standard system and the development strategy have been initially formed up to now.

The book of "The Theory and Method of Design and Optimization for Railway Intelligent Transportation Systems (RITS)" is devoted to scholarly research on China's RITS development courses, system framework, optimization design, key technologies and current situation etc. RITS utilizes synergistic technologies and system concepts to achieve high efficiency, high safety and high-quality service for railway transportation. It encompasses the full scope of information technologies used in railway transportation, including control, computation intelligent and communication, as well as the algorithms. RITS optimization design mainly resolves the problems of function optimization organization, sub-system partition and function optimization setting of the sub-system. These optimization design theories and methods are applied in practical system, such as Chinese Qinghai-Tabit railway comprehensive monitoring system etc.

Authors of the book have many years' research and practical experience in RITS fields, and complete Chinese RITS framework and development strategy establishment. They have exerted their utmost effort in the book and have elaborated their work. I believe this academic monograph of RITS is indeed beneficial to readers of graduates and researchers in related fields of university or institute, as well as related people in railway transportation fields in their research and work.

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# PREFACE

Railway is a form of public transport which serves the society, and its aim is to transport passengers and freight safely, rapidly, reliably, accurately and economically. With an implementation of railway great-leap-forward development, the realization of new-generation rail transport system- Railway Intelligent Transportation System (RITS), whose purpose is to ensure security, improve transport efficiency, elevate service quality and achieve the international standards, has become the inevitable development trend.

Aiming to provide high security, high efficiency, and high quality service to the rail transport, for the first time the authors put forward the concept of " RITS ", and systematically discussed its connotation and substantive characteristics, structural model, development framework and core technology, developmental pattern etc; they deeply analyze the service framework, logical framework and physical framework of typical subsystem of RITS --- Intelligent Emergency Rescue and Safety System, and execute optimization design. The purpose of optimization design for RITS is to coordinate system target-oriented designs and realizations among various subsystems, making the entire work better, to achieve a system with best overall performance, the construction of RITS system in China.

Combining years' research and practical experience in RITS, we proposed the "The Theory and Method of Design and Optimization for Railway Intelligent Transportation Systems (RITS) ", presenting it in the form of a book to meet the urgent needs of theory and methods of intelligent transport systems for railway transport. We hope that this book can play the role of throwing a brick to allure a gem, and accelerate further expansion research and application of RITS. The authors of the book engaged in research work of RITS and related fields for many years, successively undertaking and completing the key project of National Natural Science Foundation of "Research on Integrated Information System and Key technologies of High-speed Railway Intelligent Transportation", Ministry of Science and Technology research project "Railway Geographic Information System", "Research on Railway Intelligent Transportation System Standard System", "National Railway GIS Application Service Platform" and "Research on Development Strategy of Railway Intelligent Transportation System", Ministry of Railways research project" Railway Geographic Information System Design and Development", "Research and Development on Qinghai-Tibet Railway Emergency Rescue System and Emergency Rescue Command & Management Information System", "Research on the Railway Emergency Preplan Management" and "Research on Railway Intelligent Transportation System (RITS) Framework", China Postdoctoral Science Foundation-funded project" Research on RITS Framework Design and Optimization Method", faulitating the development of application systems, granting achievements in these projects .

We sincerely express our gratitude to the National Natural Science Foundation of China, The Ministry of Science and Technology of China, and The Ministry of Railway of China for their financial support. We would also like to thank Dr. Li ping, Dr. Meng yan, Dr. Qinyong, Master Jia Tianli and Master Shao Yikun etc, for their valuable advice, selfless support and assistance for completion of the book.

In the process of writing the book, we reviewed a large number of references, to seek clear concepts, using familiar examples to illustrate various theories and methods, which may enable various types of readers to have a clear understanding and knowledge of the optimized design of RITS. With the limitation of the authors' knowledge level and the depth as well as the breadth of research, there must be some irregularities of views, methods and theories in the book, which the readers may duly criticize. This book combines theories and applications closely, and is convenient for readers' self-study. The book is also adequate for colleagues engaged in work and research in the rail transportation field, as well as colleges and universities, graduate students and scientific researchers in interrelated fields.

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**CHAPTER 1**

# Outline of Railway Intelligent Transportation System (RITS)

**Abstract:** Railway Intelligent Transportation System (RITS) has been initially proposed in this chapter. Being a railway transportation system of this era, its basic purpose lies in strengthening safety of transportation, raising transportation efficiency and improving service quality. Compared with Intelligent Transportation System, RITS has the same research purpose, emphasis and similar advanced technology has been adopted. The substantive characteristics of RITS is a complex, distributed and open system, belonging to the category of Open Complex Giant System (OCGS), the meta-synthesis method being qualitative and quantitative is integrated for the research of OCGS. Finally, the development of RITS in China and the current research in Japan, USA, and Europe *etc.* are introduced in this chapter.

## OUTLINE OF ITS AND RITS

### Conception of ITS and Present Situation

Being a brand-new technological means and management system, ITS research has already become a hotspot and front topic in the worldwide transportation field. Initiation of ITS concept is not only a process of technical progress, but also a continuous process of recognition while facing multiple problems caused by traffic [1]. Now many different conceptions of ITS have been defined, mainly three kinds being General concept of ITS including programming, design, implementation and operational guidance intellectualization of traffic system; while the narrow one mainly refers to the intellectualization of management and organization in the traffic system. ITS is actually the reconstruction of traditional traffic system, exploiting the High-tech, in order to formulate a late-model modernized traffic system which is information-based, intellectualized and socialized [2, 3].

According to the information and communication technology, ITS unites people, vehicles and roads closely and harmoniously. It establishes a large-scale and all-directional transportation management system which acts real-timely, precisely and efficiently.

ITS is a combination of technology of advanced computer processing, information, data transmission, auto-controlling, artificial intelligence and electronic technology comprehensively and efficiently in traffic transportation management system. [4].

Although the understanding of domestic and international ITS is not quite similar, there are common grounds, ITS is a transportation system of the new era which exploits information technology to improve efficiency of transportation, guarantee safety of transportation, increase the energy utilization and eventually enhance the service quality. Currently, three research bases have been formulated, including America, Europe and Japan, which contribute great manpower and materials and pay high attention to intelligent transportation systems [5].

America is one of the first countries executing ITS research. In 1970s, America developed an electronic road guidance system and began the research on important issues of ITS in 1986. American Intelligent Vehicle Highway System, which was established on August 8th, 1990, was renamed as ITS America in September, 1994, and developed into Department of American Federation transportation's government elements of consultation. In 1991, U.S. Congress passed "Program of Comprehensive Ground Transportation Efficiency", which conducted a research on ITS great-scale national comprehensive developmental item, and decided that the Department of America transportation would be responsible for the development of ITS. In March 1995, America transportation department issued "National Program Plan for ITS" officially and stipulated 7 subsystems and 29 service functions of ITS, which defined yearly development plans until 2005. The subsystems included: travel and traffic control system, travel demand management system, public traffic operation system, commercial vehicle operation system, electronic charging system, emergency management system, registration of vehicle and security system.

Japan is one of the countries whose population density and degree of road crowdedness are very high, therefore the demand for research and application of ITS require immediate action. In 1994, Japan established a nationwide

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VERTIS (Vehicle Road Traffic Intelligent Society) in which four provinces and one city participated [6]. Its ground work is to promote and coordinate the exploitation, institution and formulation of rules in ITS, sponsor ITS by world and Asia-Pacific conference, and finally draw up a 20-year development plan with a budget of 7.8 trillion JRY. Japan successfully developed ERGS in 1970s [7], however, the technology of computer application still lagged behind and limited the large-scale generalization and application. Since then, with the development of IT, advanced guidance system equipped with digital map and infrared two-way communication was developed in succession of Vehicle Information and Communication System (VICS) [41]

VICS is a technology used in Japan for delivering traffic and travel information to road vehicle drivers. It can be compared with the European TMC technology. It can be transmitted using: infrared, microwaves in the ISM band, FM, similar as RDS or DARC.

It is an application of ITS.

The VICS information can be displayed on the car navigation unit at 3 levels:

**Level-1:** Simple text data

**Level-2:** In form of simple diagrams

**Level-3:** Data superimposed on the map displayed on navigation unit (e.g., traffic congestion data)

Information transmitted includes traffic congestion data, data on the availability of service areas (SA) and parking areas (PA), information on road works and road accidents. Some advanced navigation units might utilize this data for route calculation (e.g., choosing a route to avoid congestion) or the driver might use his own discretion while using this information.

As Europe is based on many countries, geography and development levels are different from each other, they promote ITS in terms of Road Informatization, be dividing into it 3 stages: Stage 1 of DRIVEI in 1988 and DRIVEII (Dedicated Infrastructure for Vehicle Safety in Europe，DRIVE) in 1991; Stage 2 of wireless data communication network (Telematics) plan; Stage 3 of PROMETHEUS (Program for Europe Traffic with High-est Efficiency and Unprecedented Safety, PROMETHEUS) eSafety, the first pillar of the Intelligent Car Initiative, is a joint initiative of the European Commission, industry and other stakeholders. It aims to accelerate the development, deployment and use of Intelligent Vehicle Safety Systems that use information & communication technologies to increase road safety and reduce the number of accidents on Europe's roads [42].

Research on ITS in Asia began late but the development was rapid, for example, Korean and Singaporean governments invested large amounts of money into ITS. Korea made GuangZhou city as an experimental city of ITS and invested 12500 thousand dollars for the first time. Singapore has established advanced Urban Transport Management System which mainly includes detection of traffic flow, dynamic information guidance, *etc.*

With the development of Chinese economics, traffic congestion problems have become prominent on a daily biases, especially in metropolises; traffic congestion driving rush hours caused great inconvenience to passengers. Traditional experience could no longer meet the demands of efficient transportation system which is essential for China’s modernization. In the early 1990s, Chinese scholars began to turn their attention to the development of ITS and participated in partial work of ITS World council's Direction committee and International Standardization Organization. Although ITS started late in China, it developed fast, especially after 1995, since the research and international communication on ITS became rapid. Ministry of communication put ITS on the list of “The ninth five years plan” technology foresight program and long-term planning of 2010[8]. At the same time, Ministry of Communications Science Institute established ITS Engineering Research Centre, with many universities simultaneously establishing ITS Research Centre, to execute Chinese ITS research.

Currently, ITS research centers mainly on the road traffic, covering partial contents of transportation modes including water carriage, aviation, but seldom on Railway Intelligent Transportation System (RITS). Railway, as most important continental transport mode, aliens from others in transportation forms, management system, constitution of foundational equipments and so on, especially its features of transportation based on rail, which keeps railway transportation fast, mass in transport, high in organization and controllability. As speed continued to become faster and network scale expanded continuously, railway developed in the direction of high-speed and high density in passenger transport, heavy-load and long-distance in freight traffic, with simultaneously high demands in ITS transportation.

## Conception and Connotation of RITS

The main purpose of railway transportation which is supported by information flow is to realize safety, efficient, convenient transportation of passengers and freight, on condition that mobile and fixed infrastructures are defined. Whether or not modern railway transportation, which is broad in scale, wide in area, comprehensive in business and social needs, could implement the optimum utilization of resources, as well as safety, efficiency and convenience in transportation process, depends on unimpeded and sharing degree of information flow. Consequently, modern railway transportation system is in fact a freight and passenger flow transportation system which is based on the foundation of information flow.

Currently, society brought forward a claim “higher, faster and farther” to railway transportation, which brought unprecedented chances for railway transportation. Plentiful achievements in related area of modern science and technology including IT, communication technology, sensing technology, intelligent control and decision-making technique were integrated organically, which provided the possibility for establishing railway transportation system of the new era. This railway transportation system which possessed epitomizing characteristics was the Railway Intelligent Transportation Systems (RITS) which will bring revolutionary changes to the entire railway transportation.

RITS, vehicle and foundational infrastructure constitutes three technical equipment systems of railway transportation. The most basic condition on improving transportation efficiency is to raise the technical equipments levels. Consequently, strength and perfection of RITS need to be focused upon for technological innovation and rapidly implement action of new vehicles to improve technical merit of infrastructure including lines, power supply and communication signals, to realize high efficiency, safety and high-quality service for new railway transportation patterns.

In recent years, nations interested in railway transportation such as Japan, Europe and so on, all actively invested in the research on ITS. They also made many significant achievements in many respects such as traffic safety and control, passenger service, railway location, automatic control of train operation and so on. At the present time, there is no unified definition on RITS internationally, and we provide a definition as follows:

RITS is a railway transportation system of new era which integrated electronic technology, computer technology, modern communication technology, present information processing technology, system and control technology, management and policy-making support technology, intelligent automation technology, *etc.*, on the basis of implementing information collecting, transmission, processing and sharing, according to efficient utilization of all mobile, fixed, space, period and human resources on railway transportation, to ensure safety, raise transportation efficiency, improve management and administration and improve service quality with low costs [9]. To be brief, RITS is to attain intelligence of total railway transportation system according to realization of intelligence of information collecting, transmission, processing, management and policy-making, transportation services and relevant infrastructure. Its basic purpose lies in strengthening safety of transportation, raising transportation efficiency and improving service quality.

With the conditions of Chinese railway transportation and information, an actual connotation of Chinese RITS is: taking advantage of today’s high technologies such as present-day advanced intellectual technology, information processing technology, data communication technology, automatic control technology, management science, on the foundation of information, according to integration, to realize information sharing, strengthen establishment of railway control system and security system. With the assurance of vehicle safety, it further raises transportation efficiency, strengthens establishment of electronic commerce and customer information service system, improves service quality, efficiency and adaptation to market substantially, strengthens intelligent compound decision-support construction based on management and controlling, and improves ageing and science of strategic decision. After establishment, the system will cover transportation management of freight and passenger, consumer service, railway control and dispatching, safety assurance, management and maintenance of infrastructure and so on. It will formulate an integrated new-generation railway transportation system which synthesizes intelligent control, management, policy-making, in order to ensure safety, improve transportation efficiency, improve operation and management, raise service quality and realize purpose of integration to the world.

## Substantive Characteristics of RITS

Geographic coverage of railway in China has a big span (sentence structure is weak). Maintenance of transportation system, transit organization pattern and market demand are considerably comprehensive. Flow capacity of passengers' carriage is large and hard to master besides some complex procedues: from semi-militarized management system and management mode of compartmentalization, to unbalanced railway development and so on., During the process of Chinese railway transformation, some concrete applicable information systems were formulated, such as Transportation Management Information System (TMIS), Dispatching Management Information System (DMIS) and railroad computer booking system. These systems are distinct from each other in structures, technical construction, management mode, business philosophy and openness, contributing to further complexity of the railway transportation system. While catering to these diverse and complicated procedures, railway intelligent transportation systems find it hard to adopt a simple standard structure procedures. This required the establishment of an open system structure which may integrate subsystems with all kinds of structures, standards and criteria. In terms of system development, structures and functions of RITS must be dynamic, be reconfigurable and have enough dynamic behavioral trait to address all kinds of complex activities. These characteristics will cause each subsystem, which possesses capability of autonomy and independence, spare information to obtain understanding and formulate competitive and synergic mechanism for an ideal system. Therefore, essence of RITS

is a substantive system mainly including three aspects which are as follows [10]:

### *RITS is a Complex System*

Complexity, which is the most important characteristic of RITS, includes complexity of structure, target, environment, behavior object, technical mechanism embodied in the process of system development. Facing huge complexity of Chinese railway, main way for solving this problem is in technical aspect. According to an application of high-tech including electron technology, computer technology and communication technology and so on, we underwent reorganization in digitalization and information with railway transportation technology, achieved resource sharing, improved railway transportation efficiency, ensured railway transportation safety. Simultaneously in terms of system science, we conducted a research Chinese railway transportation system in every scientific stratification plane, processed relationships between technology and system complexity well, eventually resolving all complexity problem effectually, achieving complicated target of railway transportation and generating continuous motive force of development.

### *RITS is an Open System*

RITS possesses characteristics of open system structures. On one hand, RITS possesses favorable information input and output. On the other hand, information self-organized behavior of RITS is an essential behavior of its open structure, according to which RITS could be compatible with different database technology and data communication technology, integrations digital information systems with different application purposes. All these mentioned above will offer genuine flexibility and expansibility, achieve system information sharing and exchange with other transportation modes.

### *RITS is a Distributed Systzem*

Physically, Chinese railway system is distributed among regions and business subsystems are dispersed and independent from each other. Therefore, every subsystem of RITS needs to formulate collective decision-making ability by "negotiation/ compromise" mechanism, solve complex questions faced by RITS together, in order to receive explanation of overall optimization. Because of the complexity of RITS, every subsystem may not offer plenary intelligence initially. The learning capacity and adaptive ability should be possessed, and capacity for team work should be improved during the process of dealing complex processes. By the way, distributed system structures have higher application level than open system.

According to substantive characteristics of RITS, it is obvious that research should not only be in respect of hard technology, but we should also exploit systemic view to study complex questions in terms of system science, and define substantive characteristics of RITS from deeper level and greater macrograph angle.

**Relationship Between RITS and ITS**

RITS is the product of combination of ITS and rail transportation. First, foundation, purpose, emphasis on RITS and ITSA being adopted and key technology has many similarities. They are mainly embodied as:

1. Starting point and research purpose for RITS and ITS are the same. First in respect of service, from road transit to railroad transportation, service provided at present cannot meet the demands of customers, such as rapid development of network technology. launching user information guidance service, implementing electronic commerce and developing multimodal transport are all necessary for both systems. Secondly, in respect of efficiency, massive congestions exist in the road transit; while in railway transportation, despite many railway facilities, damages caused by natural disasters every year also lead to traffic congestions, delay of trains and so on. What’s more, in the perspective of safety, traffic accidents of road transit happen frequently, and there are also congestions and delays in railway transportation which are caused due to breakdown of infrastructure, incorrect manipulation of drivers, faults of dispatch at all levels of operations. The problems jointly faced by both systems decide that the research purposes of the two are the same, which ensure high efficiency, security and high-quality service of transportation system.
2. Emphases in researches of both RITS & ITS are the same. First in respect of service, both the systems provide elaborate travel guidance and interrelated information, how to adopt advanced network technology to develop electronic commerce and how to provide aid in decision making for multimodal transport. Secondly, in respect of efficiency, they both have solutions for how to adopt intellectual technology, communications technology and so on to realize vehicle’s automatic drive, message communication between vehicles, intelligent dispatch control of vehicles, and information sharing at all levels. Ultimately in respect of safety, two questions exist about how to detect conditions of infrastructure, make intellectualized maintenance decision and formulate comprehensive disaster prevention decision-making with intelligent testing technology.
3. The adopted advanced technology for both is similar. With the development of computer and interrelated technology, construction information of road transit has received many achievements: systems including dispatch control and management information system, public transportation management information system, GPS system, Wire plan auxiliary support program were established successively; ITS is based on various foundations. Information on construction of railway has laid the massy foundation for development of RITS: for example, the establishment of entire road communication network, TIMS, DMIS and so on. Both the systems need to exploit advanced sensing technology to detect information of infrastructure, adopt advanced communication technology to solve information communication problem among moving objects or between moving objects and fixed objects, implement advanced location finding technique to realize location of railway, arrune advanced message processing technology, intelligent decision-making technique to realize interrelated strategic decision and control.

Second, the two different transportation modes have differences in technical details which are as follows:

Firstly in respect of information service, ITS mainly provides services such as route guidance, travel information *etc.* for drivers. While in RITS, emphasis is given on providing services as journey decision-making, ticket information, travel information and so on for drivers, and providing consignment decision-making support, cargo tracking *etc.* on for consignors.

Secondly, in respect of automatic fare collections, main objections faced by ITS are ETC, when vehicle passes toll stations and Auto Fare Collection of public transport, while RITS needs to deal with problems like voluntary payment from passengers for long-distance tickets booking via modes like internet or telephone *etc.*, automatic fare collection of long-distance consignation from consignors, as well as long-distance payment for interrelated services in railway.

In respect of vehicle control and dispatch, trains in RITS have typical life cycle characteristics: manufacture---operation---evanishment. Before operation, trains need marshalling in marshalling station; during operation, trains have to run on the rail, and cannot randomly change travel routes and directions, as well as observe requests of contemplated schedule, dispatching center, restrictions of close-by vehicles and fixed installation. Once late, trains must adjust the plan according to the train adjustment programs from the dispatching center. At the same time, trains may not stop optionally. After operation, trains need to return to the marshalling station for disassembly. Yet, life cycle characteristics in ITS are not clear: trains may change travel routes at any time and park in proper place; vehicles, except buses, could run at any time; instructions from dispatching center may be non-instructional.

In respect of operation management, RITS needs to establish and adjust may the timetable of the trains regularly according to the demands of the passengers, organize route planning according to consigners' requests and resources situation of railway freight transportation, simultaneously carry on intelligent optimization management to operating procedures including arrival, separation, and marshalling, sending. Regarding marshalling of transportation plans and marshalling station, the main assignment is to formulate traffic control policy according to traffic conditions collected by control center and convey it to the drivers.

## Research and Design Methods of RITS

RITS, representing the high-level development phase of railway information, possesses numerous subsystems, complex structure, wide-scope with its structures being open and intelligent in distribution. All these features above prove that RITS as an Open Complex Giant System (OCGS).

Theoretical research about OCGS at present mainly adopts the means of system science. Practice has proved that meta-synthesis integrated is the efficient way for the research of OCGS. Its substance is to integrate qualitative understanding obtained by expert community according to the experience and quota knowledge reflected by multiple messages, establish models by an integration of computer technology, and ultimately formulate a highly intellectualized man-machine union system; in order to exert global advantage and meta-synthesis superiority of this system, eventually ascend as quota understanding.

Design of RITS system is the important stage of developing process, which determines the costs of system establishment, usability, suitability and reliability for functioning directly. During the process of RITS system design, environmental technology involved is complex, construction cycle is long and expense are tremendous, it is hard to ensure reliability, suitability, expandability and system overall optimality only according to the experience. Consequently, RITS has many subsystems, complex structures and big-scope space. The system design of RITS is divided into three levels:

1) System design of macro-level, which means qualitative design of RITS, which is also called framework design of RITS. It mainly includes service framework design, logical and physical framework design.

   Service framework design of RITS begins in analyzing user demands, adopts the method that integrates both bottom-up and top-down. For the demand analysis to be complete, it combines similar demands must be combined so should be and mines potential demands, be definite service field division formulated and service function definition of Chinese RITS.

   Logical framework design of RITS describes internal structures of RITS in terms of logic, which refers to all kinds of user services defined by the service framework, organizes input and output data flows as well as deals with the process structurally inside the system [11].

   Physical framework design of RITS distributes definition process of logical framework into RITS physical entities, and defines framework streams among entities according to data flows contained in every process of entities, there by ensuring the interconnection method between physical entities.

2) System design of median level, which means quantitative design of RITS, is also called overall structure design of RITS. It mainly includes logical structure design, physical structure design and majoring mapping from logical structure to physical structure.

   Logical structure design of RITS emphasizes the rationalization to information demands and functions, lays emphasis upon relationship between data flows and functions: consequently, organization and optimization of functions are the primary coverage of logical structure design.

   Physical structure design of RITS divides physical subsystems rationally from different angles, different standards and different levels.

   The main task of mapping from logical structure to physical structure in RITS is to consider the most superior type of distribution among physical subsystems, according to functional units designed by logical structure, as well as equipment providing plan of physical subsystems under entire distribution.

3) System design of micro-level, which means detailed design of every subsystem in RITS, mainly includes code design, database design, interface design and treating processes design.

   RITS involves scientific theory of many subjects including electronic, communications, computer, management and decision making, intelligent control and so on, and adopts meta-synthesis cencentulizing that quality and quantity are integrated to deal with the system design problem of RITS. In the first phase, we must integrate experience and knowledge of specialists with railroad background of all subjects, execute system design of macro-level, propose qualitative understanding of macro-system design of RITS, and establish system framework model; in the second phase, we must implement the system design of median level, which will determine target system together with system framework model and other multiple messages, make quantity calculations with all design and optimization methods, and then obtain the best structure design. System design of RITS takes qualitative design----framework design of RITS as premise; it emphasizes on the quantitative design----structure design of RITS. As regards the system design of micro-level, as the design purposes and requests of every subsystem in RITS are different, so are the detailed design contents. It will therefore not be introduced as a universal system design.

## DEVELOPMENT OF RITS IN CHINA

### Essentiality of RITS Research in China

Synthetically contrasting the present domestic and foreign procedures of RITS development, compared with the developed countries, there is still a marked difference between the Chinese railway information and intellectualized construction level in the developed countries. They are mainly embodied as follows:

In respect of services:

- It provides traveler's detailed information service, personalized travel guidance, transmission and demonstration of related information in stations and trains, *etc.* It provides consignors real-time information and inquiry service related to freight transportation resources, in order to meet consignors' demands for entire journey surveillance of freight transportation process.
- It provides information platform for sharing and communication with other transportation modes, in order to meet the demands for multi-modal transport.
- It strengthens the e-business marketing methods of railway passenger transport as well as freight traffic and establishes nationwide logistics distribution system, in order to welcome challenges from transport companies both here and abroad.

In respect of safety:

- It provides mobile units which ensure operation safety, maintenance efficiency, real-time monitoring, evaluation and maintenance support system under fixtures conditions, as well as security evaluation decision system under the foundation of sharing safety data.
- It provides junction monitoring and station monitoring system, which include image recognition technology, to ensure safety of trains operation and prevent conflicts between railway and other related systems.

- It provides perfect railway disaster prevention, salvage, decision and direction information system which is the basis of real-time condition examination system, information supported by picture transmission system including language, data, static/dynamic state pictures transmission system, takes LBS/GIS as localization method and shows quick responses in respect of efficiency:
- It provides integrated railway operation and management system, intellectualized train operation control system, to achieve high-speed and high-density rail transportation.
- It adopts on-vehicle network technology to realize rolling stock control integration.
- It provides high-degree information sharing among railway transportation subsystems and effective use of means. Simultaneously executes central management to all the related information to improve entire efficiency and ensure coordinated operation among service systems.
- It provides reliable high-bandwidth vehicle high-speed data OSA API, to satisfy data procurement and sharing between railway mobile unites and fixtures.
- It provides marshalling station synthesized information management and automatic system which could realize trains efficient safety disintegration and marshalling.
- It provides marketing decision-making support system, to improve capability of adapting to market requirement, as well as increasing efficiency and benefit of railway operation.

Meanwhile, with the rapid development of Chinese market economy, society proposes difficult requests of “faster, higher”, besides, accession to WTO which requests all-around opening cargo market which brings many competition pressures. In order to cut down distance with developed countries as quickly as possible and raise international competitiveness of rail transport, simultaneously preferably satisfying the demands of national economic development, we must speed up the institution on RITS.

Therefore, it only the information of construction, may not radically solve questions on efficiency, security and service the best solution for above is to develop RITS. At the same time, we should know that research on RITS system framework around the world lies in initial phase, if we could grab this hard-won development opportunity, there will be a very important strategic sense for increasing Chinese railway competitive strength and speeding modernization of rail transport.

### Present Status of Chinese Railway Informationization

ITS is an integration of “intelligent system” and “transportation system”, with “intelligent system” being the most important characteristic of ITS, distinguishing it from conventional transportation system. Intelligence is the essential psychological condition and characteristic when people acquire knowledge and utilize it to solve practical considerations, which include the study or comprehension capabilities from experience, capabilities of acquiring and maintaining knowledge, capabilities of responding to new surroundings quickly and successfully, and of utilizing reasoning to solve problems effectually. Significance of intelligence is that it possesses hot only perceptibility, memory and thinking ability, but also learning ability and adaptive capability in addition to behavior decision ability. For system possessing the capabilities mentioned an above is called intelligent system, which owns collection, storage, transmission, processing and conveying of information, decision-making and decision-executing capabilities based on information, and the level of these capabilities determines the level of intelligence of an intelligent system.

ITS, which makes the entire traffic system imitate human intelligence, possesses all the capabilities above and could think, perceive, study, ratiocinate, judge and solve problems automatically. It could perceive changes of surrounding environment and own conditions, and initiatively adopt relevant countermeasures in connection with these changes. The final purpose of ITS is to make transportation system more efficient and more safe, according to the imitation of human intelligence.

In accordance with personal different degrees and grades of intelligence, development of RITS is divided into three periods which are as follows:

1. Junior RITS (railway informatizaiton period): in this period, we mainly apply computer technology, information processing technology, geographical information technology, data communication technology *etc.* to collect, transport, share kinds of information from railway transportation environment, and execute junior policymaking and control according to above messages.
2. Superior RITS (transition stage from railway informatization to railway intelligence): during this period, we mainly apply system identification, and mode identification technology to establish mathematical model for definite surroundings, so as to program and speculate for future.
3. Advanced RITS (railway intellectualized stage): in this period, as we mainly apply mathematical models for model building, we also cite knowledge model for model building of non-definite object, thereby imitate human comprehension ability and completing decision-making under complex environment.

Railway information is the primary stage of railway intellectualization and the only way for future existence and development of railway intellectualization. However, it may not radically achieve requests of “high safety, high efficiency and high-quality service” required by society development only by information construction. Therefore, railway information has to further develop and pursue its higher stage----railway intellectualization.

Chinese railway at present lies in the junior and superior development stages of RITS. Tasks of junior stage have been accomplished partly, such as the digitalization of railway infrastructure, entire informatization of mobile device, rolling stock monitoring integration, locomotive one-number integration etc; simultaneously, many advanced operation systems have been successfully developed, such as: TMIS, DMIS, ATIS, and RGIS, *etc.* Related institution has been done for part work of superior stage, as train schedules organized by operational research model, automatic-shunting system in marshalling stations, intelligent control of railway speed etc, while many problems needs further solutions. Tasks in advanced stage as integrated dispatching system, intellectualized operation management system, trains robot guiding system *etc.* are in process of design and preparation.

### *Transportation Management Information System (TMIS)*

TMIS, which is called the most complex and the most enormous engineering model of Chinese railway transport, was established in 1994 and implemented in 1995, having made many achievements. This system not only covers every competent department of ministry of railways, road bureau and substations, but also extends each basic unit of stations, and is an integrated railway computer net. TMIS system intends to improve transportation production, especially freight management level, provides railway dispatch department real-time information for mastering system-wide wagons, locomotives, trains, containers, as well as locations to merchandise, changes of state, and also execute macro-decision-making for departments including leading, planning, statistics, amd finance, to provide reliable dependencies for scientific management. Simultaneously, it could be regarded as important dependencies for firms organizing production and adapting turns of the market that provides dynamic information of freight to consignors. TMIS comprises station management information system, JZX, QBS, freight marketing and production management system, transport dispatching information system, wagon tracking system, and container tracking system, *etc.* Main information adopted by TMIS includes: (1) dynamic information of system-wide commodity transport market requirement; (2) dynamic information of commodity transport implementing, (3) accouterment of transportation resources including locomotives, vehicles, containers, tarpaulins and usage of dynamic information; (4) trains constitution dynamic information; (5) train arrived and passing information; (6) loading/ unloading vehicle operation information; (7) other transportation production and management information. Information adopted by TMIS station system and information Gather Mate, not only builds database in locality, but also sends original information by computer network to railway sub-bureau, bureau and ministry of railways timely, all levels of applications share the same message source and establish dynamic SDOK XAP which is under the sphere of jurisdiction and integral.

### *Dispatching Management Information System (DMIS)*

Purpose of the system is to improve managerial effectiveness of railway command and dispatch, sufficiently exert traffic ability of stations and intervals, increase driving degree of safety and on-schedule rate, alleviate labor intensity of scheduling staffs, implement open directions, real-time adjustments and integrated control, eventually creating environment for modernization of Chinese railway dispatch and command. The system realizes dispatch supervision and administration of the trains and provides policy-making basis for railway operation dispatching, on foundation of adoption of real-time dynamic operation data of the trains. According to different levels of control system formulated from routes, the system provides TMIS station train time report message, formulates driving dispatch and stage adjustment plans by TMIS, completes issue of dispatching orders by driving control system and automatic generation of stations logbooks. By interaction, driving control system and TMIS sub-bureau dispatching system formulate message sharing among train dispatching (planning platforms), locomotive dispatching, freight dispatching, passenger dispatching in center of driving dispatching, as well as data unload and issuing between driving dispatching and stations microcomputer time report, planning platform and out report, locomotive dispatching and terminal, freight dispatching and station consignment, passenger dispatching, technical station for passenger, passenger and ticket centers. Driving control system and TMIS sub-bureau dispatching system together constitute technological base for railway transport and production plan, as well as real-time dispatching and control.

***Passenger ticket selling and booking system***

With respect to commuter service, it develops railway passenger ticket selling and booking system. The application of the system resolves the long-standing problem of difficulty for buying tickets, and improves the management level and service quality of railway transport of passenger. Railway passenger ticket selling and booking system are constituted by passenger ticket center of railway ministry and region, station passenger ticket system: station ticket selling system mainly takes charge of real-time transaction services of ticket selling; region passenger ticket center mainly takes charge of dispatching control and operational management of passenger transport in center of pew; passenger ticket center of railway ministry mainly takes charge of coordinated management, and marketing analysis for entire-road passenger transport, and ensures entire-road ticket-selling on network.

***Comprehensive control and management information system of Chinese driving safety***

This system is the key research project of railway ministry's "the tenth five years" and national technology innovation project. Overall, the goal of the system is: to adopt advanced computer network technology, establish driving safety information network, set up transmission platform of safety monitoring data; insist the combination of technological innovation and institutional innovation, put up safety monitoring and management center and driving safety management system adapting the new forms; unify information channel, realize automatic adoption, transmission and integration, as well as integrated management and resource sharing of monitoring date of all kinds of safety monitoring message, develop complete information service application of electronic safety monitoring and management; build driving safety control and management information system which integrates monitoring, controlling and management decision-making into an organic whole.

Near-term target of the system takes typical busy main-line of passenger transport---Shanghai-Nanjing highway as a research background, adopts the program of concentration-distribution combined together, installs one road bureau safety monitoring and manages center, two sub-bureau safety monitoring and management centers, sufficiently utilizes existing road bureau network channels and road bureau, sub-bureau, terminal landing institution net, to constitute safety information network which links all kinds of safety monitoring equipments. According to data transmission network, it sends all the safety monitoring messages to safety monitoring centers and managing units of monitoring target in terms of progressive management and specialized management. Service objects of system could access all safety information stored by database of road bureau and sub-bureau safety monitoring & management centers by internet, and integrated organically with information management system (IMS) of business segments, to achieve information sharing. Among them, sub-bureau safety monitoring and management centers mainly store and manage essential data, safety monitoring information and safety transaction processing information of sub-bureau, in terms of function laying particular emphasis on supporting and coordinating daily driving safety assurance service & tracking of safety monitoring information of business segments. Road bureau safety monitoring & management centers mainly store and manage essential data of overall importance, safety monitoring information, safety transaction processing information and safety monitoring gathering & analysis of data. The functions lay particular emphasis on supervision & check of global driving safety, analysis by synthesis of information and assistant decision support.

**Intelligent Automation Research Institutions of Chinese Railway**

In the sphere of RITS, Chinese railway has made many research & development and exploratory applications. Since 1987, research and application of intelligent technique started under the system framework of railway transport intelligent automation. Through 10 years' research and development, currently better defined theory and methodology of railway intelligent automation and intelligent control have been preliminarily established, on the basic of a series of major research items including "operation and intelligent control of high-speed railroad train", "intelligent directions of high-speed railroad trains", "research of driving control intelligent software of high-speed railroad", "WTIS of high-speed operation" and "WTIS of Guangzhou-Shenzhen railway operation" etc all have acquired breakthrough development under support of state natural sciences fund and ministry of railway, and partial technique has been utilized successfully. All these works laid solid theory and technique foundations for further development of intelligent technique in railway transport system.

On the foundations of works above, Ministry of Science and Technology approved and set up RITSC in the year 2000. Ministry of Railways and Railroad academy of science invested nearly 50,000,000 together, to purchase main research equipment, trial installation, and development of key technology and construction of demonstration project. Since 2001, RITSC supported basic research project such as《"system framework of RITS"》,《"concept design of RITS simulation tests"》etc, and elaborated service field, logical frame, physical Architecture, general technique platform, demonstrated environment and so on for the first time. At the same time, under the support of Chinese hard technology research center of RITS, China, Japan and Korea unfolded joint research of RITS system framework and key technology. What is more, with the purposes of "high operation efficiency, high transportation safety, high quality service" of RITS, they started such projects as overall design and development of railway geographic information system (2002-2003), key technology platform research of railway geographic information system（2002-2002, pilot project research of railway geographic information system 2002-2003, network technology tentative design for safety of monitor control information and research of administrative center of Shanghai-Nanjing Railway Line（2001-2002）, information network of safety monitoring and control & software study of administrative center of Shanghai-Nanjing Railway Line（2001-2002）, manufacture of shakes vehicle instrument （2001-2002）, research and development of train net （2001-2002）, manufacture of coach operation safety monitoring reading plotter（2001-2002）, manufacture of railway freight security archway （2001-2002）, research and development of flitting access systems of railway safety monitoring data（2001-2002）, research of operational control simulation system of high-speed trains--- research of high-speed railway integrated dispatching system simulation centre proposal（2002-2002）, key technology research of stations interlock system of zone control （2001-2002）, research of interlocking train control all-in-one safe practice（2001-2003）, research of rolling speed self-adaptation control of hump rail （2000-2001）, research of hump Intelligence Process automation controlling system（2001-2002）, user's needs of high-speed railway Integrated Dispatching System（2000-2001）, research of technical condition of high-speed railway Integrated Dispatching System（2002-2002）, research of RITS Intelligent Modeling, control and optimization software platform （2002-2002）, High-speed railway intelligent transportation information system and its key technology(2004-2007), Qinghai railway information system engineering (2005-2006), Qinghai railway urgent rescue system and its command information system (2006-2007), Railway emergency plans management (2008-2009) *etc.*

### *Relationship Between Chinese Railway Intellectualization and Informatization*

According to the 20-year development, informatization of Chinese railway has acquired remarkable achievements with respect to the development and application that TMIS, DMIS, selling and booking system of passenger ticket and so on, laid solid foundation for railway intelligent development. Construction of RITS is neither the negation of railway intellectualization, nor detruding and repeating the same, however the supplement and development of Chinese railway informatization construction, is the high optimization of railway information in terms of railway intelligent transportation, and the higher stage pursued by further development of railway informatization.

According to the development trend of international railway transportation, and contrasted with the requirement of Chinese modernization of railway and concept of RITS, we analyzed the current situation and planned objectives of Chinese railway informatization. Currently, railway informatization construction has obvious deficiencies as follows in respect of objectives, system framework, implementation technique etc, and these deficiencies will bring long-term, deep-going negative effect for railway modernization construction:

In respect of bottom train control, research category of informatization planning is restricted to realize automation based on automatic control technology, not involved in how to realize automation of train control. A significant amount of human knowledge is involved in train control, and conventional automatic control technology could not build a model for human knowledge, only intellectual technology could better reflect humanity's experience knowledge. Therefore, if we want to realize intellectualized train control, and eventually achieve automatic drive without or little manual intervention, we must realize them depending on intelligent construction.

In respect of compound decision, research category of informatization planning is still limited to decision support in each professional system, not comprehensively considering factors such as routes, bridge, tunnel, traction power supply, system of signal, vehicle dynamics, trains' operation and transport organization etc, and makes overall and systemic science decision. This compound decision problem basically belongs to multiple objectives, multiple constraints, probabilistic optimization problem, and traditional message processing methods that could not resolve optimization of these problems; we must adopt intelligent operation technique to make rational decisions. Take dispatching for example, informatization solves freight dispatching, passenger transport dispatching, train dispatching, locomotive dispatching, vehicle dispatching, electricity dispatching, and special dispatching in terms of business field, however intellectualization is the dispatch based on comprehensively considering all kinds of resources.

In respect of system combination and information sharing, currently, railway informatization construction consists of separately installed problems, and informatization planning promotes the proposal of information sharing among operating information systems, while RITS institute system combines and shares information in terms of establishing unified GIS shared platform, greatting encompassing and covering information system, train control and information service, obtaining a system of higher level in respects of all-in-one, compatibility and information utilization.

In respect of society informatization service, RITS will reinforce research of all-in-one electronic commerce systems, enhance research of network service between vehicle and land, and provide the clients more convenient travels services and fast cargo transportation service.

### System Framework and Standards System of Chinese RITS

In the sphere of RITS, Chinese railway also carried out large quantities of development and exploratory applications. Since 1987, research and application of intelligent technique were started under system framework of railway transport intelligent automation. After 10-year research and development, presently better defined theory and methodology of railway intelligent automation and intelligent control have been preliminarily formulated. On the above foundation, a succession of major research items including "high-speed trains operation intelligent control", "high-speed railway operation intelligent simulation system" and "operation intelligent simulation system of Guangzhou-Shenzhen railway" all achieved breakthroughs under the support of state natural sciences fund and Ministry of Railways, and partial technology has been successfully applied. All these above laid solid theory and technology foundations for further development of intelligent technique in railway transport system.

On the grounds discussed of above, national ministry of Science and Technology set up RITSC in 2000. Since 2001, RITSC chaired basic research projects such as 'System Framework of RITS', 'standards system of RITS', 'development strategy of RITS' etc, and elaborated service framework, logical frame, physical frame, general technology platform, standards system, demonstrated environment, etc of RITS. Under the support of Chinese RITS hard technology center, joint research of RITS system framework and key technology have been developed by China, Japan and Korea. System framework content about Chinese RITS will be elaborated in the following chapters.

## RITS RESEARCH CURRENT SITUATION ABROAD

### Japanese CyberRail System Architecture

Japan Railway Technology Research Institute began the research of railway intelligence traffic system based on information and communication technology in the year 2000 and proposed a 21st century railway system, which could efficiently use the concept of combined transport system for public traffic system. The system is called CyberRail. CyberRail is a railway-related information business model that has been developed to facilitate passenger travel while improving the efficiency and business opportunities for railway operators [12]. The basic concept of CyberRail is not to offer mass public transport, but to offer tailor-made transport choices centered on railways [14].

The first version of system architecture of ITS in Japan became public in 1999. Although they do have some user services which are related to railways, the overall structure of the architecture seems to be road-oriented, thus lacking the standpoints from railways. Currently, it is widely accepted by ITS experts that the scope of ITS should not be restricted to road transport but it must incorporate all modes including road, rail, air, *etc.* Incorporation of railway into ITS is particularly important in Japan considering the number of travelers who use railways, the reason due to is why we have started the study of system architecture for CyberRail, which we believe can be an important part of future ITS in Japan [15].

These user services are derived in a top-down analysis in which requirements are allocated and decomposed from the top level, down through detailed requirements, hardware components, or software modules in an orderly fashion. During the process of stepwise refinement of requirements, we have to make sure that the originating requirement is satisfied by the decomposed requirements so that the intended functions of the system can be reflected in the lower level specification or the implementation of the system. The process adopted in building the system architecture of CyberRail is depicted in (Fig. **1**) [13].

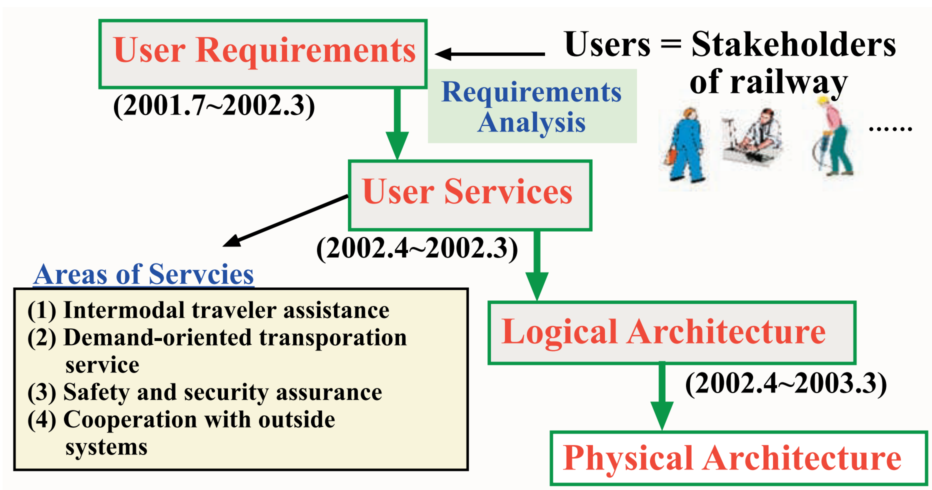


**Figure 1:** Architecture Development Process

These user services are broken down into logical architecture, which define sets of functions or processes that are required to satisfy the user service. (Fig. **2**) shows a simplified version of our top-level logical architecture of the CyberRail traveler support systems. In (Figs. **2**) processes (functions) are represented in circles annotated with corresponding process names. Directed arcs represent data flows in the direction of the arrows. Data flow symbols are annotated with names of data they carry. Rectangles represent external entities (i.e. terminator) which input data to the system or consume data produced by the system [13].

The development of logical architecture of CyberRail will be followed by the development of physical architecture, which defines all the physical entities that make up CyberRail systems and the interconnections and interactions among these entities. We will have several alternatives, physical models, in which every process captured in logical architecture is mapped onto a physical entity. This facilitates the development and deployment of interoperable systems without impeding innovations as technologies advance or new approaches evolve [13].

Before going on to the development of physical architecture, however, we will have to verify in advance that the logical architecture that we have developed has sufficient generality and expressive power to include potential CyberRail applications. This is why we have decided to proceed to case studies which include an experimental implementation of CyberRail traveler support system rather than going directly on to physical architecture development. The evaluation of the experimental implementation of CyberRail is expected to show some feedback to our logical architecture [13].

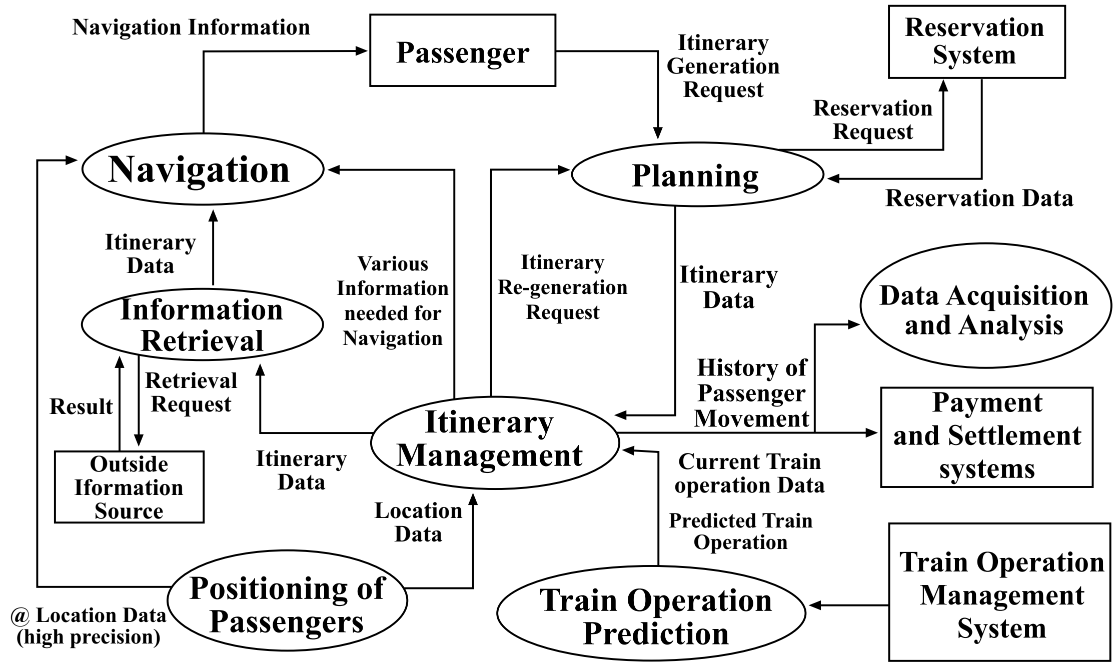


**Figure 2:** Top-level Logical Architecture of CyberRail Traveler Support

The first version of system architecture of ITS in Japan became public in 1999. Although it did not have some user services which are related to railways, the overall structure of the architecture seems to be road-oriented, thus lacking the standpoints from railways. Currently it is widely accepted by ITS experts that the scope of ITS should not be restricted to road transport but that it must incorporate all modes including road, rail, air, *etc.* Incorporation of railway into ITS is particularly important in Japan since the number of travelers who use railways is much larger than any other country in the world. This is why we have started the study of system architecture for CyberRail, which we believe, can be an important part of future ITS in Japan [17].

Door-to-door intermodal traveler navigation will be one of the ultimate goals of CyberRail. In order to make intermodal trips efficient and comfortable, traveler information systems (including navigation systems) for different modes must be interoperable so that travelers do not have to worry about the difference of the modes by which they are traveling and of the traveler information systems they are using. In order for traveler information systems in different modes to be interoperable, we must clearly define the interfaces between subsystems belonging to different modes, share data dictionaries and message sets, and establish–standardized protocols. Since CyberRail has numerous outside systems to cooperate with, building its system architecture before going into implementation details will be indispensable for achieving interoperability [17].

Our approach to the system architecture of CyberRail is similar to that of ITS in Japan. As the first step, we are now discussing user services of CyberRail [16]. A user service is the description of a particular service or a particular functionality of transportation, with emphasis on the relationship between service users and service providers. In other words, the notion of “users” may include all stakeholders of railway. Passengers, railway operators, operators of other transport modes (buses, taxis, *etc.*), travel agencies, information providers, shops, *etc.* all can be the users of CyberRail. Four potential user services of CyberRail, which we are currently discussing at RTRI, are (1) Intermodal Passenger Assistance and Personal Navigation, (2) Platform for Distribution and Exchange o Railway-related Information, (3) Demand-oriented Transportation Planning and Rescheduling, and (4) Intelligent Train Control [17].

The purpose of CyberRail is to provide efficient information system, in order to implement the centralized function of comprehensive information in traffic system. It could connect passengers, automobiles, trains, roads and tracks with two-way mobile communication. In this intelligent, central and combined-traffic system and CyberRail system, two sides of functions will be implemented: the first is to provide real-time information for combined traffic passengers. It could provide more convenient, more reliable and more real-time information, including information before travels, door to door travel guidance, the adjustment of travel plan when the traffic is blocked and so on. The second is to make railway operation more flexible, safer and more competent, which means the implementation of real-time, facing-demands train operation program and intelligence train control based on communication.

Present goals of ITS mainly include: (1) Improving the efficiency and capacity in transportation system; (2) Strengthening mobility, convenience and comfort level of traffic system; (3) Improving security and reliability of traffic system; (4) Decreasing energy and environment consumption; (5) Making effective use of present infrastructure; (6) Creation of commercial opportunities related to journey; (7) Providing integrated, unified and standardized information.

Table **1** demonstrates situations of RITS responding to ITS research area, apparently, CyberRail could better offset shortage of current institution of Japan RITS.

**Table 1:** situations of RITS responded to ITS research area

| **Exploitation area** | **details** | **Related railway system** | **Situations in railway** |
|---|---|---|---|
| Advanced electronic charging system for guidance system | Navigation, routes guidance, other information of electronic charging | Untouched personal guidance intelligence card, automatic door for passengers | Having been implemented in CyberRail research |
| Assistant safety driving | Danger warning, assistant driving, automatic highway system | ATS, ATC and other controlling system of railway running | Under implementation |
| Optimization of traffic management | Optimization of traffic flow and information under accidents | Planning system for railway operation | CyberRail is researching |
| Raise efficiency in road management | Added amending work and danger information | Maintaining and Supporting system, early period-alarm system of earthquake | Under research |
| Support to public transportation which raises operation efficacy of commercial vehicles | Assistant public transportation and transportation management, operation management of commercial vehicles | Combined transportation, freight traffic, container management system, controlling system for commodity transportation | Having been implemented in CyberRail research |
| Assistance to pedestrian | Routes Guidance for pedestrian | Without barrier, under guidance of station, running across the street safely | CyberRail is researching |
| Vehicle operation controlling under urgent conditions | Automatic urgent alarm | Wireless controlling structure for railway dispatching | under implementation |

Since the existing ITS puts too much emphasis on road transport that it lacks consideration from the standpoint of railways, simultaneously, the railway in Japan could not meet the transport demand of the increasing multimodal transport passengers. RTRI started the research of intelligent railway system which comprehensively uses information and communication technology in 2001, named “CyberRail”, to improve transport efficiency and capacity of the railway system, enhance individual mobility, convenience and comfort, in railway transportation system, reduce energy consumption and environment pollution, increase the utilization rate of the existing infrastructure, create travel-related commercial opportunities, provide centralized, unified and standardized information, and improve the safety and reliability of rail transport system. Currently, the main task of CyberRail system research carried out by RTRI is to define the framework of the CyberRail system, and now the division of user service area and the initial definition of logical framework of system have been completed.

The user service of CyberRail is divided into the following four fields: intermodal transport information and personal navigation, common information platform, demand-oriented transportation planning and rescheduling, intelligent train control, as is shown in (Fig. **3**).

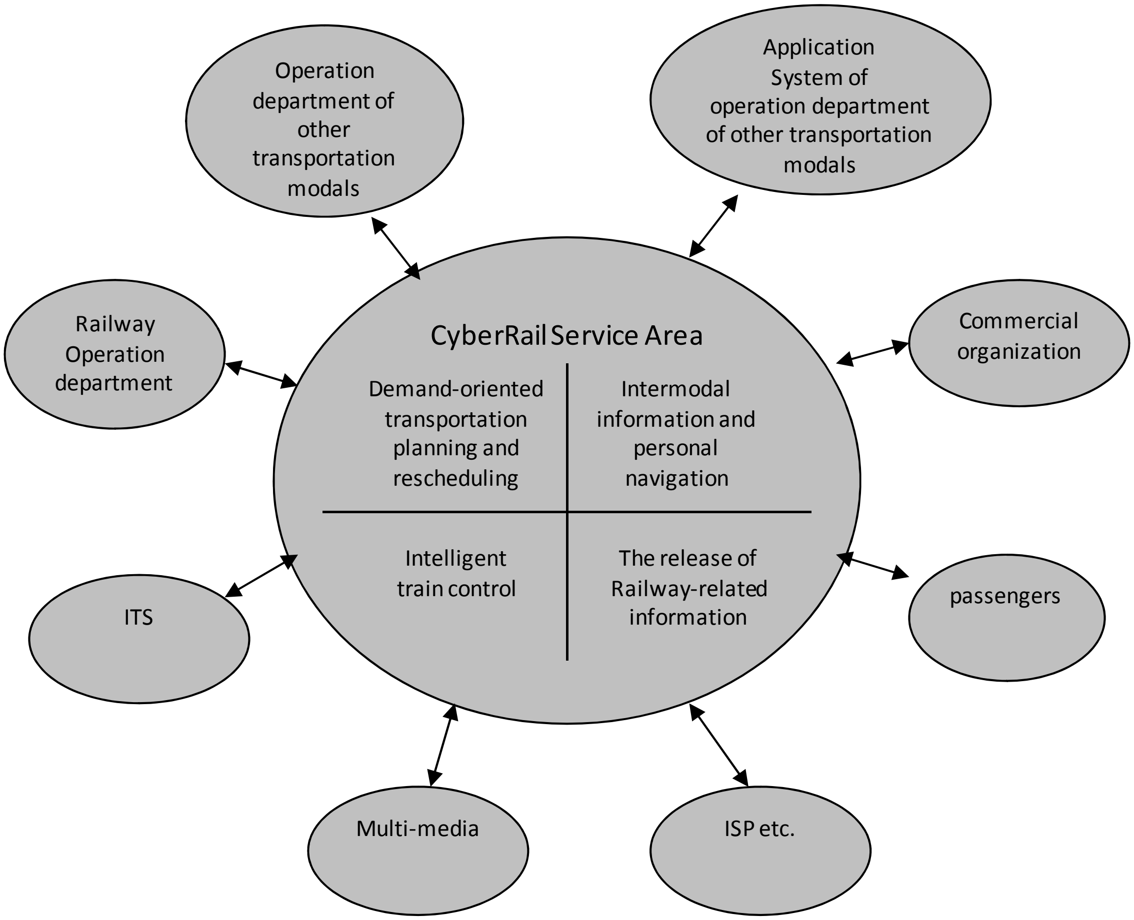


**Figure 3:** The areas of user service in CyberRail

***Demand-Oriented Transportation Planning and Rescheduling***

It optimizes and formulates transportation planning from the standpoint of passengers, and carries out train schedule adjustment in the case of disorder.

***Intermodal Information and Personal Navigation***

This user service helps passengers make before departure or modify on travel, the intermodal travel plan, and navigates passengers according to their intended routes. Usually owing to reasons of passengers or reasons of transport service providers (like delay or the train stopping owing to accident or congestion, *etc.*), the passengers' routes may often be modified. In these consequences, the system must simply and smoothly assist the passengers to modify their travel plans. Now, Japan is experimenting on new railway passenger navigation system, which detects passengers through the use of Bluetooth wireless communication technology, and provides real-time travel information for passengers, automatically modifying passengers' routes when accident happens and ensure the optimization of the newest train running operation.

***Intelligent train control;***

This user service is used to realize more advanced train control system based on communication, and its enhanced function is mainly embodied in three aspects:

***<u>Predictive Train Control</u>***

Predictive train control predicts the traffic conditions ahead to reduce the train track interval, earlier recovery from operation disorder, and decrease the energy consumption.

***Monitoring and Obstacle Detection***

According to monitoring railway tracks from train or the trackside, monitoring and obstacle detection protects trains from derailment and avoids collisions. Its major targets are on the station platforms and level crossings.

***Protection of Trackside Workers and Maintenance Vehicles***

Through portable terminals, it provides information of approaching trains to workers and maintenance vehicles based on location information controlling, to protect them from colliding with running trains.

***Common Information Platform for Release and Exchange of the Railway-Related Information***

The platform conducts the release, management and support of the railway-related information [18].

The corresponding relationship between the CyberRail user service and technique example is shown in (Fig. **4**).

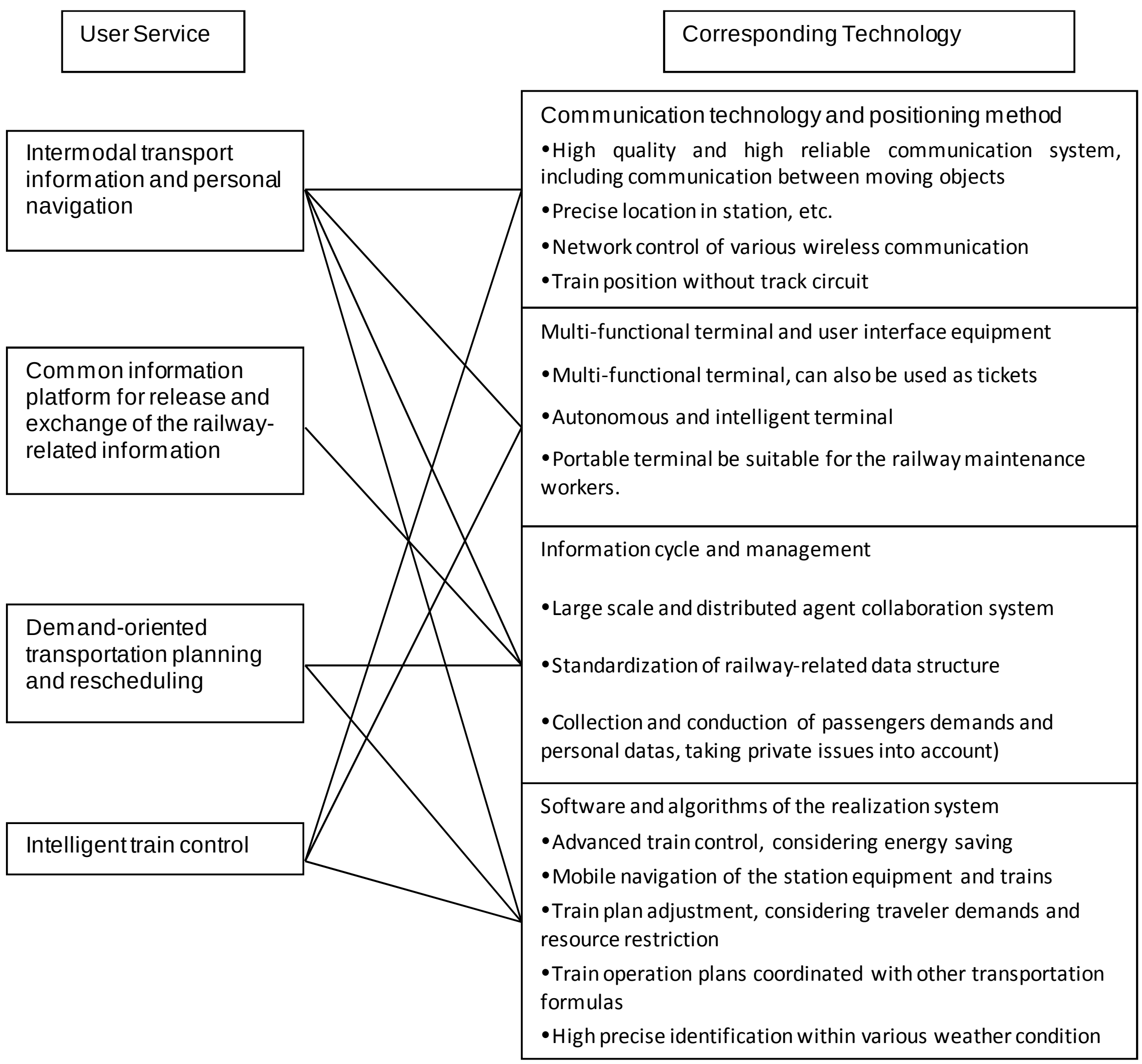


**Figure 4:** CyberRail user service and technology examples

**Japanese Computerized Safety Maintenance and Operation System Sinkansen (COSMOS)**

COSMOS originated as an EU-funded research and development project carried out by an international consortium of nine organizations in different European countries. Having been completed in May of 2001, the project produced an integrated system for mobile operations support in the construction industry, focusing on construction sites lacking a permanent network infrastructure. COSMOS' objectives were based on the following considerations: Traditional network infrastructures, systems, and tools are inadequate for frequent and ubiquitous handling of information that is, although centrally stored at the company headquarters, continuously being accessed, generated and updated both at the headquarters and at the construction sites. Operations involve very complex processes at the construction site level, calling for an integrated information system and thus for efficient communication within the construction site itself and between the site and the headquarters. Such communication should be supported from any site location and with different kinds of devices [19].

Japanese Sinkansen is basically an independent system. Its establishment of dispatching system completely shakes off the shackles of existing lines and sufficiently considers the high risk brought by the high-speed train and traffic safety dependence on the scheduling system, highlighting the importance of safety; it sufficiently considered the high-speed passengers' strong desire to effectively utilize time, taking punctuality as the core of the work. From the concept of the broad transport system, it established a comprehensive scheduling system with various functions and powerful total function. Besides the whole business contained in traditional system, the comprehensive scheduling system still catered to the management, maintenance of routes, monitoring and remote operation of power supply system, monitoring and overhauling of communication signals system, forecasting and pre-warning of disaster, accidents repair, *etc.*

The comprehensive scheduling system should be supported by modern new technologies and equipments, to provide a good working environment for each business scheduling table. COSMOS realizes a larger scale of centralization and completely concentrates on the management of EU base and routes management on the scheduling center. COSMOS (Computerized Safety Maintenance and Operation System of Sinkansen) is constituted of 8 sub-systems, as shown in (Fig. **5**).

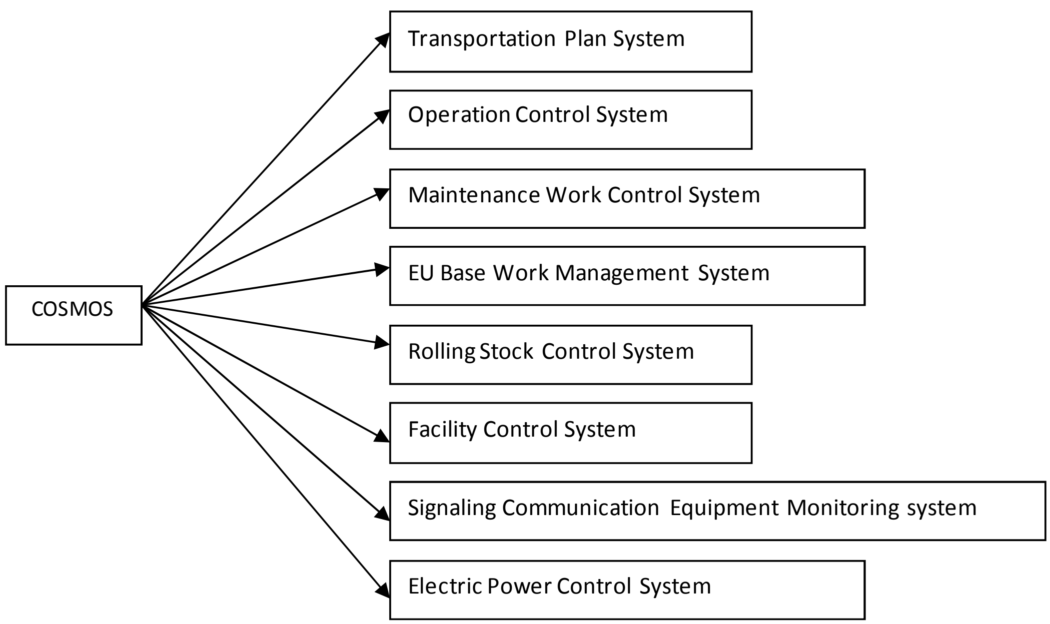


**Figure 5:** COSMOS Subsystems

COSMOS system possesses following functions:

***Transportation Plan Management***

Transportation plan Sub-system is the system for the preparation and management of Sinkansen transportation plan. It mainly prepares train running plans (including the basic operation lines, seasonal fluctuated lines, daily fluctuated lines and temporary lines on traveler demands), rolling stock usage plans, crew duty plans and rolling stock inspection basic plans; meanwhile, it carries out preparation and summary and plans transmission of statistics.

The prepared plans are sent to the operation control system on one day; the next day plans are automatically transmitted to the station, crew office (train crew), crew area (train crew) and the head and branch office. Then the essential running condition form at the station, as well as the essential crew form at the station will be the automatic result.

It receives train operation alteration of the current day from the operation control system, to statistical work including the running miles of trains and so on.

***Operation Control Management***

Based on the train schedules prepared according to the transportation plan system, OCM adjusts the train operation and provides information to passengers. Its main functions are: ① train operation adjustment; ② operation indication; ③ train schedule management; ④ approach control; ⑤ traveler service guidance, *etc.*

The Operation Control System consists of the central operation and station operation, of which two are connected by specialized network.

On display, dispatchers of the central operation and management directly operate the operation lines, including train operation alternation and train approach components operation, *etc.* The dispatchers directly make the temporary speed control when braking is demanded. The alternative security method of ATC equipment which is in fault condition could be executed only by the central dispatchers and drivers.

The Station Operation and Management is constituted of the station PRC management system, control system and passenger guide device. The station PRC management system performs the management to approach control, operation information, running chart and manual control, *etc.*; the station PRC control system accepts instruction of the approach component from the station PRC management system, to inspect the condition of the approach conflicts and output of the signal equipments. In the maintenance period, the maintenance work terminal controls the maintenance of rolling stock approach. Passenger guide system broadcasts information to passengers and controls the information board on the basis of the tracking information in the station.

From the center to the station operation and management, the system transfers the running charts of the day and the next day, and the station performs the control according to conditions of the track circuit, and consequently, the train control system can work only depending on the station PRC when the network is in fault.

***Maintenance Work Control System***

The Maintenance Work Control System is the system that supports the plan and implements related maintenance work. The Central system and all maintenance area terminals are connected by network. The operation schedules logged in each maintenance area are saved in the central system, and the central system manages the beginning and end of the maintenance work and the coming in and going out of the Sinkansen of the day. The constructor executes operation applies and the beginning and end of the operation reports through wireless telephones.

***EU Base Work Management System***

Based on the EU use and inspection plans prepared by the system, the system supports the specific operations, personnel placement, arena and time allocation, *etc.*, and simultaneously performs the management of the switching operation, the approach and so on.

***Rolling Stock Control System***

The Rolling Stock Control System is the system that supports the EU checking and repairing works. The central system and EU base are connected with common network. This system mainly carries out the inspection of the EU, the failure data management and the EU loaded parts management. Main functions are as follows: ① EU file management; ② failure data management; ③ maintenance data management; ④ construction management. The data of rolling track (EU) are managed in the central system, as well as the component management in the database of the EU base.

### *Facility Control Subsystem*

This system is the management system of the equipped maintenance data including lines, electric power and communication signals *etc.*, and the central system and maintenance sections are connected by a common network. The central system analyzes the data from the comprehensive test vehicle and sends the data to the corresponding departments. Each maintenance section processes and manages its own equipment maintenance data. The central system and planning system share the hardware devices.

### *Signaling Communication Equipment Monitoring System*

This system monitors the disaster prevention information along the Sinkansen as well as status of signal communications equipment (CMS: Centralized information Monitoring System). According to the dedicated line, the central system can centrally monitor information from the station (wind, rain, rail temperature, ATC signal level, action status of linkage equipment, *etc.*), and it could also carry out remote control.

### *Electric Power Control System (Monitoring and Management System)*

The system manages the substation control and timed power on and off of the Sinkansen. Central system and every regional system are connected with specialized network. All the regional systems can be controlled by the central system.

Japanese comprehensive scheduling system, especially the COSMOS system, nearly contained all the scheduling management works of the transportation production. The scheduling center of the comprehensive scheduling system generally has: train (traffic) scheduling table, passenger scheduling table, EU scheduling table, electric power scheduling table, communication signaling scheduling table and maintenance scheduling table.

The Japanese Sinkansen system has been in operation for 38 years, has carried over 6 billion passengers and more than 750 high-speed trains operate per day, but has no passenger casualty due to train operation accident, and the average delay time is within 1 minute. For all these, the comprehensive scheduling system made great contribution. To conclude, the Japanese experts drew from the practice, that “For the safety, accurate and smooth running Sinkansen, the most important thing is the ‘comprehensive scheduling office’ which is the brain of the Sinkansen that works night and day”, is justified.

## American Intelligent Railway Systems (IRS)

The American Railway Research Institute is working at the research of the Intelligent Railway Systems (IRS) which would incorporate the new sensor, computer and digital communication technologies into train control, braking systems, grade crossing, faults testing, planning and scheduling systems. The benefits of developing IRS include: avoidance of collision and over speed accidents, prevention of abduction and out-of-control, increasing transportation capacity and assets utilization, perfection of passenger service, raising efficiency of energy use and emissions, promotion of economic growth and profits, and allowing railway to measure and control costs, as well as dealing with emergency situations. IRS can make the railway respond to the rapidly changing transport market mechanically and flexibly. The service areas of IRS contain ten systems, as shown in (Fig. **6**). IRS simplified architecture is shown in (Fig. **7**).

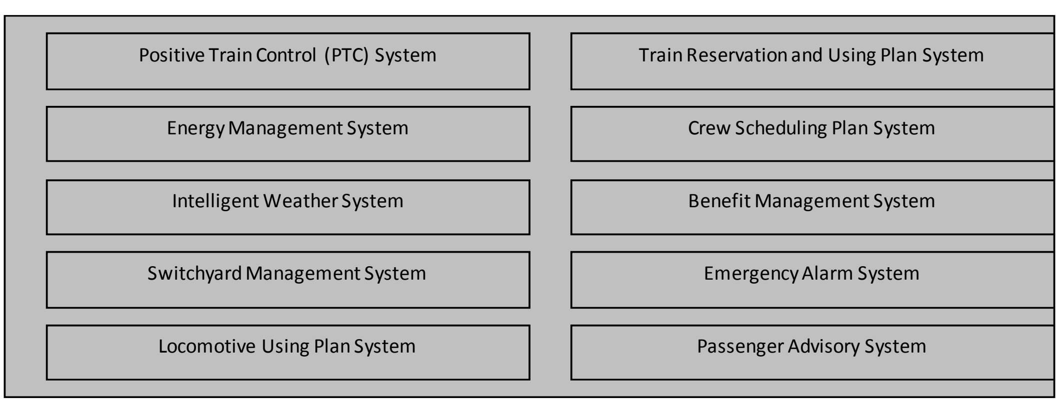


**Figure 6:** IRS Service Area

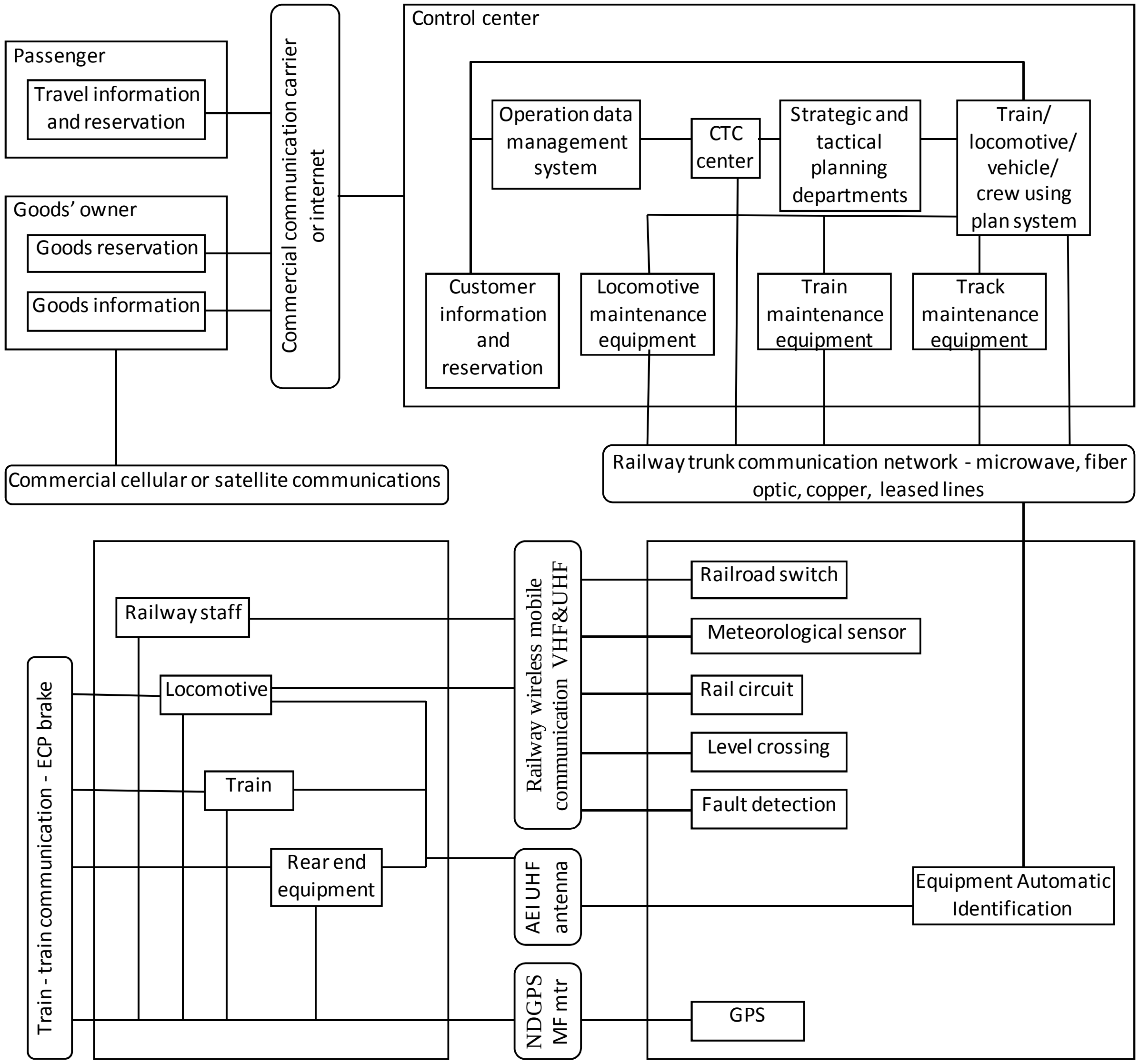


**Figure 7:** IRS Simplified Architecture

1) Positive Train Control (PTC) System is the system that integrates the command, control, communications and information. It is used to control safe, reliable, punctual, efficient running of trains and it improves the railway transportation safety by effectively avoiding collisions, reducing negligence line side staff, lowering the equipment damage and over speed accident.

2) Energy Management System (EMS) is a computer program installed in the locomotives in order to optimize fuel consumption and emission. This system receives the following information: track properties and conditions, speed limits, consistence of trains and locomotives, fuel characteristics, *etc.* According to above information, it ascertains the proposed train speed which meets the services demand, minimizes fuel consumption and (or) release, and provides excellent train operating characteristics.

3) Intelligent Weather System is constituted of the local meteorological sensor network and equipment. It provides pre-warning disasters caused by climatic such as flood, track erosion, snow, debris flow, landslide, strong wind, fog, risk of high curve radius and other conditions that need the maintenance department to adjust the train operation.

4) Switchyard Management System receives the real-time location and components information of every train, and tracks all the vehicles in the switchyard. Based on the optimism, it decides the best way to

control a train, i.e the disintegrate order of the arrival trains, the train playback order and the train marshalling order.

5) Locomotive Using Plan System utilizes the data of the train schedule, topography, locomotive characteristics, information of locomotive in good order, locomotive service and maintenance plan and the train marshalling *etc.*, on and adopts a linear program algorithm to distribute the locomotives over trains.

6) Train Reservation and Using Plan System. The train reservation system allows customers to make an early reservation of the capacity and pass ways of the trains. The train using plan system allows the railway to arrange the operation of every train to meet the customers' needs.

7) Crew Scheduling Plan System could also be ascertained a few days or a few weeks earlier when the train using plan is set up. It is better for the crew to rationally arrange rest and leisure time, lower the stress from family and society, as well as emotional and physical pressures.

8) Benefit Management System can make the railway establish flexible fare policy, which could be used on cargo and passenger transportation. This system needs to reserve and plan the transport capacity and comprehensive information system to track the constantly changing capacity, complex demand changes and diverse prices.

9) Emergency Alarm System is installed in the control center, to make automatic alarm for railway accident, disasters and harmful tendencies. It provides better cooperation and control for related organizations, including railway staff, the public security departments, the fire brigade, emergency medical service, as well as principals of other organizations.

10) Passenger Advisory System uses the real-time train location information to provide the predicted train arrival time to the passengers in the intercity trains and suburban trains. The information is shown on the dynamic screen of the station or the internet map.

**American Advanced Automatic Train Control (AATC)**

AATC（Advanced Automatic Train Control） was developed by American BART (Bay Area Rapid Transit; San Francisco Bay Area Rapid Transit) and Hughes Aircraft Company together in 1992 based on the wireless train control system. Its function is similar to the European ERTMS/ETCS and Japanese ATACS system. AATC utilizes the U.S. Army's Enhanced Position Location Reporting System (EPLRS) to realize the train tracking and locate the train position measuring the propagation time of radio waves between the wireless device of the train's head and tail and the line side ground wireless devices. The characteristic of this system is that there is an intelligent system on the ground (the station). The train station monitors the operation conditions of a number of trains, and realizes the train's efficient energy operation by flexibly using information.

AATC is composed of a series of different station equipments and automotive equipments, as shown in (Fig. **8**).

The backbone of AATC is a powerful broadcasting network which provides the function of data exchange and train location. According to the broadcasting network rather than the induction coil, AATC exchanges important data of the train position.

The network central computing function is completed by being installed at station or other convenient places. The computers collect position and other information, calculate the train position, control the train speed, control the moving block, *etc.* The control center of the BART could interfere with this function, to perform temporary speed limit or traffic management.

Each computer is connected with two station radios, as the main broadcast in the network. As part of the line side network, the station broadcast communicates with other line side broadcasts near the station.

The onboard broadcast receives the broadcast of the line side wireless device, receives information sent out by station computer and provides feedback the train condition information. The train can receive the latest line side broadcast from four places. Therefore, even in tunnels, the train still has many opportunities to accept instructions. The adoption of the line side wireless equipment makes it feasible for trains to install simple and low cost hardware devices.

The information transmission is synchronized and utilizes the measuring equipment to test train position, speed and direction. The head and tail broadcast on the train provides train redundant communication and monitor integrity and length. Updating the train speed control command every 0.5s, the station computer could provide the trains basic point automatic operation in the closed-loop control.

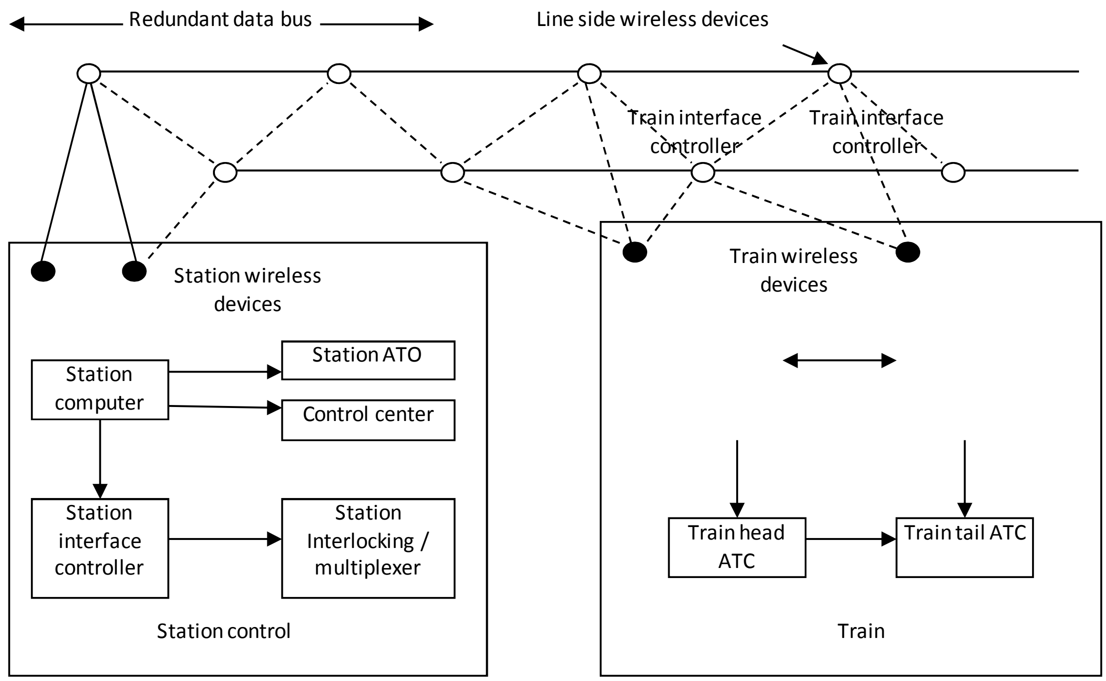


**Figure 8:** Form of AATC

**European Rail Traffic Management System (ERTMS）**

The European Train Control System (ETCS) is being developed within the European Rail Traffic Management System (ERTMS) to provide a new generation of train control and signaling. This includes automatic train protection (ATP) by continuously supervising train speed and braking.

ERTMS uses the Global System for Mobile communications – Railways (GSM-R) radio system for signaling data transmission.

Trains use data to calculate safe speeds. ERTMS intervenes if the train over speeds to bring it back to safe levels. The system stops a train safely to prevent a train from exceeding its movement authority.

The ERTMS technology has different levels of capacity and performance. All levels of ERTMS include ATP. Current UK plans are to introduce a level 2 system.

All countries in the European Union are working together to improve railways throughout Europe. One aim is to allow ERTMS fitted trains from one member state to operate on other member states' ERTMS fitted lines. This aligns itself with interoperability where trains from member states are able to operate on other Members' railway systems. This "interoperability" eventually creates a single European market for rail products.

ERTMS is a complex, modern train control system which will eventually enable one common signaling system across Europe, when the Euro Interlocking Project is completed. This will bring with it benefits of improved efficiency of operation as well as safety.

In the network of the 300.00-kilometer European high-speed railway line, there are more than ten different kinds of train control systems, such as the euro star (an international high-speed train) furnished with 6 types, and 8 types on

Thalys (another international high-speed train). When a train is crossing the border of two European countries, it must stop to switch the operating standards. On one hand, the expensive equipments lead to the increasing fare of the train operation and maintenance, and on the other hand, board-switch increases travel time and brings more inconvenience for passengers. For this situation, in order to establish a unique Europe-wide signal standard for railway signaling, ensure the interoperability on the international railway in Europe and enhance the management of rail transportation, the European community established the European Rail Traffic Management System (ERTMS) program in December 1989. Thereafter, revolving around technical specifications, EC carried out 5 stages of the works related to the institution, refinement, evaluation, simulation test, legislation and the business promotion, shown in (Fig. **9**).

The first phase was from the year 1990 to 1998. The EEIC, ERRI and the European special interest group together formulated the basic specification, ensured the functional requirements and system requirements; the second phase was from 1998 to 2000, the Steering Committee of the ERTMS program development and implementation fulfilled the classification of the function and system, to meet the basic requirement of the interactive usage; the third phase was from 1999 to 2003, the Steering Committee of the ERTMS program development and implementation and the railway departments tested the system function, verified the interoperability of the system and function, and proposed amendments; the fourth phase was from 2000 to 2002, the European Electrical Standardization committee, European Railway Interoperation Association and the railway departments made the improvement of the interoperability standard, and set technical specification for completion of ERTMS; the fifth phase was from 2000 to 2005, the railway department and industrial organization implemented the commercialization and popularized the ERTMS worldwide.

The program framework of ERTMS mainly includes three parts: new-type mobile unit based on open computer architecture (EUROCAB), discontinuous system for data transmission (EUROBALISE), and new continuous system for data transmission (EURORADIO).

The general construction of ERTMS has three components: radio block center (RBC), on-road equipment (EVC) and railway communication system (GSM-R). The GSM-R is a 4MHz bandwidth frequency for uplink and down link. It works in the 900MHZ band, and provides the interoperability function in the railway communication network.

The assured application range of ERTMS mainly includes: Controller—driver operational communication, Automatic train control, Shunting operation, Remote control, Emergency regional broadcast, Stations and depots local communication and Passenger services.

The ERTMS, with ETCS as standard, GSM-R as platform, European point transponder as location method, has three sub-systems: the European Train Control System (ETCS), GSM-R and Transportation Management. The main function is [24]:

1. Operation Command/Control; ensuring the safety operation of the train on the railway network;
2. Transportation Management; handling the management problems of trains and fundamental facilities and ensuring the optimized allocation of route capacity and train application.

Considering multi functional operation requirements of different countries, ERTMS/ETCS defined three function levels:

ERTMS/ETCS level 1 uses conventional line side signals, adopts the fixed block system to operate, and sends the movement requirements to the train through the point-transponder. The track circuits always check the integrality and the location of the train.

ERTMS/ETCS level 2 introduces the GSM-R. It does not need the line side signals, and only requires the train detective equipment, and therefore decreases line side signal installations. By GSM-R, it makes continuous speed limitation and provides trains automatic protection and cab signals. It also uses inquiry transponder to position trains, and checks the train integrality with the inside radio block centers (RBC).

ERTMS/ETCS level 3 conceals the line side signal installations, and adopts "moving block" technology. The system uses GSM-R to determine the movement authorities, uses the transponder to achieve train location and uses the onboard equipment to check the integrality.

To sum up, main characteristics of ERTMS lie in:

1. Compatibility with the existing road network. The ERTMS can use a specific transmission module to read the information of existing equipments.
2. Meeting the special needs of different countries. The ERTMS takes specificity of the products into account, such as the certain channel of the transponder, and satisfies the special uses.
3. Easiness to upgrade. The level 1 can be upgraded to level 2 by adding up the wireless network. The level 2 can be upgraded to level 3 by merging the train integrality detection with the onboard equipment.
4. Increasing the number of the trains. ETCS level 3 can implement the moving block running, and take the trains and fixed fundamental facilities for better use, consequently increasing capacity on existing lines.
5. Reducing traveling time and operation cost.

European countries carried out tests on ERTMS one after another. Germany, Netherlands, the United Kingdom, Switzerland, France and Italy all run the test of level 1, 2, 3 respectively in the designated routes [25].The testing items are as follows [31]:

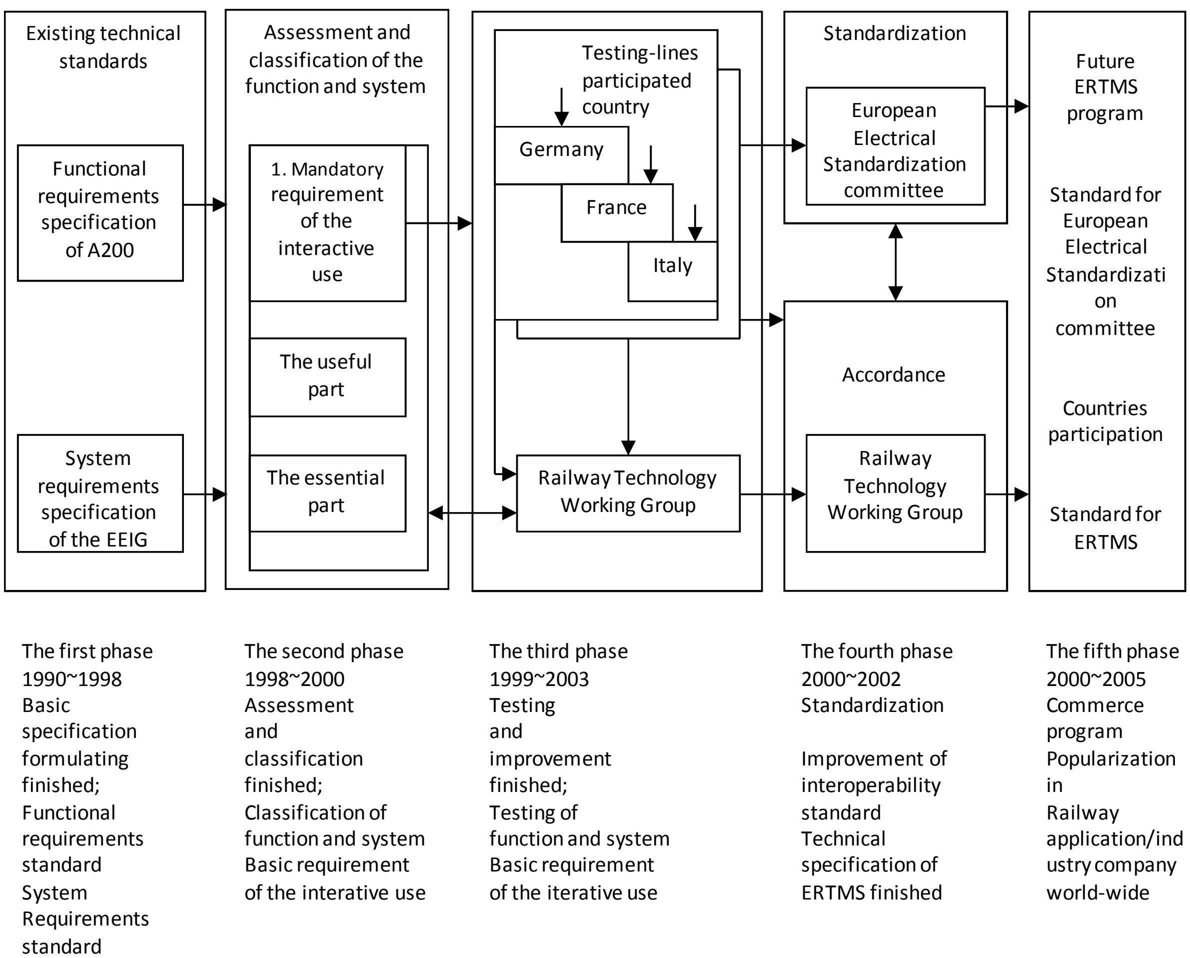


**Figure 9:** Five Stages

1. Germany, on the line Ludwigsfelde-jüterborg,40km long, ETCS1＋2;
2. Netherlands, on the line Heerlen－Masstricht, three test vehicles, ETCS2;on the line Maple－Leeuwarden, two test vehicles, ETCS2;
3. The UK, the Old Dalby rail, Leeuwarden, two test vehicles, ETCS1,2;
4. Switzerland, on the Walenstadt－Sargans－Landquart part of the line Zurich—Chur. Adopting the non-continuous Europe link data transmission system, installing 29 signals and 6 test vehicles; on the Zofingen-Sempach part of the line Olten-Lucerne, 63 test vehicles, ETCS2;
5. France, some 25km high-speed connecting line which connected to Paris, ETCS2; on the line Tournan－Marles-en－Brie, 10km long, ETCS1;
6. Italy, on the Florence—Arezzo (66km) and Arezzo—Rigutino (20km) part of the high-speed line Florence—Rome, ETCS1+2.

The test shows, the Railway Control System based on the GSM-R wireless communication, together with the mature technology like the existing information technology, the network technology *etc.*, could effectively improve service quality and transportation efficiency. Instead of original track circuit and the ground signal machine, installing of GSM-R on the existing lines greatly promoted convenience and high efficiency. Research fronts show that ERTMS will be the total solution for European Main Railway Transportation Route in the 21st century [26-30].

In order to substantially shorten life cycle costs of the future interlocking system, and meet the new function requirement of the future ERTMS / ETCS system, the UIC-funded project team is on research of instituting open signal interface standard and European common basis for description of railway demands [32].

**European Intermodal Transport Unit (ITU)**

In Europe, the research on the ITU (Intermodal Transport Unit) is mainly aimed at freight transportation, because the intermodal freight transportation is one important section of European Commission White Paper "European Transport Policy in 2010". Though the electronic data interchange (EDI) among multi transportation modes, the study is aimed at establishing an intermodal transport system based on electronic market to realize the high efficiency, low consumption and sustainable door-to-door transport among freights on the integrated chain.

The research is mainly focused on the establishment of information system for the intermodal transportation chain, operation of connected stations and the urban freight transportation distribution. Currently, cooperation information system based on the internet communication interface had been developed, and development of this system can provide information such as reservation and freight transportation condition. Now, the concept information model has been designed, and it provides the integrated information system, containing all the operators, to realize transportation between the consignors and consignees on the transport chain.

The formed project results at present include:

1) Started in Sept. 1997, the project “Internet-based International railway freight simulation —— Rail Tracking System”, tried to research the streamlining of international railway freight transportation, and is mainly used to improve the quality and reliability of transportation information and logistics among the European Union, Russia and other countries of Independent States. This project belongs to a section of remote information management project (TEDIM) of foreign trade logistics and delivery management. Rail tracking is an information system integrating, handling and publishing the delivery management information by internet, and specifies the way bill information of van, intermodal transport and containerized cargo, can be delivered to global different parties and staffs. The system is expected to passed the test in 1999 and was put into complete operation in 2000.
2) Seamless tracking and tracing. Because of different parties adopting different ways, the mutual simulation among the freight movements on the transport chain is very time consuming. And the corresponding distribution system has passed the validation to trace the information chain and freight.
3) Operation of intermodal transport transfer point. Transportation at network nodes often increases the cost and time of door-to-door transport, which is also the bottleneck to realize the high efficient intermodal transportation, especially the efficient transport among the vessels, barges and land.

4) Automatic freight processing. Researches have appraised the components of automatic freight processing system, generated new van prototype that could effectively manage the Intermodal Transport Units (ITUs) and appraised the ITUs automatic positioning system. Concept of interface between port and ship has shaped, including freight processing system between transfer point and related vessels.

Additionally, the ETCS (European Train Control System) on research could also provide corresponding service for future freight transport, mainly including [33]:

- Realizing train tracking and tracing by telemetry technology and labeling technology;
- Train freight logistics and transportation as well as travel planning;
- Visualization of freight exchange process;
- Train positioning system;
- Train diagnosing and fleet management.

The areas in active development include:

1) Freight information service of intermodal transportation. It defines a thematic network to form the information exchange layer between different freight transport information and traffic management information, and provides good proposal for realizing more significant transport service. With the combination of the transport activities and a broader range of transport corridor and the various kinds of transportation modes on inter-modal transport chain, another project has made a further expansion of the internet-based information distribution system which has been successfully developed.
2) New technology of intermodal transport transfer point. An important aspect of the thematic of the optimized research on transfer point is to develop and integrate new technology. The research mainly concentrates on the innovation of freight transportation and coordinating orders of other transport modes. The track-automatic freight transportation and the LCMM containers can be used, according to information integration, to reduce delays in transfer points and accelerate the connection among various kinds of transport modes, realize decrease of cost, increase efficiency i and time saving. CargoRoo Trailer intelligent freight train or LCMM containers can make railway freight within 300KM more competitive and attractive than highway. The utilization of intelligent freight train can achieve the automation of the exchange between logistics and cargo, and reduce the cost of transfer point freight through the freight-based technology.
3) The project “Marco Polo”[34]. The project “Marco Polo” [34] emphasizes on the realization of the switch transport from road transport to railway, air and sea mode transportation. This project was approved in Feb. 4th, 2002, invested 115 billion euro and began the implementation in the year 2003. Sub-projects of the research activity include:

- The intermodal comprehensive solution between European Union and CEEC’s(INTERMODA). The project objectives are: the refinement of the European intermodal transport network platform; refinement of technology performance, market positioning and ascertainment of adjustment data about network condition; recording, analysis and evaluation on the network status; future demand forecast; method research of the improving existing and future network.
- The European Thematic Network on Freight Transfer Points (EUTP). EUTP integrate and analyze information about research and technology development strategy for the inter-modal freight transfer point. The research result drew a comprehensive network based on database and policy recommendations to be used as decision support, and make up the deficiencies of existing nation and European research power.

In the mobile service, with the appearance of new digital technology and the fusion of the whole Europe, the railway organization under the leadership of the European Union decided to establish a new standardized broadcasting system, to enhance the interactive and opening of every system, and make the GSM the basis of the broadcasting system, which could help the CSM users get various information services more conveniently [35].

In addition, with the internet technology, European ITS also provided information service and inter-modal service for users. The European electronic commerce focused on research to data exchange of different traffic modes to improve the intermodal mobility. For example, the European ITS project “TRIDENT”, which began in January 2000, is related to the inter-modal data exchange. This project is established to positively respond to the transport policy. People can make streamlets travel in different transport modes (public transport, urban rail transit, metro, railway and road) benefiting from the project, and it raised several public regulations for sharing and exchanging data among different transport modes, inter-modal transport operators, public transport managers and service providers. The target of this project is to establish a document model and norm by using the DATEX technology, a data model and norm facing the whole Europe by using object-oriented technology such as XML, a TRIDENT platform to meet the needs of users. Moreover, the related project that can improve the inter-modal mobility also contained EU-SPIRIT, which was completed at the end of the year 2001 and realized the internet-based “door-to-door” travel planning. European ITS also emphasized on the research of road safety, promoted the Safety project, paid attention to the use of many kinds of information access technology and provided driving safety information for drivers.

In addition, European ITS is researching to adopt several ways (such as Wap, Bluetooth, GPRS and other technologies) to provide users with services and accelerate development of electronic commerce. For example, the projects related to the European “Delivery of Multimedia ITS Information Services” and the ITSWAP project, *etc.* Otherwise, Europe also explored the establishment of comprehensive transport service network, with the related project ITS-net, which is the significant area of the European Communities sixth framework project and the target is to set a reliable and virtual network, providing traffic and traveler information for public and commercial terminal users. This project involves not only the definition and provides technologies of information, but also relates to the information exchange technologies like the EDI, *etc.* technologies, and could support the carry-on of intermodal transportation [36-40].

# CHAPTER 2

# Research on RITS System Framework

**Abstract:** Research on RITS system framework is the approach and strategy to guide the general planning and implementation for future development of the railway transport system. This Chapter presents RITS system framework in China. It is mainly based on several components including service framework, logical framework, and physical framework. Service framework combines user's demand and system function, which is the basis for the establishment of logical framework and physical framework. Logical framework describes RITS internal structure from logical point of view, and physical framework assigns the definition process of logical framework to RITS physical entities. Finally in this chapter, the intelligent emergency rescue and safety system framework are introduced as an example.

## GENERAL STUDIES ON RITS SYSTEM FRAMEWORK

### Research Purposes of RITS System Framework

Chinese railway information construction and development to date shows that: the research and formulation of the system framework is the starting point and basis for all the construction of large-scale system. It can be said that precisely because of railway information construction at the beginning lacked the formulation of system framework, this led to the current situation of application chaos in each operation system, the lack of uniform technical standards and interconnecting difficulties. In view of this, the most pressing and core work currently of RITS development is to formulate system framework.

Simultaneously, the present various railway information systems may play an effective role only when provided complete, unified, intelligent information systems. Their role and effectiveness are much larger than the systems with simple integration, overlapping and sharing. Only through processing and handling of intelligent system, railway information resources can be used effectively. When railway information resource is under constraint and security assurance by the system framework, it can be extended from the inner railway to the entire network, improving the quality of services while protecting the inner safety of the railway system.

Research on RITS system framework aimed at fundamentally changing the bias of considering railway information simply from a technical perspective. However, RITS system framework should be a kind of thought, ideas and philosophy, rather than a set of MIS systems or just a set of standards. It is the approach and strategy to guide the general planning and step-by-step implementation for future development of the railway transport system.

RITS system framework works for the identification and description of necessary functions, which provides services for all RITS users, established RITS model logically and physically by realizing interface and information flow of the subsystems achieving these functions, between various subsystems and between the external environments, defining function modules including the interfaces between modules, which include the full sub-system design to achieve customer service functions.

To sum up, the development of RITS is aimed at:

1. Specifying the development of RITS system, avoiding the duplicating research and unplanned development by relevant departments, which led to the colossal waste of funds and human resources arising thereof, ensuring the seamless operability when RITS system is integrated.
2. Providing a basis for the research and formulation of relevant standards that arose from RITS, to check the standard omission, overlap, inconsistencies and other issues.
3. Formulation of RITS system framework may increase the impact of RITS, attract concern from users, manufacturers and various experts, and promote further development of RITS. Simultaneously, the research on RITS system framework confirms the development gap between China Railway and foreign well-developed railway countries, as well as areas and direction which should give priority to

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the development to make up the gap. Additionally, the construction of demonstration projects such as minimum simulated test environment, etc. and so on will properly guide research direction of railway transportation in China.

## Research Principles and Methods of RITS System Framework

As we all know the achievement of RITS is no easy task, hence in the formulation of RITS system framework we must comply with the principles of flexibility and openness. Flexibility refers to enabling the system to possess the ability of continuous development and extension, and openness refers to open data interaction and open technical reference.

The Core of RITS development lies in the achievement of a new generation of rail transport which possesses "high-security, high efficiency, high service quality", and the main objective of Chinese RITS research lies in the achievement of the above-mentioned transport. Series of questions including what services should RITS provide and how to organize and achieve these services, concretely lies in:

1. Confirming general requirement of Chinese RITS from rail transport participants (including passengers, shippers, rail operation managers) and other relevant departments, as well as key technology areas which should give priority to the development for achieving the above-mentioned requirements;
2. Confirming China’s RITS system framework, taking "high-efficiency, high security, high-quality service" as the core, comprehensively studying general framework structure of China's RITS, analyzing basic composition of the system and inter-relationship of various components;
3. Analyzing technical and economic factors’ impact on the development of China's RITS.

Currently there are mainly two methods used for the modeling of complex information systems: procedure-oriented method and object-oriented method. Procedure-oriented approach for development describes the function of the system in respect of data flow, uses top-down and stepwise decomposition method to conduct structured analysis to the system, designs a series of function modules with mutually independent structure and single function corresponding to various types of user services, and these modules achieve inter-linkages by data flow. Method for data flow diagram (DFD) is adopted to describe the process. This method is suitable for modeling the requirements analysis phase, and its advantage lies in taking function as the center, having clear structure, and ease to understand and grasp, furthermore facilitating to actually deploy and realize. The disadvantage is that the separation of functions and data may lead to some deficiency in flexibility.

Object-oriented development method has been derived from object-oriented software engineering method It abstracts component element of system functions into object with concrete entities, attributes and capacity for action, packages function (method) and data (attributes) together, achieves system function through collaborative work between objects. It adopted Unified Modeling Language (UML) and corresponding development tools for development and expression. The method is suitable for modeling in the stage when accurate functional requirements of the system have been established and the internal logic of the system is being refined Its advantage lies in achieving the unification of functions and data, to achieve minimum dependence between objects, possessing good adaptability and scalability. Its main drawback is too abstract and inferior to understand.

Taking into account that procedure-oriented design methods have greater advantage on usability, understandability, accuracy etc., the United States and the European Union adopted procedure-oriented design method when firstly carrying out the design of ITS system framework. While ITS system framework in Japan has been formulated on the basis of appropriate reduction to ITS system framework of the United States and the European Union, functional requirement of the system is relatively clear. Design methods being object-oriented which have good flexibility have been adopted.

In view of the research on China's RITS system framework it is clear that it is the first time in the world, there is no prior experience and template to refer to and to follow. Simultaneously, requirement of RITS system framework is not very clear at the beginning of the research, and a lot of experts who are familiar with object-oriented technology are required to participate in the discussion and revision during research. Based on the above considerations, research on RITS system framework in China adopted the procedure-oriented method.

### Main Content of RITS System Framework

RITS system framework in China is mainly composed of several components including user agent, server agent, service framework, logical framework, physical framework, and tech-economy assessment, which together constitute the organic whole of RITS system framework [11]. The main content of RITS system framework is shown as (Fig. **1**).

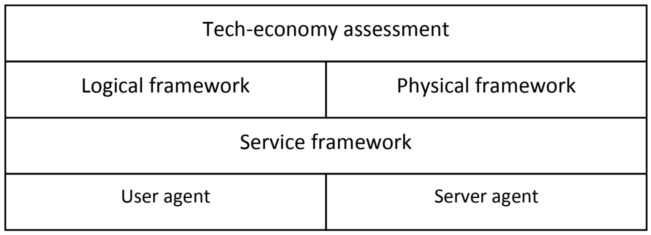


**Figure 1:** Main content of RITS system framework

User agent represent the main users of the system service (), delineating the main demand in some service field; server agent is provider of the service, providing service for user agent. Relationship between user agent and server agent is to serve and to be served with respectively The two platforms for supply and demand of RITS service field, are premise and foundation to determine RITS service framework.

The definition of service framework is the starting point to execute the design of RITS system framework. During the design of RITS service framework, we should first clear the requirements to RITS from railway external users (passengers, shippers, relevant departments, etc.) and the railway internal users (operation management department, train controlling and scheduling departments, emergency rescue department, etc.), raise the standard of services that are provided by RITS to meet users' needs, based on the analysis of requirements above. Establishment of service framework is base on hierarchical structure, with layer-by-layer refinement from the top to the bottom, and culminating in the complete definition of RITS service framework.

RITS logical framework logically describes the internal structure of RITS, that is, aiming at various types of user services confirmed by RITS service framework, to define the most reasonable source of data, data output, process, as well as an interrelation between data input, intermediate data, output data and process.

RITS physical framework describes the physical achievement of RITS It integrates various functional modules and data flow defined in logical framework defines the subsystems to achieve various types of RITS functions, as well as the interactive framework flows and their relationships between these subsystems.

Tech-economy assessment of RITS evaluates economic rationality, technical feasibility, social returns, environmental impacts and risk of RITS project, provides an integrated, comprehensive evaluation of results, and also offers the scientific basis for comparison, optimization and decision-making of specific items' feasibility study, implementation effect and program.

### Technical Route of RITS System Framework

According to the development experiences of ITS in the United States, Europe, Japan and other countries, we can see that implementation of system framework may be divided into the following steps: user service, logical framework, physical framework, common technology platform, tech-economy assessment, etc. This method has become the common approach for establishing models of transport system, whose comprehensiveness, completeness and reasonableness have passed tests in many countries and regions. Therefore, enactment of RITS system framework can be based on the method mentioned above.

Research on RITS system framework adopted a method t starting from the requirements, defining RITS service architecture and then determining necessary logical, physical architecture and technical elements constitution for the achievement of RITS service functions. As shown in (Fig. **2**), its technical route is roughly as follows [43]:

**Step1:** Planning the development of RITS, including giving common definition, target and characteristics, development principles and long-term plan for RITS.

**Step2:** Requirements of user service is the starting point for formulating RITS system framework, therefore firstly we should define user agent and server agent, and make clear the two sides in service. Secondly, according to the characteristics of China's railway transportation, we divided service areas and defined services.

**Step3:** Executing classification and combination of system functions, and formulating RITS logical architecture. Subsystems are divided according to system functions which therefore formulate RITS physical architecture.

**Step4:** Establishing system framework of common technology platform for RITS.

**Step5:** Formulating relevant standards and norms.

**Step6:** Carrying out tech-economy assessment, and providing relevant theories and preparation methods for project approval and specific implementation of RITS-related projects [11].

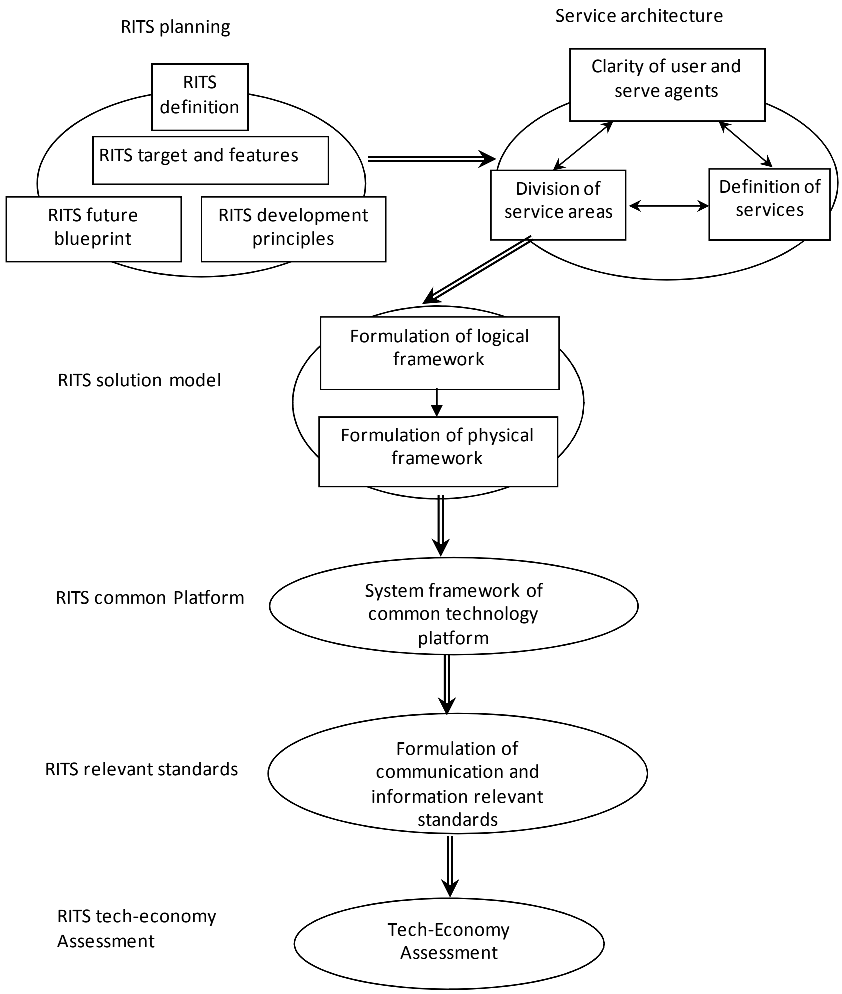


**Figure 2:** Research on technology route of RITS system framework

## MAIN COMPONENT OF CHINA'S RITS SYSTEM FRAMEWORK

### User and Server Agent

User agent of Chinese RITS is divided into two major categories that is: railway internal users and railway external users, as detailed in Table **1**. Server agent is divided into 5 main categories, as detailed in Table **2**.

**Table 1:** User agent table

| user group | users |
|---|---|
| **1. railway internal users** | Railway passenger transportation management department |
| | Railway freight transportation management department |
| | Scheduling and command department |
| | Fixed-facilities management department |
| | Mobile facilities management department |
| | Emergency and security management department |
| **2. railway external users** | Passengers |
| | Freighters |
| | Producers, Circulating merchant、Information service provider、partners etc. |
| | Other transport mode management department |

**Table 2:** Server agent table

| Server agent group | Server agent |
|---|---|
| **1. Operation management department** | Railway passenger transportation management department |
| | Railway freight transportation management department |
| | Scheduling and command department |
| | military transportation and special traffic management department |
| **2. Fixed-facilities management department** | Engineering facilities management and maintenance department |
| | Electricity facilities management and maintenance department |
| | Electricity power |
| | Railway land management department |
| **3. Mobile facilities management department** | Locomotive facilities maintenance and management department |
| | Vehicle facilities maintenance and management department |
| **4. Railway transportation information service department** | Railway basic information providing department |
| | Railway passenger real-time information providing department |
| | Railway freight tracking information providing department |
| **5. Emergency and security management department** | Railway emergency rescue center |
| | Dangerous goods management department |
| | Medical emergency center |
| | Fire protection department |

## RITS Service Framework

Referring to research experience of ITS system framework, establishment of RITS service framework starts from the analysis of user needs, and adopts modes that combine bottom-up with top-down. On the basis of more complete demand analysis, it fuses the same kinds and mines the potential demand, to formulate a clear partition of service areas and definition of the service functions for Chinese RITS. Particular research courses are as follows. First comes the definition of RITS user agent. User agent represents the main user of services, and appoints demands in some service area, which is premise and basic to execute demands analysis, define user service and user sub-service. Combined with the particular condition of Chinese railway transport, RITS user agent is divided into three categories: outside-road users (passengers, freight owners), internal-road users (operation management department, scheduling management department and security management department), and relevant departments (roads ITS, water ITS and aviation ITS, etc.). Then come the demands analysis of user agent, and users' demands. Demand analysis is an important basis to divide RITS service areas, and also one of the key elements for assurance of RITS success. The task of demand analysis is to illustrate what kind of system functions and system characteristics are needed by users from the users' point of view. User demand, as the basis of user services and definition of sub-service, is consequently the most important work during the stage of user services definition. When executing demand analysis for Chinese railway transportation system, we adopt the following principles:

1. Combination of recent demands and the long-term demands RITS is a system involving all levels of rail transport and having a very complex running behavior. Establishment of such systems usually requires a longer time to obtain basic achievement, which requires enough foreseeing ability while carrying out system design. At the same time, in order to maintain the stability and instructiveness of whole system framework, and minimize the impact to entire RITS system framework from the ever-changing user demands and ever-developing technologies, we should take into sufficient consideration the current user needs and the needs which may arise in future with the development and maturity of technologies.
2. Combination of bottom-up and top-down strategies; In the analysis of user demands, we adopt bottom-up and top-down strategies, which implies starting from the needs of transportation, maintenance, public works, electrical works, each vehicles business department, in accordance with bottom-up order, proposing initial RITS users demand. Then the goal-driven analysis method is adopted, in accordance with top-down order and objectives of RITS "high-security, high-efficiency, high-quality service", to identify complete and accurate user demands of RITS.
3. Sufficient learning experiences from foreign large-scale ITS systems construction; United States, Japan, Europe and other developed countries and regions have been engaged in research on ITS system framework as early as the late 90's of last century, continuously proposing improved version, and the current ITS services area division has formed a set of international standards. Proposing of these results provided the basis for research on RITS service framework.
4. Combination of demand summary, analysis and demand excavation; RITS demand analysis serves not only for the recent RITS construction, but also for planning of RITS after decades. Consequently, when conducting demand summary, it is not simply the classification and division to present demands, but deep excavation into current demand to propose a demand analysis which meets the present development stage and profits the demand analysis for future planning, combined with future technological development, national policy directions of transportation, change of future travel, etc. Finally, according to the user demand analysis results, we define users service, which is to satisfy services provided by RITS user demands The bridge combines user's demand and system function, with the basis for establishment being logical framework and physical framework.

Revolving around three high targets such as" high-quality services, high-security, high-efficiency" of RITS, RITS is divided into the following seven service areas [43], as shown in (Fig. **3**).

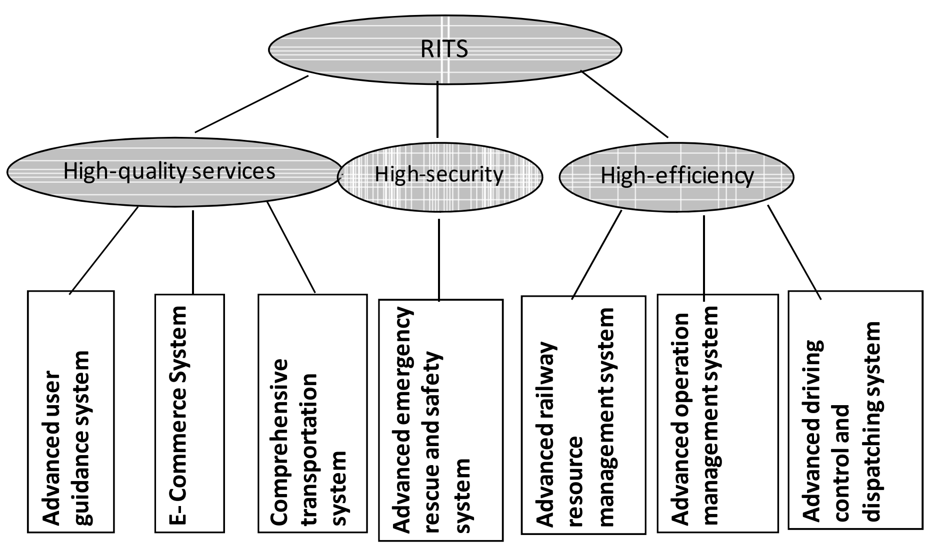


**Figure 3:** RITS seven service areas

At the same time, the above service areas are subdivided into 22 service sub-areas, as shown in Table **3**.

**Table 3:** Sub-service areas

| | Servers unit | Sub-server |
|---|---|---|
| | Advanced user guidance system | 1.1 To provide information and assistant decision-making services before passengers traveling and freighters consigning.<br>1.2 To provide information and assistant decision-making services when passengers are in the train and freighters on the way.<br>1.3 Passengers station guidance services |
| 1. | E-commerce System | 2.1 Passenger e-commerce<br>2.2Railway e-commerce transaction platform<br>2.3 Freight e-commerce |
| 2. | Comprehensive transportation system | 3.1 Intermodal foundational transportation data sharing<br>3.2 lntermodal transport decision-making |
| 3. | Advanced emergency rescue and safety system | 4.1 Advanced emergency rescue system<br>4.2 Train operation safety and maintenance decision<br>4.3 Railway integrated disaster prevention<br>4.4 Accommodation crossing monitoring |
| 4. | Advanced railway resource management system | 5.1 Transportation resource management<br>5.2 Transportation resource maintenance management system<br>5.3 Financial management |
| 5. | Advanced operation management system | 6.1 Passengers management<br>6.2 Freight and container management<br>6.3 Intelligent marshalling station system |
| 6. | Advanced driving control and dispatching system | 7.1 Intelligent train control<br>7.2 Integrated dispatching control<br>7.3 Station control |

## RITS Logical Framework

### *Description Method of the Logical Framework*

Logical framework describes RITS internal structure from logical point of view, that is, various kinds of user services are determined according to RITS service framework. It carries out structural organization to input data stream, output data stream and processing from the system inside. Construction of logical framework does not consider the management system and technical factors; it only determines functions of the system, regardless of who will achieve the function and how to achieve it, with concrete implementing work handed to physical framework. Separation from concrete implementing of the system makes it easier to improve the logical framework, having relatively better stability and supporting designs of widely different systems.

Logical framework is usually described by hierarchical data flow diagram (DFD). Hierarchical data flow diagram (DFD) is a modeling tool for structured process which describes decomposition. It can clearly describe data flow, data changes, processing performed by system, etc. with intuitive graphical. Hierarchical DFD diagram usually consists of the top, bottom and a number of middle layers. The structural representation of hierarchical DFD diagram is shown as (Fig. **4**). The top diagram shows the system boundary, which is input and output data stream of the system. The bottom diagram is composed of a number of non-decomposable processing. The middle layer describes decomposition of some handling process; simultaneously, its component element still needs further decomposition. Each layer of DFD diagram is usually composed of elements such as data stream, processing, entities, data storage, etc.

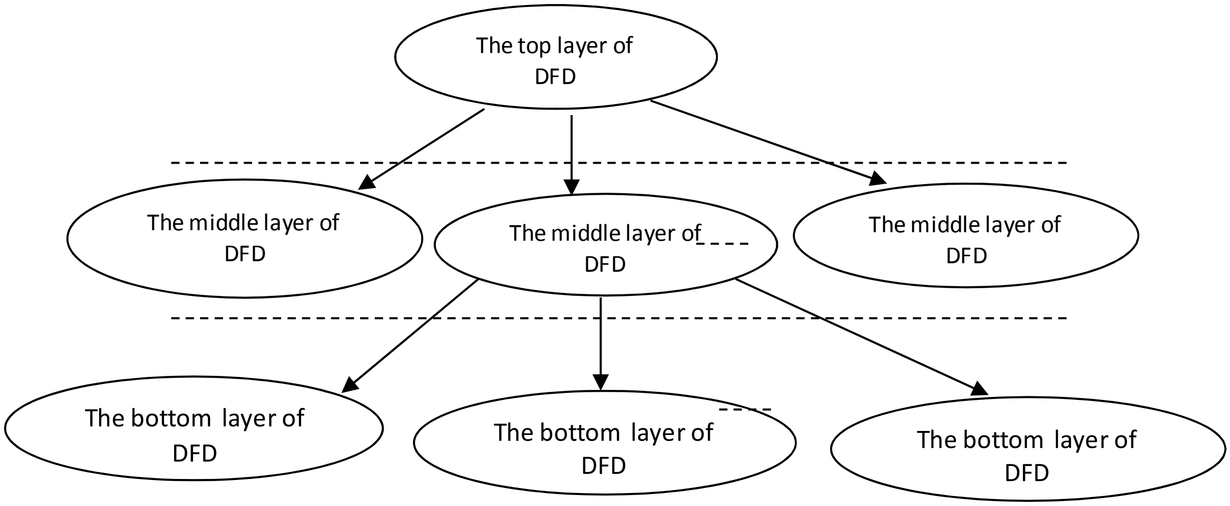


**Figure 4:** Structural representation of hierarchical DFD diagram

Data flow is a set of data flowing direction with arrows, and the information transmitted among handling processes as well as information between handling process and terminals in the logical framework. In the data flow diagram, data flow is expressed as an arrow and executes definition in data dictionary of logical framework. According to the principle that starting-point and terminus are the same, data flows are integrated to formulate the framework flow of logical framework. Handling is processing of data, performing the functions to be implemented, in form of the circle. Entity is the source point or terminus of data flow, performed by pane. Entity defines the system boundary, sends information to the subsystem in RITS or receives information from the subsystem. Data storage indicates the data storage location, indicated by a cylindrical.

### *Steps to Establish Logical Framework*

Based on the definition of RITS service framework, logical framework provides ordered organization of system functions and data flow. The establishment of logical framework is divided into the three following steps:

1) According to the function demands analysis, build function layer table;

Function demands analysis executes analysis from the point of view of system, to obtain RITS functions needed for providing user service. Based on function demands analysis, we collate and summarize the results of demands analysis, combine the similar functions aimed at different user agents, carry out the division of functional domain to service area, which will be the main basis for the construction of logical framework.

2) According to function level table, build top-level data flow diagram of the system.

According to the relationship between system and the external environment, we determine the data flow between entities of the top-level data flow diagram as well as the data flow between the systems. Still taking advanced emergency rescue and security system as an example, the top-level data flow diagram is as follows.

3) Combined with function layer table, in accordance with the principle of "strong cohesive, loosely coupled", we implement refinement to processing functions and data flow. Even if the connection between each sub-function decomposed is relatively loose and simple, the connection within various parts of sub-function is relatively close and complex. Simultaneously during the process of refinement, we try to keep the balance of data flow diagram at all levels, and gradually generate the next level of data flow diagram.

Top-level structure of Chinese RITS logical framework is shown in Fig. **8**, and the most important content of logical framework is the description of system functions and the data flow between functions.

## RITS Physical Framework

Physical framework assigned the definition process of logical framework to RITS physical entities, and in accordance with data flow included the entities of various processes, to determine the framework flow among entities, and thus determine interconnection mode of physical entities. Determination of the physical entities considers not only the functional demands, but also the non-functional demands which include management system and market factors, etc. Functional demands are embodied by determined logical framework process and data flow, which determine the function that must be completed by RITS physical entities on functional demands affect distribution mode of RITS function on the physical entities. This research describes various parts of the physical framework from the perspective of the systems and sub-systems. Firstly, we adopt physical architecture context diagram (PACD) to describe the relationship among each system, external users and environment, to determine their mutual information exchange relationship. Secondly, we describe the corresponding relationship between physical framework and logical framework. Finally, we determined physical structure information flow which needs to be exchanged between subsystems, as well as adopted what type of communication means may help to achieve information exchange. The research divided physical framework of RITS into 5 sub-systems, namely: the user subsystem, the central management subsystem, the station subsystem, the trackside subsystem, the train subsystem.

### *The User Subsystem*

User subsystem serves all users of RITS, mainly responsible for the management of the user interface, and is the means for an exchange between system user and system information. It receives various input requests from users mainly through the internet, fax, telephone, mobile phone, etcThen the system response to user requests and implements appropriate action, simultaneously showing results to users.

### *The Central Management Subsystem*

Central management system completes the main function for RITS, including user navigation and e-commerce, inter-modal transportation, emergency rescue and maintenance management, train control and integrated dispatching, operation management, transportation resources management and maintenance system.

- User navigation and e-commerce system

  Based on internet and e-commerce, freight service system, passenger presale ticket system and traveler service system provide users various passenger and freight service information accurately on time, to meet the requirements of users as much as possible, providing a variety of convenient and high-quality services.

- Inter-modal transportation System

  It achieves data sharing and joint transportation with other transportation modes, to actually achieve door-to-door transport.

- Emergency rescue and maintenance management system

  Its goals are safety and unblocked railway transportation, timely and accurately collecting and processing related railway transportation information including weather, disasters, accidents, equipment faults and so on, rapidly carrying out rescue and dealing with railway transportation incidents, executing railway disaster prevention and remediation. It mainly completes functions such as railway accident rescue and treatment, railway disaster prevention, detection for railway transportation infrastructure condition, railway transportation security information management, etc.

- Transportation resource management and maintenance system

  It efficiently manages the railway transportation resources and facilities as which mainly include railway equipments and lines in good condition and maintenance, collection of repair demands information, formulation of processing and management programs. It includes the line (including bridges, tunnels, etc.) facilities management system, rolling stock management system, electrical facilities management system, station facilities management system, traction and power supply facilities management system, human resources management system, financial management system, materials management systems and plan management system.

- Operation management and marketing decision-making system

  Through information management of freight yard, freights, vehicles, containers etc. on, the system executes decision-making for loading and unloading of vehicles and train operation plans, dynamically adjusts the vehicles flow distribution of railway network to achieve the harmonious unity of logistics management and transportation plan, raises the level of transportation decision-making, and improves transportation producing efficiency. Through information management of passenger flow and ticket sales, the system improves the decision-making level of passenger transportation organizations to ensure the safety and punctuality of passenger transportation; reasonably compiles passenger transportation plans; and provides solutions to organizations transportation program for passenger flow in different periods under the imbalance condition, generating various transportation programs intelligently.

- Intelligent train control and the integrated dispatching system

  This system intelligently controls trains operation, and realizes automatic driving of trains. According to trains' operation conditions, various equipments related to train operation and external environment, the system organizes trains operation and carries out control of related equipments to ensure safe operation of trains according to the plan, in order to improve the transportation efficiency.

***Station Subsystem***

Station is the basic operation unit of RITS, and the station subsystem is the key to achieve intelligent stations operation. According to the type of operation, the station is divided into the passenger station, freight station, and marshalling station; the station subsystem includes:

a. Station signal interlocking control system;
b. Signal detection system;
c. Marshalling station hump operation system;
d. Freight station operation system;
e. Passenger information automatic processing system;
f. Luggage operation system;
g. Railway ticket booking and presale system (PMIS);
h. Automatic ticket checking system;
i. Freight reservation system;
j. Freight query system;
k. Train number recognition system;
l. Container management system;
m. Railway Transportation Management Information System (TMIS);
n. Dispatching Management Information System (DMIS);
o. Car Management Information System (CMIS);
p. Passenger enquiry system;
q. E-commerce system.

***Trackside Subsystem***

Trackside subsystem is the source of foundation-information to obtain information from detecting equipment, signal machine, track circuits, transponders laid along the track, mainly including: disaster monitoring system (weather, earthquakes, landslides, etc.), accident scene monitoring system, mobile devices monitoring system, fixed equipment monitoring system, the sending and receiving unit of track circuits, signal control unit, etc;

### *Train Subsystem*

The train subsystem is used to achieve trains information and train control, mainly including: mobile devices monitoring system, on-vehicle information services and decision-making system, on-vehicle train control systems, on-vehicle communication system, on-vehicle e-commerce system, etc. [46]. Physical framework is the concrete realization of logical framework. Top structure of Chinese RITS physical framework is shown in (Fig. **5**).

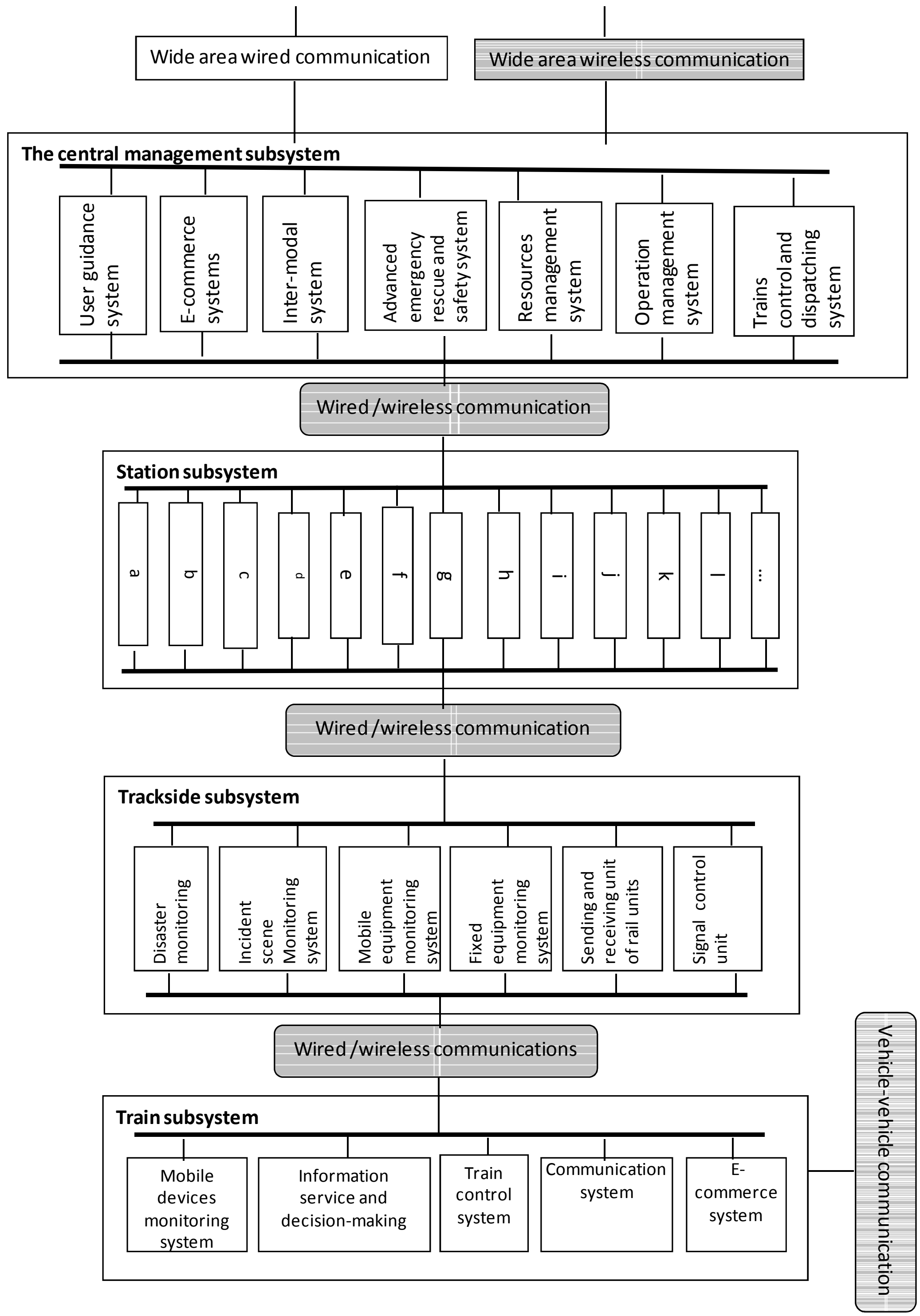


**Figure 5:** RITS overall physical framework.

## INTELLIGENT EMERGENCY RESCUE AND SAFETY SYSTEM FRAMEWORK

### Service Framework of Intelligent Emergency Rescue and Safety System

| User agent | Users' demands for RITS |
|---|---|
| Emergency Rescue and Safety Department | 1. Transmitting dynamic images to the local administrative department by GIS technology, strengthening real-time monitoring to the rescue situation on site. Establishing emergency incidents information database and rescue knowledge database, providing assistant decision-making support for emergency rescue disposal. Optimizing the dispatch, command and rescue equipments and making fault analysis after accidents have occurred.<br>2. Monitoring equipments situation periodically and effectively, which are directly related to train safety, including locomotives, trains, lines, bridges, tunnels, communication signals, intersections, etc. Establishing entire-road safety database to manage the mentioned-above information. Building safety standard and estimating safety conditions for equipments working condition based on the entire-road safety databases in order to grasp the entire-road safety situation. Establishing maintenance decision-making support system and proposing maintenance decision-making proposals for the mobile and fixed equipments to management department according to risk level in assessment results.<br>3. Establishing and maintaining the entire-road comprehensive disaster-prevention database with GIS, including the line-side environmental background gallery, line-side specific map gallery of disasters like earthquake, debris flows, landslides, collapse, frozen soil, and sand wind etc., line engineering drawings, scatter gram of disaster prevention engineering and disaster prevention material reserve places, scatter gram of all kinds prediction and early warning equipments. Monitoring real-time disaster data, providing prediction and estimation of disaster including earthquake, debris flows, wind speed, landslides, rainfall and water level. Deeply mining the system space database and providing disaster prediction and assessment by establishing applied analysis model including prediction model, disaster mitigation decision-making model and disaster evaluation model. Meanwhile, through the accidents simulation provide assistant support for accident prevention and analysis. Providing decision support for places where disasters occur frequently. Secondly, providing effective rescue decision support after disasters oumed.<br>4. Using (GIS technology) video or laser to make real-time monitoring on the situation of Road-rail Level crossing and transmitting images and data to related department. Estimating safety situation of road-rail level crossing by image identification technology to ensure safety. |

| Service unit | Service content | User agent | Service agent |
|---|---|---|---|
| 7. Advanced emergency rescue and safety system | Monitoring railway transportation recourses dynamically, managing railway operation safety information, and making decisions to railway comprehensive disaster prevention and emergency rescue, including emergency rescue and management, train safety and maintenance support, railway comprehensive disaster prevention and Road-rail Level crossing monitoring etc. | Passengers, consignor, transportation management department, emergency rescue center, medical institution | Transportation management department, emergency rescue center, medical institution, fire department |
| 7.1 Emergency incidents rescue and dispose | Locating the accident spot accurately by LBS technology, and rapidly providing related information like terrain, human landscape, hydrology, medical institutes and fire departments around the accident spot by GIS technology.<br>Transmitting dynamic images and related condition on the accident spot on time and accurately to the administrative department by data and image transmission technology. | | |

| | |
|---|---|
| | Establishing emergency information database and rescue knowledge database, and providing assistant decision-making support for rescue plans by intelligent analysis.<br>Using various output functions to allocate resources reasonably, optimizing the dispatch, command and rescue equipments, choosing proper rescue routes, providing emergency rescue and maintenance service, and making fault analysis after the accidents have occurred. |
| 7.2 Train safety and maintenance decision-making support | Using advanced traffic safety monitoring system to carry out timely or real-time intelligent monitoring of the equipments condition of locomotives, trains, routes, bridges, tunnels, communication signals, road-rail level crossings that are related to the train safety directly. Through the information collection, transmission and acquisition, establishing the entire-road safety database and managing the information mentioned-above by the train safety information system to make the equipments related to train safety under monitoring.<br>Building safety standard, making intelligent analysis for various kinds of data by the train safety system and estimating safety condition for various kinds of equipments to grasp the entire-road safety conditions.<br>Establishing maintenance decision-making support system, relaying on time the maintenance decision-making proposal on mobile equipments and fixed equipments to the management department according to the danger level of assessment result, and improving pertinence and efficiency of maintenance.<br>Building automatic maintenance system to transfer detailed inspection data and proposal about the maintenance decision to the station through computer data interface. With the establishment of the maintenance management of the computer network, analyzing and handling the faults and providing potential safety of hidden danger. |
| 7.3 Railway comprehensive disaster prevention | Establishing and maintaining the entire-road comprehensive disaster prevention database with GIS, including the line-side environmental background gallery, line-side specific map gallery of disasters like earthquake, debris flows, landslides, collapse, frozen soil, sand wind and etc., line engineering drawings, scatter gram of disaster prevention engineering and disaster prevention material reserve places, scatter gram of all kinds of prediction and early warning equipments.<br>Monitoring real-time disaster data, providing prediction and estimation of disaster including earthquake, debris flows, wind speed, landslides, rainfall and water level. Deeply mining the system space database and providing disaster prediction and assessment by establishing applied analysis model including prediction model, disaster mitigation decision-making model and disaster evaluation model. Providing decision-making support of disaster prevention for the places where disaster occurs frequently. And providing effective rescue decision-making support after disasters have happened.<br>Meanwhile, through the analog simulation of accidents, provide assistant support for accident prevention and analysis. |
| 7.4Road-rail level crossing monitoring | Using video or laser to make real-time monitoring on the condition of road-rail level crossing. Transmitting images and data to related department by using technologies such as the data transmission and network. Estimating safety condition of road-rail level crossing by image identification technology. Sending the information of the level crossing condition to trains on time and disposing the dangerous factors of the level crossing in order to ensure safety. |

## LOGICAL FRAMEWORK OF INTELLIGENT EMERGENCY RESCUE AND SAFETY SYSTEM

### Function Table

| “Logical framework of Intelligent Emergency Rescue & Safety System ” DFD4 | | |
|---|---|---|
| **Function field** | **The first function layer** | **The second function layer** |
| 4.1 Emergency rescue | 4.1.1 Making decision of emergency rescue | 4.1.1.1 Information collection of accident spot |
| | | 4.1.1.2 Information collection of rescue resources |
| | | 4.1.1.3 Making decision of rescue |

| | | |
|---|---|---|
| | 4.1.2 Management of emergency rescue | 4.1.2.1 Providing staff interface of emergency rescue |
| | | 4.1.2.2 Emergency train dispatching |
| | | 4.1.2.3 Emergency material providing |
| | | 4.1.2.4 Resource and equipment preparation |
| | | 4.1.2.5 Emergency rescue and maintenance service |
| | 4.1.3 Information release and operation platform of emergency rescue | 4.1.3.1 Information release of emergency rescue |
| | | 4.1.3.2 Providing material of train operation and emergency accidents |
| | | 4.1.3.3 Update information of rescue progress |
| | | 4.1.3.4 Unified management of materials of emergency accidents |
| 4.2 Train safety and maintenance decision support | 4.2.1 Real-time collection of various safety data | 4.2.1.1 Real-time collection of data of ground- to-train monitoring |
| | | 4.2.1.2 Real-time collection of data of ground- to-ground monitoring |
| | | 4.2.1.3 Real-time collection of data of train-to -train monitoring |
| | | 4.2.1.4 Real-time collection of data of train-to- ground monitoring |
| | 4.2.2 Management center of safety data | 4.2.2.1 Collecting fundamental data |
| | | 4.2.2.2 Storage and real-time update of safety monitoring data |
| | | 4.2.2.3 Management of safety monitoring data |
| | | 4.2.2.4 Inquiry of safety monitoring data |
| | | 4.2.2.5 Statistical analysis of safety monitoring data |
| | 4.2.3 Safety assessment | 4.2.3.1 Building safety standard |
| | | 4.2.3.1 Establishing statistical model of safety monitoring data |
| | | 4.2.3.2 Estimating safety condition |
| | | 4.2.3.3 Providing intelligent decision |
| | 4.2.4 Maintenance decision support | 4.2.4.1 Establishing maintenance knowledge model |
| | | 4.2.4.2 Providing maintenance decision support |
| | 4.2.5 Automatic maintenance | 4.2.5.1 Receiving data and maintenance decision |
| | | 4.2.5.2 Failures analysis |
| | | 4.2.5.3 Eliminating safety hidden dangers |
| 4.3 Railway comprehensive disaster prevention | 4.3.1 Real-time collection of natural disaster information | |
| | 4.3.2 Unified management of disaster information | |
| | 4.3.3 Real-time monitoring of natural disaster | |
| | 4.3.4 Establishing applied analysis model and provide disaster prediction and assessment | |
| | 4.3.5 Providing decision support of disaster prevention and disaster rescue | |
| | 4.4.1 Collecting condition information of Road-rail Level crossing | |
| | 4.4.2 Monitoring road-rail level crossing | |
| | 4.4.3 Estimating safety condition | |
| | 4.4.4 Information release of Road-rail Level crossing | |
| | 4.4.5 Disposing safety hidden dangers | |

## DATA FLOW DIAGRAM

Advanced emergency rescue and safety system is composed of 4 functional fields: emergency rescue, train safety and maintenance decision support, railway comprehensive disaster prevention, and road-rail level crossing.

Emergency rescue is composed of 3 data flow diagrams and 10 processes. The 3 data flow diagrams are emergency rescue decision, emergency train dispatching, and emergency rescue information release and operation platform.

Train safety and maintenance support are composed of 4 data flow diagrams and 14 processes. The 4 data flow diagrams are real-time collection of various kinds of safety data, safety data management center, safety assessment and maintenance decision support.

Railway comprehensive disaster prevention is composed of 1 data flow diagram and 4 processes.

Road-rail Level crossing monitoring is composed of 1 data flow diagram and 4 processes.

Details are given in from Fig **9** to Fig. **21**.

## PROCESS DEFINITION DIAGRAM

| Process No. | Process name | Process description | Inputting data flow | Outputting data flow |
|---|---|---|---|---|
| PS 4.1.1.1 | Collecting related information of accident spot | Collecting information of accident spot, such as the site and the surrounding circumstance of accident spot, train damage condition, route damage condition, communication signal damage condition, staff and freight condition, dangerous goods information, nearby trains information, accident freight characteristic, causes of accident, etc. | Site and surrounding circumstance of accident spot, train damage condition, route damage condition, communication signal damage condition, staff and freight condition, dangerous goods information, nearby trains information, accident freight characteristic, causes of accident, application of data providing. | Response of data providing |
| PS 4.1.1.2 | Collecting related information of rescue resource | Collecting information of rescue resource, such as distribution of rescue train, distribution of rescue unit, rescue staff condition, rescue equipment condition, rescue material condition, road network condition | Distribution of rescue train, distribution of rescue unit, rescue staff condition, rescue equipment condition, rescue material condition, road network condition, application of data providing. | Response of data providing |
| PS 4.1.1.3 | Making rescue decision | Providing rescue decision according to information of accident spot | Data inquiry results, weather condition, route condition, rescue attentions. | Freight and staff processing approach, traffic control approach, and works rescue approach, electric work rescue approach, train rescue approach, danger goods processing approach. |
| PS 4.1.1.4 | Related information management of accident spot | Managing related information of accident spot | Data export | Data logging |
| PS 4.1.1.5 | Related information management of rescue resources | Managing related information of accident spot | Data export | Data logging |
| PS 4.1.2.1 | Providing interface emergency rescue staff | Providing data input, inquiry and interface for emergency rescue staff by the usage of telephone, mobile telephone and display screen | Information of accident spot, rescue decision, dispatching command | |

| | | | | |
|---|---|---|---|---|
| PS 4.1.2.2 | Dispatching emergency trains | Generating dispatch-plan of rescue trains by intelligent optimization technology | Road network condition, climate condition, emergency dispatching request | Dispatching plan of rescue trains, emergency dispatching response |
| PS 4.1.2.3 | Emergency material providing | Generating emergency material providing approach according to intelligent decision | Emergency material providing request, material supply source condition | Emergency material providing approach, emergency supply response |
| PS 4.1.2.4 | Resource equipment allocation | Generating resource equipment allocation approach according to intelligent decision | Resource equipment allocation request, resource equipment condition | Resource equipment allocation approach, resource equipment allocation response |
| PS 4.1.2.5 | Rescue maintenance service | Generating rescue maintenance service approach according to intelligent decision | Rescue maintenance service request | Rescue maintenance approach, rescue maintenance service response |
| PS 4.1.3.1 | Updating information of accident spot | Updating information of accident spot and information of rescue progress | Updating request of accident material | Accident material updating response, information of the scene of rescue |
| PS 4.1.3.2 | Providing train operation and emergency accident material | Providing material of related accident train operation an emergency accident | Data inquiry request | Data inquiry result, accident causes, accident condition, accident time and spot, accident rescue approach |
| PS 4.1.3.3 | Emergency rescue information release | Issuing emergency rescue information to the departments of vehicles, aircraft, engineering, electricity, transport and passengers | Information of accident spot | Train rescue information, engineering district rescue information, communication and signal district information, spot rescue information, passenger rescue information, freight condition, real-time rescue information, rescue result |
| PS 4.1.3.4 | Unified management of emergency accident material | Centralized management of related material of emergency accident | Accident causes, accident condition, accident time and spot, accident rescue approach, rescue result, data inquiry request | Data inquiry result |
| PS 4.2.1.1 | Real-time collection of data of ground-to-train monitoring | Collecting data by ground-to-train monitoring | Train operation condition, freight safety door information, station level aisle condition | |
| PS 4.2.1.2 | Real-time collection of data of ground-to-ground monitoring | Collecting data by ground-to-ground monitoring | Switching statue data, switching capacity monitoring data, switching electrical appliance characteristic data, station black box data | |
| PS 4.2.1.3 | Real-time collection of data of train-to-train monitoring | Collecting data by train-to-train monitoring | Train operation safety information, locomotive operation monitoring data, locomotive failure monitoring data | |
| PS 4.2.1.4 | Real-time collection of data of train-to-ground monitoring | Collecting data by train-to-ground monitoring | Infrared axle temperature detection car data, comprehensive detection car data, locomotive signal analyzer data, track inspection car data, flaw detection car data. | |
| PS 4.2.2.1 | Data real-time update | Various monitoring data real-time update | Engineering district monitoring data, communication and signal district monitoring data, locomotive depot monitoring data, train operation depot monitoring data, data providing application | Data providing response |
| PS 4.2.2.2 | Collecting related fundamental data | Collecting line side fundamental data | Road network material, line side landform and physiognomy, safety standard specification, train basic information, other equipments information, information providing application | Information providing response |

| | | | | |
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| PS 4.2.2.3 | Safety monitoring data inquiry | Providing data inquiry for engineering district, communication and signal district, locomotive depot and train operation depot. | | Locomotive depot monitoring data, engineering district monitoring data, communication and signal district monitoring data, train operation depot monitoring data |
| PS 4.2.2.4 | Safety monitoring data statistical analysis | Carrying out statistical analysis of safety monitoring data | | Locomotive depot statistical report, train operation depot statistical report, engineering district statistical report, communication and signal district statistical report |
| PS 4.2.2.5 | Related fundamental data management | Managing related fundamental data information | Data export | Data logging |
| PS 4.2.3.1 | Establishing safety data statistical model | Establishing safety data statistical model according to historical data by intelligent modeling method | Model providing application, locomotive failure inspection report, locomotive safety monitoring information, signal failure inspection report, signal monitoring information, road network material, line side landform and physiognomy, safety standard specification, route failure inspection report, route safety monitoring information, train operation depot failure inspection report, train operation depot safety monitoring information | Model providing response |
| PS 4.2.3.2 | Evaluate safety condition | Evaluate system safety level, predict system safety trend | Real-time monitoring information | Safety level evaluation result, safety trend prediction |
| PS 4.2.3.3 | Providing intelligent decision | Providing assistant decision by intelligent decision method for system safety tactic | Real-time monitoring information, experts' experience | Fault regularity, safety early warning, speed-limit or operating-stop disposal, safety policy setting disposal |
| PS 4.2.4.1 | Establishing maintenance knowledge model | Establishing maintenance knowledge model according to historical information and experts' experience by intelligent method | Various kinds of transport resources curriculum vitae, historical data, original inspecting record, other related information, experts' knowledge, failure phenomenon, accident file material, accident management report, model providing application | Model providing response |
| PS 4.2.4.2 | Providing maintenance decision support | Based on technology files and maintenance files, providing maintenance plan and tactic by knowledge model | Locomotive technology files, locomotive maintenance files, locomotive operation report, signal technology files, signal maintenance files, route technology files, route maintenance files, real-time safety monitoring data, failure regularity, safety level | Locomotive maintenance plan, train maintenance plan, signal system maintenance plan, engineering district maintenance plan |
| PS 4.3.1 | Real-time collection of natural calamities information | Real-time collected natural calamities information include: earthquake data, debris flow information, wind speed data, landslide information, rainfall information, water level information, etc. | Data providing application, earthquake data, debris flow information, wind speed data, landslide information, rainfall information, water level information | Data providing response |
| PS 4.3.2 | Unified management of disaster information | Carrying out unified management of various kinds of natural calamities information | Data export | Data logging |

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|---|---|---|---|---|
| PS 4.3.3 | Establishing applied analysis model | Establishing disaster prediction model, disaster mitigation decision model, disaster evaluate model | Model providing application | Disaster prediction model, disaster mitigation decision model, disaster evaluate model, model providing response |
| PS 4.3.4 | Providing disaster prevention and rescue decision support | Providing disaster prevention and rescue decision support | | Disaster prevention decision, disaster rescue decision, disaster prediction method |
| PS 4.4.1 | Collecting related information of road-rail Level crossing condition | Collecting road-rail Level crossing safety condition information | Level crossing traffic condition, control device condition, Level crossing congestion information, track condition, line side equipment condition, Level crossing accident information, information release application, information providing application | Information providing response, information release response |
| PS 4.4.2 | Monitoring road-rail Level crossing condition | Monitoring road-rail Level crossing condition | | Tracking maintenance disposal, control device maintenance disposal, safety information, accident information, monitoring information |
| PS 4.4.3 | road-rail Level crossing information release | Release road-rail Level crossing information | | Road traffic information, train driving near information, train driving out information, train send road-rail Level crossing information to trains |
| PS 4.4.4 | road-rail Level crossing dangerous factor management | Managing dangerous factor of road-rail Level crossing according to monitoring information and disposal | Tracking maintenance disposal, control device maintenance disposal, safety information, accident information, monitoring information | Road hidden danger management, track hidden danger management, other hidden danger management |
| PS 4.4.5 | Related information management of road-rail Level crossing | Managing related information of road-rail Level crossing | Data export | Data logging |

## DATA FLOW DEFINITION DIAGRAM

| No. | Data flow name | Start point | End point | Introduction |
|---|---|---|---|---|
| 1 | Emergency rescue response | DFD4.1 | DFD4.2 | Emergency rescue management provides emergency rescue response for train safety monitoring |
| 2 | Emergency rescue request | DFD4.2 | DFD4.1 | Train safety monitoring makes emergency rescue request for emergency rescue management |
| 3 | Emergency rescue response | DFD4.1 | DFD4.4 | Emergency rescue management provides emergency rescue response for railway comprehensive disaster prevention |
| 4 | Emergency rescue request | DFD4.4 | DFD4.1 | Railway comprehensive disaster prevention makes emergency rescue request for emergency rescue management |
| 5 | Emergency rescue response | DFD4.1 | DFD4.5 | Emergency rescue management provides emergency rescue response for Road-rail Level crossing safety monitoring |
| 6 | Emergency rescue | DFD4.5 | DFD4.1 | Road-rail Level crossing safety monitoring |

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|---|---|---|---|---|
| | request | | | makes emergency rescue request for emergency rescue management |
| 7 | Maintenance decision response | DFD4.3 | DFD4.2 | Maintenance decision provides maintenance decision response for train safety monitoring |
| 8 | Maintenance decision request | DFD4.2 | DFD4.3 | Train safety monitoring makes maintenance decision for maintenance decision |
| 9 | Safety monitoring data | DFD4.2 | DFD4.3 | Train safety monitoring provides safety monitoring data to maintenance decision |
| 10 | Safety level | DFD4.2 | DFD4.3 | Train safety monitoring provides safety level to maintenance decision |
| 11 | Maintenance decision response | DFD4.3 | DFD4.5 | Maintenance decision provides maintenance decision response for Road-rail Level crossing safety monitoring |
| 12 | Maintenance decision request | DFD4.5 | DFD4.3 | Road-rail Level crossing safety monitoring makes maintenance decision request for maintenance decision |
| 13 | Intersection monitoring data | DFD4.5 | DFD4.3 | Road-rail Level crossing safety monitoring provides intersection monitoring data for maintenance decision |
| 14 | Emergency rescue response | DFD4.1.1 | DFD4.1.3 | Making emergency rescue decision provides emergency rescue response for emergency rescue information release and operation platform |
| 15 | Emergency rescue request | DFD4.1.3 | DFD4.1.1 | Emergency rescue information release and operation platform make emergency rescue request for making emergency rescue decision |
| 16 | Emergency rescue plan | DFD4.1.1 | DFD4.1.2 | Making emergency rescue decision provides emergency rescue plan for emergency rescue |
| 17 | Emergency rescue processing condition | DFD4.1.2 | DFD4.1.1 | Emergency rescue make information inquiry of emergency rescue processing condition for making emergency rescue decision |
| 18 | Resource and staff allocation information | DFD4.1.2 | DFD4.1.3 | Emergency rescue gives resource and staff allocation information for emergency rescue information release and operation platform |
| 19 | Material supply information | DFD4.1.2 | DFD4.1.3 | Emergency rescue provides material supply information for emergency rescue information release and operation platform |
| 20 | Train dispatching information | DFD4.1.2 | DFD4.1.3 | Emergency rescue provides train dispatching information for emergency rescue information release and operation platform |
| 21 | Rescue processing information | DFD4.1.2 | DFD4.1.3 | Emergency rescue provides rescue processing information for emergency rescue information release and operation platform |
| 22 | Information providing response | PS4.1.1.1 | PS4.1.1.4 | "Collecting Accident Spot Related Information" process provides information providing response for "Accident Spot Related Information Management" process |

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| 23 | Information providing application | PS4.1.1.4 | PS4.1.1.1 | “Accident Spot Related Information Management” process applies to “Collect Accident Spot Related Information” process for information application |
| 24 | Data logging | PS4.1.1.4 | Accident spot data storage | “Accident spot Related Information Management” process inputs data into accident spot data storage |
| 25 | Data export | Accident spot data storage | PS4.1.1.4 | Accident spot data storage exports data to “Accident Spot Related Information Management” process |
| 26 | Data inquiry request | PS4.1.1.3 | Accident spot data storage | “Making Rescue Decision” process makes data inquiry request for accident spot data storage |
| 27 | Data inquiry result | Accident spot data storage | PS4.1.1.3 | Accident spot data storage provides data inquiry result for “Making Rescue Decision” process |
| 28 | Information providing response | PS4.1.1.2 | PS4.1.1.5 | “Collect Accident Spot Related Information” process provides information inquiry response for “Accident Spot Related Information Management” process |
| 29 | Information providing application | PS4.1.1.5 | PS4.1.1.2 | “Collect Accident Spot Related Information” process provides information inquiry application for “Accident Spot Related Information Management” process |
| 30 | Data logging | PS4.1.1.3 | Rescue resources data storage | “Making Rescue Decision” process inputs data into rescue resources data storage |
| 31 | Data export | Rescue resources data storage | PS4.1.1.3 | Rescue resources data storage exports data to “Making Rescue Decision” process |
| 32 | Data inquiry request | PS4.1.1.3 | Rescue resources data storage | “Making Rescue Decision” process makes data inquiry request for rescue resources data storage |
| 33 | Data inquiry result | Rescue resources data storage | PS4.1.1.3 | Rescue resources data storage provides data inquiry request for “Making Rescue Decision” process |
| 34 | Emergency supply response | PS4.1.2.3 | PS4.1.2.1 | “Emergency Material Supply” process provides emergency supply response for “Provide Emergency Rescue Staff Interface” process |
| 35 | Emergency supply request | PS4.1.2.1 | PS4.1.2.3 | “Providing Emergency Rescue Staff Interface” process makes emergency supply request for “Emergency Material Supply” process |
| 36 | Emergency dispatching response | PS4.1.2.2 | PS4.1.2.1 | “Dispatching Emergency Car” process provides emergency dispatching response for “Provide Emergency Rescue Staff Interface” process |
| 37 | Emergency dispatching request | PS4.1.2.1 | PS4.1.2.2 | “Providing Emergency Rescue Staff Interface” process makes emergency dispatching request for “Dispatch Emergency Car” process |

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| 38 | Dispatching command | PS4.1.2.2 | PS4.1.2.1 | "Dispatching Emergency Car" process provides dispatching command for "Provide Emergency Rescue Staff Interface" process |
| 39 | Resource equipment allocation response | PS4.1.2.4 | PS4.1.2.1 | "Resource Equipment Allocation" process provides equipment resource response for "Provide Emergency Rescue Staff Interface" process |
| 40 | Resource equipment allocation request | PS4.1.2.1 | PS4.1.2.4 | "Provide Emergency Rescue Staff Interface" process makes resource equipment allocation request for "Resource Equipment Allocation" |
| 41 | Rescue maintenance service response | PS4.1.2.5 | PS4.1.2.1 | "Rescue Maintenance Service" process provides rescue maintenance service response for "Provide Emergency Rescue Staff Interface" process |
| 42 | Rescue maintenance service request | PS4.1.2.1 | PS4.1.2.5 | "Providing Emergency Rescue Staff Interface" process makes rescue maintenance service request for "Rescue Maintenance Service" process |
| 43 | Accident material update response | PS4.1.3.1 | PS4.1.3.2 | "Updating Accident Spot Information" process provides accident material update response for "Rescue Maintenance Service" process |
| 44 | Accident material update request | PS4.1.3.2 | PS4.1.3.1 | "Providing Train Operation and Emergency Accident Material" process makes accident material update request for "Update Accident Spot Information" process |
| 45 | Data inquiry result | PS4.1.3.2 | PS4.1.3.3 | "Providing Train Operation and Emergency Accident Material" process provides data inquiry result for "Emergency Rescue Information Release " process |
| 46 | Data inquiry request | PS4.1.3.3 | PS4.1.3.2 | "Emergency Rescue Information Release " process makes data inquiry request for "Provide Train Operation and Emergency Accident Material" process |
| 47 | Data inquiry result | PS4.1.3.4 | PS4.1.3.3 | "Emergency Accident Material Unified Management" process provides data inquiry result for "Emergency Rescue Information Release " process |
| 48 | Data inquiry request | PS4.1.3.3 | PS4.1.3.4 | "Emergency Rescue Information Release " process makes data inquiry request for "Emergency Accident Material Unified Management" process |
| 49 | Rescue result | PS4.1.3.3 | PS4.1.3.4 | "Emergency Rescue Information Release " process provides rescue result for "Emergency Accident Material Unified Management" process |
| 50 | Accident cause | PS4.1.3.2 | PS4.1.3.4 | "Providing Train Operation and Emergency Accident Material" process provides accident causes for "Emergency Accident Material Unified Management" process |

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| 51 | Accident time and spot | PS4.1.3.2 | PS4.1.3.4 | "Providing Train Operation and Emergency Accident Material" process provides accident time and spot for "Emergency Accident Material Unified Management" process |
| 52 | Accident condition | PS4.1.3.2 | PS4.1.3.4 | "Providing Train Operation and Emergency Accident Material" process provides accident condition for "Emergency Accident Material Unified Management" process |
| 53 | Accident rescue plan | PS4.1.3.2 | PS4.1.3.4 | "Providing Train Operation and Emergency Accident Material" process provides accident rescue plan for "Emergency Accident Material Unified Management" process |
| 54 | Safety data upload response | DFD4.2.2 | DFD4.2.1 | Safety data management provides safety data upload response for real-time collection of various safety data |
| 55 | Safety data upload | DFD4.2.1 | DFD4.2.2 | Real-time collection of various safety data provides safety data upload for safety data management |
| 56 | Safety data upload request | DFD4.2.1 | DFD4.2.2 | Real-time collection of various safety data makes safety data upload request for safety data management |
| 57 | Data logging | DFD4.2.2 | Real-time safety data storage | Safety data management inputs data into real-time safety data storage |
| 58 | Data export | Real-time safety data storage | DFD4.2.2 | Real-time safety data storage exports data to safety data management |
| 59 | Data inquiry response | Real-time safety data storage | DFD4.2.4 | Real-time safety data storage provides data inquiry response for maintenance decision support |
| 60 | Data inquiry request | DFD4.2.4 | Real-time safety data storage | Maintenance decision support makes data inquiry request for real-time safety data storage |
| 61 | Inquiry result | Real-time safety data storage | DFD4.2.3 | Real-time safety data storage provides inquiry result for safety evaluation |
| 62 | Inquiry request | DFD4.2.3 | Real-time safety data storage | Safety evaluation makes inquiry request for real-time safety data storage |
| 63 | Evaluation result | DFD4.2.3 | Real-time safety data storage | Safety evaluation provides evaluation result for real-time safety data storage |
| 64 | Evaluation request | Real-time safety data storage | DFD4.2.3 | Real-time safety data storage makes evaluation request for safety evaluation |
| 65 | Safety evaluation result sending response | DFD4.2.4 | DFD4.2.3 | Maintenance decision support provides safety evaluation result sending response for safety evaluation |
| 66 | Safety evaluation result sending request | DFD4.2.3 | DFD4.2.4 | Safety evaluation makes safety evaluation result sending request for maintenance decision support |
| 67 | Data upload response | DFD4.2.2.5 | PS4.2.1.1 | Safety monitoring data network provides data upload response for "Real-time Collection of |

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| | | | | Ground-to-car Monitoring Data” process |
| 68 | Data upload request | PS4.2.1.1 | DFD4.2.2.5 | “Real-time Collection of Ground-to-car Monitoring Data” process makes data upload request for safety monitoring data network |
| 69 | Data upload response | DFD4.2.2.5 | PS4.2.1.2 | Safety monitoring data network provides data upload response for “Real-time Collection of Ground-to-car Monitoring Data” process |
| 70 | Data upload request | PS4.2.1.2 | DFD4.2.2.5 | “Real-time Collection of Ground-to-car Monitoring Data” process makes data upload request for safety monitoring data network |
| 71 | Data upload response | DFD4.2.2.5 | PS4.2.1.3 | Safety monitoring data network provides data upload response for “Real-time Collection of Ground-to-car Monitoring Data” process |
| 72 | Data upload request | PS4.2.1.3 | DFD4.2.2.5 | “Real-time Collection of Car-to-car Monitoring Data” process makes data upload request for safety monitoring data network |
| 73 | Data upload response | DFD4.2.2.5 | PS4.2.1.4 | Safety monitoring data network provides data upload response for “Real-time Collection of Car-to-ground Monitoring Data” process |
| 74 | Data upload request | PS4.2.1.4 | DFD4.2.2.5 | “Real-time Collection of Car-to-ground Monitoring Data” process makes data upload request for safety monitoring data network |
| 75 | Data presentation response | PS4.2.2.1 | DFD4.2.2.5 | “Data Real-time Update” process provides data presentation response for safety monitoring data network |
| 76 | Data presentation request | DFD4.2.2.5 | PS4.2.2.1 | Safety monitoring data network makes data presentation request for “Data Real-time Update” process |
| 77 | Information supply response | PS4.2.2.2 | PS4.2.2.5 | “Collecting Related Fundamental Data” process provides information inquiry response for “Related Fundamental Data Management” process |
| 78 | Information supply application | PS4.2.2.5 | PS4.2.2.2 | “Collecting Related Fundamental Data” process makes information supply application for “Related Fundamental Data Management” process |
| 79 | Data logging | PS4.2.2.5 | Fundamental data storage | “Related Fundamental Data Management” process inputs data into fundamental data storage |
| 80 | Data export | Fundamental data storage | PS4.2.2.5 | Fundamental data storage exports data to “Related Fundamental Data Management” process |
| 81 | Data providing response | Fundamental data storage | DFD4.2.2.5 | Fundamental data storage provides data inquiry response for safety monitoring data network |
| 82 | Data providing request | DFD4.2.2.5 | Fundamental data storage | Safety monitoring data network makes data inquiry request for fundamental data storage |

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| 83 | Data inquiry response | DFD4.2.2.5 | PS 4.2.2.3 | Safety monitoring data network provides data inquiry response for “Safety Monitoring Data Inquiry” process |
| 84 | Data inquiry request | PS 4.2.2.3 | DFD4.2.2.5 | “Safety Monitoring Data Inquiry” makes data inquiry request for safety monitoring data network |
| 85 | Data inquiry response | DFD4.2.2.5 | PS 4.2.2.4 | Safety monitoring data network provides data inquiry response for “Safety Monitoring Data Statistical Analysis” process |
| 86 | Data inquiry request | PS 4.2.2.4 | DFD4.2.2.5 | “Safety Monitoring Data Statistical Analysis” process makes data inquiry request for safety monitoring data network |
| 87 | Upload monitoring data | Sub-bureau safety monitoring management center | Highway bureau safety monitoring management center | Sub-bureau safety monitoring management center uploads monitoring data to highway bureau safety monitoring management center |
| 88 | Download copied data | Highway bureau safety monitoring management center | Sub-bureau safety monitoring management center | Highway bureau safety monitoring management center downloads copied data from sub-bureau safety monitoring management center |
| 89 | Upload safety affair management report | Sub-bureau safety monitoring management center | Highway bureau safety monitoring management center | Sub-bureau safety monitoring management center uploads safety affair management report to highway bureau safety monitoring management center |
| 90 | Data sending response | Engineering district safety monitoring | Sub-bureau safety monitoring management center | Engineering district safety monitoring provides data sending response for sub-bureau safety monitoring management center |
| 91 | Data sending request | Sub-bureau safety monitoring management center | Engineering district safety monitoring | Sub-bureau safety monitoring management center makes data sending request for engineering district safety monitoring |
| 92 | Data sending response | Locomotive depot safety monitoring | Sub-bureau safety monitoring management center | Locomotive depot safety monitoring provides data sending response for sub-bureau safety monitoring management center |
| 93 | Data sending request | Sub-bureau safety monitoring management center | Locomotive depot safety monitoring | Sub-bureau safety monitoring management center makes data sending request for locomotive depot safety monitoring |
| 94 | Data sending response | Train operation depot safety monitoring | Sub-bureau safety monitoring management center | Train operation depot safety monitoring provides data sending response for sub-bureau safety monitoring management center |
| 95 | Data sending request | Sub-bureau safety monitoring management center | Train operation depot safety monitoring | Sub-bureau safety monitoring management center makes data sending request for train operation depot safety monitoring |

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| 96 | Data sending response | Communication and signal district safety monitoring | Sub-bureau safety monitoring management center | Communication and signal district safety monitoring provides data sending response for sub-bureau safety monitoring management center |
| 97 | Data sending request | Sub-bureau safety monitoring management center | Communication and signal district safety monitoring | Sub-bureau safety monitoring management center makes data sending request for communication and signal district safety monitoring |
| 98 | Safety affair management report | Business depot | Sub-bureau safety monitoring management center | Business depot provides safety affair management report for sub-bureau safety monitoring management center |
| 99 | Automatic alarm information | Sub-bureau safety monitoring management center | Business depot | Sub-bureau safety monitoring management center provides automatic alarm information for business depot |
| 100 | Safety affair management report | Station | Sub-bureau safety monitoring management center | Station provides safety affair management report for sub-bureau safety monitoring management center |
| 101 | Automatic alarm information | Sub-bureau safety monitoring management center | Station | Sub-bureau safety monitoring management center provides automatic alarm information for station |
| 102 | Upload monitoring data | Highway bureau safety monitoring management center | Road-wide safety monitoring management center | Highway bureau safety monitoring management center uploads monitoring data to road-wide safety monitoring management center |
| 103 | Upload safety affair management report | Highway bureau safety monitoring management center | Road-wide safety monitoring management center | Highway bureau safety monitoring management center uploads safety affair management report to road-wide safety monitoring management center |
| 104 | Upload monitoring data | Highway bureau safety monitoring management center | Road-wide safety monitoring management center | Highway bureau safety monitoring management center uploads monitoring data to road-wide safety monitoring management center |
| 105 | Upload safety affair management report | Highway bureau safety monitoring management center | Road-wide safety monitoring management center | Highway bureau safety monitoring management center uploads safety affair management report to road-wide safety monitoring management center |
| 106 | Model providing response | PS4.2.3.1 | PS4.2.3.2 | "Establishing Safety Data Statistical Model" process provides model response for "Evaluate Safety Condition" process |
| 107 | Model providing request | PS4.2.3.2 | PS4.2.3.1 | "Evaluating Safety Condition" process makes model request for "Establish Safety Data Statistical Model" process |
| 108 | Model providing response | PS4.2.3.1 | PS4.2.3.3 | "Establishing Safety Data Statistical Model" process provides model response for "Provide Intelligent Decision" process |

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| 109 | Model providing request | PS4.2.3.3 | PS4.2.3.1 | "Providing Intelligent Decision" process makes model request for "Establish Safety Data Statistical Model" process |
| 110 | Model providing response | PS4.2.4.1 | PS4.2.4.2 | "Establishing Maintenance Knowledge Model" process provides model response for "Provide Maintenance Decision Support" process |
| 111 | Model providing request | PS4.2.4.2 | PS4.2.4.1 | "Providing Maintenance Decision Support" process makes model request for "Establish Maintenance Knowledge Model" process |
| 112 | Data providing response | PS4.3.1 | PS4.3.2 | "Real-time Collection of Natural Calamity Information" process provides data inquiry response for "Unified Management of Calamity Information" process |
| 113 | Data providing request | PS4.3.2 | PS4.3.1 | "Unified Management of Calamity Information" process makes data inquiry request for "Real-time Collection of Natural Calamity Information" process |
| 114 | Data providing response | Calamity information data storage | PS4.3.4 | "Providing Disaster Prevention and Rescue Decision Support" process provides data inquiry response for calamity information data storage |
| 115 | Data providing request | PS4.3.4 | Calamity information data storage | Calamity information data storage makes data providing request for "Provide Disaster Prevention and Rescue Decision Support" process |
| 116 | Data providing response | Calamity information data storage | PS4.3.3 | Calamity information data storage provides data inquiry response for "Establish Applied Analysis Model" process |
| 117 | Data providing request | PS4.3.3 | Calamity information data storage | "Establishing Applied Analysis Model" process makes data providing request for calamity information data storage |
| 118 | Data logging | PS4.3.2 | Calamity information data storage | "Unified Management of Calamity Information" process inputs data into calamity information data storage |
| 119 | Data export | Calamity information data storage | PS4.3.2 | Calamity information data storage exports data to "Unified Management of Calamity Information" process |
| 120 | Model providing response | PS4.3.3 | PS4.3.4 | "Establishing Applied Analysis Model" process provides model response for "Provide Disaster Prevention and Rescue Decision Support" process |
| 121 | Model providing request | PS4.3.4 | PS4.3.3 | "Providing Disaster Prevention and Rescue Decision Support" process make model request for "Establish Applied Analysis Model" process |
| 122 | Information release response | PS4.4.1 | PS4.4.3 | "Collecting Related Information of Road-rail Level crossing Condition" process provides information release response for "Road-rail |

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| | | | | Level crossing Information release" process |
| 123 | Information release request | PS4.4.3 | PS4.4.1 | "Road-rail Level crossing Information release" process makes information release request for "Collect Related Information of Road-rail Level crossing Condition" process |
| 124 | Information providing response | PS4.4.1 | PS4.4.5 | "Collecting Related Information of Road-rail Level crossing Condition" process provides information inquiry response for "Road-rail Level crossing Condition Related Information Management" process |
| 125 | Information providing application | PS4.4.5 | PS4.4.1 | "Road-rail Level crossing Condition Related Information Management" process applies for "Collect Related Information of Road-rail Level crossing Condition" process |
| 126 | Data logging | PS4.4.5 | Road-rail Level crossing condition data storage | "Road-rail Level crossing Condition Related Information Management" process inputs data into Road-rail Level crossing condition data storage |
| 127 | Data export | Road-rail Level crossing condition data storage | PS4.4.5 | Road-rail Level crossing condition data storage exports data to "Road-rail Level crossing Condition Related Information Management" process |
| 128 | Information providing response | Road-rail Level crossing condition data storage | PS4.4.2 | Road-rail Level crossing condition data storage provides information response for "Monitoring Road-rail Level crossing condition" process |
| 129 | Information providing request | PS4.4.2 | Road-rail Level crossing condition data storage | "Monitoring Road-rail Level crossing condition" process makes request for Road-rail Level crossing condition data storage |
| 130 | Track maintenance proposal | PS4.4.2 | PS4.4.4 | "Monitoring Road-rail Level crossing condition" process provides track maintenance proposal for "Unsafe factor management at Road-rail Level crossing " process |
| 131 | Controlling device maintenance disposal | PS4.4.2 | PS4.4.4 | "Monitoring Road-rail Level crossing condition" process provides control device maintenance disposal for "Unsafe factor management at Road-rail Level crossing " process |
| 132 | Safety information | PS4.4.2 | PS4.4.4 | "Monitoring Road-rail Level crossing condition" process provides safety information for "Unsafe factor management at Road-rail Level crossing " process |
| 133 | Accident information | PS4.4.2 | PS4.4.4 | "Monitoring Road-rail Level crossing condition" process provides accident information for "Unsafe factor management at Road-rail Level crossing " process |
| 134 | Monitoring information | PS4.4.2 | PS4.4.4 | "Monitoring Road-rail Level crossing condition" process provides monitoring information for "Unsafe factor management at Road-rail Level crossing " process |

## DATA STORAGE DEFINITION DIAGRAM

| No. | Data storage name | Data storage content |
|---|---|---|
| 1 | Accident spot data storage | Accident spot site and circumstance around<br>Train damage extent<br>Route damage extent<br>Communication signal damage extent<br>Staff and freight condition<br>Dangerous goods information<br>Nearby train information<br>Accident freight characteristic<br>Accident happening causes |
| 2 | Rescue resource data storage | Rescue train distribution<br>Rescue unit distribution<br>Rescue train condition<br>Rescue staff condition<br>Rescue equipment condition<br>Rescue material condition<br>Road network condition |
| 3 | Real-time safety data storage | Train operation condition<br>Freight safety door information<br>Station level aisle<br>Intersection condition data<br>Intersection switch power monitoring data<br>Intersection electrical appliance<br>Station black box data<br>Train operation safety information<br>Locomotive operation monitoring data<br>Locomotive failure monitoring data<br>Infrared axle temperature detection car data<br>Comprehensive detection car data<br>Locomotive signal analyzer data<br>Track inspection car data<br>Flaw detection car data |
| 4 | Disaster information data storage | Data providing application<br>Earthquake data,<br>Debris flow information<br>Wind speed data<br>Landslide information<br>Rainfall information<br>Water level information |
| 5 | Road-rail Level crossing condition data storage | Intersection traffic condition<br>Control device condition<br>Track condition<br>Line side equipment condition<br>Intersection accident information |

## PHYSICAL FRAMEWORK OF INTELLIGENT EMERGENCY RESCUE AND SAFETY SYSTEM

### System --- Circumstance Relationship Diagram

Emergency rescue and safety system refers to 11 external circumstance systems. This external circumstance system alternates with emergency rescue and safety system by wire or wireless communication approach [43]. The relationship of system and circumstance is shown as (Fig. 6).

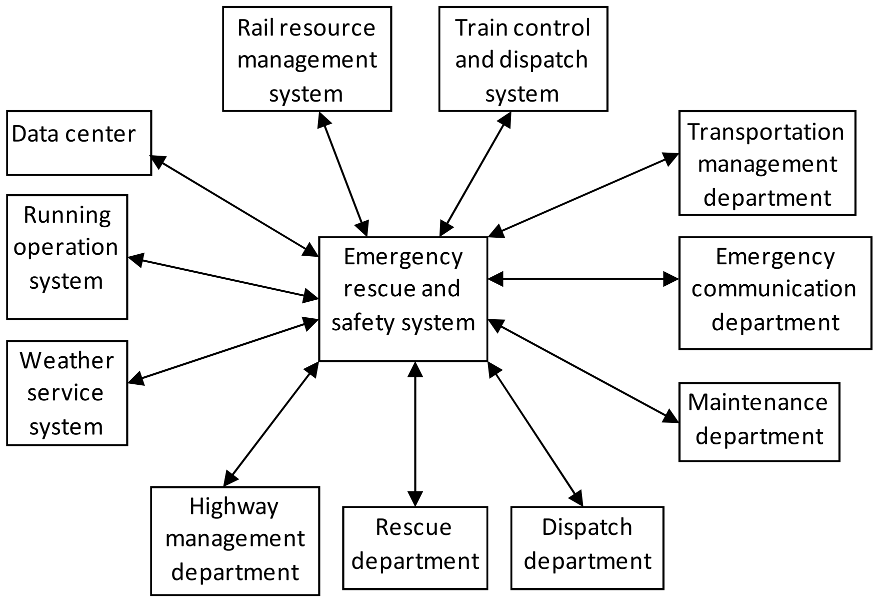



**Figure 6:** System --- circumstance relationship diagram

### System and Sub-System Description

Emergency rescue and safety system physical framework contains 4 sub-systems as shown in (Fig. 7), including center management sub-system, station sub-system, track side sub-system and train sub-system. External user service sub-system communicates with center management sub-system by wide area wire or wireless communication. Center management sub-system communicates with station sub-system and track side sub-system by LAN or WAN. Station sub-system communicates with train sub-system and track side sub-system by wireless communication. Specific short-range wireless communication is used between one train and another.

Center management sub-system contains 5 sub-systems: emergency rescue and management system, train safety monitoring system, maintenance decision support system, railway comprehensive disaster prevention system, and Road-rail Level crossing monitoring system. Station sub-system contains 3 sub-systems: station equipment monitoring system, intersection inspection system and safety information management system. Train sub-system contains 5 sub-systems: freight train transportation condition monitoring system, on-board failures monitoring and self-diagnosis system, infrared axle temperature detection system, on-board track safety inspection system and every train operation safety monitoring system. Track side sub-system contains 4 sub-systems: meteorological disaster monitoring system, route condition monitoring system, communication signal equipment monitoring system and train operation condition ground safety monitoring system.

#### *Center Management Sub-System*

In emergency rescue and management system, the center management sub-system plays the main role in monitoring, dispatching, management and intelligent assistant decision. This sub-system also completes railway accident rescue and management, railway comprehensive disaster prevention and railway transportation devices condition inspection, and improves functions such as transportation safety information management, etc. One center management sub-system transmits information to others by wide area wire communication.

| Sub-system name | Description | Correspondent logical process |
|---|---|---|
| Emergency rescue and safety system | This sub-system needs to be equipped with correspondent hardware and software equipment environment. The main function is to carry out the railway emergency rescue, management and assistant decision. | PS4.1.1.3<br>PS4.1.2.2<br>PS4.1.2.3<br>PS4.1.2.4<br>PS4.1.2.5 |
| Train safety monitoring system | This sub-system needs to be equipped with correspondent hardware and software equipment environment. The main function is to find safety hidden danger in time and make safety evaluation and early warning. | PS 4.2.2.4<br>PS4.2.2.5<br>PS4.2.3.1<br>PS4.2.3.2<br>PS4.2.3.3 |
| Maintenance decision support system | This sub-system needs to be equipped with correspondent hardware and software equipment environment. The main function is to carry out maintenance decision support of fixed and mobile equipments and eliminate safety hidden danger in time. | PS4.2.4.1<br>PS4.2.4.2 |
| Railway comprehensive disaster prevention system | This sub-system needs to be equipped with correspondent hardware and software equipment environment. The main function is to manage various kinds of natural calamity intelligence data and related disaster prevention data. It also provides basis of train operation control and carry out real-time monitoring and management of road-wide natural calamity condition. | PS4.3.2<br>PS4.3.3<br>PS4.3.4 |
| Road-rail Level crossing monitoring system | This sub-system needs to be equipped with correspondent hardware and software equipment environment. The main function is to monitor and manage the road-rail level crossing safety condition and protect the road-rail level crossing traffic safety. | PS4.4.2<br>PS4.4.3<br>PS4.4.4<br>PS4.4.5 |

### *Station Sub-System*

The station sub-system has a main role to play in the monitoring and related information collection and management of station fixed and mobile equipment and Road-rail Level crossing. Station sub-system transmits information to center management sub-system by wire communication approach.

| Sub-system name | Description | Correspondent logical process |
|---|---|---|
| Station equipment monitoring system | This sub-system needs to be equipped with correspondent hardware and software equipment environment. The main function is to carry out efficient monitoring of station equipment condition. | PS4.2.1.2 |
| Level crossing inspection system | This sub-system needs to be equipped with correspondent hardware and software equipment environment. The main function is to inspect Road-rail Level crossing equipment condition and safety condition. | PS4.4.1 |
| Safety information management system | This sub-system needs to be equipped with correspondent hardware and software equipment environment. The main function is to carry out unified management of station safety information. | PS4.2.2.1<br>PS4.2.2.3 |

### *Train Sub-System*

The train sub-system which carries out real-time monitoring of train operation condition by on-board devices is mainly used to realize train information collection and monitoring. This sub-system transmits information to center management sub-system and track side sub-system by wireless communication.

| Sub-system name | Description | Correspondent logical process |
|---|---|---|
| Freight train transportation condition monitoring system | This sub-system needs to be equipped with correspondent hardware and software equipment environment. The main function is to carry out real-time monitoring of freight loading condition and to realize scientific management to guarantee the freight transportation safety. | PS4.2.1.1 |
| On-board failures monitoring and self-diagnosis system | This sub-system needs to be equipped with correspondent hardware and software equipment environment. The main functions are to rapidly identify, prompt and reserve the failures happened during train operating and eliminate them in time. | PS4.2.1.3 |
| Infrared axle temperature detection system | This sub-system needs to be equipped with correspondent hardware and software equipment environment. The main function is to grasp steel rail temperature and ascertain rail temperature control standard to provide further decision basis for running command. | PS 4.2.1.4 |
| On-board track safety inspection system | This sub-system needs to be equipped with correspondent hardware and software equipment environment. The main function is to get information such as time-varying locomotive characteristic, route condition and route abnormal condition, etc. | PS 4.2.1.4 |
| Passenger train operation safety monitoring system | This sub-system needs to be equipped with correspondent hardware and software equipment environment. The main function is to record information such as operation condition during train operating. | PS 4.2.1.3 |

### *Track Side Sub-System*

The track side sub-system mainly carries out real-time monitoring of information, containing train operation condition, route equipment condition and natural calamity, etc., by track side inspection devices. This system transmits information to center management sub-system and station sub-system by LAN or WAN wire communication.

| Sub-system name | Description | Correspondent logical process |
|---|---|---|
| Meteorological disaster monitoring system | This sub-system needs to be equipped with correspondent hardware and software equipment environment. The main function is to carry out real-time monitoring of road-wide meteorological disaster condition. | PS4.3.1 |
| Route condition monitoring system | This sub-system needs to be equipped with correspondent hardware and software equipment environment. The main functions are to efficiently monitoring railway route condition and to eliminate safety hidden danger in time | PS4.2.1.2 |
| Communication signal equipment monitoring system | This sub-system needs to be equipped with correspondent hardware and software equipment environment. The main functions are to carry out real-time monitoring of railway route communication signal equipment condition and to eliminate safety hidden danger in time. | PS4.2.1.2 |
| Train operation condition ground safety monitoring system | This sub-system needs to be equipped with correspondent hardware and software equipment environment. The main functions are to identify trains in poor operation condition, to monitor–uneven loaded freight train and to identify wheel tread scratching, etc. | PS4.2.1.1 |

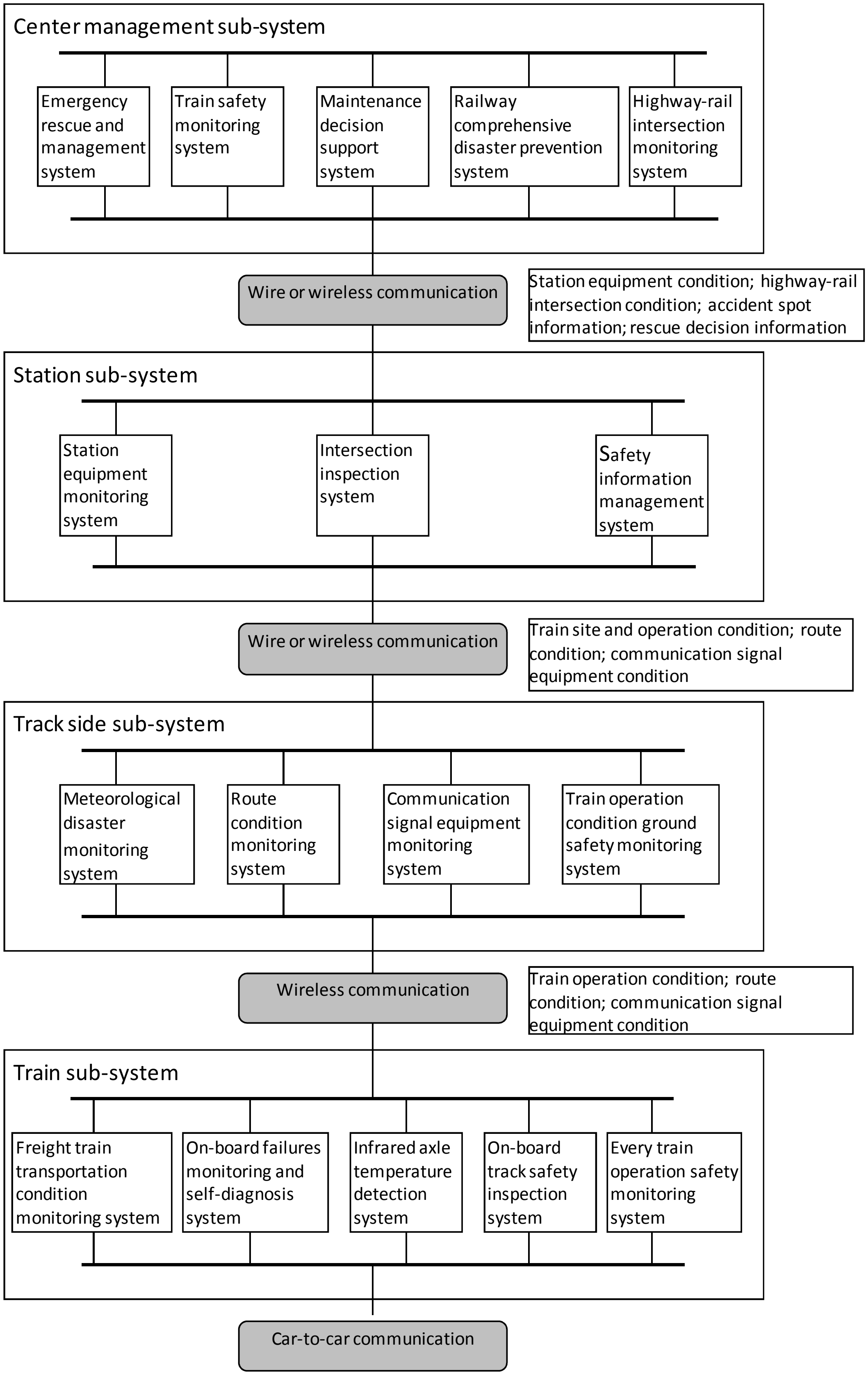



**Figure 7:** Physical framework of Emergency rescue and safety system

## PHYSICAL FRAMEWORK FLOW DESCRIPTION

| **Sub-system** | **Physical framework flow** | **Correspondent logical data flow** | **Transmission mode** |
|---|---|---|---|
| Center management sub-system<br>←→<br>Station sub-system | Station equipment condition | Station level aisle condition;<br>Switch condition data;<br>Switch switching power monitoring data;<br>Switch electric appliance characteristic data;<br>Station black box data; | Wide area wire or wireless communication |
| Center management sub-system<br>←→<br>Station sub-system | Road-rail Level crossing condition | Intersection traffic condition;<br>Control device condition;<br>Intersection conjunction information;<br>Track condition;<br>Track side equipment condition;<br>Intersection accident information; | Wide area wire or wireless communication |
| Center management sub-system<br>←→<br>Station sub-system | Accident spot information | Accident spot site and circumstance around;<br>Car damage extent;<br>Route damage extent;<br>Communication signal damage extent;<br>Staff and freight condition;<br>Dangerous goods information;<br>Nearby cars information;<br>Accident freight property; | Wide area wire or wireless communication |
| Center management sub-system<br>←→<br>Station sub-system | Rescue decision information | Freight staff processing approach;<br>Traffic control approach;<br>Emergency rescue plan;<br>Engineering district rescue plan;<br>Communication and signal district plan;<br>Train rescue plan;<br>Dangerous goods processing approach; | Wide area wire or wireless communication |
| Station sub-system<br>←→<br>Track side sub-system | Train site and condition | Train operation site;<br>Train running safety information;<br>Locomotive operation monitoring data;<br>Locomotive failure monitoring data; | Wireless communication |
| Station sub-system<br>←→<br>Track side sub-system | Route condition | Route safety condition; | Wireless communication |
| Station sub-system<br>←→<br>Track side sub-system | Communication signal equipment condition | Communication signal equipment condition; | Wireless communication |
| Track side sub-system<br>←→<br>Train<br>sub-system | Train condition | Train running safety information;<br>Locomotive operation monitoring data;<br>Locomotive failure monitoring data; | Wireless communication |
| Track side sub-system<br>←→<br>Train<br>sub-system | Route condition | Route safety condition; | Wireless communication |
| Track side sub-system<br>←→<br>Train<br>sub-system | Communication signal equipment condition | Communication signal equipment condition; | Wireless communication |

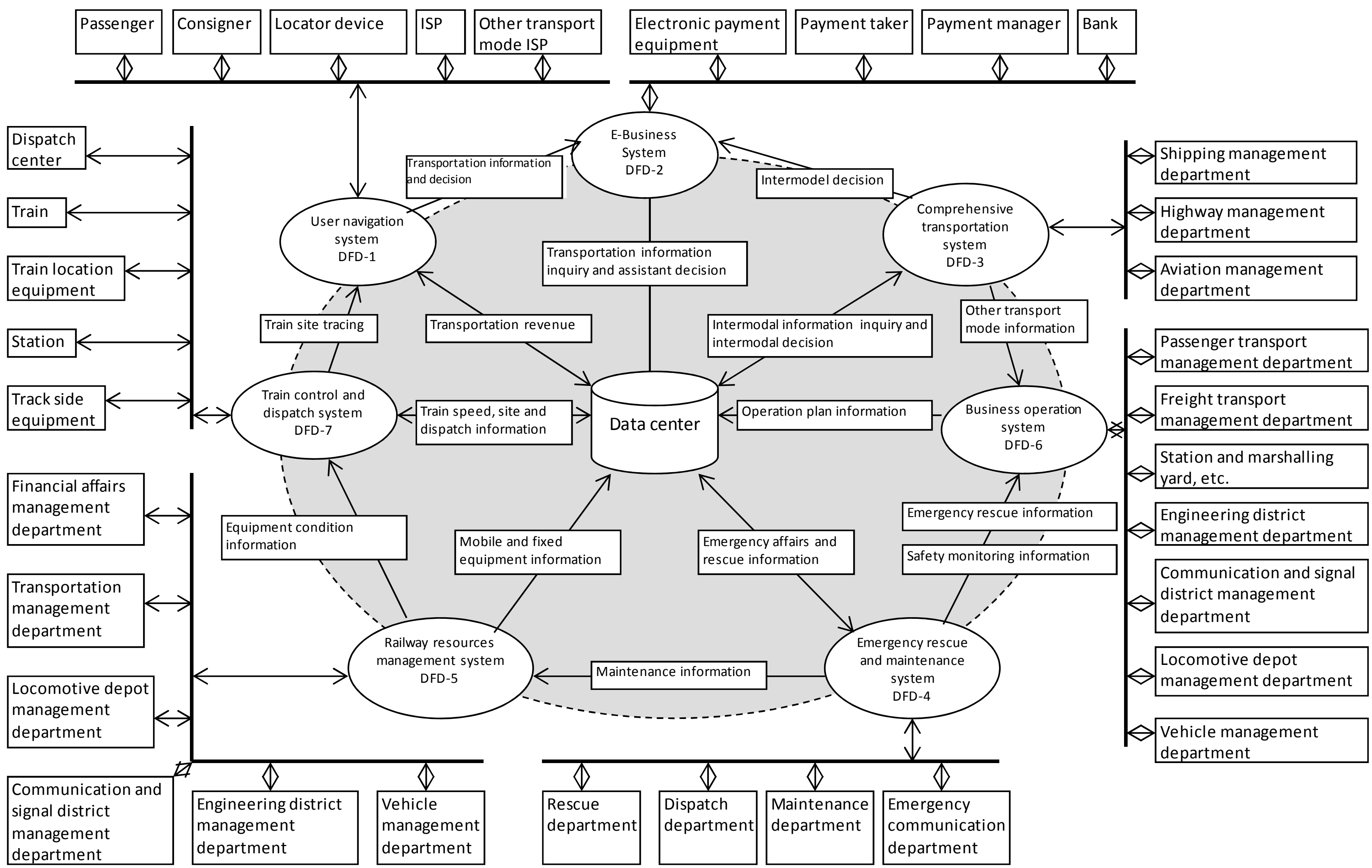
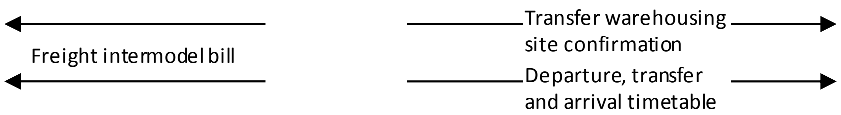



**Figure 8:** RITS top-level logical framework (DFD-0)



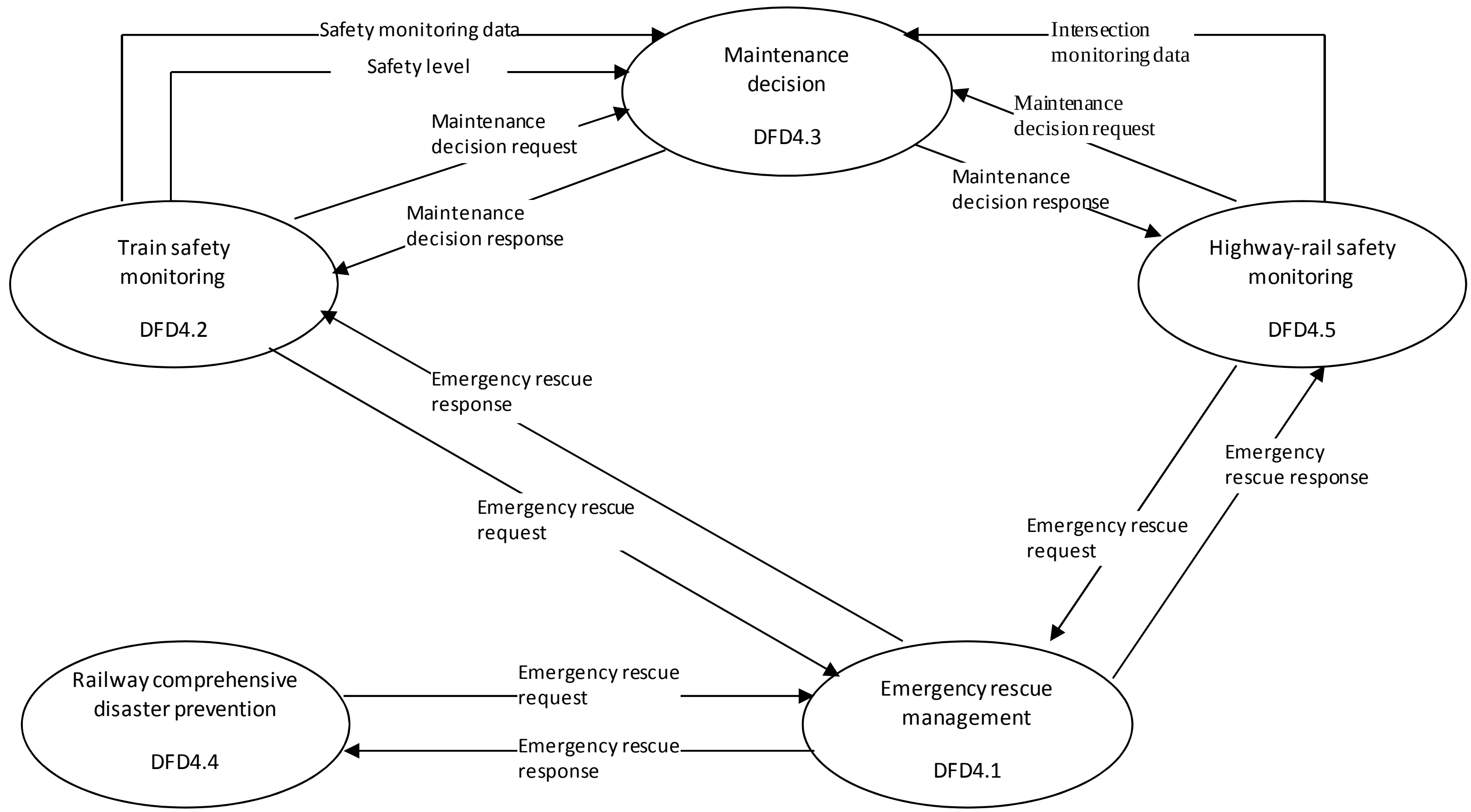




**Figure 9:** Emergency rescue and safety system (DFD4)

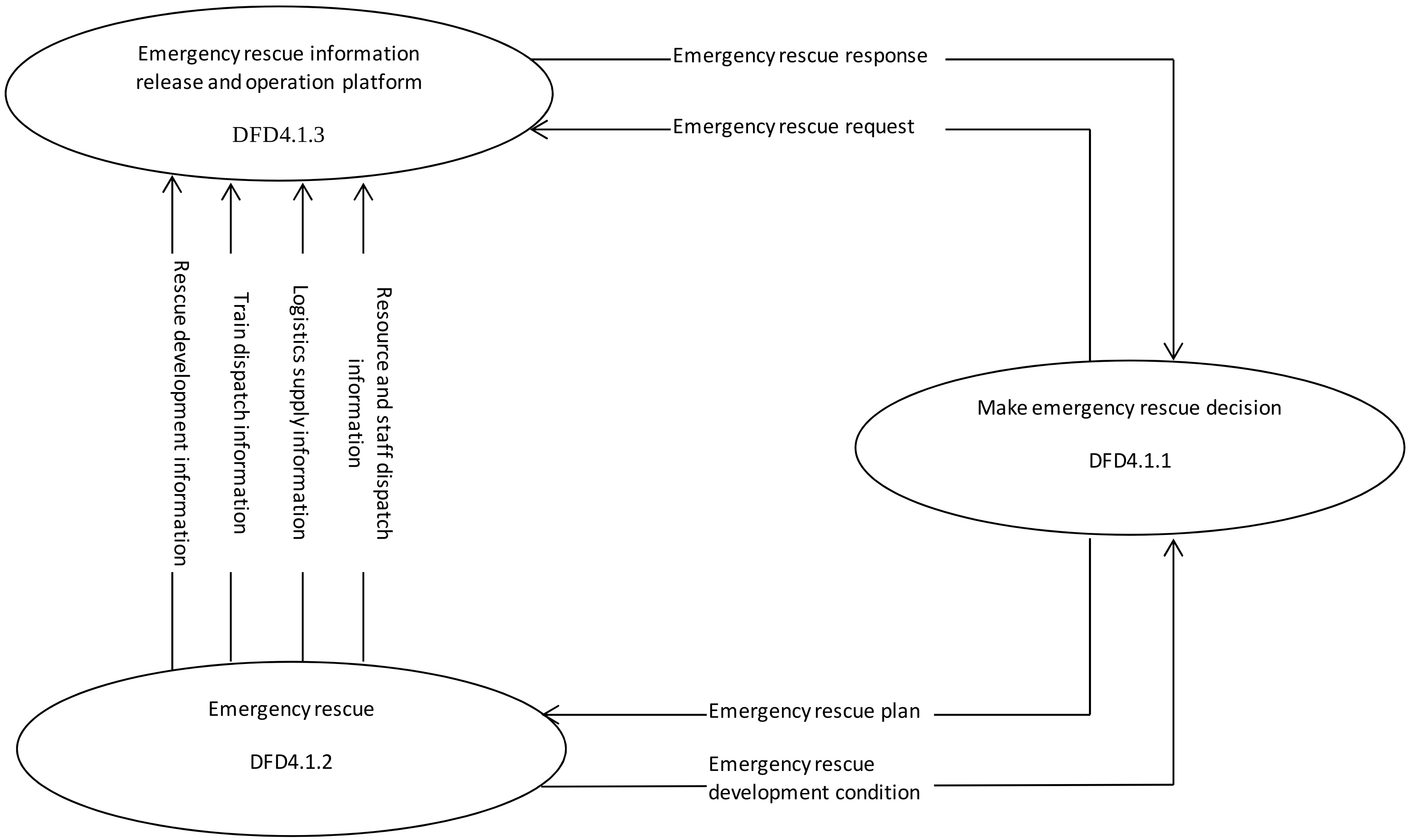



**Figure 10:** Emergency rescue (DFD4.1)

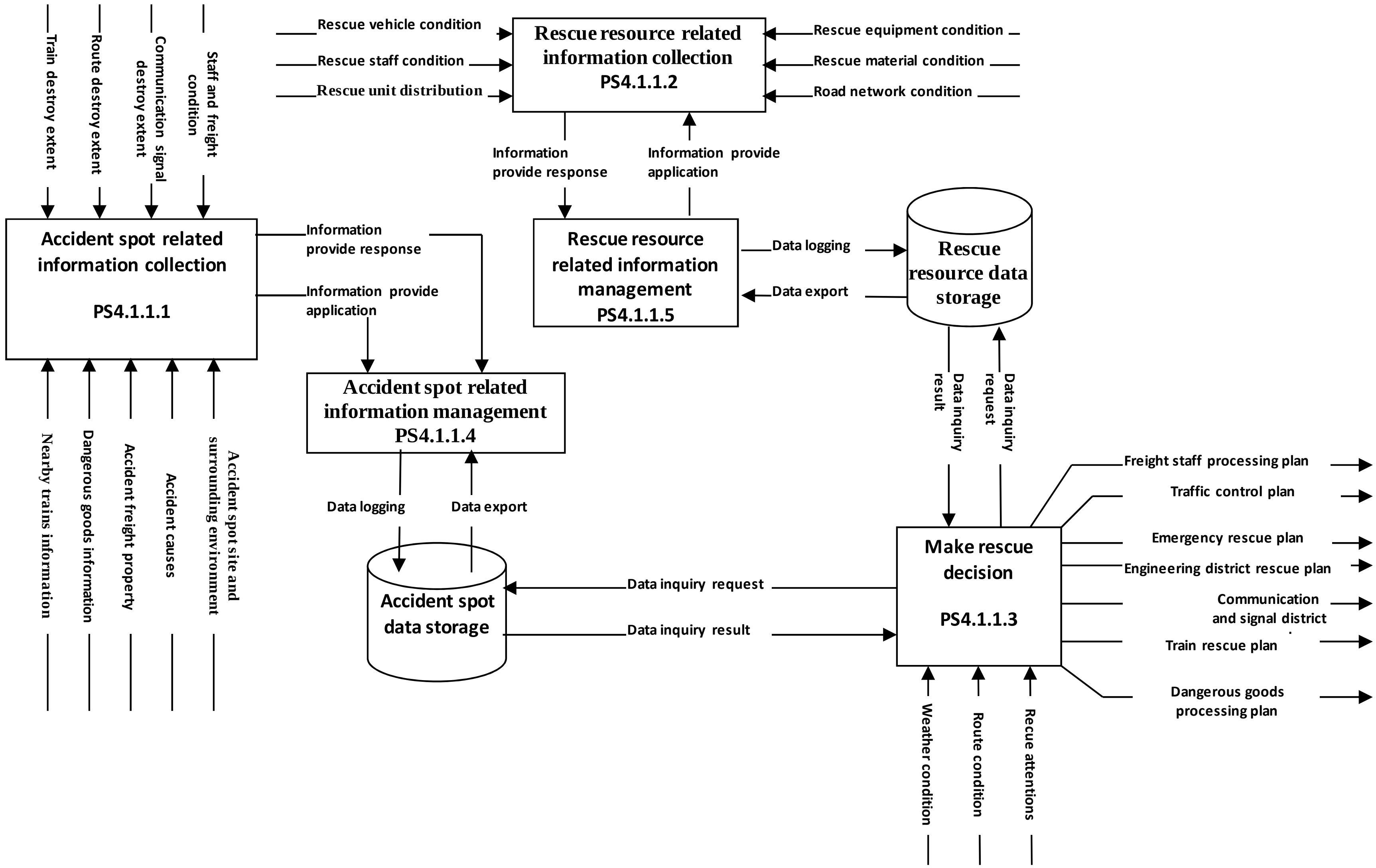



**Figure 11:** Make emergency rescue decision (DFD4.1.1)

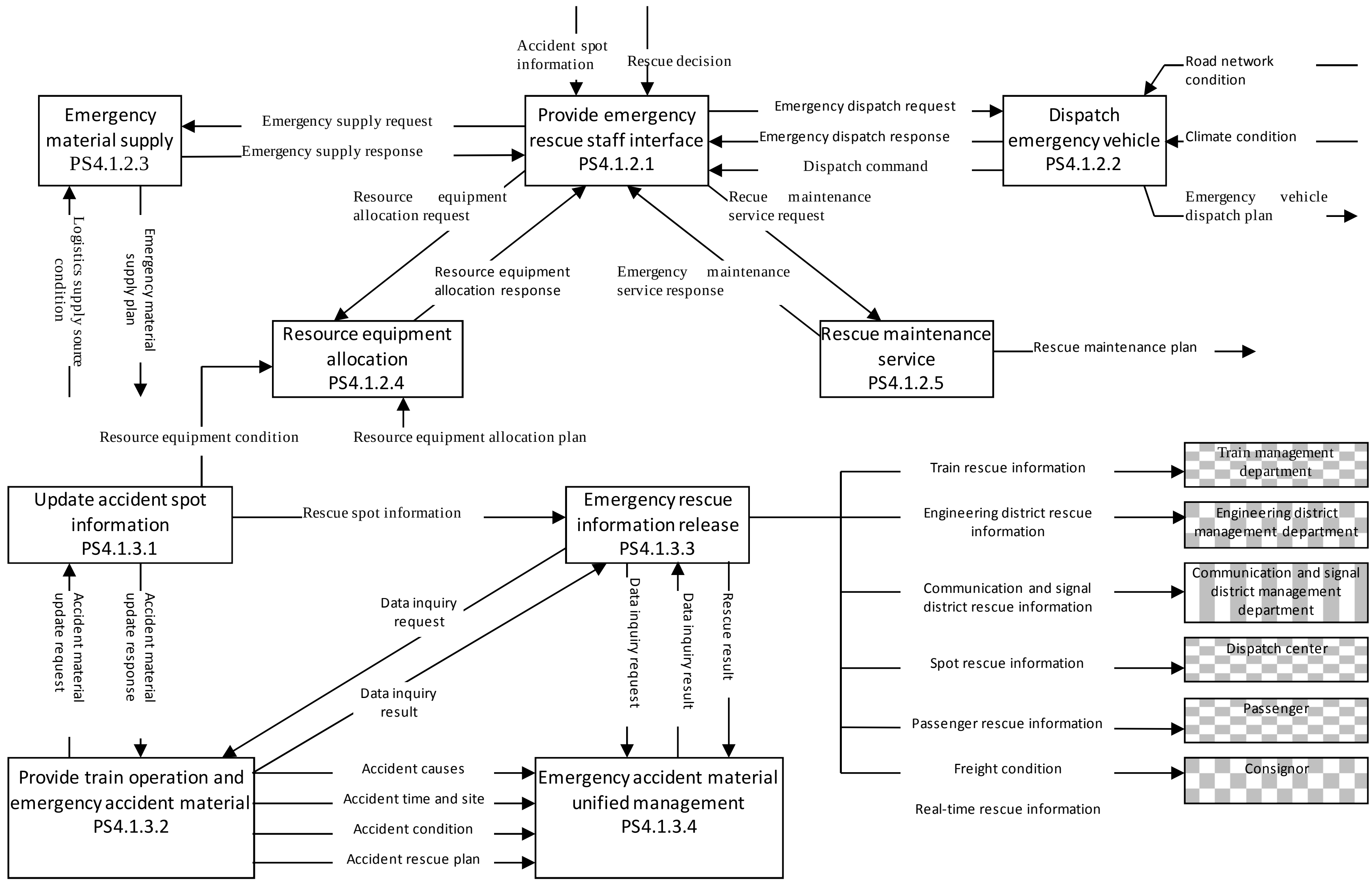



**Figure 12:** Emergency rescue process (DFD4.1.2)

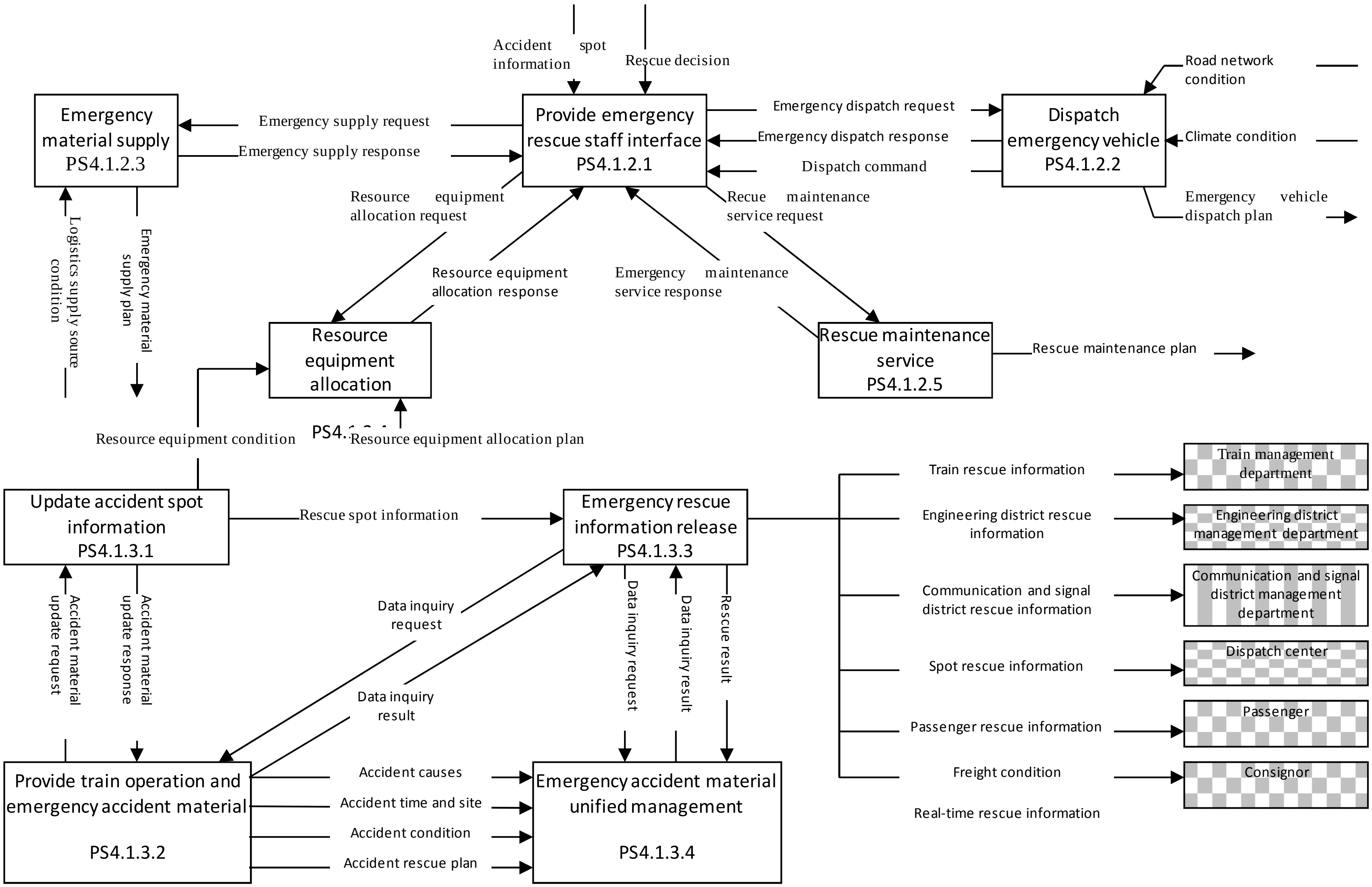



**Figure 13:** Emergency rescue information release and operation platform (DFD4.1.3)

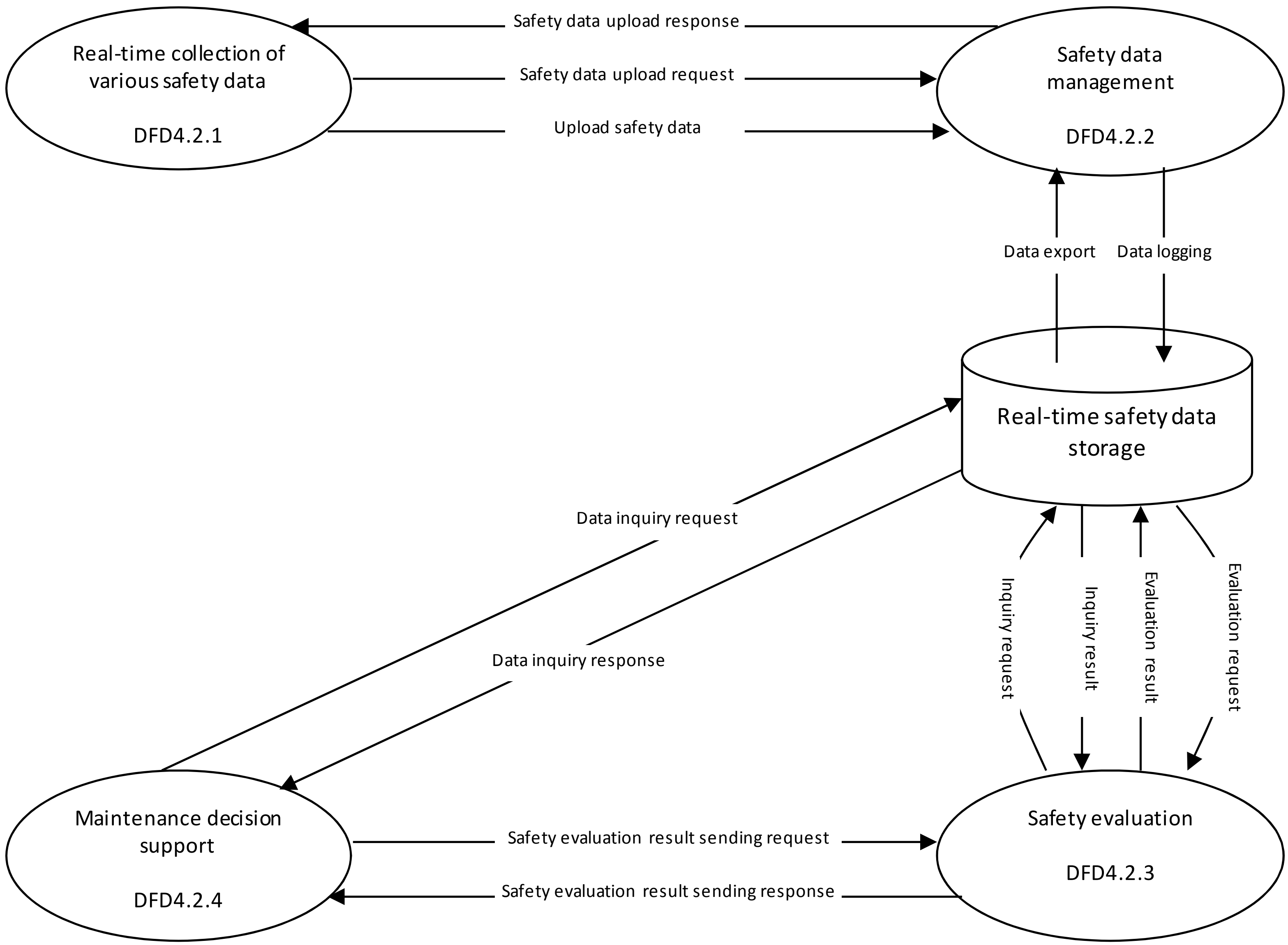



**Figure 14:** Train safety and maintenance decision support (DFD4.2)

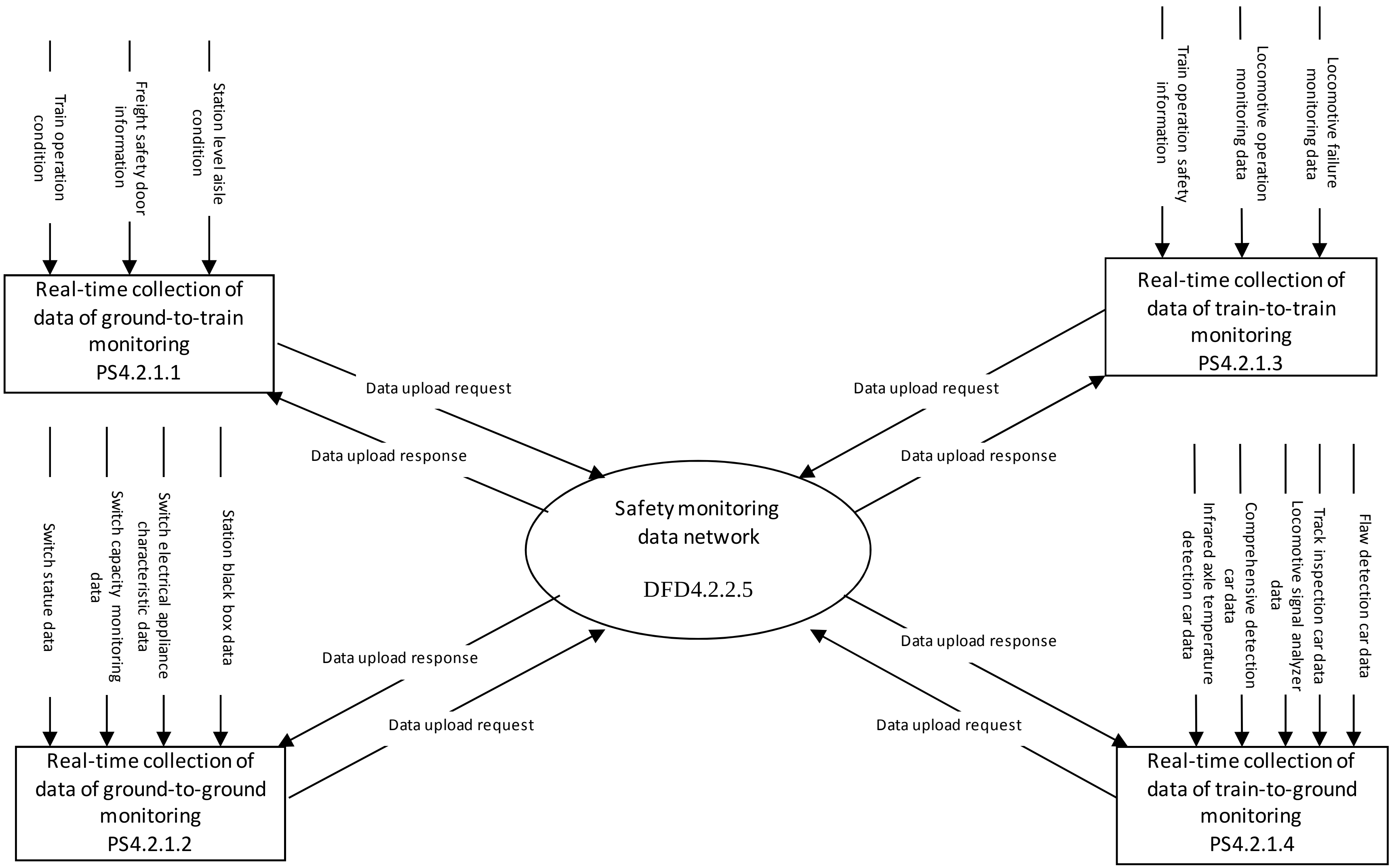



**Figure 15:** Real-time collection of various kinds of safety data (DFD4.2.1)

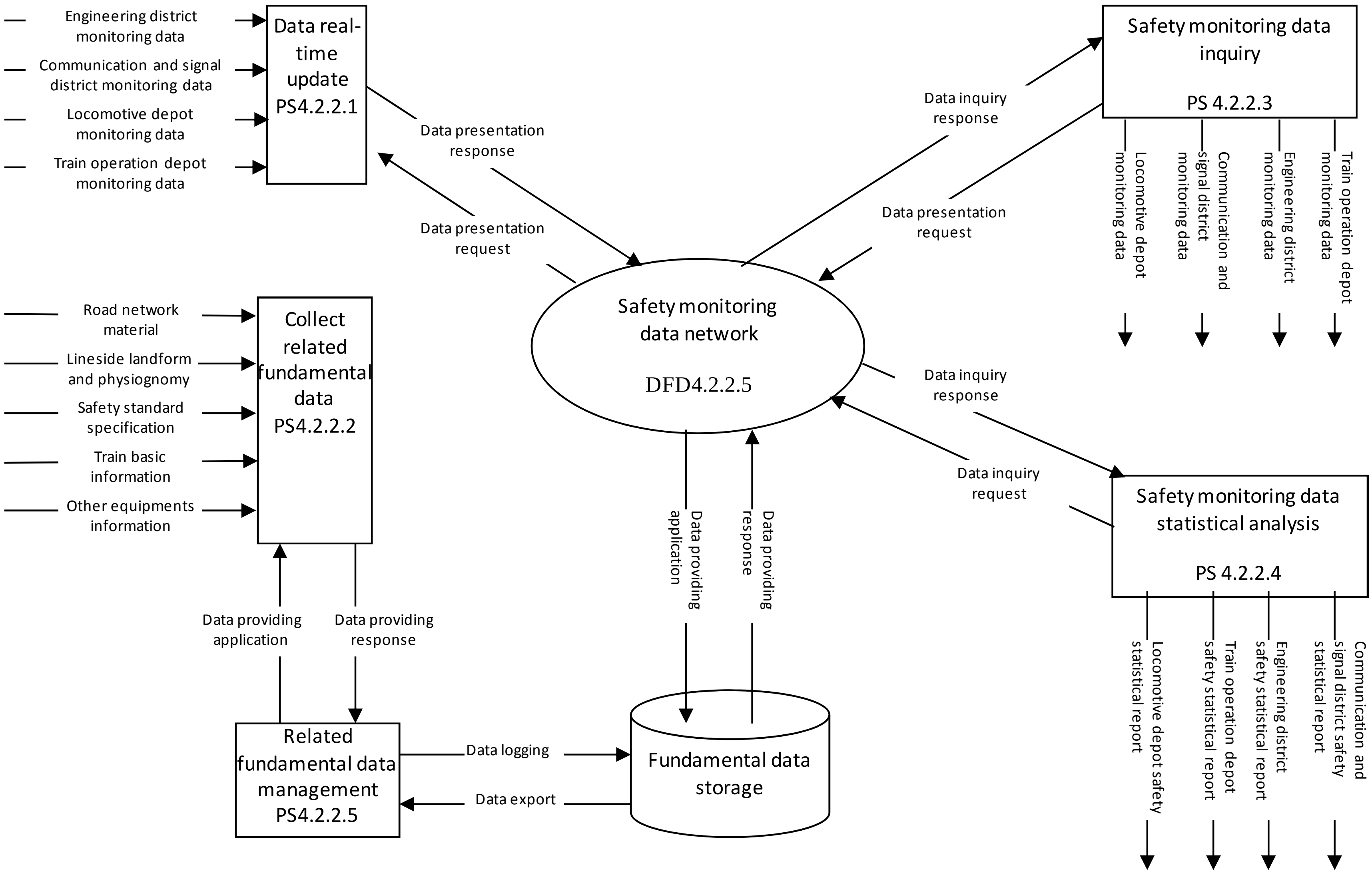



**Figure 16:** Safety data management (DFD4.2.2)

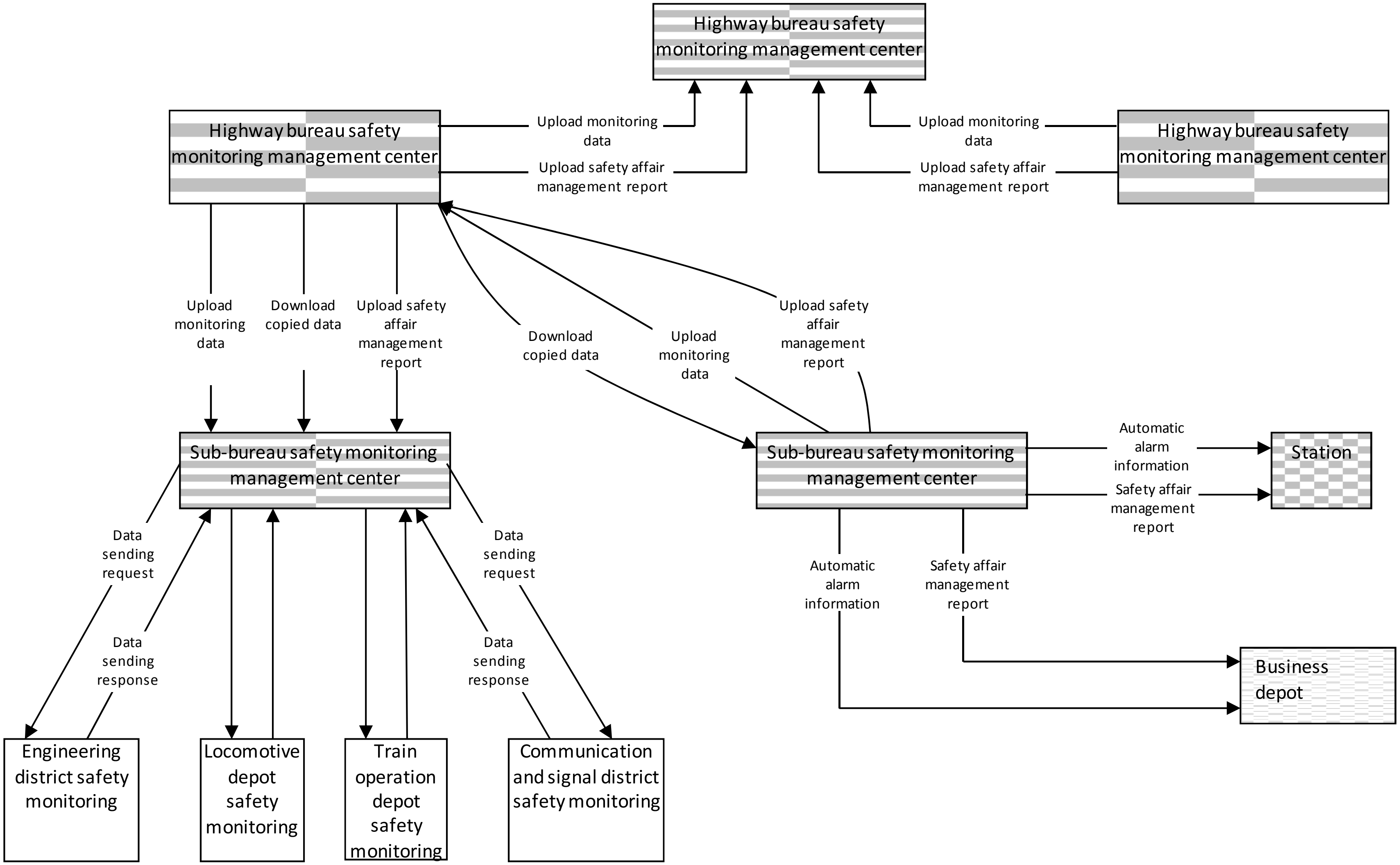



**Figure 17:** Safety monitoring data network (DFD4.2.2.5)

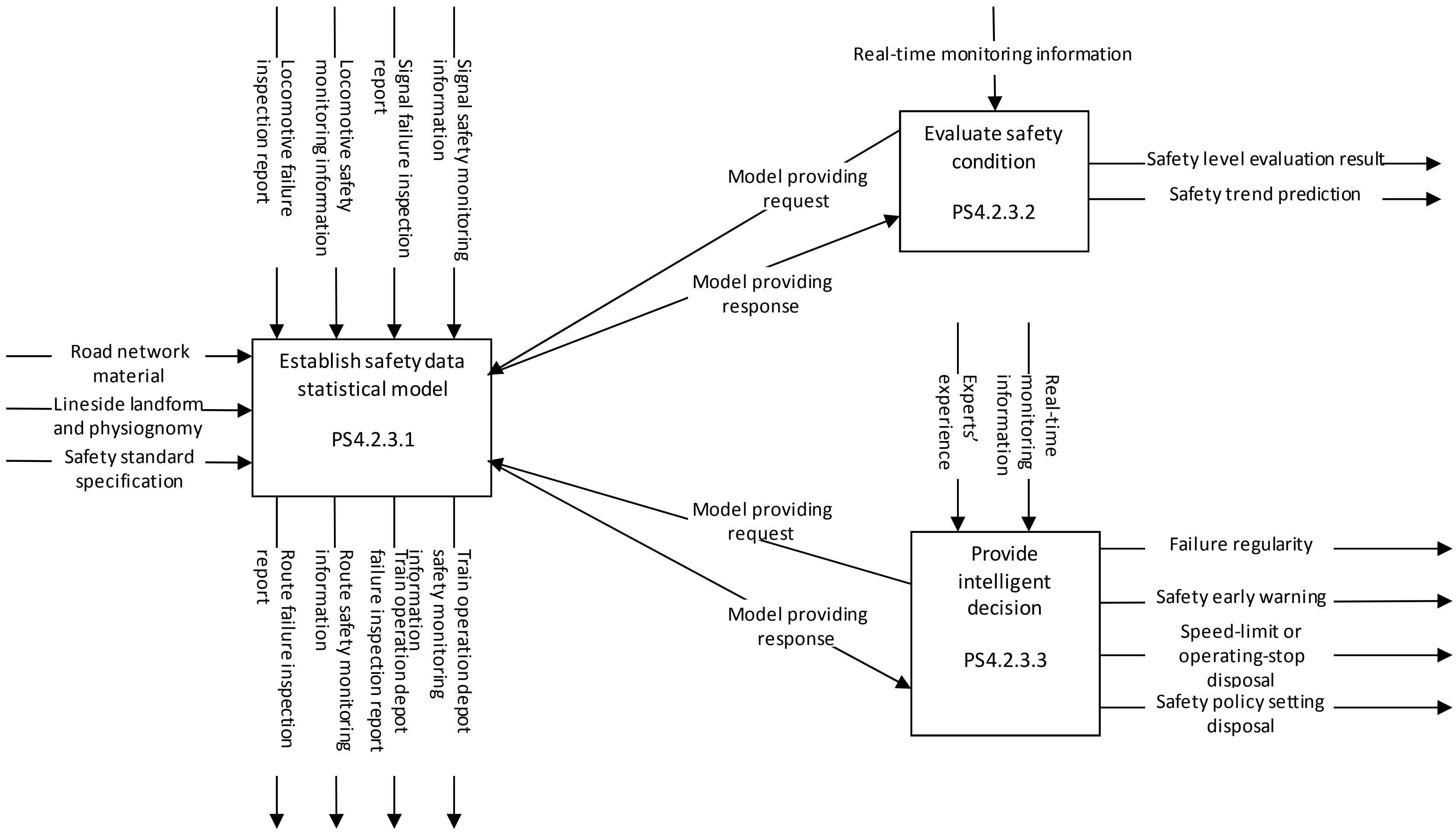



**Figure 18:** Safety evaluation (DFD4.2.3)

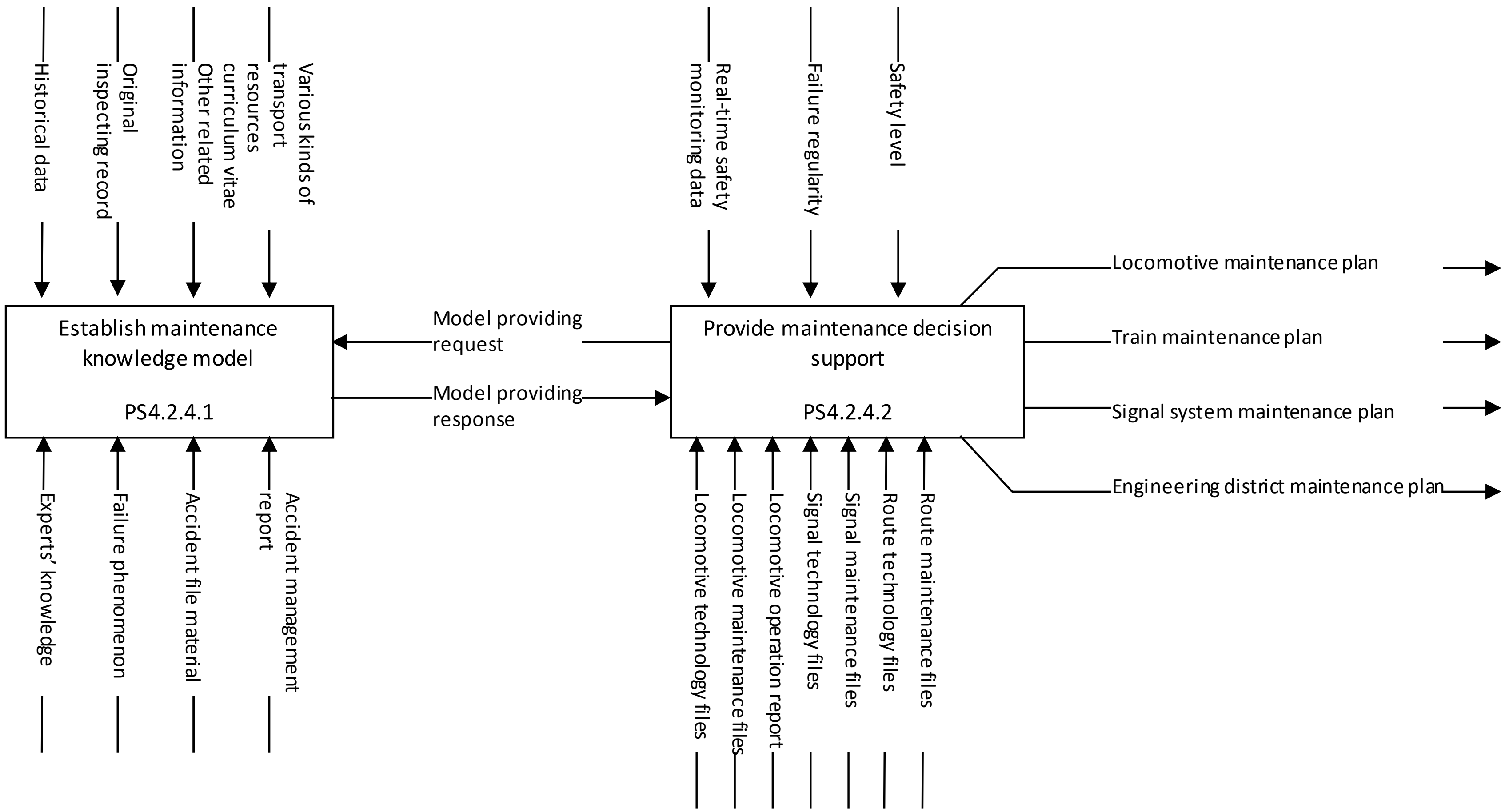



**Figure 19:** Maintenance decision support (DFD4.2.4)

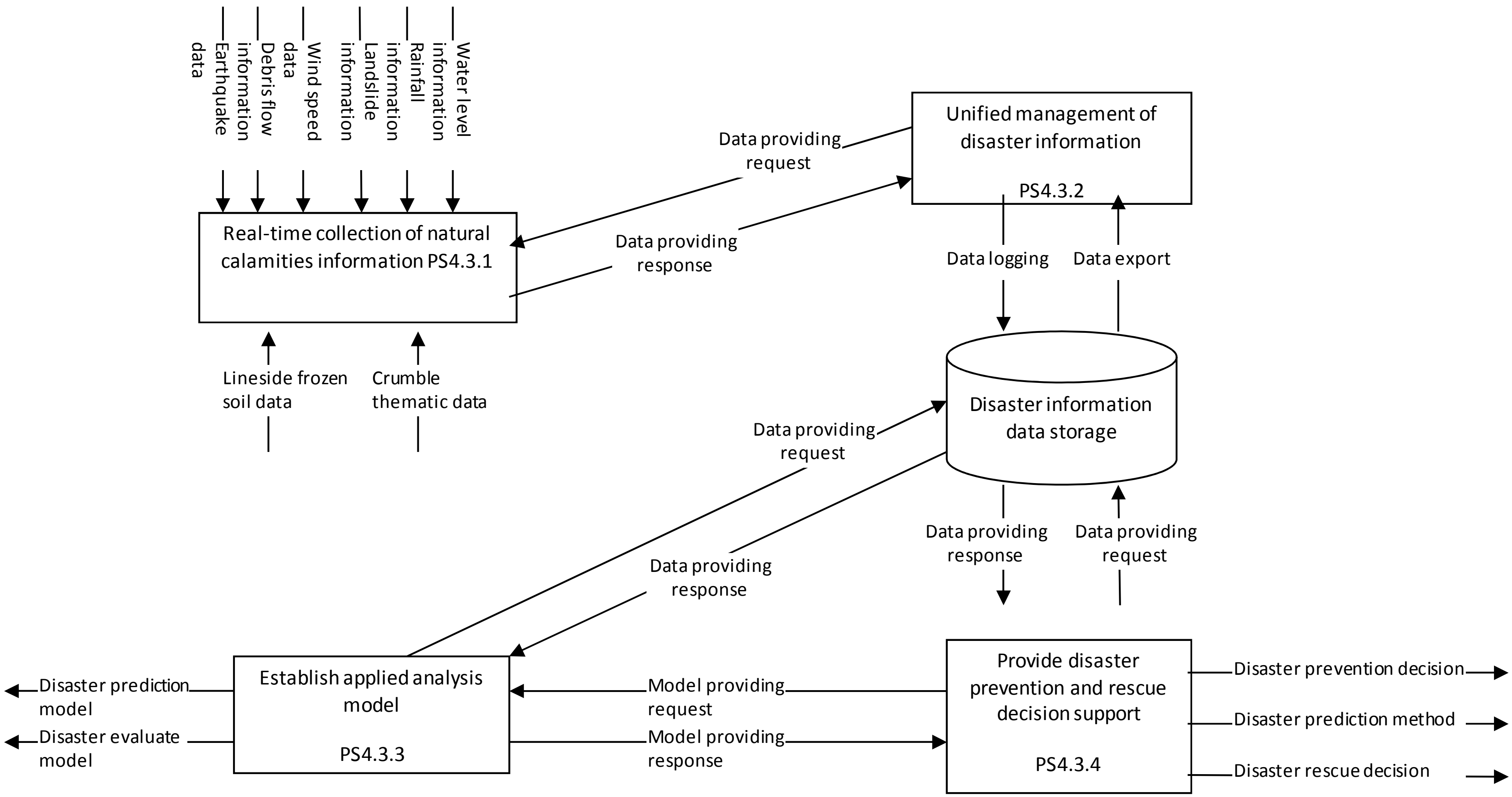



**Figure 20:** Railway comprehensive disaster prevention (DFD4.3)

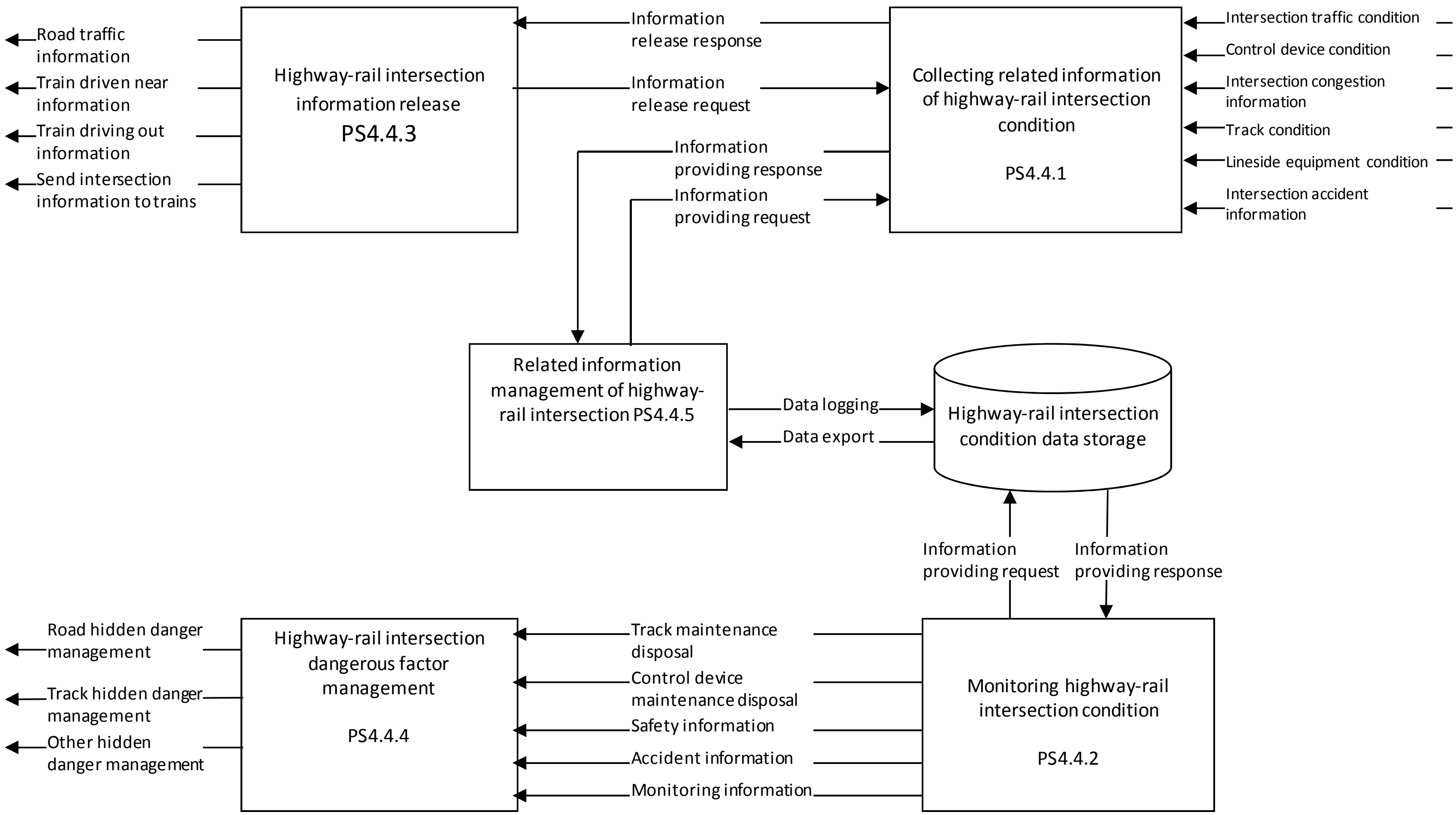



**Figure 21:** Road-rail Level crossing safety monitoring (DFD4.4)

# CHAPTER 3

# RITS Structure Optimization Design Theory

**Abstract:** Overall structural design of RITS is a process which solves functional optimization of organizations, reasonable division of subsystems, as well as optimal mapping between functions and sub-system. RITS overall structural design carries out qualitative analysis of content of RITS framework design, and then qualitatively carries out renewed organization and optimization to its internal structure and organization. Main content of RITS overall structure design is divided into the following two aspects: Logic structural design, and optimal design from logical structure to the physical structure. The RITS structure optimization design theory is introduce either in this chapter, such as fuzzy Interpretative Structural Modeling (ISM), fuzzy clustering, fuzzy matter element analysis etc. Finally the main content, formalization descriptions and general steps for RITS structural optimization design are introduced in this chapter.

## RITS OVERALL STRUCTURAL DESIGN

### Main Content of RITS Overall Structure Design

RITS system is an aggregate which consists of a series of various interrelated elements (functions and sub-systems), to complete some specific functions. Because of the complicated coupling relationship between various elements, it is difficult to obtain relatively clear and rational understanding of internal organization structure of the system. In order to grasp the inherent mechanism of RITS, it is necessary to assemble the process that several data closely commute into a range of functional units, in accordance with some designated rules, simultaneously, the system is divided into a number of physical subsystems with the appropriate particle size, relatively independent, and then respectively configures functional unit into different physical subsystems to be realized.

RITS system framework design executed qualitative overall planning and designing to its internal organizational structure by virtue of expertise, and gave the major coverage to logical framework design and physical framework design, as shown in (Fig. **1**). Logical framework layer is divided into two levels: process level and functional unit level. Process-level element is a number of independent processes to complete single-function with input/output; based on principles including high cohesion, low coupling, interoperability, being reusable, suitable for the of particle size etc; level of functional unit polymerizes several processes of process-level into one functional unit. In accordance with the principles above, the logical framework design could assemble several affinitive processes into one functional unit. Based on the expert experience, physical framework design integrated various types of process definitions of logical framework level and data flows, to form certain number of physical subsystems which possesses certain functions and meets the needs of the RITS. According to real environment requirements, such as business processes, workflow, organizational structure, business objects and so on, we configured via mapping process of logic layer to subsystems which meet the needs and is homologous to physical layer.

Whether or not the functional organizations, subsystems division and allocation plan of function on subsystems are reasonable, they will directly affect the quality, performance and development costs, etc. of system design. RITS system framework design is a qualitative empirical judgment, lacks rigorous scientific methods to prove the correctness of the judgment, and needs to exploit relational data and information to execute quantitative description and evaluation. First of all, RITS overall structural design executes qualitative analysis on of RITS framework design, and then qualitatively executes renewed organization and optimization to its internal structure and organization, according to selection sort among multiple programs, to obtain as optimal as possible design. As shown in (Fig. **2**) below, main content of RITS overall structure design is divided into the following two aspects:

1. Logic structural design: it executes qualitative analysis to main contents of logical framework design, using relevant basic theory and methods of the overall structure design to reorganize functional units of logical framework, to form some new physical subsystems. The design executed reasonable classification on the process and corresponding data, and assembled them into functional unit with appropriate size, clear function and certain independence, translating complicated system design into design of some functional units.

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2. Optimal design from logical structure to the physical structure: the design executed qualitative analysis to main contents of physical framework, using relevant basic theory and methods of the overall structure design, to reorganize the functional unit of logical framework, and form some new physical sub-systems. In some way, the design compactly integrated some functional units, to constitute a physical sub-system that adapts to existing railway management system and future development, and could relatively independently complete part of the functions.

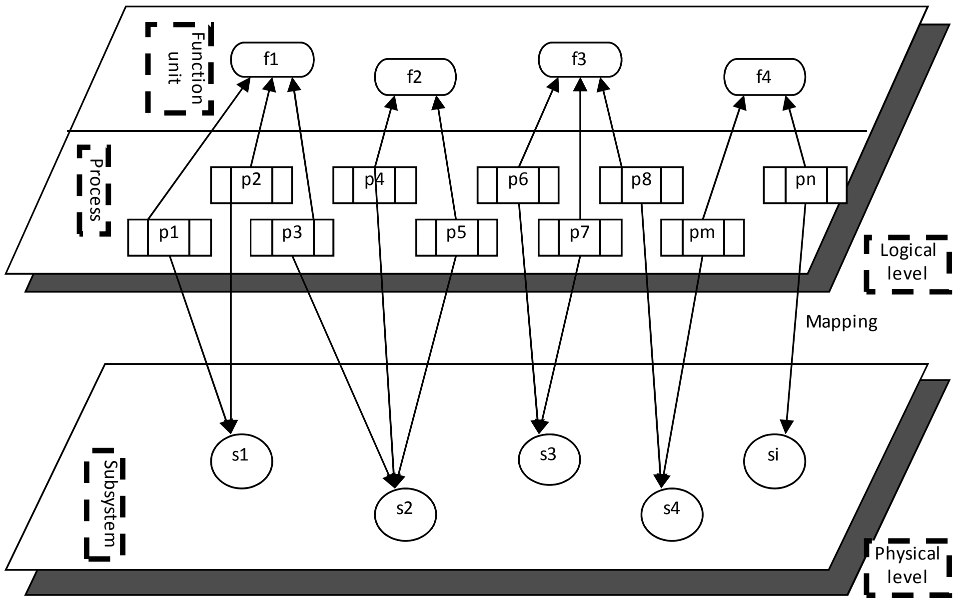


**Figure 1:** RITS system framework design

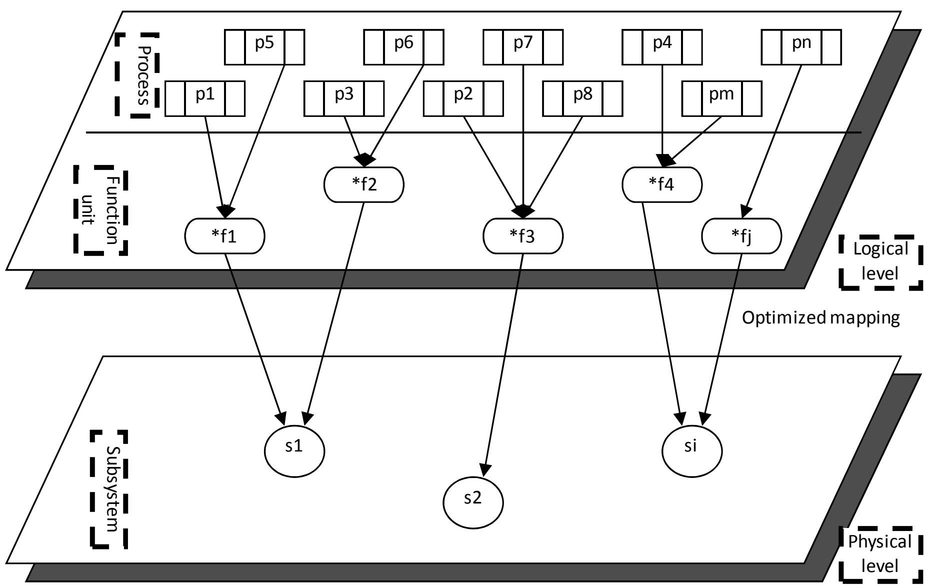


**Figure 2:** RITS overall structure design

It is the crucial link to raise qualitative and empirical judgments of RITS framework design to quantitative calculation of RITS overall structural design. Quantitative calculation of RITS overall structural design has no more than two kinds of results, believable or unbelievable. If the result is unbelievable, then improvements are needed, such as choosing different membership function, adjusting the target system and its weighing and so on, and then to repeat process of RITS overall structure design, repeatedly contrast, until the experts agreed that quantitative results can be believable. At this time result of RITS system design is no longer the empirical judgment, but scientific conclusion after rigorous argumentation. If quantitative calculation results of RITS overall structure design negated the empirical judgments done by RITS framework design, it is also a new awareness and will bring about new qualitative and empirical judgments [46].

### Characteristics and Principles of RITS Overall Structure Design

To sum up, overall structural design of RITS is a process which solves functional optimization of organizations, reasonable division of subsystems, as well as optimal configuration between functions and sub-system. This process has the obvious characteristics including multi-solvability, hierarchy, approximation, binding character and optimization etc, being a complex decision-making process.

1. Multi-solvability: multi-solvability of RITS overall structural design is mainly reflected in its diversity of design methods, paths and design results. Different functions of the organization, different classification criterion of subsystems, different constraint condition and different optimization objectives will generate completely different designs.
2. Hierarchy: hierarchy of RITS overall structural design is mainly embodied in two aspects: on one hand, the overall structure design acts respectively in logic layer and physical layer, and completes mapping from logic layer to physical layer, such as the function definition and function acts in logic layer, and division of subsystems acts in physical layer, with the mapping relationship linking the two layers. On the other hand, there is also hierarchical relationship of their own in logical layer and physical layer, such as functional organization in logical layer put functions upward from one level to the last level, and hierarchy of functions also determines the hierarchy of subsystems in physical layer, function at different levels corresponding to different levels of subsystems.
3. Approximation: RITS overall structural design is based on the premise of RITS framework design, and from the beginning of demand information the framework design is uncertain, incomplete, non-quantifiable, therefore RITS overall structure design based on framework design content has the similar nature.
4. Binding character: RITS overall structure design is executed under limitations and restrictions of various factors, including management system, technology, economy, etc, simultaneously involved in environmental, social and other factors. These restrictions and requirements constitute a set of boundary conditions, and formulate the "design space" for designers to execute decision-making and conceiving.
5. Optimization: essential distinction between RITS overall structure design and RITS framework design lie in optimization, including optimization of functional organization, optimization of sub-systems division, as well as optimization of mapping and so on. RITS overall structure design focused on the overall performance and overall co-ordination, and results of optimization design could provide decision support for the future development of railways.

The following principles should be followed in RITS overall structure design:

1. we should endeavor not to break the existing railway operation and management system, avoid or reduce adjustment of the existing organizational structure, as far as possible adapt and meet the future development change and reform demands of railway.
2. When design requirements change or organizational structure adjusts, we should limit changes of the system to a lesser scope; we ensure the transplantation from a physical environment to another is on the premise of as little changes as possible, simultaneously conducive to gradual integration of application system and convenient to optimization and reorganization of organizational structure.
3. We maintain the stability of function (process) and the relative independence of each subsystem, to ensure logic relationship between close functional units having a good coherence, at the same time make sure that each subsystem has flexibility and adaptability of a high degree.
4. We ensure that RITS overall structure design could meet the needs of users to maximum extent, lower costs, and improve the quick response [46].

## RITS STRUCTURE OPTIMIZATION DESIGN THEORY

### Fuzzy Interpretative Structural Modeling

All systems must have the structure as, system structure determines system function and behavior; destruction of the structure will completely destroy the system's overall function. This shows universality and importance of system structure. No matter whatever the structure is, it can be abstractly expressed as:

System Structure = {entire system elements, the link or relationship between the elements}

Definition (1) Suppose that the unit set $\Omega$ on discuss is limited, which is the collection of structural system units, and there are kinds of relationships $R$ between system units, then system structure is defined as:

$$S = \left\{\Omega, R^2, R^3, \cdots, R^n, R(2), R(3), \cdots, R(m)\right\} \quad \textbf{(1)}$$

In the formula:

$R(i) \subseteq R(i-1) \times R(i-1), i = 2, 3, \cdots, m$

$R(i)$ is the $i$ -order relationship, when $i = 2$ , $R(2)$ is the 2-order relationship, $R^i$ is the $i$ -dimension relationship（$i = 2, 3, \cdots, n$ ) .

The so-called structural model applies connected to digraph to describe the relationship between various system elements, to indicate a system model as elements aggregation.

Taking into account the need of engineering practice, high-level relations retain to the second-order, third-order and above are omitted. Definition (1) is simplified as follows:

$$S = \left\{\Omega, R, R^3, \cdots, R^n, R(2)\right\} \quad \textbf{(2)}$$

Formula (2) is the general formula of system structure model. In the formula, the connection between system unit set $\Omega$ and units is embodied through relationship between elements $R, R^3, \cdots, R^n, R(2)$ .

Structural model is a kind of geometric model. Through structural model, we can analyze whether the selection of system elements is reasonable, and the impact on overall system when system elements as well as the relationship between them changes. Extensive use of structural models, makes systematic evaluation, decision-making, planning, targeting and so on which in the past only relies on human experience, intuition or inspiration in the past for qualitative analysis, can rely on structural models to conduct quantitative analysis. Structural modeling technology is a methodology for establishment of structural model, and currently structural model technology has many kinds of available methods, particularly the most commonly used method is Interpretative Structural Modeling (Interpretative Structural Modeling referred to as ISM) .

ISM was developed as a method for analysis of related complex socio-economic system issues, by American J. China Felt Professor in 1973; It is an effective method used to analyze and reveal complex relationships structure, which can break down the complex, messy relationship between various system elements into clear hierarchical structure. Its characterization is that it breaks down complicated system into several subsystems (elements), utilizes people's practical experience and knowledge, and ultimately constructs the system into a multi-level hierarchical structure model. Basic steps for the application of ISM method are to choose the elements for system constitution, establish adjacency matrix and reachability matrix, build structure model after division of reachability matrix, and build ISM through structural model.

Since 1965, American experts LAZadeh in control theory, proposed fuzzy set theory and fuzzy system theory, greatly progressed, as well as achieved a lot of application results in many aspects, especially the research of complex systems and structural model using fuzzy method is one of them. Therefore, it is necessary to do fuzzy promotion on ISM, and then propose FISM.

Interpretative Structural Modeling, ISM for short, is a method developed to analyze problems that are related to comprehensive society and economic system, analyze and disclose complex relational structure. It breaks down the complex relationships among elements into clear and layered structural style.

1. Selecting elements for system consisting:

Set formula:

$S = \{\Omega, R, R^3, \cdots, R^n, R(2)\}$

$\Omega$ : System unit set;

$R(i) \subseteq R(i-1) \times R(i-1), i = 2, 3, \cdots, m$ ;

$R(i)$ indicates $i$ -order relation;

2. Building adjacency matrix and reachability matrix,

(1) According to the oriented (Fig. **3**), we could obtain square matrix as follow:

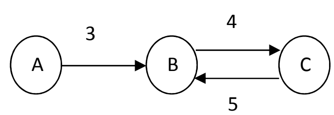


**Figure 3:** Directed graph

Then according to Figure **3**, A could be registered as:

$$A = \begin{bmatrix} 0...3...0 \\ 0...0...4 \\ 0...5...0 \end{bmatrix}$$

After normalization processing to A, we obtain:

$$A = \begin{bmatrix} a_{11}...a_{12}...a_{13} \\ a_{21}...a_{22}...a_{23} \\ a_{31}...a_{32}...a_{33} \end{bmatrix} = NB = N \begin{bmatrix} \beta_{11}...\beta_{12}...\beta_{13} \\ \beta_{12}...\beta_{22}...\beta_{23} \\ \beta_{31}...\beta_{32}...\beta_{33} \end{bmatrix}$$

Matrix A is called the fuzzy adjacency matrix of fuzzy matrix B, and in B any $\beta_{ij} \in [0,1]$, N is a positive number, generally registered as positive integer.

(2) In fuzzy interpretative structural modeling, definition of reachability matrix is: if fuzzy matrix B meets the condition that $(B+I)^{k-1} \neq (B+I)^k = (B+I)^{k+1} = M$ , then M is called the reachability matrix of B.

3. Build structural model, after division of reachability matrix,

4. Build interpretative structural model, according to structural model.

## Fuzzy Clustering

The clustering method that applies general mathematical method to classify is called ordinary cluster analysis, and can be called hard partition; while the clustering analysis that applies fuzzy mathematical method to analyze is called the fuzzy cluster analysis, and can be called soft division. Fuzzy clustering analysis is a mathematical method based on the features among objective things, degree of closeness and similarity, through the establishment of fuzzy similarity relations to categorize objective things. Following are two kinds of fuzzy clustering methods.

### *Transitive Closure Method*

Set $X = \{x_1, x_2, ..., x_n\}$ as domain in binary fuzzy relationship, having known fuzzy equivalent matrix $R \in M_{n\times n}$, then we can calculate transitive closure to obtain fuzzy equivalent matrix.

Set $\lambda$ from 1 to 0 to execute $\lambda$-order calculation on fuzzy equivalent matrix, in turn we obtain general equivalence relation $R_{\lambda_i}, i = 0,1,...,m$, which divides $X$, as $\lambda_1 < \lambda_2 \Rightarrow R_{\lambda_1} \supseteq R_{\lambda_2}$, hence for any $(x_1, x_2)$

$$(x_1, x_2) \in R_{\lambda_2} \Rightarrow (x_1, x_2) \in R_{\lambda_1}$$

That is to say, when $\lambda$ changes between 1 and 0, the classification will coarsen generally, and will formulate a dynamic clustering figure.

### *Direct Clustering*

After establishment of fuzzy similar matrix, we can start clustering analysis directly from R. The specific process is as follows:

(1) Calculate fuzzy similar matrix R;

(2) Set $\lambda$ separately as $\lambda_1, \lambda_2, \cdots \lambda_m$, for k, $\lambda = \lambda$ if $r_{ij} \geq \lambda_k$, then $x_i$ and $x_j$ are divided into one class. If intersection of two classes is not of a void class, then they are called conjoint. We integrate all conjoint classes, and finally obtain the equivalence partitioning on $\lambda$k. Through direct clustering, different confidence levels of $\lambda$ will bring about different division results of the system.

## Fuzzy Matter Element Analysis

### *The Analysis Overview of Matter-Element*

Matter-element analysis method is initiated by Professor CaiWen in 1983, well-known Chinese scholar. it is a method for studying resolutions of the contradiction problem, the interdisciplinary subject intersected by system science, thinking sciences, mathematics, and the cross-disciplinary which is through the natural and social sciences, with the broader application. According to the analysis of substantial examples it was found that: when handling incompatibility issues, only by comprehensive consideration of matters, the characteristics and the corresponding quantity value,, more appropriately describe the changing laws of objective matters, and formalize the process of solving paradoxical problem. The main idea of this method is to describe matters with three elements i.e. "matters, characteristics, quantity value", and form the basic element of ordered triple, which is matter-element. Matter-element analysis is an effective way to study matter-element as well as its changing laws which are used to solve real-world incompatible issues. The use of matter-element analysis methods, can create the evaluation model with multi-indexed performance parameters, and able to represent assessment results with quantitative numerical value, to relatively integrally reflect comprehensive level of matters quality, and being easy for computer to carry on programming process.

If the quantity value of matter-element involves ambiguity, then it forms the fuzzy incompatible problem. Fuzzy matter-element analysis organically combine vague mathematics and matter-element, melt extraction, crossly infiltrate, inflict analysis and integration on ambiguity processed by quantity value corresponding to characteristics of matters and incompatibility affecting between many factors of matters, thus obtain a new method to resolve incompatible and fuzzy problem [44].

### *Relational Basic Concepts*

**(1) Matter-Element**

By setting matter the name N, the quantity value v related to characteristic c, we could get ordered triple:

$$R = (N, c, v) \tag{3}$$

As the basic element to describe matter. The name N, characteristic c and the quantity value v of matters are known as the three elements of matter-element.

One matter could have many characteristics, if matter N is described by n characteristics such as $c_1, c_2, \cdots, c_n$ as well as the corresponding quantity value such as $v_1, v_2, \cdots, v_n$, it could be expressed as:

$$R = \begin{bmatrix} N, c_1, v_1 \\ c_2, v_2 \\ \cdots \\ c_n, v_n \end{bmatrix} = \begin{bmatrix} R_1 \\ R_2 \\ \cdots \\ R_n \end{bmatrix} \quad \textbf{(4)}$$

We name $R$ as n-dimensional matter-element and $R_i = (N, c_i, v_i)(i = 1, 2, \cdots, n)$ is called sub-matter-element of $R$ .

**(2) Fuzzy Matter-Element**

For the triple matter-element, if one quantity value has ambiguity, then there are ordered triple (sentence structure check) : "matters, characteristics, fuzzy quantity value" are served as the basic matter-element to describe matters, and this matter-element is called as the fuzzy matter-element.

In order to distinguish with the matter-element, fuzzy matter-element is recorded as:

$$\tilde{R} = \begin{bmatrix} & M \\ c & \mu(x) \end{bmatrix} \quad \textbf{(5)}$$

In the formula above, $\tilde{R}$ indicates fuzzy matter-element, $M$ indicates matters, indicates characteristics possessed by matters, $\mu(x)$ indicates membership grade of quantity value $x$ corresponding to matters characteristics, namely fuzzy quantity value.

If the matter $M$ is described with $n$ characteristic $c_1, c_2, \cdots, c_n$ as well as corresponding fuzzy quantity value $\mu(x_1), \mu(x_2), \cdots, \mu(x_n)$ , then we name it $n$ -dimensional fuzzy matter-element, designated as:

$$\tilde{R}_n = \begin{bmatrix} & M \\ c_1 & \mu(x_1) \\ c_2 & \mu(x_2) \\ \cdots & \cdots \\ c_n & \mu(x_n) \end{bmatrix} \quad \textbf{(6)}$$

In the above formula, $\tilde{R}_n$ indicates $n$ -dimensional fuzzy matter-element $c_i$ indicates the $i$ characteristic; $\mu(x_i)$ indicates membership grade of quantity value $x_i$ ( $i = 1, 2, \cdots, n$) corresponding to the $i$ characteristic $c_i$ of matter $M$ , which could be defined by membership function.

**(3) Compound Fuzzy Matter-Element**

If $m$ matters are described with their common $n$ characteristics $c_1, c_2, \cdots, c_n$ as well as corresponding fuzzy quantity value $\mu(x_{1i})$ $\mu(x_{2i})$ , …, $\mu(x_{mi})$ ( $i = 1, 2, \cdots, n$ ), we name it as $n$ -dimensional compound fuzzy matter-element of the $m$ matters, namely:

$$\tilde{R}_{mn} = \begin{bmatrix} & M_1 & M_2 & \cdots & M_m \\ c_1 & \mu(x_{11}) & \mu(x_{21}) & \cdots & \mu(x_{m1}) \\ c_2 & \mu(x_{12}) & \mu(x_{22}) & \cdots & \mu(x_{m2}) \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ c_n & \mu(x_{1n}) & \mu(x_{2n}) & \cdots & \mu(x_{mn}) \end{bmatrix} \quad \textbf{(7)}$$

In the formula above, $\tilde{R}_{mn}$ indicates $n$ -dimensional compound fuzzy matter-element of $m$ matters, $c_j$ indicates the $j$ characteristic, $M_i$ indicates the $i$ matter, $\mu(x_{ij})$ indicates the membership grade of quantity value $x_{ij}$ $(i = 1, 2, \cdots, m; j = 1, 2, \cdots, n)$ corresponding to the $i$ matter $M_i$ and the $j$ characteristic $c_j$ .

**(4) Compound Weighing Matter-Element**

If we indicate compound weighing matter-element of each characteristic with $R_w$ , then

$$R_w = \begin{bmatrix} & c_1 & c_2 & \cdots & c_n \\ w_i & w_1 & w_2 & \cdots & w_n \end{bmatrix} \quad \textbf{(8)}$$

In the formula above, $w_j\,(j = 1, 2, \cdots, n)$ indicates weighing of the $j$ characteristic of each matter.

**(5) Correlation Compound Fuzzy Matter-Element**

Correlation is a measure of relatedness of size between all things and ideal matters. Set $\tilde{R}_k$ the correlation compound fuzzy matter-element consisted of $m$ correlation, then the correlation compound fuzzy matter-element is:

$$R_k = \begin{bmatrix} & M_1 & M_2 & \cdots & M_m \\ k_i & k_1 & k_2 & \cdots & k_m \end{bmatrix} \quad \textbf{(9)}$$

In the formula above, $k_i$ is the degree of association of the $i$ matter.

***Optimization Principles***

The optimization principle is measured, based on preferential membership grade of individual characteristic, which could be named as preferential membership grade principle for individual characteristic, namely optimization principle. The so-called preferential membership grade is in fact the corresponding fuzzy quality value of each characteristic, also the fuzzy quality value subordinate to corresponding characteristics of standard matters. Principle established on this foundation is the optimization principle.

This model also has three types of indicators [44]:

**(1) Large Superior-Type**

$$\mu_{ij} = \frac{x_{ij} - \min x_{ij}}{\max x_{ij} - \min x_{ij}} (i = 1, 2, \cdots, m;\ j = 1, 2, \cdots, m) \quad \textbf{(10)}$$

**(2) Small Superior-Type**

$$\mu_{ij} = \frac{\max x_{ij} - x_{ij}}{\max x_{ij} - \min x_{ij}} (i = 1, 2, \cdots, m;\ j = 1, 2, \cdots, n) \quad \textbf{(11)}$$

**(3) Moderate Type**

$$\mu_{ij} = \frac{\min(x_{ij}, \mu_0)}{\max(x_{ij}, \mu_0)} (i = 1, 2, \cdots, m;\ j = 1, 2, \cdots, n) \quad \textbf{(12)}$$

In the formula above, $\mu_{ij}$ indicates the preferred membership grade of the $i$ matter the $j$ characteristic; $x_{ij}$ indicates the quantity value corresponding to the $i$ matter the $j$ characteristic; $\max x_{ij}$ , $\min x_{ij}$ respectively indicates the maximum value and the minimum value of $x_{ij}$ ; $\mu_0$ indicates the moderate value of one indication, and is a determined value.

### Fuzzy Matter-Element Correlation Analyses

In the correlation compound fuzzy matter-element, the methods that according to the size of each correlation, sort orderly, and then execute analysis on the matter or factor, are known as the fuzzy matter-element association analysis. Its purpose is to seek the primary and secondary relationship between matters, identify important factors affecting the target value, so as to grasp the main features of matters, promote and guide matters that can develop quickly and effectively, and determine the best matters among them.

#### (1) Correlation Function and the Correlation Transformation

All those functions who describe extension set quality value with algebraic expression, are known as correlation function, recorded as $\xi(x)$ .

Since the element contained in correlation function and membership function all belongs to intermediary element, the difference between these two functions, is only the scope of quantity value, which could be conditionally transformed, of correlation function over membership function. When Classical domain coincides with section domain, the correlation function becomes equivalent to the membership function.

When some feature value $x_{ij}$ is determined in the correlation function, corresponding function value, which is named as correlation function and normally expressed by $\xi_{ij}$ , could be calculated. Since correlation function is equivalent to membership function, then correlation coefficient could be determined by membership grade, therefore:

$$\xi_{ij} = \mu_{ij} = \mu(x_{ij}), i = 1, 2, \cdots, n \tag{13}$$

The $\xi_{ij}$ here indicates correlation coefficient between the matter $i$ and the characteristic $j$ of standard matters, among them, the membership grade could be determined by membership function, or determined by fuzzy statistical method, or by principle of optimality. This kind of inter-conversion between correlation function and membership function is called correlation transformation.

Corresponding membership grade of each characteristic of every matter obtains its of own correlation coefficient by transformation, hereby structure correlation coefficient compound matter-element of $m$ matter $n$ characteristic, called correlation coefficient compound fuzzy matter-element and designated as $\tilde{R}_\xi$ :

$$\tilde{R}_\xi = \begin{bmatrix} & M_1 & M_2 & \cdots & M_m \\ c_1 & \xi_{11} & \xi_{21} & \cdots & \xi_{m1} \\ c_2 & \xi_{12} & \xi_{22} & \cdots & \xi_{m2} \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ c_n & \xi_{1n} & \xi_{2n} & \cdots & \xi_{mn} \end{bmatrix} \tag{14}$$

#### (2) Calculation of Correlation Degree

Set $\tilde{R}_k$ indicates correlation compound fuzzy matter-element consisted by m correlation degree, and adopt weighted average processing, we could reason out that:

$$\tilde{R}_k = Rw * \tilde{R}_\xi \tag{15}$$

The “*” here indicates operation symbol, in accordance with different modes adopted, there are different arithmetic modes, the remaining are same with the former.

#### (3) Evaluation Principle for the Maximum Correlation Degree

Correlation degree of each matter is sorted according to their sizes, to choose the maximum $k^*$ as an evaluation principle, and this principle is called maximum correlation degree principle, that is:

$$k^* = \max(k_1, k_2, \cdots, k_m) \quad \textbf{(16)}$$

This principle has a wide range of uses, which can not only identify, assemble, assess decision-making to assemblage, but also execute analysis on its value, etc. It is one theoretical basis for fuzzy matter-element analysis.

Fuzzy matter-element optimization theory

**(1) N-Dimensional Fuzzy Matter-Element Structure of Excellent, Second-Class Matter**

According to optimization principle, n-dimensional fuzzy matter-element structure of excellent, second-class matter, which is used as a comparison standard of optimization, therefore correlation should be the maximum correlation coefficient corresponding to index arm of all matters, $y_1, y_2, \cdots, y_n$. If $\tilde{R}_y$ is used to express n-dimensional fuzzy matter-element of excellent matters, then:

$$\tilde{R}_y = \begin{bmatrix} & M \\ c_1 & y_1 \\ c_2 & y_2 \\ \vdots & \vdots \\ c_n & y_3 \end{bmatrix} \quad \textbf{(17)}$$

In a similar way, correlation coefficient of inferiority matters n characteristic is the minimum correlation coefficient $z_1, z_2, \cdots, z_n$ corresponding to all matters indexing, and then the following formula is calculated:

$$\tilde{R}_z = \begin{bmatrix} & M_z \\ c_1 & z_1 \\ c_2 & z_2 \\ \vdots & \vdots \\ c_n & z_3 \end{bmatrix} \quad \textbf{(18)}$$

In the formula above, $M_y, M_z$ means excellent matters i.e second-class matters, and the remaining are same as the former.

**(2) Structure Compound Fuzzy Matter-Element**

For correlation coefficient, compound fuzzy matter-element in the formula above, with the consideration of difference between the matter superiority matter or inferiority matter, and according to the definition of matter-element simple difference, we can calculate:

$$(\tilde{R}_y - \tilde{R}_\xi) = \begin{bmatrix} & M_1 & M_2 & \cdots & M_m \\ c_1 & y_1 - \xi_{11} & y_1 - \xi_{21} & \cdots & y_1 - \xi_{m1} \\ c_2 & y_2 - \xi_{12} & y_2 - \xi_{22} & \cdots & y_2 - \xi_{m2} \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ c_n & y_n - \xi_{1n} & y_n - \xi_{2n} & \cdots & y_n - \xi_{mn} \end{bmatrix} \quad \textbf{(19)}$$

$$\tilde{R}_{zd} = \begin{bmatrix} & M_1 & M_2 & \cdots & M_m \\ Z_d & \sum_{j=1}^{n} w_j(\xi_{1j} - Z_j) & \sum_{j=1}^{n} w_j(\xi_{2j} - Z_j) & \cdots & \sum_{j=1}^{n} w_j(\xi_{mj} - Z_j) \end{bmatrix} \quad \textbf{(20)}$$

If $\tilde{R}_{yd}, \tilde{R}_{zd}$ respectively indicate compound fuzzy matter-element of superior distance and inferior distance, and $y_d, z_d$ respectively indicate superior distance and inferior distance, then with weighted average centralized processing we can calculate that:

$$\tilde{R}_{yd} = \begin{bmatrix} & M_1 & M_2 & \cdots & M_m \\ y_d & \sum_{j=1}^{n} w_j (y_j - \xi_{1j}) & \sum_{j=1}^{n} w_j (y_j - \xi_{2j}) & \cdots & \sum_{j=1}^{n} w_j (y_j - \xi_{mj}) \end{bmatrix} \quad \textbf{(21)}$$

$$\tilde{R}_{zd} = \begin{bmatrix} & M_1 & M_2 & \cdots & M_m \\ Z_d & \sum_{j=1}^{n} w_j (\xi_{1j} - Z_j) & \sum_{j=1}^{n} w_j (\xi_{2j} - Z_j) & \cdots & \sum_{j=1}^{n} w_j (\xi_{mj} - Z_j) \end{bmatrix} \quad \textbf{(22)}$$

$w_j$ indicates weighing of the characteristic $j$ , and the remaining marks are same with the former.

**(3) Determine the Optimal Matter**

In order to select superior thing, we firstly establish objective function, and then calculate its least

squares solution. Set $F(k_i)$ as objective function of matters, $k_i$ as well as $\sum_{j=1}^{n} w_j (y_j - \xi_{ij})$ and in formula (24) and (25) are all real function, so in the field of

real numbers ", if extended as "squared sum of weighing distance is the minimum", it still is applicable, then the formula is following

$$\min F(k_i) = \sum_{i=1}^{m} \left\{ [k_1 \sum_{j=1}^{n} w_j (y_j - \xi_{ij})]^2 + [(1-k_i) \sum_{j=1}^{n} w_j (\xi_{ij} - z_j)]^2 \right\} \quad \textbf{(23)}$$

In the formula, $k_i$ is the required value, every $k_i$ is derivative, and set $k_i$ zero, that is $dF(k_i)/dk_i = 0$ , with $y_j \to 1, z_j \to 0$ , so we could calculate that:

$$k_i = \left\{ 1 + \left[ \frac{\sum_{i=1}^{n} w_j (1 - \xi_{ij})}{\sum_{j=1}^{n} w_j \xi_{ij}} \right]^2 \right\}^{-1} \quad \textbf{(24)}$$

$$i = 1, 2, \cdots, m$$

This is the correlation degree computing formula of the matter $i$ , by which correlation degree compound fuzzy matter-element of $m$ matters is established, recorded as $\tilde{R}_k$ , as follows:

$$\tilde{R}_k = \begin{bmatrix} & M_1 & M_2 \\ k_j & k_1 = \left\{ 1 + \left[ \frac{\sum_{j=1}^{n} w_j (1 - \xi_{1j})}{\sum_{j=1}^{n} w_j \xi_{1j}} \right]^2 \right\}^{-1} & k_2 = \left\{ 1 + \left[ \frac{\sum_{j=1}^{n} w_j (1 - \xi_{2j})}{\sum_{j=1}^{n} w_j \xi_{2j}} \right]^2 \right\}^{-1} \\ \cdots & M_m & \\ \cdots & k_m = \left\{ 1 + \left[ \frac{\sum_{j=1}^{n} w_j (1 - \xi_{mj})}{\sum_{j=1}^{n} w_j \xi_{mj}} \right]^2 \right\}^{-1} & \end{bmatrix} \quad \textbf{(25)}$$

6 Optimization theory of multi-objective fuzzy matter-element

Objective pursued by most design issues is not single. For example, the design of a reducer, we hope it weighs lightest, having strongest carrying capacity, longest life expectancy, the best stability, etc. The issue that simultaneously requests several design indicators reach optimal, is known as multi-objective optimization issue. The general form of mathematical model for multi-objective optimization issue is as follows:

Objective function:

Constraint condition: $s.t \quad g_i(X) \le 0,\ j = 1, 2, \cdots, 5$ **(26)**

To calculate $X = (x_1, x_2, \cdots, x_n)^T$

In the formula, indicators expressed by each objective function $f_1(X), f_2(X), \cdots, f_l(X)$ are usually contradictory, that is to say optimum points of sub-objectives are usually not of the same point, and it is hard to reach each sub-objective function the optimum at the same time, moreover most multi-objective optimization problems do not exist optimum solution in this sense, they need overall coordination to obtain realistic optimal decision, namely decision for multi-objectives optimum design.

Objective function $f_i(X)$ is a generalized function, that is $f_i(X)$ could be an aggregate of qualitative reviews, such as stability of objective function, $f_i(X)$={good, better, common, worse, bad}. Then calculated $f_i(X)$ belongs to one comment of aggregate. Fuzzy matter-element analysis method could be adopted for this multi-objective optimization model, to transform multi-objective optimization issue into optimization problem of single objective, which is called as multi-objectives fuzzy matter-element optimum method [45].

Multi-objective optimization problem can be described in the form of matter-element. If the multi-objective optimization design is taken as characteristics of matter-element, and the value of the objective function money as quantity value of matter-element, then the multi-objective optimization matter-element model is as follows:

$$R = \begin{bmatrix} M & c_1 & f_1(x) \\ & c_2 & f_2(x) \\ & \cdots & \cdots \\ & c_l & f_l(x) \end{bmatrix} \tag{27}$$

In the formula, $M$ indicates program name of the product to be optimally designed**:** $c_i$ indicates the name of the sub-objective $i$ , $x$ indicates the design variable, and $f_i(x)$ indicates the $i$ objective function.

As some of the targets are just qualitative collection of terms, it is difficult to carry on quantitative calculations directly. Even if the objective function is a conventional mathematical approach, because of the dimensionless difference for each objective function and the comparatively large gap between sub-objectives function values. Therefore, we transform the form of design objective from matter-element into fuzzy matter-element, making fuzzy matter-element model of formula as:

$$\tilde{R}_l = \begin{bmatrix} & M \\ c_1 & \mu(f_1(x)) \\ c_2 & \mu(f_2(x)) \\ \cdots & \cdots \\ c_l & \mu(f_l(x)) \end{bmatrix} \tag{28}$$

In the formula, $\tilde{R}_l$ indicates fuzzy matter-element of $l$ -dimensional products to be optimally designed, $c_i$ indicates the name of the sub-objective $i$ , $\mu(f_i(x))$ indicates preferential membership degree (optimum membership for short) corresponding to quantity value $f_i(x)$ $(i = 1, 2, \cdots, l)$ of product $M$ 's $i$ sub-objective $c_i$ , $\mu(f_i(x)) \in [0,1]$ .

Given $f_i(x)$ is an aggregate of qualitative reviews, which are needed to be quantified and expressed by numbers in section [0, 1].

In the process of optimization design, each sub-objective respectively has its weigh. If $R_w$ indicates weighing compound matter-element of each sub-objective in the fuzzy matter-element program, and $w_i(i = 1,2,\cdots,l)$ indicates weighing of each sub-objective, we can get the following formula:

$$R_w = \begin{bmatrix} & c_1 & c_2 & \cdots & c_l \\ w_i & w_1 & w_2 & \cdots & w_l \end{bmatrix} \quad \textbf{(29)}$$

Of which $w_i$ is determined by analytic hierarchy process.

Membership degree is used as standard to estimate the quality of programs: the higher the of program membership degree the more superior the program. Computing formula of membership degree $k$ becomes:

$$k(x) = \sum_{i=1}^{l} \xi_i w_i \quad \textbf{(30)}$$

Here $\xi_i$, calculated by correlation transformation $\xi_i = \mu(f_i(x))$, is the incidence coefficient.

Then multi-objective optimization issue transforms into single objective optimization issue as is in the following formula:

$$\text{Solve } X = \{x_1, x_2, \cdots, x_n\}^T$$

## THEORY AND METHOD OF RITS STRUCTURAL OPTIMIZATION DESIGN

### Optimization Design of RITS Logical Structure

#### Main Content of Logical Structure Optimization Design

RITS system has a large-scale, complex structure, many system elements, requiring thorough analysis and design of logical structure, to help understand function organization structure of the inner system, to ensure the reasonableness and effectiveness of the logical structure. Design process of RITS logical structure is in essence, the organizational and optimization process of system functional unit. According to decomposition of RITS into a number of interrelated functional units, we can reduce the complexity of the whole system; logical structure is designed to aggregate the processes with similar function and the same type of data together, as well as separation and flexibility between the functional units. As shown in (Fig. **4**), the main task of logical structure design is based on expert knowledge and experience of RITS logical framework, to obtain information of process generation / use of data, uses association

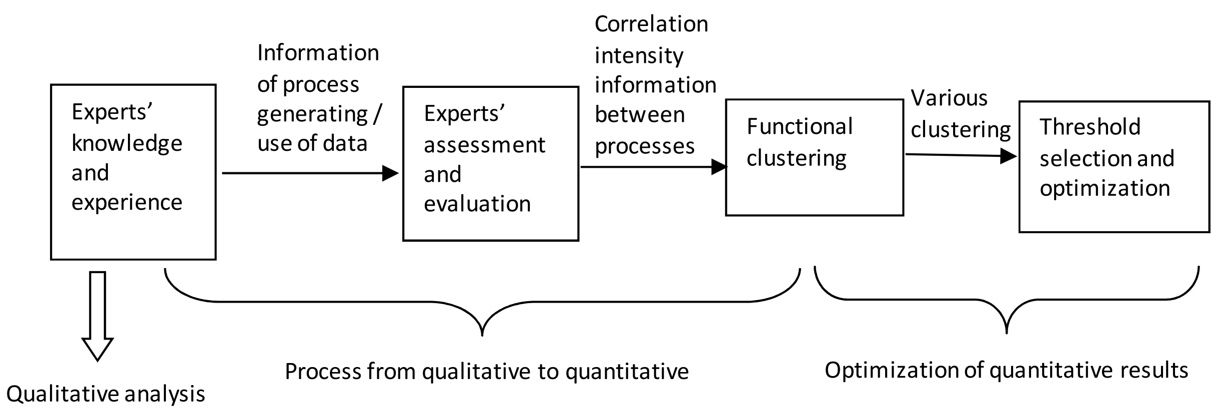


**Figure 4:** Main content of logical structure design

strength of process and data assessed by experts; according to function clustering, closely associated processes and data together aggregate into new functional units, and then select the threshold to get optimized logical structure design program. Of the whole logical structure design process, the first is qualitative analysis, and then the transformation from qualitative to quantitative, finally obtaining optimized quantitative results [46].

## Formalization Description of Logical Structure Optimization Design

Definition and organization of function in the present RITS logical structure also basically depend on the experience, not yet has in-depth analysis of the functional elements and inherent relationship, and lacks a more rigorous quantitative formalization description. In order to quantitatively research and analyze function elements and organizational forms from logical framework, we take functional organization forms, from typical emergency rescue and security system logical framework in RITS, as an example to analyze.

Emergency rescue and security system mainly achieve dynamic monitoring to railway transport resources, unified management to traffic safety information, and develop railway comprehensive disaster prevention decision-making and rescue decision-making of emergencies. Logical framework of emergency rescue and security system is usually described by function-level table and setting up data flow diagram. As function-level table is shown in Table **1**, processes in it possess independent input / output and is the smallest functional unit that can never be further divided; functional unit is based on the principles of high-cohesion, low coupling, interoperability, reusability, suitable particle size etc, to aggregate a number of processes into a collection with relative independence and flexibility; while functional domain is a collection consisting of a number of functional units. Essence of process, functional units and function domain all refer to functions needed to be achieved by the RITS system, and the three of them connected are contained to each other, that is process $\subset$ functional unit $\subset$ function domain.

We define the "process" and "data class" of bottom data flow diagram in logical framework as the basic elements of RITS logical structure design. Data class is data result generated by some process, and can be used by a number of other processes.

Consequently, RITS logical structure could be expressed as a unit doublet consisting of a process set $P$ and data class set $D$:

$$S = \{P, D\}$$

In the formula $P = \{p_i \mid i = 1, 2, \cdots, n\}$ indicates process set of RITS bottom data flow diagram, $p_i$ indicates process, $n$ is process quantity; $D = \{d_j \mid j = 1, 2, \cdots, m\}$ indicates data class set, $d_j$ indicates data class generated by a process, and $m$ is quantity of data class.

Because there are data generating relationship between processes $p_i$ and $p_j$, we could define correlation degree of $p_i$ to $p_j$ according to this relationship, designated as $u_{ij}, u_{ij} \in [0,1]$, as shown in (Fig. **5**).

Correlation degree describes reciprocity (or influence) degree between processes. In order to be convenient for quantitative calculation, we can define figure DFD of RITS logical framework as a weighted directed graph $G = \{P, U\}$, of which $P = \{p_1, p_2, \cdots, p_n\}$ is the process node set, $U$ is a binary relation defined on $P$, indicating side congregation of linking process node, weight on side expresses the correlation between processes, as shown in (Fig. **6**) . Different adoptions of evaluation criterion to define correlation degree will generate different decomposition methods [47].

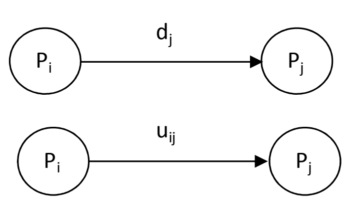


**Figure 5:** Correlation relationship among processes

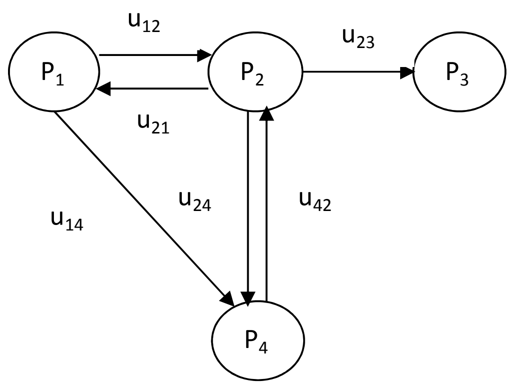


**Figure 6:** Transformation from DFD diagram to weighted directed graph

As the relative stability of RITS logical structure, we can adopt static structured technique - interpretation of the structural model (ISM) for the establishment of logical structure model. However, adjacency matrix in the ISM is a Boolean matrix, which only describes whether there are coupling effects or correlation between various elements in the system, and does not have a deeper description to the extent of correlation. While relations between elements usually have distinction of strong and weak in actual system, and the fuzzy set is an effective tool to describe and deal with this correlation strength, Fuzzy matrix can effectively and efficiently deal with the correlation degree between various elements, therefore we can establish fuzzy correlation degree matrix to describe the degree of correlation between elements.

In order to quantitatively describe correlation degree between process $p_i$ and $p_j$ in a logical structure, we should firstly establish fuzzy correlation degree matrix. We define dependency relationship from process to data class as fuzzy correlation relationship $Q$, which is the fuzzy set of direct product $P \times D = \{(p,d) | p \in P, d \in D\}$, moreover:

$$\mu_Q : P \times D \to [0,1]$$

Then fuzzy relationship $Q$ could be indicated as the following matrix (named as process utility data class matrix) :

$$Q = \begin{bmatrix} \mu_Q(P_1,d_1)\,\mu_Q(P_1,d_2)\cdots\mu_Q(P_1,d_m) \\ \mu_Q(P_2,d_1)\,\mu_Q(P_2,d_2)\cdots\mu_Q(P_2,d_m) \\ \vdots \qquad\qquad \vdots \qquad\qquad \vdots \\ \mu_Q(P_n,d_1)\,\mu_Q(P_n,d_2)\cdots\mu_Q(P_n,d_m) \end{bmatrix}$$

The membership function $\mu_Q(p_i,d_j)(i=1,2,\cdots,n; j=1,2,\cdots,m)$ indicates correlation degree between process $p_i$ and data class $d_j$.

We could adopt expert judgment weighted mean to determine membership function $\mu_Q(p_i,d_j)$. As correlation degree among RITS each process is closely related to the system business, we should seen business personnel or experts of application field to score the correlation degree between processes, and then execute weighted average on these scores as the membership function value. The definition of correlation between processes from different angles of selection of different criteria to measure strength of the relationship can be obtained from different results of functional organizations. Division of process that data closely links in one functional unit, will make the internal structure functional unit close-knit, and reduce interconnection and impaction degree among each functional unit, for easy to physical realization, improvement system response of speed, and saving realization cost [47].

An evaluation criterion of the dependence degree from process to data class is as follows:

1. Data amount used by process.

2. Size of the importance degree from data to process.
3. Frequency of process using data.

We may determine generating matrix (referred to process generating data class matrix) from process to data class as $C = (c_{ij})_{n\times m}$, as:

$$c_{ij} = \begin{cases} 1, \text{When process } p_i \text{ generates data type } d_j \\ 0, \text{Others} \end{cases}$$

Building fuzzy correlation degree matrix $R = CQ^T$, $Q^T$ is transpose matrix of $Q$.

In the fuzzy oriented graph defined by $R$, for arbitrary two nodes $p_i$ and $p_j$, if there is at least one route to join $p_i$ and $p_j$, then we claim $p_i$ and $p_j$ are inter-related. The element value of fuzzy correlation degree matrix specifically indicates the correlation strength of corresponding RITS logical structure, namely the correlation degree.

Let $R_\lambda$ as $\lambda$ section matrix of $R$. In the oriented graph defined by $R_\lambda$, if process (process) $p_i$ -could be reached, and $p_j$ could reach $p_i$, then we would say $p_i$ and $p_j$ are $\lambda$ interrelated, of which $\lambda$ is an adjustable parameter to measure correlation levels. Logical structure design method is to aggregate the process of $\lambda$ strong correlation into one functional unit, to realize reorganization of functions. We adopt fuzzy clustering method to carry out clustering of logic functions, with the value of $\lambda$ changing from small to big, system process $p_i$ gradually clustering into several functional unit $F_i$ with different functions, and granularity of system decomposition become-on thinner, and internal system structure gradually appearing with aggrandizement of $\lambda$.

Granularity of system decomposition directly relates with the value of $\lambda$, Different values of $\lambda$ corresponding to different division granularities and results of system, directly affect the complexity degree of logical structure design. Consequently, value of $\lambda$ also has optimization problem, that is to say having an optimum value $\lambda^*$. We could adopt entire process optimization method to calculate $\lambda^*$, whose specific thread is: to execute logical structure design for every value of $\lambda$, with every $\lambda$ corresponding to one design program, contributing to a program collection, and then adopting synthetic evaluation method to select optimum program from this collection, with the value of $\lambda$ corresponding to $\lambda^*$.

**<u>Ordinary Steps For Logical Structure Optimization Design</u>**

We adopt fuzzy transitive closure method or direct clustering method to execute RITS logical structure design under different correlated intercepts $\lambda \in [0,1]$, as shown in (Fig. **7**), ordinary step for logical structure optimization design are:

1. Determine system basic elements according to DFD diagram of RITS logical framework, that is process class and data class,
2. According to expert assessment and evaluation (such as brain storming, Delphi method etc.), determine the fuzzy relationship between process and data class, to get fuzzy matrix $Q$;
3. Establish generating matrix $C$ from process to data class, and calculate fuzzy correlation strength matrix $R = CQ^T$;
4. Calculate accessible matrix $G$; $G = I + R$;
5. Calculate fuzzy similarity matrix $G \cup G^T$;
6. Adopt transitive closure method or direct clustering method to classify system processes under different correlation intercepts $\lambda \in (0,1]$, and processes of one kind could integrate into one functional unit;
7. Evaluate feasibility of system division results. Select functional clustering results which meet constraint condition corresponding to $\lambda$, with the most functional units as optimum logical structure design program.

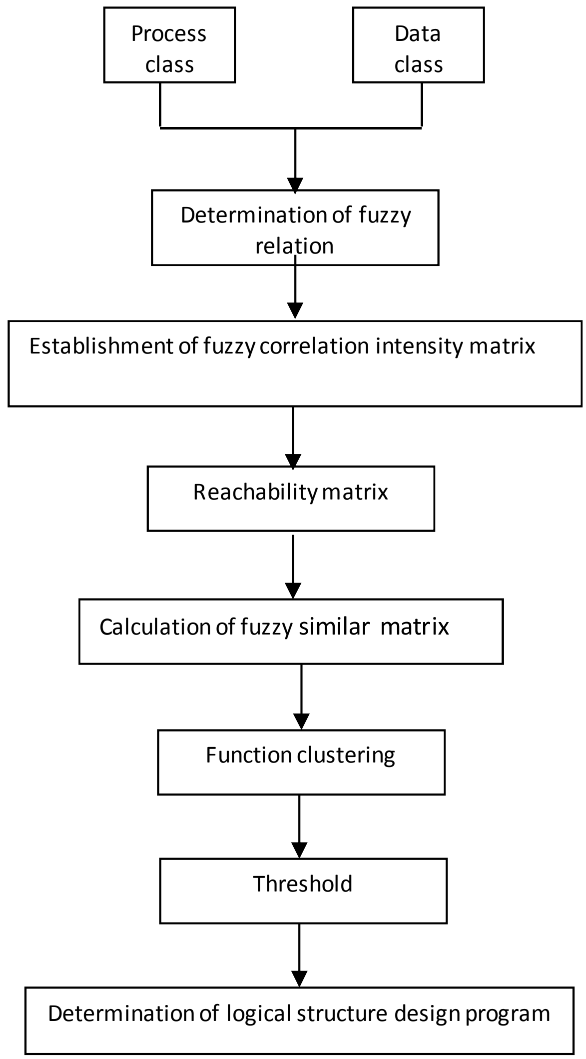


**Figure 7:** Ordinary steps for logical structure design

## Optimization Design from RITS Logical Structure to Physical Structure

### Main Content of Optimization Design from Logical Structure to Physical Structure

Elements of RITS logical structure design can be divided into procedure level and functional unit level, fuzzy clustering method can be used to aggregate processes into several functional units, and quantification method can be used to reduce complexity degree of system design. Different combinations of different functional units in logical structure design may generate different internal compositions of physical subsystem. Obviously, there are some mapping relationship between logical structure and physical structure, and various possible mapping relations may constitute a mapping collection. As shown in (Fig. **8**), function units 1 and 2 of the logical structure can be mapped to subsystem A of physical structure, and the functional unit 3 and 4 can be mapped to sub-system B.

The Main task of optimization design from RITS logical structure to physical structure is to divide the physical subsystem from different angles, according to different standards or different levels. Division of physical sub-systems not only considers the functional requirements, but also considers non-functional requirements. Functional requirements are embodied by functional unit of the logical structure design, and determine functions that must be completed by RITS physical structure. Yet, non-functional requirements affect the distribution modes on physical subsystems from RITS functional units, restricted factors of management system, technique, economic and social environment etc.

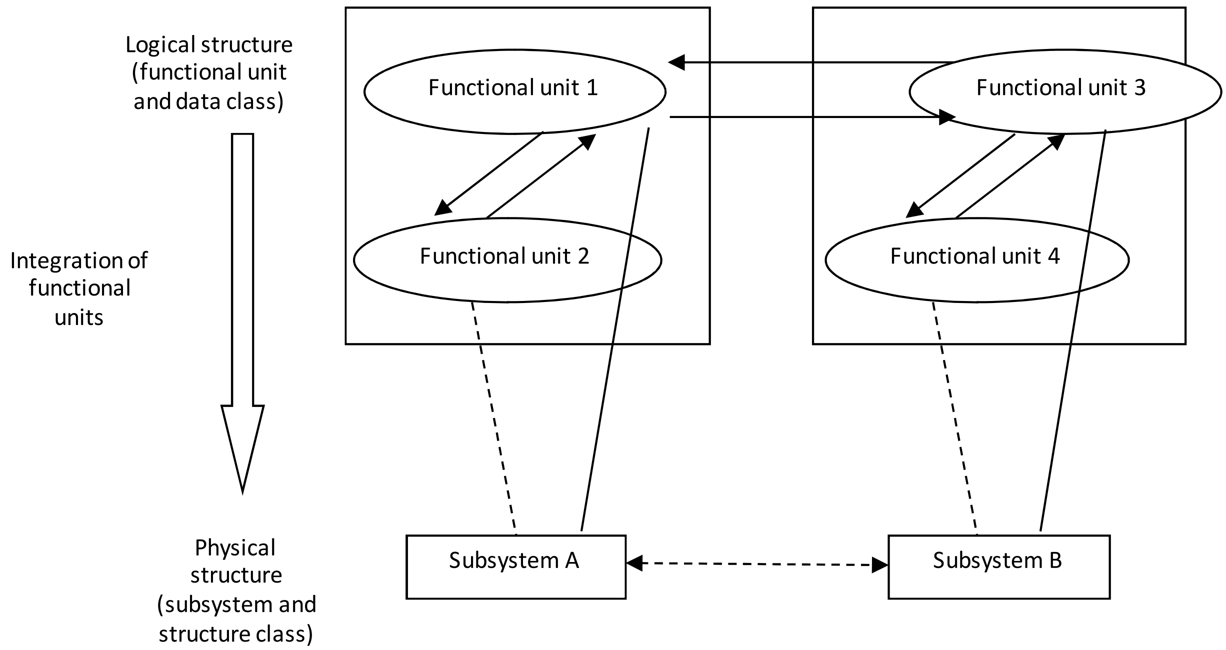


**Figure 8:** Mapping relations between logical structure and physical structure

RITS optimization design from logical structure to physical structure is essentially the process that RITS system breaks down into several physical subsystems through successive layer. The most important of RITS physical structure design is to determine existence purpose of the system, that is what kind of goal should be achieved by the system, and then through constant optimization finally determine physical sub-systems division adapting to current management system and future development. It should be noted that the socio-economic and technological development is continuously moving forward, and then the development goal of RITS will also increase continuously; simultaneously, RITS physical structure design cannot be divided simply by organization system of the administration management organization, but divided in accordance with the requirements of functional units, and then make the appropriate adjustments taking into account the existing organizational system, so RITS physical structure design should be dynamic or appropriate. As shown in (Fig. **9**), the main tasks of optimization design from

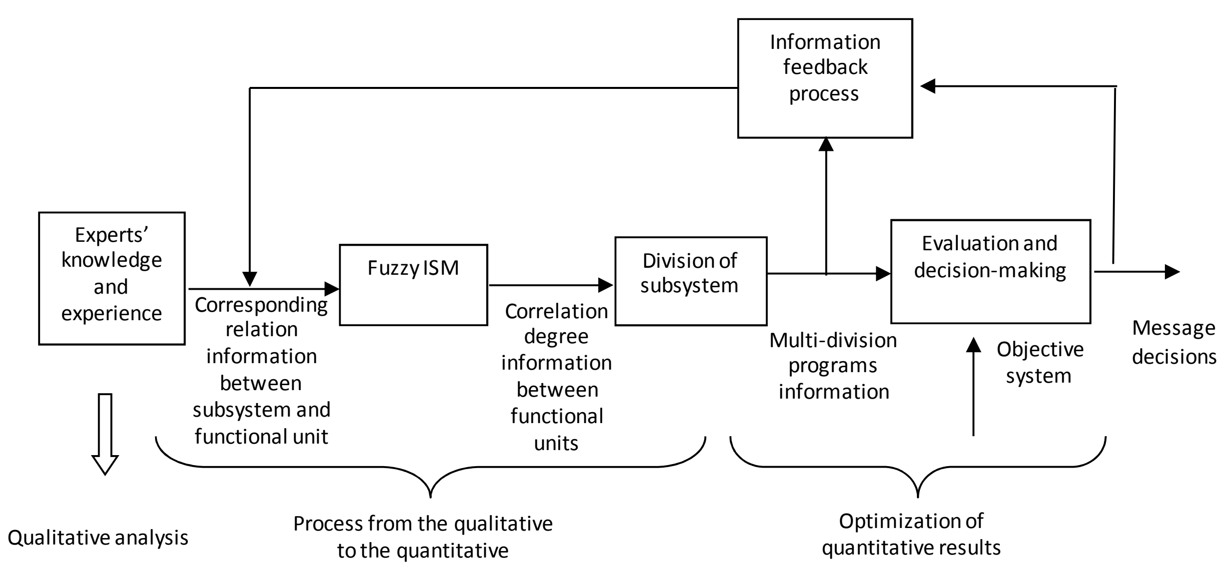


**Figure 9:** Main content of optimization design from logical structure to physical structure

logical structure to physical structure are to collect knowledge and experience of experts from the physical framework, to obtain the corresponding information of subsystems and the functional unit, through fuzzy inference to establish correlation intensity matrix reflecting closeness extent among functional units, in accordance with closeness extent among functions to divide physical subsystems, to form a variety of sub-systems division programs, establish target system for systematic evaluation, and provide decision-making and optimization information for RITS physical structure design. Then according to status quo evaluation and results of actual analysis to adjust the behavior of future systems, feedback mechanism of internal physical structure and the overall RITS can be established, with adjustment means such as management system, technique, economic and social environment etc, making the division of sub-system not deviate from RITS current system and future development goals. The entire physical structure design process is similar to the design of logical structure process, except from some difference in the selection of design elements and design modes; besides, the main processes all are firstly qualitative analysis, followed by transformation from the qualitative to the quantitative, and finally to obtain optimal quantitative results[46].

## Formalization Descriptions from Logical Structure to Physical Structure

System is a whole that is constructed by many elements having organic relations and specific functions. RITS is composed by too many elements, with different attributes logical attribute and physical attribute. The element with logical attribute is the function; the element with physical attribute is the sub-system.

The conception of set is that some objects with some attributes are taken as a whole, thereby a set is formed. Some functions with logical attribute are made to be regarded as a whole, thereby a function element set is formed, note that $F=\{F_1, F_2, \ldots, F_n\}$. some sub-systems with physical attribute are made to be regarded as a whole, thereby a sub-system set is formed, note that $S=\{S_1, S_2, \ldots, S_n\}$.

We can see from the analysis of RITS system framework, certain mapping relation exists between the function element set with logical attribute and the sub-system element set with physical attribute. The RITS structure design is to fix on this mapping relation, it includes two processes:

(1) When the function element set is fixed on, then a new sub-system element set can be obtained, through fixing on the mapping relations.

(2) When sub-system element set is fixed on, then a new function element set can be obtained, through fixing on the mapping relations.

According to the differences of mapping relations, with the same function element set, a new sub-system set with completed differences of formation and composing can be obtained; on the contrary, according to the differences of mapping relations, with the same sub-system element set, a new function element set of formation and composing can be obtained.

Relation matrix is fixed on generally according to experts experience or professional discussion, it provides the reliable basis for calculating the relevance degree between the elements with the same attribute.

The relation between function element set and sub-system element set can be expressed by a matrix R（m，n), that is shown as Table **1**, where m, and n separately represents the element amount of function set and the element amount of sub-system set.

**Table 1:** The relation matrix

| | **Sub-system** | **Sub-system** | | **Sub-system** | **Sub-system** |
|---|---|---|---|---|---|
| | **$S_1$** | **$S_2$** | **…** | **$S_j$** | **$S_n$** |
| Function$F_1$ | R (1,1) | R (1,2) | … | R (1,j) | R (1,n) |
| Function$F_2$ | R (2,1) | R (2,2) | … | R (2,j) | R (2,n) |
| Function $F_i$ | R (i, 1) | R (i, 2) | … | R (i, j) | R (i, n) |
| Function $F_m$ | R (m, 1) | R (m, 2) | … | R (m, j) | R (m, n) |

In the relation matrix R, R (i，j) $(0 \le i \le m, 0 \le j \le n)$ is a real number between 0 and 1, represents the relation between function element $F_i$ and sub-system element $S_i$. When R (i，j) =0, represents that there is no relation between function element $F_i$ and sub-system element $S_i$, the function element $F_i$ is not included in sub-system element $S_i$. When R (i，j) =1, represents that there is having relation between function element $F_i$ and sub-system element $S_i$, the function element $F_i$ is included in sub-system element $S_i$. When0〈R (i，j)〈1, represents that the relation between function element $F_i$ and sub-system element $S_i$ is fuzzy, need to choose threshold properly, thereby the relation between function element $F_i$ and sub-system element $S_i$ can be fixed on [43].

The relevance degree between the elements with the same attribute is defined as relevance intensity, which is expressed by a real number between 0 and 1.

The relevance intensity between function element $F_i$ and $F_j$ is expressed by $w_{ij}$, so the relevance intensity matrix $W$ between function elements is shown as Table **2**.

**Table 2:** The relevance intensity matrix between function elements

| $W$ | **Function $F_1$** | **Function $F_2$** | **…** | **Function $F_m$** |
|---|---|---|---|---|
| Function $F_1$ | $w_{11}$ | $w_{12}$ | … | $w_{1m}$ |
| Function $F_2$ | $w_{21}$ | $w_{22}$ | … | $w_{2m}$ |
| … | … | … | … | … |
| Function $F_m$ | $w_{i1}$ | $w_{i2}$ | … | $w_{mm}$ |

The relevance intensity between sub-system element $S_i$ and $S_j$ is expressed by $\beta_{ij}$, so the relevance intensity matrix $B$ between sub-system elements is shown as Table **3**.

**Table 3:** The relevance intensity matrix between sub-system elements

| $B$ | **Sub-system $S_1$** | **Sub-system $S_2$** | **…** | **Sub-system $S_n$** |
|---|---|---|---|---|
| Sub-system $S_1$ | $\beta_{11}$ | $\beta_{12}$ | … | $\beta_{1n}$ |
| Sub-system $S_2$ | $\beta_{21}$ | $\beta_{22}$ | … | $\beta_{2n}$ |
| … | … | … | … | … |
| Sub-system $S_n$ | $\beta_{i1}$ | $\beta_{i2}$ | … | $\beta_{nn}$ |

The relevance intensity between the elements with the same attribute is fixed on through the membership function of fuzzy mathematics. The higher the membership degree is, the higher the relevance intensity between the elements with the same attribute is; on the contrary, the lower the membership degree is, the lower is the relevance intensity between the elements with the same attribute. The membership degree of the element itself is 0. The methods of fixing on the membership function are manifold in practice, which have no unite mode. The relevance intensity matrix is different with the different membership function, but the obtained relevance intensity matrix is divided into two kinds: one is the relevance intensity matrix with symmetry character; the other is the relevance intensity matrix with asymmetry character.

If the relevance intensity matrix $W$ between function elements satisfies the condition, $(W+I)^{k-1} \ne (W+I)^k = (W+I)^{k+1} = P$, thereby $P$ is called as the reachable matrix of $W$.

If the relevance intensity matrix $B$ between sub-system elements satisfies the condition, $(B+I)^{k-1} \ne (B+I)^k = (B+I)^{k+1} = Q$, then by $Q$ is called as the reachable matrix of $B$.

And then the $\lambda$ level cut matrix of reachable matrix is calculated.

Given the relevance intensity reachable matrix $P = (p_{ij})$ between function elements, for random $\lambda$ between 0 and 1, note that $P_\lambda = (\lambda p_{ij})$, where:

$$\lambda p_{ij} = \begin{cases} 1 & (when \quad p_{ij} \geq \lambda) \\ 0 & (when \quad p_{ij} < \lambda) \end{cases}$$

Therefore $P_\lambda = (\lambda p_{ij})$ is called as the $\lambda$ level cut matrix of $P$.

Given the relevance intensity reachable matrix $Q = (q_{ij})$ between sub-system elements, for random $\lambda$ between 0 and 1, note that $Q_\lambda = (\lambda q_{ij})$, where:

$$\lambda q_{ij} = \begin{cases} 1 & (when \quad q_{ij} \geq \lambda) \\ 0 & (when \quad q_{ij} < \lambda) \end{cases}$$

Therefore $Q_\lambda = (\lambda q_{ij})$ is called as the $\lambda$ level cut matrix of $Q$.

The relevance intensity reachable matrix is a boolean matrix that only includes 0 and 1.

The partition method of the reachable matrix can adopt cluster analysis.

The basic process of fuzzy cluster analysis is to set up fuzzy resemble matrix R, if R is a fuzzy equivalence matrix, the cluster figure can be obtained directly at a proper level. If R is not a fuzzy equivalence matrix, however the square method can be adopted to calculate the transfer closure t (R) of R, t (R) is a fuzzy equivalence matrix on discussion region U, then clustering directly on a proper level. The matrix having self in reverse character, symmetry character and transfer character is a fuzzy equivalence matrix. The relation of it is a fuzzy equivalence relation; one of the most important functions of fuzzy equivalence relation is that the set can be classified according to some certain request, namely fuzzy cluster.

The partition process of the relevance intensity reachable matrix is actually the cluster process, which clusters the resemble function elements or sub-system elements into one kind. The relevance intensity reachable matrix has self in reverse character and transfer character besides symmetry character, the relation of it is the equivalence relation, so the clustering result can be obtained directly at a proper level. The relevance intensity reachable matrix also has the general matrix characteristic, that is: random two rows (or two lines) can be exchanged each other, the function of the total system cannot be affected; so the clustering disposal is to exchange the rows or lines with the same or near distribution together according to the characteristic of the relevance intensity reachable matrix, the essential of the process is the same state mapping of the relevance intensity reachable matrix.

Using the fuzzy cluster analysis can realize the partition of the relevance intensity reachable matrix with symmetry character, the clustering result is the new function elements set or the new sub-system elements set of RITS structure design [46].

## General Steps of Optimization Design from Logical Structure to Physical Structure

Optimization design from RITS logical structure to physical structure is essentially for the achievement of RITS development goals, from a variety of physical structure design programs, in accordance with a variety of constraints such as society, economic, technology, management etc, to determine optimal RITS physical structure design. Optimization design from RITS logical structure to physical structure is a continuous process. From now on, to a certain period, RITS optimization is being executed by the minute. Difficult point of optimization design from RITS logical structure to physical structure lies in longer time span of RITS optimization design, complex target, many constraint from policies and management systems etc, hence there must be feasible and clear thread.

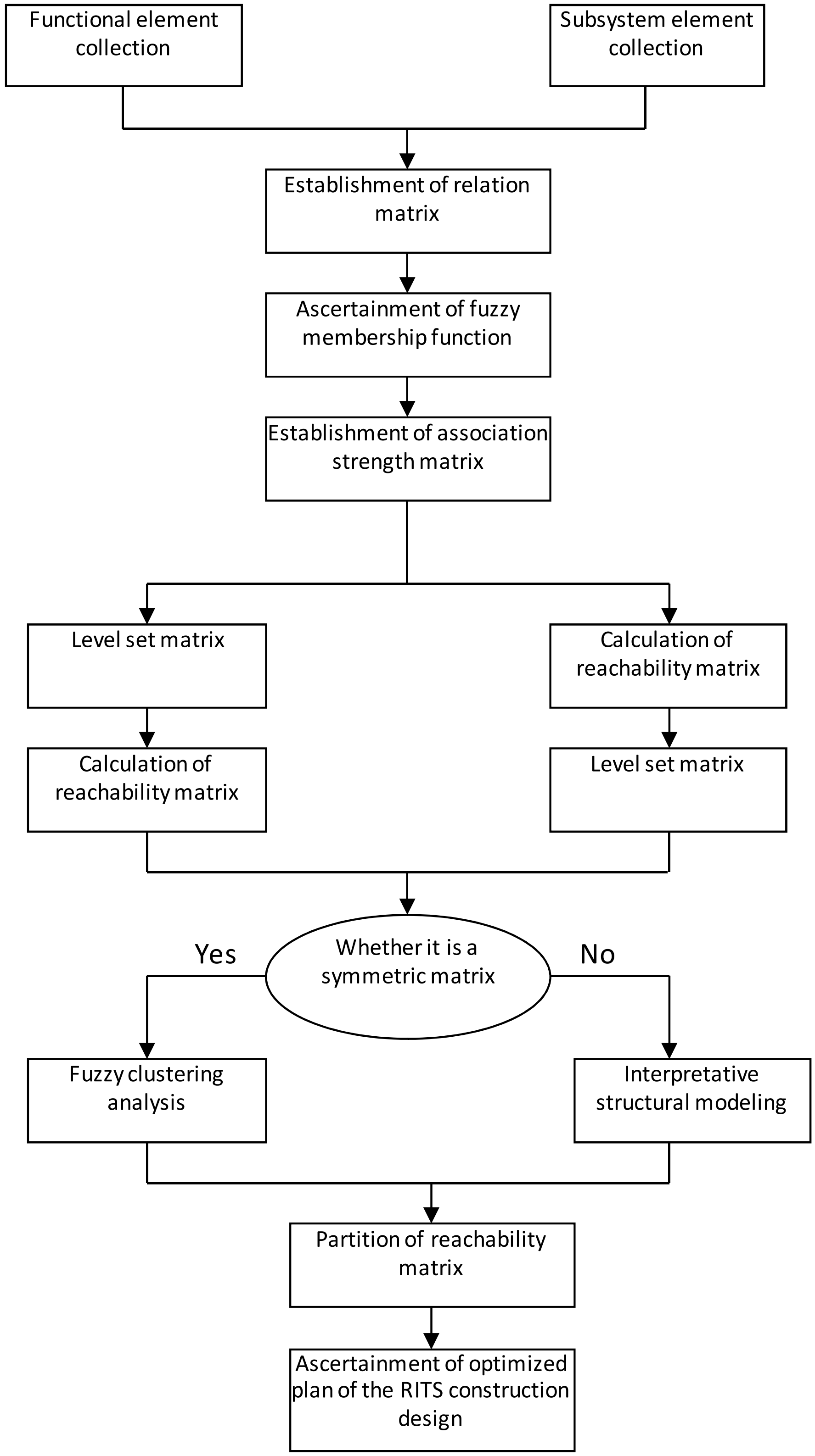


**Figure 10:** General steps from logical structure design to physical structure design

As shown in (Fig. **10**), general design steps from RITS logical structure to physical structure, when adopting fuzzy interpretative structural modeling, are as follows [46]:

1. According to the main contents of RITS logical framework and physical framework design, to determine functional elements of the sub-systems and subsystem elements for subsystems division,
2. In accordance with corresponding information between function and subsystems provided by RITS physical framework, to establish relational matrix between functional elements and subsystem elements,
1. 3.Through identification of fuzzy membership function, to establish correlation intensity matrix between functional elements or subsystems elements,
3. Calculate correlation intensity accessibility matrix under different levels of $\lambda$ intercepts; or firstly calculate accessibility matrix of correlation intensity matrix, and then check intercept matrix of $\lambda$ level,
4. If the accessibility matrix is a symmetric matrix, then we adopt fuzzy clustering method for partitions; if the accessibility matrix is a non-symmetric matrix, then we adopt interpretative structural modeling for partitions,
5. Obtain a number of physical structure designs.

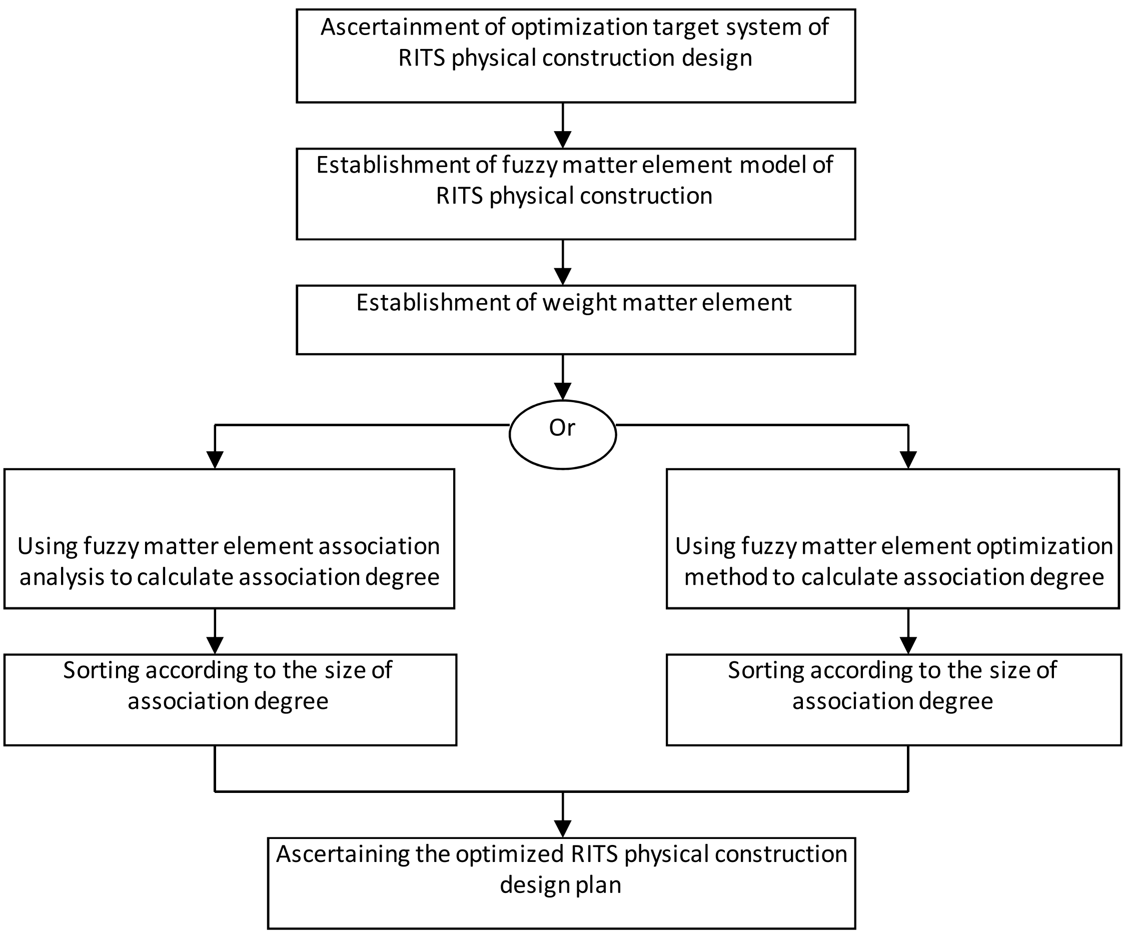


**Figure 11:** General steps of design optimization from logical structure to physical structure

The most important basis of optimization design from RITS logical structure to physical structure is optimization goals and only under the guidance of reasonable optimization will result in the correct direction, and effectively save human and material resources on premise of ensuring realization of function. Targets of RITS physical structure optimization design could be divided into qualitative targets and quantitative targets. The current goals of RITS physical structure optimization are very difficult to quantify, so most of the goals are described as qualitative objectives. For RITS, its core objective is to build a China's intelligent railway transport system meeting national economic development and needs of people. Providing a new rail transport mode with high security, high efficiency, high service quality and high benefit to China railway, was an attempt to win the domestic market by virtue of good service and safety, and also to win the international market by virtue of excellent efficiency. Its specific goals are manifested in: efficient transport, capability to effectively developed rail transport resources, meeting various needs of transport; high transport security, while the realization of efficient transport, running of rail transport system has good safety, high reliability ; high-quality service, providing a great convenience for passengers and shippers to use rail transport; high-efficiency of transport, on premise of providing quality services for passengers and shippers, to create optimal transport effectiveness. The realization of these goals involves restriction from various conditions including technique, economic and management etc, needs of system design and preferences of decision makers determine the importance of each goal [46].

As shown in (Fig. **11**), general steps of design optimization from RITS logical structure to physical structure by fuzzy matter-element analysis are as follows:

1. Determine objective system of RITS physical structure design optimization,
2. According to each target value of every structural design given by experts' assessment, establish compound fuzzy matter-element mode of RITS structural design optimization,
3. Determine weighing of each target by AHP, and establish compound weight matter-element,
4. Adopt fuzzy matter-element correlation analysis or fuzzy matter-element optimization method to calculate correlation degree.

We sort each structural design program by the size of correlation degree, to determine the optimal physical structure design.

# CHAPTER 4

# Optimization Design Example of Intelligent Emergency Rescue and Safety System

**Abstract:** In this chapter, the intelligent emergency rescue and safety system is taken as an example to explain the optimization design course. The element analysis of logical structure design and optimization design from logical structure to physical structure are carried out, functions are clustered in accordance with certain rules based on fuzzy clustering method, the fuzzy structure model method is used to part subsystem, and the scheme of optimization is carried out based on the fuzzy matter element analysis method.

## LOGICAL STRUCTURE OPTIMIZATION DESIGN OF INTELLIGENT EMERGENCY RESCUE AND SAFETY SYSTEM

### Element Analysis of Logical Structure Design

According to GIS technology, emergency rescue and safety system rapidly provide information about terrain, human landscape, hydrology, medical institutes and fire departments etc; with technology such as data and image transmission, precisely and in time transmitting dynamic images of the locale and related status to the departments in charge, to carry on real-time monitoring on the accident site; establish emergency information database and rescue knowledge database, and provide assistant decision for rescue plans by intelligent analysis; utilize various output functions to reasonably allocate resources, optimize dispatch, command and rescue equipments, properly select rescue routes, provide emergency rescue and maintenance service, and make failure analysis after occurrence etc. The basic function (process) is shown in the following Table **1** [43]:

**Table 1:** Basic function (process) definition table of the emergency rescue and safety system

| Process No. | Process name | Process description | Inputting data flow | Outputting data flow |
|---|---|---|---|---|
| P0 | Releasing assistant request | Making assistant request | Users proposing assistant request | Collecting information request of accident locale; make rescue decision request; release request of rescue information |
| P1 | Collecting related information of accident locale | Collecting information of accident locale, such as site and surrounding circumstances of accident locale, damage conditions of trains, damage conditions of routes, communication signal damage condition, staff and freight status, dangerous goods information, nearby trains information, accident freight characteristic, causes of accident, etc. | Collecting accident locale information request, site and surrounding circumstances of accident locale, train damage conditions, route damage conditions, communication signal damage conditions, staff and freight status, dangerous goods information, nearby trains information, accident freight characteristic, causes of accident, application of data providing | Response of data providing |
| P2 | Related information management of accident locale | Managing related information of accident locale | Data export | Data logging |
| P3 | Collecting related information of rescue resource | Collecting information of rescue resource, such as distribution of rescue train, distribution of rescue unit, rescue staff conditions, rescue equipment status, rescue material status, road network status | Collecting rescue information request, distribution of rescue train, distribution of rescue unit, rescue staff condition, rescue equipment status, rescue material status, road network status, application of data providing | Response of data providing |
| P4 | Related information | Managing related information of accident locale | Data export | Data logging |

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| | | | | |
|---|---|---|---|---|
| | management of rescue resources | | | |
| P5 | Receiving rescue decision request | Startup rescue decision | Appling for rescue decision | Startup rescue decision command |
| P6 | Making rescue decision | Providing rescue decision according to information of accident locale | Data inquiry results, weather condition, route condition, rescue attentions | Freight and staff processing approach, traffic control approach, works rescue approach, electric work rescue approach, train rescue approach, danger goods processing approach |
| P7 | Providing interface of emergency rescue staff | Providing data input, inquiry and interface for emergency rescue staff by the usage of telephone, mobile telephone and display screen | Information of accident locale, rescue decision, dispatch command | Data providing application, material supply request, resource equipment dispatch request, maintenance request, train rescue request |
| P8 | Startup material supply rescue | Startup material supply rescue decision | Emergency supply request | Emergency supply response |
| P9 | Emergency material providing decision | Generating emergency material providing approach according to intelligent decision | Startup emergency material supply decision request, material supply source conditions | Emergency material providing approach |
| P10 | Startup material equipment rescue | Startup material equipment allocation decision | Material equipment allocation request | Material equipment response |
| P11 | Resource equipment allocation decision | Generating resource equipment allocation approach according to intelligent decision | Resource equipment allocation request, resource equipment condition | Resource equipment allocation approach |
| P12 | Startup maintenance rescue | Startup maintenance decision | Maintenance decision request | Maintenance decision response |
| P13 | Rescue maintenance service decision | Generating rescue maintenance service approach according to intelligent decision | Rescue maintenance service request, staff allocation condition | Rescue maintenance approach |
| P14 | Startup emergency train rescue | Startup train allocation decision | Train allocation request | Train emergency allocation response |
| P15 | Dispatching emergency train decision | Generating dispatch plan of rescue trains by intelligent optimize technology | Road network condition, climate condition, emergency dispatching request | Dispatch plan of emergency train |
| P16 | Startup rescue information release | Startup rescue information release | Rescue information release request | Update accident locale information request, inquiry train information request, inquiry rescue information request, accident causes analysis request |
| P17 | Updating information of accident locale | Updating information of accident locale and information of rescue progress | Updating request of accident material | Accident material updating response |
| P18 | Inquiry train operation material | Providing material of related accident train operation | Data inquiry request | Data inquiry response, train operation material, accident status, accident time and site |
| P19 | Inquiry emergency rescue information | Updating information of rescue progress | Rescue information inquiry request | Rescue information updating response |
| P20 | Emergency rescue information release | Releasing emergency rescue information for each specialized department and passengers as well as cargo owner | Information of accident locale | Train rescue information, engineering district rescue information, communication and signal |

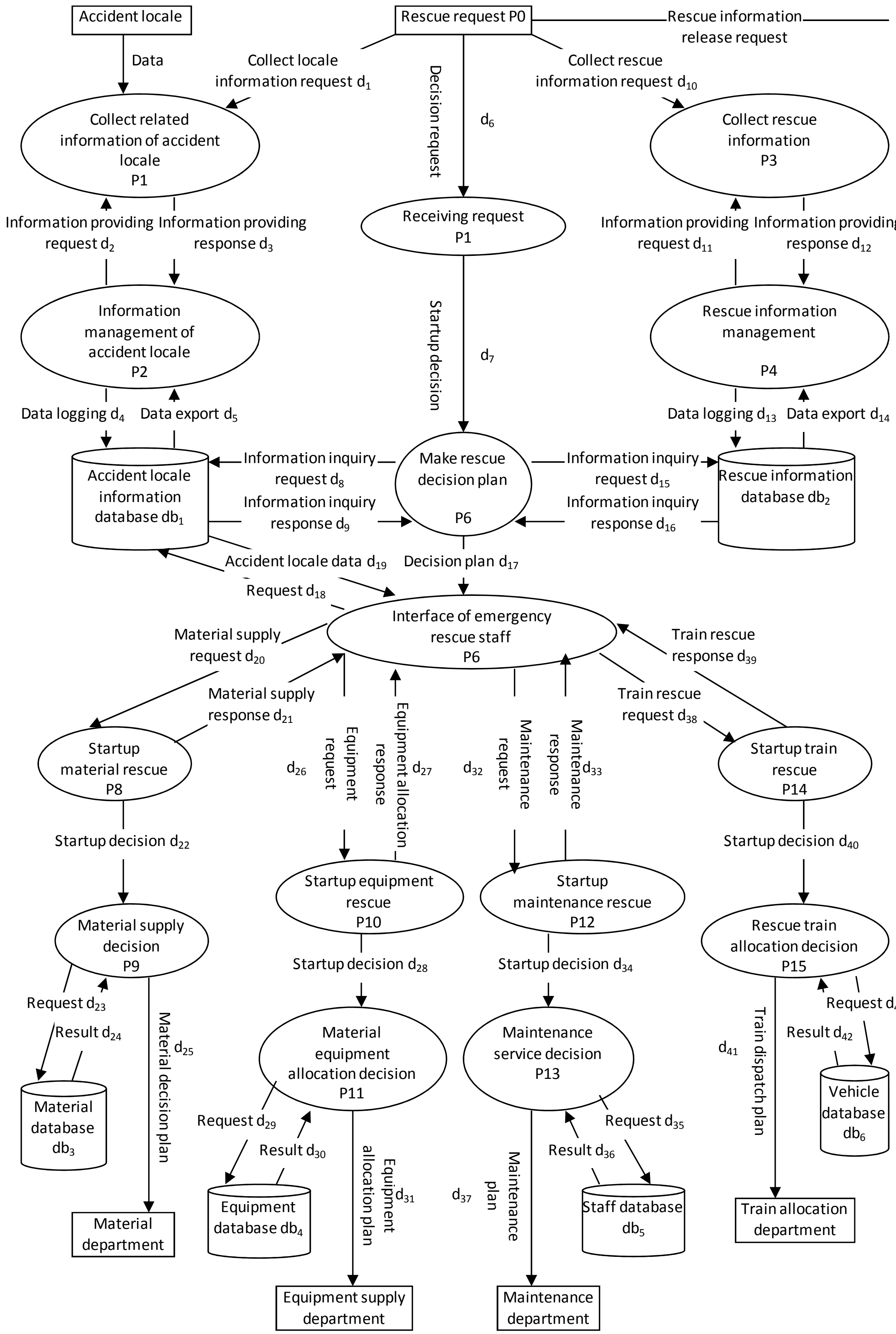
| | | | | |
|---|---|---|---|---|
| | | | | district information, locale rescue information, passenger rescue information, freight status, real-time rescue information, rescue result |
| P21 | Receiving analysis request of accident causes | Startup accident causes analysis | Accident causes analysis request | Accident causes analysis response |
| P22 | Accident causes analysis | Analyzing accident causes | Startup accident causes analysis, train-to-ground supervision data inquiry result, ground-to-train supervision data inquiry result | Train-to-ground supervision data inquiry application, ground-to-train supervision data inquiry application, accident causes |
| P23 | Accident causes release | Releasing emergency rescue information for each specialized department and passengers as well as cargo owner | Accident causes analysis result | Accident causes |
| P24 | Real-time collection of data of train-to-ground supervision | Collecting data by train-to-ground supervision | Infrared axle temperature detection car data, comprehensive detection car data, locomotive signal analyzer data, track inspection car data, flaw detection car data, information providing application | Information providing response |
| P25 | Train-to- ground supervision data management | Managing train-to- ground supervision data | Data export | Data logging |
| P26 | Real-time collection of data of ground- to-train supervision | Collecting data by ground-to-train supervision | Train operation status, freight safety door information, station level aisle status | Information providing response |
| P27 | Ground- to-train supervision data management | Managing related fundamental information | Data export | Data logging |

Database of the emergency rescue and safety system is shown in Table **2**:

**Table 2:** Database definition table of the emergency rescue and safety system

| Database No. | Database name | Inputting data flow | Outputting data flow |
|---|---|---|---|
| Db1 | Accident locale information storage | Accident locale information data logging, data inquiry request | Data export, data inquiry result |
| Db2 | Rescue resource data storage | Accident locale information data logging, data inquiry request | Data export, data inquiry result |
| Db3 | Material storage data storage | Data inquiry request | Data inquiry result |
| Db4 | Resource equipment data storage | Data inquiry request | Data inquiry result |
| Db5 | Maintenance staff data storage | Data inquiry request | Data inquiry result |
| Db6 | Rescue car data storage | Data inquiry request | Data inquiry result |
| Db7 | Train operation data storage | Data inquiry request | Data inquiry result |
| Db8 | Train-to-ground supervision data storage | Data logging, data inquiry result | Data export, data inquiry result |
| Db9 | Ground-to-train supervision data storage | Data logging, data inquiry result | Data export, data inquiry result |

DFD figure of emergency rescue and safety system is shown as (Fig. **1**).


Accident locale
Rescue request P0
Rescue information release request
Data
Collect locale information request $d_1$
Decision request
$d_6$
Collect rescue information request $d_{10}$
Collect related information of accident locale P1
Collect rescue information P3
Information providing request $d_2$
Information providing response $d_3$
Receiving request P1
Information providing request $d_{11}$
Information providing response $d_{12}$
Information management of accident locale P2
Startup decision
$d_7$
Rescue information management P4
Data logging $d_4$
Data export $d_5$
Data logging $d_{13}$
Data export $d_{14}$
Accident locale information database $db_1$
Information inquiry request $d_8$
Information inquiry response $d_9$
Make rescue decision plan P6
Information inquiry request $d_{15}$
Information inquiry response $d_{16}$
Rescue information database $db_2$
Accident locale data $d_{19}$
Decision plan $d_{17}$
Request $d_{18}$
Interface of emergency rescue staff P6
Material supply request $d_{20}$
Train rescue response $d_{39}$
Material supply response $d_{21}$
Train rescue request $d_{38}$
Equipment request $d_{26}$
Equipment allocation response $d_{27}$
Maintenance request $d_{32}$
Maintenance response $d_{33}$
Startup material rescue P8
Startup train rescue P14
Startup decision $d_{22}$
Startup decision $d_{40}$
Startup equipment rescue P10
Startup maintenance rescue P12
Material supply decision P9
Rescue train allocation decision P15
Startup decision $d_{28}$
Startup decision $d_{34}$
Request $d_{23}$
Result $d_{24}$
Material decision plan $d_{25}$
Material equipment allocation decision P11
Maintenance service decision P13
$d_{41}$ Train dispatch plan
Request $d_{43}$
Result $d_{42}$
Material database $db_3$
Request $d_{29}$
Result $d_{30}$
Request $d_{35}$
Result $d_{36}$
Vehicle database $db_6$
Equipment database $db_4$
Equipment allocation plan $d_{31}$
$d_{37}$ Maintenance plan
Staff database $db_5$
Material department
Train allocation department
Equipment supply department
Maintenance department

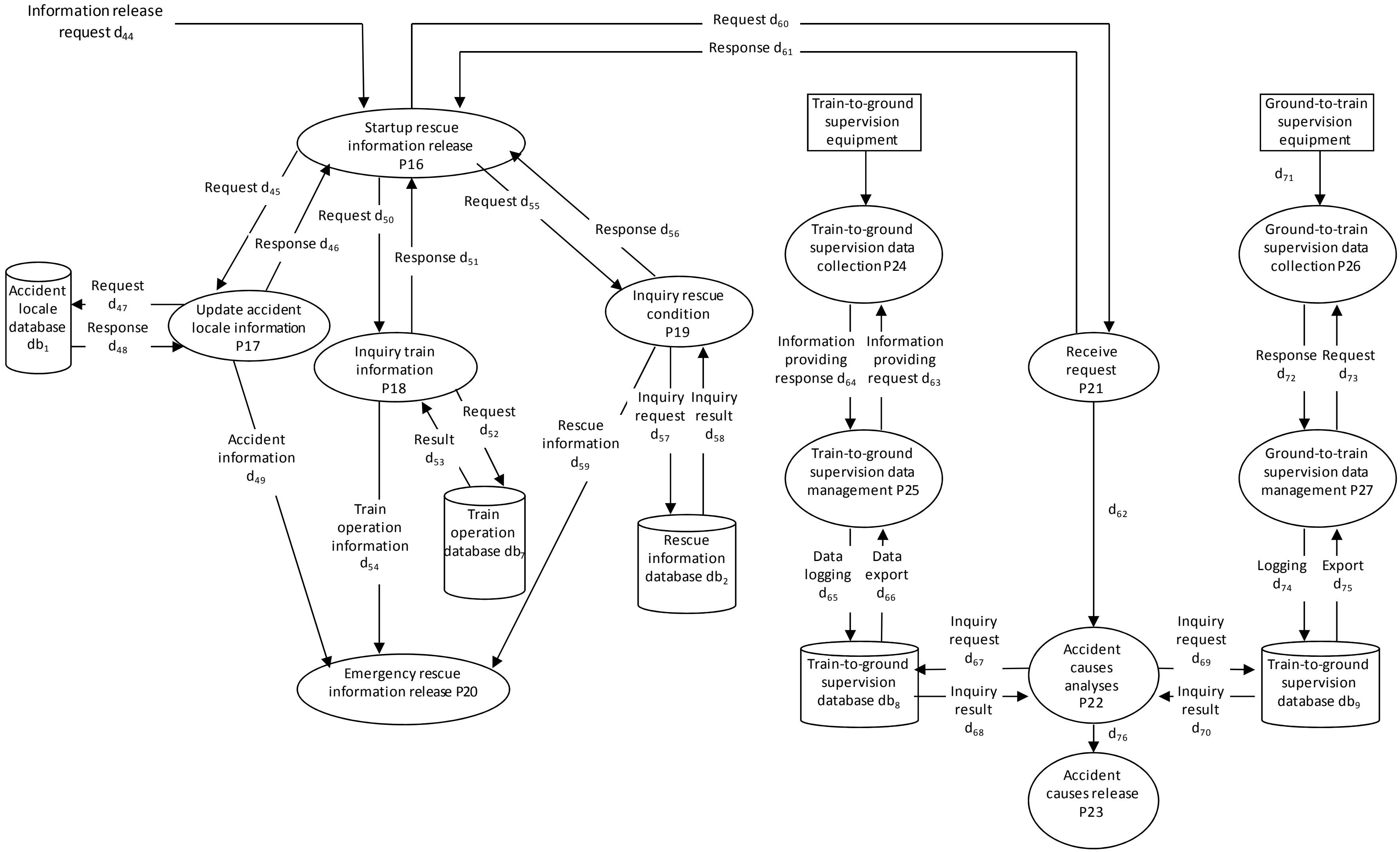



**Figure 1:** Emergency rescue and safety system DFD

### Functional Units Partition Based on Fuzzy Clustering

Emergency rescue and safety system totally include 28 basic functions (processes) and 9 databases, with complicated relationship among internal structures and elements, and is not suitable for direct design of the physical subsystems. Using partition method of logical structure based on fuzzy clustering, and through quantitative calculation, functions (processes) are clustered in accordance with certain rules, to generate several relatively independent and granularity suitable function units, based on which, physical subsystem design is carried out according to the above design method of physical structure.

DFD figure of emergency rescue and safety system can be converted into weighted and directed graph. According to assessed value given by experts, association degree among nodes is ascertained, to obtain the reachability matrix $G$ of the system, as shown in Table **3** (a), (b), (c). In order to facilitate the analysis of processes incidence relations, all the functional nodes and databases here are indicated as process nodes [47].

**Table 3:** Fuzzy association degree reachability matrix of logical structure in emergency rescue and safety system

**(a)**

| | p0 | p1 | p2 | db1 | p3 | p4 | db2 | p5 | p6 | p7 | p8 | p9 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| p0 | 1 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0 |
| p1 | 0 | 1 | 0.7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p2 | 0 | 0.1 | 1 | 0.7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| db1 | 0 | 0 | 0.3 | 1 | 0 | 0 | 0 | 0 | 0.4 | 0.6 | 0 | 0 |
| p3 | 0 | 0 | 0 | 0 | 1 | 0.7 | 0 | 0 | 0 | 0 | 0 | 0 |
| p4 | 0 | 0 | 0 | 0 | 0.1 | 1 | 0.7 | 0 | 0 | 0 | 0 | 0 |
| db2 | 0 | 0 | 0 | 0 | 0 | 0.3 | 1 | 0 | 0.4 | 0 | 0 | 0 |
| p5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.7 | 0 | 0 | 0 |
| p6 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0.1 | 0 | 1 | 0.6 | 0 | 0 |
| p7 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0 | 1 | 0.3 | 0 |
| p8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 | 1 | 0.7 |
| p9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| db3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.7 |
| p10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0 | 0 |
| p11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| db4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0 | 0 |
| p13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| db5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0 | 0 |
| p15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| db6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p17 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| db7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p19 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0 | 0 |
| p20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p24 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| db8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| db9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**(b)**

| | db3 | p10 | p11 | db4 | p12 | p13 | db5 | p14 | p15 | db6 | p16 | p17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| p0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0 |
| p1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| db1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.6 |
| p3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| db2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p7 | 0 | 0.1 | 0 | 0 | 0.3 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 |
| p8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p9 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| db3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p10 | 0 | 1 | 0.7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p11 | 0 | 0 | 1 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| db4 | 0 | 0 | 0.7 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p12 | 0 | 0 | 0 | 0 | 1 | 0.7 | 0 | 0 | 0 | 0 | 0 | 0 |
| p13 | 0 | 0 | 0 | 0 | 0 | 1 | 0.1 | 0 | 0 | 0 | 0 | 0 |
| db5 | 0 | 0 | 0 | 0 | 0 | 0.7 | 1 | 0 | 0 | 0 | 0 | 0 |
| p14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.7 | 0 | 0 | 0 |
| p15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.1 | 0 | 0 |
| db6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.7 | 1 | 0 | 0 |
| p16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.1 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| p17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 | 1 |
| p18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0 |
| db7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0 |
| p20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0 |
| p22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p24 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| db8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| db9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**(c)**

| | p18 | db7 | p19 | p20 | p21 | p22 | p23 | p24 | p25 | db8 | p26 | p27 | db9 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| p0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| db1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| db2 | 0 | 0 | 0.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| db3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| db4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| db5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| db6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| p16 | 0.1 | 0 | 0.1 | 0 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p17 | 0 | 0 | 0 | 0.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p18 | 1 | 0.1 | 0 | 0.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| db7 | 0.7 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p19 | 0 | 0 | 1 | 0.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p20 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p21 | 0 | 0 | 0 | 0 | 1 | 0.7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| p22 | 0 | 0 | 0 | 0 | 0 | 1 | 0.6 | 0 | 0 | 0.1 | 0 | 0 | 0.1 |
| p23 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| p24 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.7 | 0 | 0 | 0 | 0 |
| p25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 | 1 | 0.7 | 0 | 0 | 0 |
| db8 | 0 | 0 | 0 | 0 | 0 | 0.2 | 0 | 0 | 0.3 | 1 | 0 | 0 | 0 |
| p26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.7 | 0 |
| p27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 | 1 | 0.7 |
| db9 | 0 | 0 | 0 | 0 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0.3 | 1 |

Under different correlative intercept $\lambda$, the result of system classification is shown as follows:

When $\lambda = 0.1$, the result of system function clustering is:

{p0,p1,p2,db1,p3,p4,db2,p5,p6,p7,p8,p9,db3,p10,p11,db4,p12,p13,db5,p14,p15,db6,p16,p17,p18,db7,p19,p20,p21,p22,p23,p24,p25,db8,p26,p27,db9}.

The number of system function units: $l_{0.1} = 1$.

When $\lambda = 0.2$, the result of system function clustering is:

{p0},{p1,p2,db1,p3,p4,db2,p5,p6,p7,p8,p9,db3,p12,p13,db5,p14,p15,db6,p17,p18,db7,p19,p20},{p10,p11,db4},{p16},{p21,p22,p23,p24,p25,db8,p26,p27,db9}.

The number of system function units: $l_{0.2} = 5$.

When $\lambda = 0.3$, result of system function clustering is:

{p0},{p1,p2,db1,p3,p4,db2,p5,p6,p7,p8,p9,db3,p12,p13,db5,p14,p15,db6,p17,p18,db7,p19,p20}, {p10,p11,db4},{p16},{p21,p22,p23},{p24,p25,db8},{p26,p27,db9}.

The number of system function units: $l_{0.3} = 7$.

When $\lambda = 0.4$, the result of system function clustering is:

{p0},{p1,p2,db1,p3,p4,db2,p5,p6,p7,p17,p18,db7,p19,p20},{p8,p9,db3},{p10,p11,db4},{p12,p13,db5},{p14,p15,db6},{p16},{p21,p22,p23},{p24,p25,db8},{p26,p27,db9}.

The number of system function units: $l_{0.4} = 10$.

When $\lambda = 0.6$, the result of system function clustering is:

{p0},{p1,p2,db1,p3,p4,db2,p5,p6,p7,p17,p19,p20},{p8,p9,db3},{p10,p11,db4},{p12,p13,db5},{p14,p15,db6},{p16},{p18,db7},{p21,p22,p23},{p24,p25,db8},{p26,p27,db9}.

The number of system function units: $l_{0.6} = 11$.

When $\lambda = 0.7$, the result of system function clustering is:

{p0},{p1,p2,db1},{p3,p4,db2},{p5,p6},{p7},{p8,p9,db3},{p10,p11,db4},{p12,p13,db5},{p14,p15,db6},{p16},{p17},{p18,26},{p19},{p20},{p21,p22},{p23},{p24,p25,db8},{p26,p27,db9}.

The number of system function units: $l_{0.7} = 18$.

When $\lambda = 0.1$, the result of system function clustering is:

{p0},{p1},{p2},{db1},{p3},{p4},{db2},{p5},{p6},{p7},{p8},{p9},{db3},{p10},{p11},{db4},{p12},{p13},{db5},{p14},{p15},{db6},{p16},{p17},{p18},{db7},{p19},{p20},{p21},{p22},{p23},{p24},{p25},{db8},{p26},{p27},{db9}.

The number of system function units: $l_1 = 37$.

**Selection and Analysis of Optimization Threshold**

Method to select threshold $\lambda$ is under condition $\lambda_i$, and the number of system function units is $l_i$. On premise that constraint conditions of physical system are satisfied, and comprehensively considering principles of high cohesion, low coupling, and suitable granularity, we select the $\lambda_i$ which could make $l_i$ maximum. The so called constraint condition of physical system means that, owing to demands of management-level or requirement of business data flow, it needs to aggregate some processes into one functional collection and carry it out in one physical sub-system, with physical system constraint in line with information system business. On the basis of meeting constraint condition, it utilizes the method of fuzzy clustering, to aggregate closely related processes into functional unit, which reduces space dimensions of system design, simplifies design problem and facilitates physical system design.

From calculation results we can see that, different correlative intercept $\lambda$ has results of system logical functional unit partition of different granularities. When $\lambda = 0.1$, the system becomes an integral whole; after increasing $\lambda$, the system processes gradually aggregates into some functional units with different functions, number of functional units also increases, and the internal structure of RITS is then shown; when $\lambda = 1$, every process in the system constitutes a functional unit, and the granularity of system partition is the smallest. Comparing system partition results of different value of $\lambda$, and according to the principle of $\lambda^*$ selection, the granularity partition is relatively suitable when $\lambda = 0.7$, and then 28 processes and 9 databases in the DFD figure are aggregated into 18 functional units. The main function and processes contained are shown in Table **4**. The mutual connection relationship among functional units is shown in (Fig. **2**). Through fuzzy clustering analysis, issue for the physical structure design of 28 basic functions (processes) is converted to physical allocation issue for 18 functional units, which lowers complexity of system design. The experimental result indicates that this method is reasonable and effective [47].

**Table 4:** Functional units table

| Functional units | Basic function | Process |
|---|---|---|
| 1 | Rescue request | { p0 } |
| 2 | Collect accident information | { p1,p2,db1 } |
| 3 | Collect rescue information | { p3,p4,db2 } |
| 4 | Make rescue decision plan | { p5,p6 } |
| 5 | Emergency rescue staff interface | { p7 } |
| 6 | Material supply | { p8,p9,db3 } |

| | | |
|---|---|---|
| 7 | Resource equipment allocation | { p10,p11,db4 } |
| 8 | Maintenance service | { p12,p13,db5 } |
| 9 | Emergency car dispatch | { p14,p15,db6 } |
| 10 | Startup rescue information release | { p16 } |
| 11 | Update accident locale information | { p17 } |
| 12 | Inquiry train information | { p18,db7} |
| 13 | Inquiry rescue condition | { p19 } |
| 14 | Emergency rescue information release | { p20 } |
| 15 | Accident causes analysis | { p21,p22 } |
| 16 | Accident causes release | { p23 } |
| 17 | Train-to-ground supervision | { p24,p25,db8 } |
| 18 | Ground-to-train supervision | { p26,p27,db9 } |

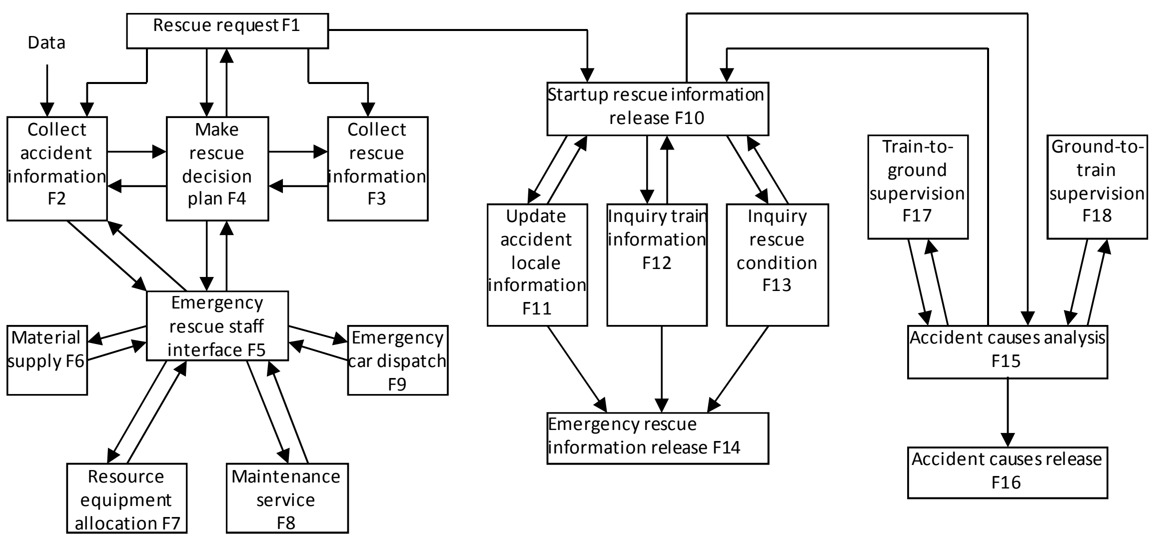



**Figure 2:** Functional units and connective relationship of emergency rescue and safety system

It needs to be pointed out that evaluation of relevancy degree among processes in this method mainly depends on experts' evaluation, which includes lack of objectivity and needs to select evaluation of more experts from many fields, through centralizing opinions from the most experts, to overcome adverse effects caused by evaluation inaccuracy from one expert.

## OPTIMIZATION DESIGN FROM LOGICAL STRUCTURE TO PHYSICAL STRUCTURE IN INTELLICTUAL EMERGENCY RESCUE AND SAFETY SYSTEM

Railway intelligent transportation system is the new generation railway transportation system. It integrates electronics technology, computer technology, modern communication technology, modern information disposal technology, control and system technology, management and decision support technology, intelligent automation technology etc., and realizes the collection, transmission, disposal and share information through full use of all moving, fixed, space, time and person resources related with railway transportation efficiently, with the aim of achieving safe guaranty, increasing transportation efficiency and improving service quality at the lower cost.

The development of RITS in China is divided into three stages: the primary stage——railway informatization; the secondary stage——the transition of railway informatization to railway intelligentization; the senior stage——

railway intelligentization. At present, China railway is being at the primary and the secondary development stage, having many problems of build repetition, share difficulty and distributing illogicality of information resources, causing the illogicality of system structure and the waste of information resources.

As an information system, the construction lifecycle of RITS includes five stages generally, that is: requirement study, logical design, physical design, and system implement as well as system maintenance. The exploitation cycle of RITS is long, and the exploitation process is complicated, due to the disjoint of logical design and physical design, the mapping relations between logical design and physical design usually given by experiences, which run short of the theory basis. Therefore, how to fix and optimize the mapping relations between the logical design and physical design, namely structure design and optimization, are the most important and urgent problems to be solved in the RITS lifecycle.

### Element Analysis of Optimization Design from Logical Structure to Physical Structure

The aim of RITS system framework research is to provide basis and direction of plan, design, implement, standard and management for RITS development.

Logical structure describes the inner structure of RITS from the logical point of view, namely, aiming at every kind of customer services, which are determined by RITS, the structural organization for input data stream, output data stream and disposal process carried through from inside system. The top logical structure of RITS in China is shown in (Fig. **3**).

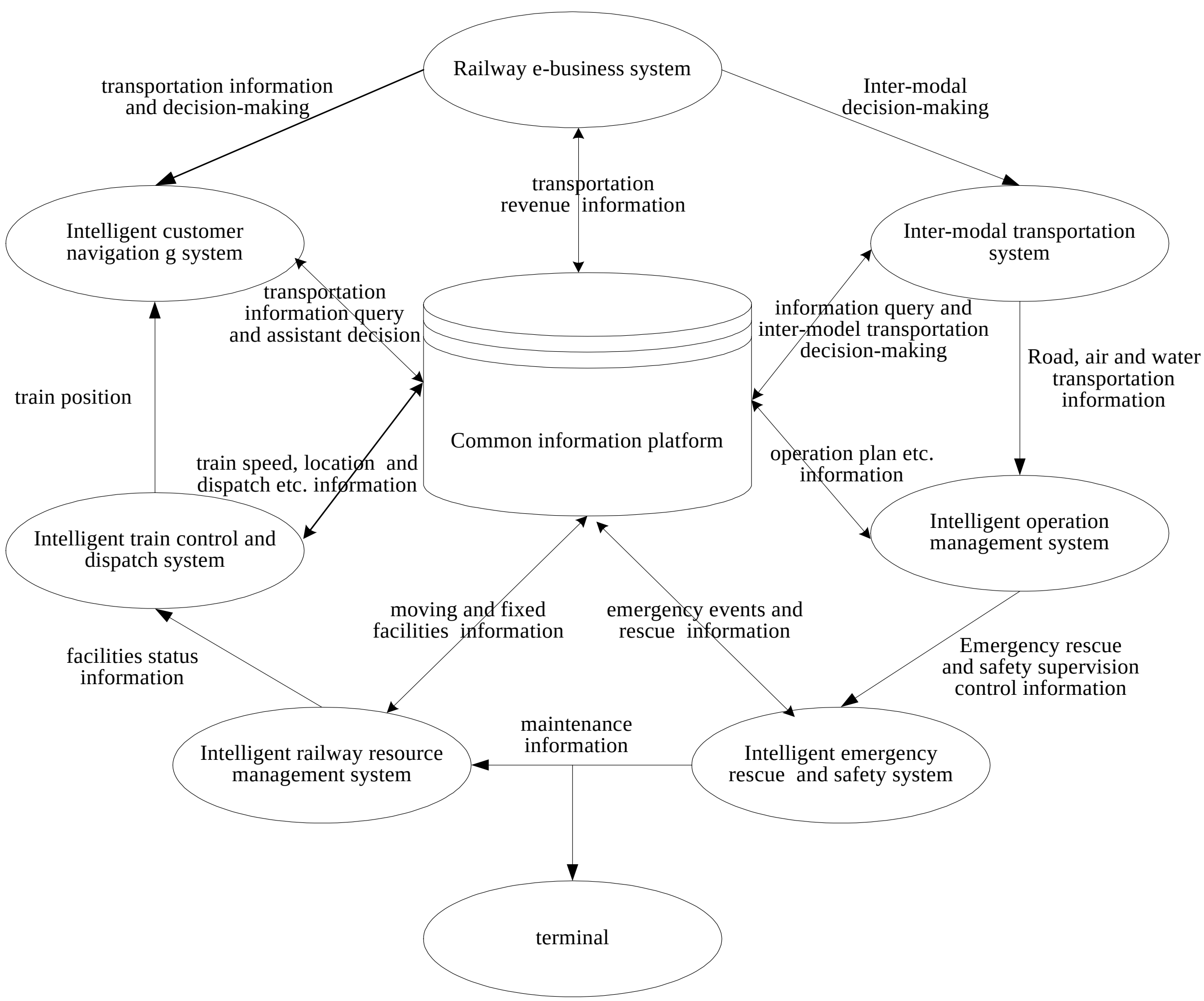



**Figure 3:** The top logical structure of RITS in China

Physical structure distributes the process defined by logical structure into the physical entities of RITS, and according to the data stream in every process, it defines the frame stream and the inter-link fashion of the physical entities. The top physical structure of RITS in China is shown as (Fig. **4**).

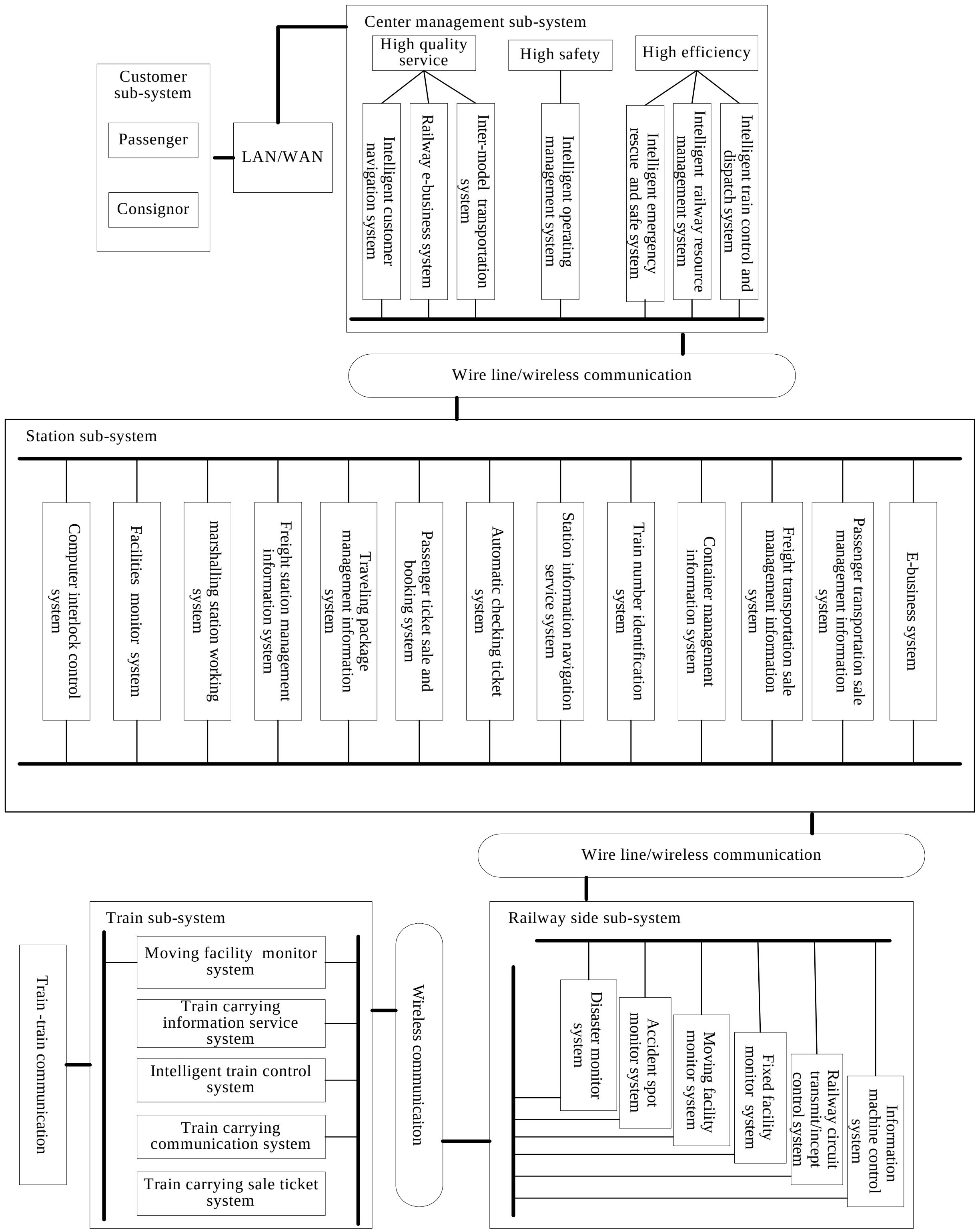



**Figure 4:** The top physical structure of RITS in China

Logical structure does not take into account the management system and technology factors, but it only defines the system function, regardless of who realizes the function and how to realize, the concrete realization work is done by physical structure, having relative by better stability, supporting extensive different system design. The physical structure is the functional entity and model in logical structure, integrating relative system function and data stream into systems and sub-systems; definition of system and sub-system in physical structure not only takes into account the functional requirements, but also takes into account functional requirements, including factors of management system, technology etc. Therefore, the same logical function with the different design principles and conditions can be obtained by the physical system with different formats and composing.

Apparently, the formation from function of logical structure layer to sub-system of physical structure layer is a mapping optimization process, as shown in (Fig. **5**). In RITS system framework, the mapping relation definition mostly depends on experts' experience, lacking a set of systemic method, and is taken as the theory basis for design in reason. So how to find a set of methods and theory to fix on and optimize this mapping relation is an urgent problem to be solved in relative systems exploitation design of RITS.

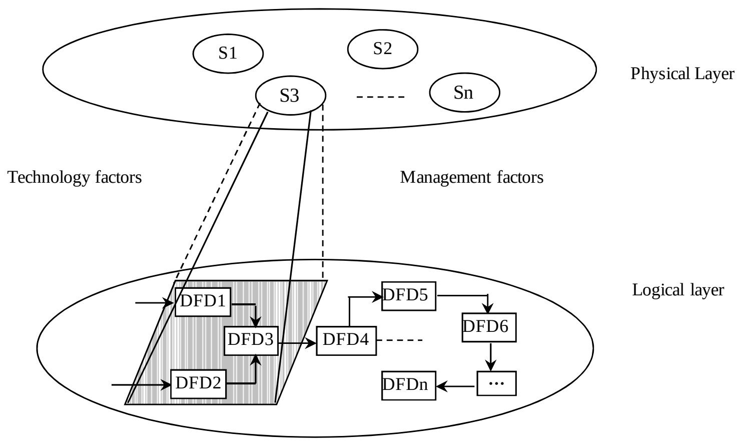



**Figure 5:** The mapping relations between logical structure and physical structure

The elements on which the RITS structure design is based can be conformed and optimized from logical structure and physical structure, according to research report of 《The railway intelligent transportation system framework》.

The definition of the element set

The function element set is fixed on F= {F1，F2，…，Fn}. Where:

F1：The information provide and assistant decision service when passengers coming out or before consignor consigning,

F2：The information provided and assistant decision service when passengers on the train or the freight are on the way,

F3：The station navigation service of passenger station,

F4：The passenger transport e-business,

F5：The railway e-business trade platform,

F6：The freight e-business,

F7：The basic transportation data share,

F8：The inter-modal transportation and unite transportation decision,

F9：The emergency affair succor,

F10：The traveling trains safety and maintenance decision-making support,

F11：The railway-integrated disasters defend,

F12：The road junction safety monitor,

F13：The transportation resources management,

F14：The transportation resources maintenance management system,

F15：The finance management,

F16：The passenger transportation management,

F17：The freight and container management,

F18：The intelligent marshalling station system,

F19：The intelligent train control,

F20：The integrated dispatch control,

F21：The rail station control,

The sub-system element set is fixed on as S={S1，S2，…，Sn}. Where:

S1：The exterior user sub-system,

S2：The station sub-system,

S3：The railway side sub-system,

S4：The train sub-system,

S5：The center management sub-system,

S6：The user navigation and e-business system,

S7：The inter-modal transportation system,

S8：The emergency rescue and safety system,

S9：The resource management system,

S10：The operation management system.

S11：The traveling train control and dispatch system;

### Subsystem Partition Based on Fuzzy Structure Modeling Method

The relation between sub-system and function region is expressed by 0 and 1; when sub-system element S has a relation with function element F, it gives 1, when sub-system element S has no relation with function element F, it gives 0. In RITS physical structure, the function unit corresponding to sub-system is given by experts experience, based on which relation matrix between elements can be constructed (refer to reference 1), as shown in Table **5** [46].

**Table5:** Relation matrix

| | S1 | S2 | S3 | S4 | S5 | S6 | S7 | S8 | S9 | S10 | S11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **F1** | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| **F2** | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| **F3** | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| **F4** | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| **F5** | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| **F6** | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| **F7** | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| **F8** | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| **F9** | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| **F10** | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| **F11** | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| **F12** | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| **F13** | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **F14** | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| **F15** | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| **F16** | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| **F17** | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| **F18** | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| **F19** | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| **F20** | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| **F21** | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |

The formula below is chosed as the membership function [10], and the relevance intensity between function elements is calculated.

$$w_{ij} = \frac{q_{ij}}{q_i + q_j - q_{ij}}$$

In the above table, $w_{ij}$ is the relevance intensity among function elements, $q_i$ is the number of the relevance degree of $F_i$ and S equaling 1, $q_j$ is the number of the relevance degree of $F_j$ and S equaling 1, and $q_{ij}$ is the number of the relevance degree of $F_i$, $F_j$ and S equaling 1 at the same time. The larger frequency of $F_i$ and $F_j$ with S, the larger relevance intensity of $F_i$ and $F_j$. $W$ meets the below formula：

$$W_{ij} = W_{ji} \text{ (Symmetry)}$$

The relevance intensity matrix $W$ is shown as Table **6**.

Calculation of the relevance intensity reachable matrix

For classics boolean matrix, calculation principle can be regarded as the most and the least calculation symbol principle, of which the multiplication can be replaced by the least calculation symbol, and the addition calculation can be replaced by the most calculation symbol.

$$0 \vee 0 = 0, 0 \vee 1 = 1, 1 \vee 0 = 1, 1 \vee 1 = 1$$
$$0 \wedge 0 = 0, 0 \wedge 1 = 0, 1 \wedge 0 = 0, 1 \wedge 1 = 1$$

From the above fuzzy operator we can see that the maximum and the minimum calculation principle is another mode for boolean matrix calculation principle. For fuzzy matrix, single numerical value is calculated as below:

$$0.2 \vee 0.6 = 0.6, 0.2 \vee 1 = 1, 1 \vee 0.2 = 1, 1 \vee 1 = 1$$
$$0.2 \wedge 0.6 = 0.2, 0.2 \wedge 0 = 0, 0 \wedge 0.5 = 0, 1 \wedge 1 = 1$$

Applying the maximum and the minimum calculation principle, constantly squaring the addition of the relevance intensity matrix W and unit matrix I through computer programming, the reachable matrix can be found. The relevance intensity reachable matrix calculation is shown as Table **7**.

**Table 6:** Relevance intensity matrix W

| F | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0.5 | 0.5 | 0.6 | 0.33 | 0.75 | 0.33 | 0.33 | 0.33 | 0.14 | 0.2 | 0.2 | 0.28 | 0.28 | 0.33 | 0.2 | 0.2 | 0.25 | 0 | 0.25 | 0.25 |
| 2 | 0.5 | 0 | 0.5 | 0.6 | 0.33 | 0.4 | 0.33 | 0.33 | 0 | 0.14 | 0 | 0 | 0.14 | 0.14 | 0.33 | 0.2 | 0.2 | 0 | 0.2 | 0 | 0 |
| 3 | 0.5 | 0.5 | 0 | 0.6 | 0.33 | 0.75 | 0.33 | 0.33 | 0 | 0.14 | 0 | 0.2 | 0.28 | 0.28 | 0.33 | 0.17 | 0.17 | 0.2 | 0 | 0.2 | 0.2 |
| 4 | 0.6 | 0.6 | 0.6 | 0 | 0.2 | 0.8 | 0.67 | 0.67 | 0.17 | 0.43 | 0.14 | 0.33 | 0.57 | 0.57 | 0.67 | 0.5 | 0.5 | 0.33 | 0.14 | 0.33 | 0.33 |
| 5 | 0.33 | 0.33 | 0.33 | 0.2 | 0 | 0.25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 0.75 | 0.4 | 0.75 | 0.8 | 0.25 | 0 | 0.5 | 0.5 | 0.2 | 0.28 | 0.17 | 0.4 | 0.43 | 0.43 | 0.5 | 0.33 | 0.33 | 0.4 | 0 | 0.4 | 0.4 |

| | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7 | 0.33 | 0.33 | 0.33 | 0.67 | 0 | 0.5 | 0 | 1 | 0.17 | 0.43 | 0.14 | 0.33 | 0.57 | 0.57 | 0.67 | 0.5 | 0.5 | 0.33 | 0.14 | 0.33 | 0.33 |
| 8 | 0.33 | 0.33 | 0.33 | 0.67 | 0 | 0.5 | 1 | 0 | 0.17 | 0.43 | 0.14 | 0.33 | 0.57 | 0.57 | 0.67 | 0.5 | 0.5 | 0.33 | 0.14 | 0.33 | 0.33 |
| 9 | 0.33 | 0 | 0 | 0.17 | 0 | 0.2 | 0.17 | 0.17 | 0 | 0.4 | 0.67 | 0.67 | 0.14 | 0.14 | 0.17 | 0.2 | 0.2 | 0.25 | 0 | 0.25 | 0.25 |
| 10 | 0.14 | 0.14 | 0.14 | 0.43 | 0 | 0.28 | 0.43 | 0.43 | 0.4 | 0 | 0.6 | 0.6 | 0.57 | 0.57 | 0.43 | 0.5 | 0.5 | 0.33 | 0.33 | 0.33 | 0.33 |
| 11 | 0.2 | 0 | 0 | 0.14 | 0 | 0.17 | 0.14 | 0.14 | 0.67 | 0.6 | 0 | 0.5 | 0.28 | 0.28 | 0.14 | 0.17 | 0.17 | 0.2 | 0.2 | 0.2 | 0.2 |
| 12 | 0.2 | 0 | 0.2 | 0.33 | 0 | 0.4 | 0.33 | 0.33 | 0.67 | 0.6 | 0.5 | 0 | 0.28 | 0.28 | 0.33 | 0.4 | 0.4 | 0.5 | 0.5 | 0.5 | 0.5 |
| 13 | 0.28 | 0.14 | 0.28 | 0.57 | 0 | 0.43 | 0.57 | 0.57 | 0.14 | 0.57 | 0.28 | 0.28 | 0 | 1 | 0.83 | 0.43 | 0.43 | 0.28 | 0.28 | 0.28 | 0.28 |
| 14 | 0.28 | 0.14 | 0.28 | 0.57 | 0 | 0.43 | 0.57 | 0.57 | 0.14 | 0.57 | 0.28 | 0.28 | 1 | 0 | 0.83 | 0.43 | 0.43 | 0.28 | 0.28 | 0.28 | 0.28 |
| 15 | 0.33 | 0.33 | 0.33 | 0.67 | 0 | 0.5 | 0.67 | 0.67 | 0.17 | 0.43 | 0.14 | 0.33 | 0.83 | 0.83 | 0 | 0.5 | 0.5 | 0.33 | 0.14 | 0.33 | 0.33 |
| 16 | 0.2 | 0.2 | 0.17 | 0.5 | 0 | 0.33 | 0.5 | 0.5 | 0.2 | 0.5 | 0.17 | 0.4 | 0.43 | 0.43 | 0.5 | 0 | 1 | 0.75 | 0.17 | 0.4 | 0.4 |
| 17 | 0.2 | 0.2 | 0.17 | 0.5 | 0 | 0.33 | 0.5 | 0.5 | 0.2 | 0.5 | 0.17 | 0.4 | 0.43 | 0.43 | 0.5 | 1 | 0 | 0.75 | 0.17 | 0.4 | 0.4 |
| 18 | 0.25 | 0 | 0.2 | 0.33 | 0 | 0.4 | 0.33 | 0.33 | 0.25 | 0.33 | 0.2 | 0.5 | 0.28 | 0.28 | 0.33 | 0.75 | 0.75 | 0 | 0 | 0.5 | 0.5 |
| 19 | 0 | 0.2 | 0 | 0.14 | 0 | 0 | 0.14 | 0.14 | 0 | 0.33 | 0.2 | 0.5 | 0.28 | 0.28 | 0.14 | 0.17 | 0.17 | 0 | 0 | 0.2 | 0.2 |
| 20 | 0.25 | 0 | 0.2 | 0.33 | 0 | 0.4 | 0.33 | 0.33 | 0.25 | 0.33 | 0.2 | 0.5 | 0.28 | 0.28 | 0.33 | 0.4 | 0.4 | 0.5 | 0.2 | 0 | 1 |
| 21 | 0.25 | 0 | 0.2 | 0.33 | 0 | 0.4 | 0.33 | 0.33 | 0.25 | 0.33 | 0.2 | 0.5 | 0.28 | 0.28 | 0.33 | 0.4 | 0.4 | 0.5 | 0.2 | 1 | 0 |

**Table 7:** Relevance intensity reachable matrix (M4=M5)

| F | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 0.6 | 0.75 | 0.75 | 0.33 | 0.75 | 0.67 | 0.67 | 0.57 | 0.57 | 0.57 | 0.57 | 0.67 | 0.67 | 0.67 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| 2 | 0.6 | 1 | 0.6 | 0.6 | 0.33 | 0.6 | 0.6 | 0.6 | 0.57 | 0.57 | 0.57 | 0.57 | 0.6 | 0.6 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| 3 | 0.75 | 0.6 | 1 | 0.75 | 0.33 | 0.75 | 0.67 | 0.67 | 0.57 | 0.57 | 0.57 | 0.57 | 0.67 | 0.67 | 0.67 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| 4 | 0.75 | 0.6 | 0.75 | 1 | 0.33 | 0.8 | 0.67 | 0.67 | 0.57 | 0.57 | 0.57 | 0.57 | 0.67 | 0.67 | 0.67 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| 5 | 0.33 | 0.33 | 0.33 | 0.33 | 1 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 |
| 6 | 0.75 | 0.6 | 0.75 | 0.8 | 0.33 | 1 | 0.67 | 0.67 | 0.57 | 0.57 | 0.57 | 0.57 | 0.67 | 0.67 | 0.67 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| 7 | 0.67 | 0.6 | 0.67 | 0.67 | 0.33 | 0.67 | 1 | 1 | 0.57 | 0.57 | 0.57 | 0.57 | 0.67 | 0.67 | 0.67 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| 8 | 0.67 | 0.6 | 0.67 | 0.67 | 0.33 | 0.67 | 1 | 1 | 0.57 | 0.57 | 0.57 | 0.57 | 0.67 | 0.67 | 0.67 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| 9 | 0.57 | 0.57 | 0.57 | 0.57 | 0.33 | 0.57 | 0.57 | 0.57 | 1 | 0.6 | 0.67 | 0.67 | 0.57 | 0.57 | 0.57 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| 10 | 0.57 | 0.57 | 0.57 | 0.57 | 0.33 | 0.57 | 0.57 | 0.57 | 0.6 | 1 | 0.6 | 0.6 | 0.57 | 0.57 | 0.57 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| 11 | 0.57 | 0.57 | 0.57 | 0.57 | 0.33 | 0.57 | 0.57 | 0.57 | 0.67 | 0.6 | 1 | 0.67 | 0.57 | 0.57 | 0.57 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| 12 | 0.57 | 0.57 | 0.57 | 0.57 | 0.33 | 0.57 | 0.57 | 0.57 | 0.67 | 0.6 | 0.67 | 1 | 0.57 | 0.57 | 0.57 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| 13 | 0.67 | 0.6 | 0.67 | 0.67 | 0.33 | 0.67 | 0.67 | 0.67 | 0.57 | 0.57 | 0.57 | 0.57 | 1 | 1 | 0.83 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| 14 | 0.67 | 0.6 | 0.67 | 0.67 | 0.33 | 0.67 | 0.67 | 0.67 | 0.57 | 0.57 | 0.57 | 0.57 | 1 | 1 | 0.83 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| 15 | 0.67 | 0.6 | 0.67 | 0.67 | 0.33 | 0.67 | 0.67 | 0.67 | 0.57 | 0.57 | 0.57 | 0.57 | 0.83 | 0.83 | 1 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| 16 | 0.5 | 0.5 | 0.5 | 0.5 | 0.33 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 1 | 1 | 0.75 | 0.5 | 0.5 | 0.5 |
| 17 | 0.5 | 0.5 | 0.5 | 0.5 | 0.33 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 1 | 1 | 0.75 | 0.5 | 0.5 | 0.5 |
| 18 | 0.5 | 0.5 | 0.5 | 0.5 | 0.33 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.75 | 0.75 | 1 | 0 | 0.5 | 0.5 |
| 19 | 0.5 | 0.5 | 0.5 | 0.5 | 0.33 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 1 | 0.5 | 0.5 |
| 20 | 0.5 | 0.5 | 0.5 | 0.5 | 0.33 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 1 | 1 |
| 21 | 0.5 | 0.5 | 0.5 | 0.5 | 0.33 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 1 | 1 |

**Table 8:** Threshold frequency statistics

| **Threshold** | **1** | **0.83** | **0.8** | **0.75** | **0.67** | **0.6** | **0.57** | **0.5** | **0.33** |
|---|---|---|---|---|---|---|---|---|---|
| Frequency | 29 | 4 | 2 | 14 | 58 | 24 | 80 | 190 | 40 |

Table **8** is the frequency statistics of threshold. The smaller the value of $\lambda$, the wider the system classifies; the bigger the value of $\lambda$, the finer the system classifies. Over wider and finer partition of system can affect the system total performance, so the value $\lambda$ must be proper, neither greater nor smaller can be allowed. Then $\lambda$ =0.67, 0.6, 0.57.

Table **9** is the level cut matrix when $\lambda$=0.67.

**Table 9:** Level cut matrix, when $\lambda$=0.67

| F | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | :0 | 0 | 0 | 0 |
| 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 13 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 |
| 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 |
| 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 |
| 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |

Table **10** is the level cut matrix when $\lambda$=0.6.

**Table 10:** Level cut matrix, when $\lambda$=0.6

| F | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 13 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 |
| 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 |
| 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 |
| 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |

Table **11** is the level cut matrix when $\lambda$=0.57.

**Table 11:** Level cut matrix, when $\lambda$=0.57.

| F | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 13 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 |
| 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 |
| 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 |
| 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |

The partition of the relevance intensity reachable matrix

The relevance intensity reachable matrix must meet the following characteristics:

$W_{ii} = 1$ (Reflection character)

$W_{ij} = W_{ji}$ (Symmetry character)

${W_{ij}}^2 \subseteq W_{ij}$ (Transformation character)

Because the relevance intensity reachable matrix has symmetry character, self-reflection character and transformation character, it is an equivalence matrix, as rows and lines are all 1 on cater-corner sub-matrix that can be clustered directly, and three alternative schemes are obtained.

The first scheme: when $\lambda$=0.67

S1={F1,F3,F4,F6,F7,F8,F13,F14,F15}、S2={F9,F11,F12}、S3={F16,F17,F18}、S4={F20,F21}、S5={F2}、S6={F5 }、S7={F10}、S8={F19}。

The second scheme: when $\lambda$=0.6

S1={F1,F2,F3,F4,F6,F7,F8,F13,F14,F15}、S2={F9,F10,F11,F12}、S3={F16,F17,F18}、S4={F20,F21}、S5={F5}、S6={F19}。

The third scheme: when $\lambda$=0.57

S1={F1,F2,F3,F4,F6,F7,F8,F9,F10,F11,F12,F13,F14,F15}、S2={F16,F17,F18}、S3={F20,F21}、S4={F5}、S5={F19}。

**Schemes Optimization Based on Fuzzy Matter-element Analysis for Physical Structure**

The main concept of matter-unit analysis method uses three elements i.e., “matter, characteristic and quantum” to describe the matter, and composes the basic unit of three unit group with order, namely matter-unit. The matter-unit analysis is the effective method to study matter and its variety rule, and to solve the incompatibility problems in the reality world. Using the matter-unit analysis method, the matter evaluation model with multi index parameters can be set up, and the result assessment can be expressed by quantitative numerical value, therefore the integrated level of matter quality can be reflected perfectly, and it is easy to carry through program disposal by computers.

The optimization target system of RITS:

The target system is the target group that composes some relative targets to achieve some study aims. Targets of RITS structure optimization are divided into qualitative targets and quantitative targets. As it is very difficult to quantify the targets of RITS structure optimization at present, quantitative targets are adopted to describe mostly.

Concrete targets include: the high efficiency of transportation, which can fully exert the resource avail of railway transportation, and meet all kinds of transportation requirements; the high safety of transportation, which guarantees the high reliability of railway transportation system operation; the high quality service, which provides most convenience for passengers and consignors who use the railway transportation; the high benefit of transportation, which creates the best transportation benefits under the better quality service for passengers and consignors.

The theory of multi-target fuzzy matter-unit optimization

The multi-target optimization of RITS structure design can be described by the structure optimization matter-unit. If the aim name of multi-target design is taken as the characteristic of matter-unit for structure optimization, the target function value is taken as the quantum of matter-unit, therefore model of matter-unit for multi-target structure optimization is shown as below:

$$R = \begin{bmatrix} M & c_1 & f_1(x) \\ & c_2 & f_2(x) \\ & \cdots & \cdots \\ & c_l & f_l(x) \end{bmatrix}$$

In the formula, $M$ is the name of structure design scheme for awaiting optimization, $c_i$ is the name of the $i$ th target, $x$ is the design variable, and $f_i(x)$ is the $i$ th target function.

Because some targets are only qualitative term set, which are difficult to directly carry through the quantitative calculation. Even if the target function is the normal mathematical fashion, because of the differences of each target function, the difference between each target function is quite great. The relative error of each target with less function value is quite great when seeking solution directly. Therefore, the matter-unit of design target is translated into fuzzy matter-unit, and the fuzzy matter-unit model is shown as below:

$$\tilde{R}_l = \begin{bmatrix} & structure\ \ design\ \ scheme M \\ efficiency\ \ c_1 & \mu(f_1(x)) \\ safety\ \ c_2 & \mu(f_2(x)) \\ service\ \ quality\ \ c_3 & \mu(f_3(x)) \\ bnefit\ \ c_4 & \mu(f_4(x)) \end{bmatrix}$$

In the formula, $\tilde{R}_l$ expresses the fuzzy matter-unit of structure design scheme with $l$ dimension for waiting optimization, $c_i$ is the name of the $i$ th target,

$\mu(f_i(x))$ Expresses the optimization membership of the $i$ th target $c_i$ corresponding value $f_i(x)$ of structure design scheme $M$ , $\mu(f_i(x)) \in [0,1]$

If $f_i(x)$ is a set of quantitative comment set, therefore, these quantitative comments need to be qualified, and expressed by numerical value belonging to 0 and 1, separately.

In the process of structure optimization, all targets have their own weight. If $R_w$ expresses the weight compound matter-unit of each target for the fuzzy matter-unit of structure design scheme, and $w_i(i=1,2,\cdots,l)$ expresses each target weight, therefore:

$$R_w = \begin{bmatrix} & efficiency\ c_1 & safety\ c_2 & service\ quality\ c_3 & benefit\ c_4 \\ w_i & w_1 & w_2 & w_3 & w_4 \end{bmatrix}$$

$w_i$ can be fixed according to AHP method.

Making the relevance degree standard for judging the structure design scheme good or bad, the stronger the relevance degree of structure design scheme, the better the scheme is expressed. The formula of the relevance degree $k$ calculated by using the fuzzy matter-unit relevance analysis is:

$$k(x) = \sum_{i=1}^{l} \xi_i w_i$$

Where $\xi_i$ is the relevance coefficient, obtained by the relevance transform $\xi_i = \mu(f_i(x))$.

So the multi-target optimization problem is translated into single target optimization problem, as shown in the formula below:

$$X = \{x_1, x_2, \cdots, x_n)^T$$

$$\max k(x)$$

The application example of RITS structure design and optimization

The definition of the relation matrix

RITS structure optimization

The establishment of structure optimization matter-unit model

M1: the first scheme; M2: the second scheme; M3: the third scheme

C1: high efficiency, C2: high safety, C3: high quality service, C4: high benefit

Because the corresponding value $x_{ij}$ of the $i$ th target for structure design scheme cannot be given at present, so the excellent membership $\mu(x_{ij})$ of $x_{ij}$ can be given subjectively by experts experience. Table **12** gives an example about qualitative comment quantified [46].

**Table 12:** Qualitative comments quantified

| Better | Good | Common | Bad | Worse |
|---|---|---|---|---|
| 0.9 | 0.75 | 0.6 | 0.45 | 0.3 |

The fuzzy matter-unit model of structure optimization relevance degree:

$$\tilde{R}_{mn} = \begin{bmatrix} & M_1 & M_2 & M_3 \\ c_1 & \xi_{11} & \xi_{21} & \xi_{31} \\ c_2 & \xi_{12} & \xi_{22} & \xi_{32} \\ c_3 & \xi_{13} & \xi_{23} & \xi_{33} \\ c_4 & \xi_{14} & \xi_{24} & \xi_{34} \end{bmatrix}$$

$\xi_{ij}$ can be fixed by membership function, or fuzzy statistics method. Consequently**,** according to Table **11**, concrete RITS structure optimization relevance degree compound matter-unit model is given.

$$\tilde{R}_{\xi} = \begin{bmatrix} & \text{scheme1} & \text{scheme2} & \text{scheme3} \\ \textit{efficiency} & 0.45 & 0.9 & 0.6 \\ \textit{safety} & 0.75 & 0.45 & 0.6 \\ \textit{service quality} & 0.9 & 0.6 & 0.75 \\ \textit{benefit} & 0.3 & 0.75 & 0.6 \end{bmatrix}$$

The weight conformation is an important content of multi-target optimization problem. Methods of weight conformation have sum normalize method, AHP method, statistics method, inherit method and try method etc. In this paper firstly the AHP method is adopted to construct model.

According to the differences between each target importance level in the design of RITS, the one another ratio between their elements can be defined using 1-9 ratio mark method, namely using 1, 3, and 5, 7, 9 or 1、1/3、1/5、1/7、1/9 to express the importance of degree of one element to another element. “1” expresses the two elements with the same importance level, “3”expresses one is more important than another, “5”expresses that one is evidently even more important than another, “7”expresses that one has intensity more important than another, “9”expresses that one is extremely more important than another; if there are factors A and B, the important level of B to A is b, therefore the important level of A to B is 1/b.

By constructing the distinguish matrix P we have:

$$P = \begin{array}{c} \begin{matrix} c_1 & c_2 & c_3 & c_4 \end{matrix} \\ \begin{bmatrix} 1 & 1 & 1/3 & 1/5 \\ 1 & 1 & 1/3 & 1/3 \\ 3 & 3 & 1 & 1/3 \\ 5 & 3 & 3 & 1 \end{bmatrix} \end{array} \begin{matrix} c_1 \\ c_2 \\ c_3 \\ c_4 \end{matrix}$$

Then use sum normalize method to calculate the weight of all characteristics.

1. Calculate the sum of all line elements of the distinguish matrix

$$P_i = \sum_{j=1}^{5} P_{ij}$$

$$p_1 = 1 + 1 + 1/3 + 1/5 = 2.533$$
$$p_2 = 1 + 1 + 1/3 + 1/3 = 2.666$$
$$p_3 = 3 + 3 + 1 + 1/3 = 7.333$$
$$p_4 = 5 + 3 + 3 + 1 = 12$$

2. Calculate the sum of all elements of the distinguish matrix

$$p_{total} = \sum_{i=1}^{5} P_i = 24.532$$

3. Calculate the weight of all characteristics, and construct the compound weight matter-unit

$$w_i = \frac{p_i}{p_{tatal}}$$

So the compound weight matter-unit of RITS structure optimization can be obtained.

$$\tilde{R}_w = \begin{bmatrix} & c_1 & c_2 & c_3 & c_4 \\ w & 0.1033 & 0.1087 & 0.2989 & 0.4892 \end{bmatrix}$$

The relevance degree calculation

Use fuzzy matter-unit relevance analysis method to calculate the relevance degree.

$$k_1 = 0.45 \times 0.1033 + 0.75 \times 0.1087 + 0.9 \times 0.2989 + 0.3 \times 0.4892 = 0.5438$$
$$k_2 = 0.9 \times 0.1033 + 0.45 \times 0.1087 + 0.6 \times 0.2989 + 0.75 \times 0.4892 = 0.6881$$
$$k_3 = 0.6 \times 0.1033 + 0.6 \times 0.1087 + 0.75 \times 0.2989 + 0.6 \times 0.4892 = 0.6449$$

From the above calculation of fuzzy matter-unit of relevance degree, we can know $k_2 > k_3 > k_1$, obviously the relevance degree of the second scheme is the biggest, so the structure design of the second scheme is the best.

From the above the calculation of relevance degree, the second scheme having the structure design scheme fixed at $\lambda$=0.6 is the best scheme, through which the new sub-system element set can be obtained. Combined with their function orientation in the RITS system, we rename them separately:

S1：The user service and resource management system,

S2：The emergency rescue and safety system,

S3：The operation management system,

S4：The operation control system,

S5：The e-business trade system,

S6：The intelligent train control system.

Basing on systematical study and analysis on RITS system framework, it is concluded that RITS structure design is the mappings and its optimization problems between RITS logical structure and physical structure. With this as starting point, the author tries to set up a system realization oriented structure design theory for RITS. The technical route is to define the mappings between logical structure and physical structure, making a set of structure design alternations and the best one is fixed on the fuzzy matter-element optimization method. The theory of structure design combined with the theory study with experts experience, and the quantity calculation with the qualitative analysis, therefore achieve the unify of science characteristic and practicability, provide credible basis for solving practice problems, and the application in RITS framework proves that this method is feasible and correct.

# CHAPTER 5

# RITS Universal Technology Platform and Application

**Abstract:** Research on RITS universal technology platform is to realize the effective management, share spatial data and non-spatial data, and change the situation of "information lonely island" in the existing railway information system. Universal technology platform is composed of the train positioning system, the communication system, railway information sharing platform and railway basic geography database. The key technologies involved in RITS universal technology platform include train position technology, communication technology, data sharing and comprehensive technology, and railway geographic information system etc. Finally the comprehensive safety monitoring system of the Chinese Qinghai-Tibet Railway is introduced as an example.

## COMPONENTS OF RITS UNIVERSAL TECHNOLOGY PLATFORM

### Research Significance of RITS Universal Technology Platform

From the angle of data flow, the core mission of RITS is to efficiently and fully utilize all data sources related with railway transport, to provide efficient and convenient operation and decision making tools for all levels of railway managers and users, and to protect rail operation safety, simultaneously offering convenient and personalized service for an extensive number of passengers and cargos, and finally realizing the achievement "high safety, high efficiency, high-quality service". The role of universal technology platform is to protect reliab1ility of collection, transmission and management of the mentioned-above data. Therefore, as the data provider, transmitter and manager for entire RITS, researches in universal technology platform have great significance.

Related data sources in the entire railway transportation system are mainly divided into six main types, including passenger and freight transport, locomotive depot, train, engineering district, communication and signal district, basic public data, etc. Specific categories are freight transport demand information (trains number, train type, tonnage, product name, start and arrival station, loading demand, etc.), freight ticket information, freight train list information report (organization structure, train number, train type, organization sequence, train arrival, empty train direction, etc.), passenger ticket information, baggage and parcel information, locomotive depot information (time division of locomotive egress and ingress depot, locomotive record, locomotive statue, train operation, organization condition, etc.), engineering district information (routes, bridge, tunnel information and statue, maintenance record, etc.), communication and signal district information (communication and signal statue, maintenance record, etc.), basic public information (dictionary of freight rate odometer, station name, line name, section name, council name and boundary, train timetable, etc.). According to the associated level with space location, information mentioned above could be divided into spatial information (such as train real-time positioning tracking information, maintenance information of engineering district, etc.) and non-spatial information. Aiming at the management of two types of information mentioned above, our country has given a number of solutions during the railway information construction in recent years, such as freight transport management information system facing freight transport, whole railway passenger ticket sale and reservation management information system facing passenger transport, transport dispatch and command system, accounting management information system, statistics management information system, office information system and so on. From the vertical view, the above information systems basically form their own structure and can better meet the needs of information management. But from the lateral view, there are the following questions about the interaction between the various systems: data of various information systems are put into the database of different fields and different structures; and for the same one object, different departments have different naming customs; during the construction process of railway information system, lack of unified planning causes barriers for railway information sharing on a nation wide and road wide scale, and increases overlapping investment and maintenance cost. Spatial data is basically the lack of unified and efficient management as well as spatial information processing and analyzing technology.

In order to facilitate smooth research and construction of RITS, realize the effective management and sharing of spatial data and non-spatial data, and change the situation of "information lonely island" in the existing railway information system, the framework system of the RITS universal technology platform must be fully studied at the beginning of railway intelligent construction. The construction significance of RITS universal technology platform is:

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1. As the data provider, RITS universal technology platform will take into account automatic collection of basic information, especially the adoption of train positioning technology, precisely providing the real-time position of trains group, and then providing data support for the train tracing display, train over speed protection, emergency rescue etc.
2. As the data transmitter, RITS universal technology platform will provide advanced wire and wireless communication method to realize information transmission of train-to-train, train-to-ground, ground-to-train, ground-to-ground.
3. As the data manager, RITS universal technology platform will firstly integrate various types of existing information resources, break every lonely information island, and research information sharing mechanism of database of different constructions and different fields, and then establish a unified and normative railway information sharing platform, considering being shared information sharing between existing information systems, between existing information systems and new-established systems, between existing information systems and out-road information systems (road, shipping, aviation). Secondly, it will establish a unified railway basic spatial database, using spatial data to integrate railway information resource to strengthen resource sharing and interconnected communication of different business information systems [43].

**Components of RITS Universal Technology Platform**

As shown earlier, the core mission of universal technology platform is data collection, transmission and sharing. Accordingly, universal technology platform is composed of the following parts: the train positioning system used to take into account data collection of train position, the communication system used for data transmission, and railway information sharing platform and railway basic geography database used for data sharing [43]. The components of RITS universal technology platform is shown as (Fig. **1**).

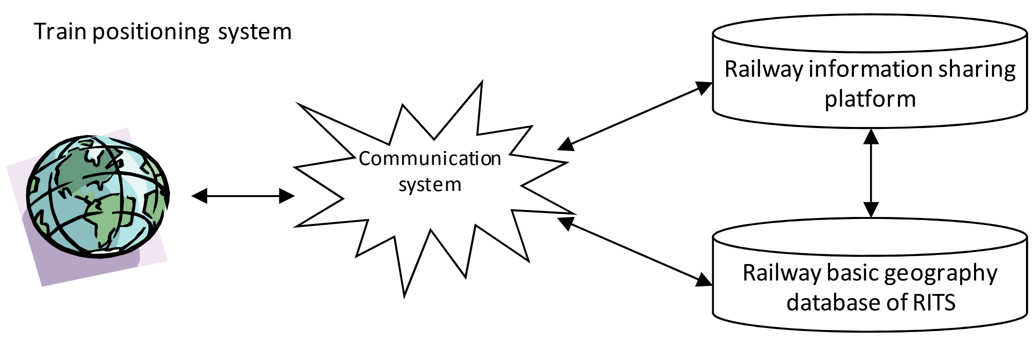


**Figure 1:** Components of the RITS universal technology platform

***Railway Positioning System***

The train four-dimensional position information is needed in every service of RITS, because the support from four-dimensional information is needed in railway traveling crane command, in train running management, maintenance and repair of railway basic devices and emergency rescue. Railway traveling crane command utilizes the train group positioning information to predict possible traveling break and makes prediction induction. Train running management system assesses dangers like over speeding trains or tracing interval according to positioning information, and provides hints and warnings for the drivers to eliminate accident danger through communication service. Consequently,, the train positioning system is one of the core components of the universal platform.

At present, many positioning system appeared worldwide. American navigation system provides positioning service for the whole world for free, and with the development of different GPS technology and codeless technology, higher precision may be obtained. In addition, with application of CDMA in onboard positioning technology, better application prospect can be worked out. The GIS technology facilitates the train motion trace in three-dimensional space, which cannot only give the precise position of trains, but also obtain the data like trains speed, orientation and acceleration, to provide dynamic supervision and navigation tools for transport running management and forms an important part for realizing RITS.

### *Communication System*

The system utilizes advanced wire and wireless communication technology, to assess information transmission between train and train, train and ground (station, dispatch center, sub-bureau, and road-bureau), ground and ground, and provide protection to have an account of train operation automatic control and intelligent traveling command.

### *Railway Information Sharing Platform*

It is used to integrate existing various types of information resources, break each lonely information island, research information sharing mechanism of different constructions and different fields, build a unified and normative railway information sharing platform and realize the information being shared between existing information systems, between existing information systems and new-established systems, between existing information systems and out-road information systems (road, shipping, aviation)

### *Railway Basic Geographic Database*

For RITS requirements, establishment of basic railway geographic database is to manage intelligent traffic information such as static route inducing information, traffic running statue information, traffic tools position information, traveling method and route information and decision making command.

## System Construction of RITS Universal Technology Platform

Based on the information source constitution of RITS universal technology platform and from the view of direction of the information flow, universal technology platform can be divided into 3 layers: data accessing layer, internal construction layer, and application service layer, as shown in (Fig. **2**). The mission of data accessing layer lies in extracting the sharing information resource, the real-time information coming from railway transport production locale, and relative information coming from other transportation modes and organs, and then conveying them to the internal construction layer of RITS universal technology platform. Internal construction layer utilizes data fusion technology and middleware technology and so on, to store and manage initial data after approaching normalization. This layer is composed of 3 platforms: ministerial universal platform, road-bureau universal platform and sub-bureau universal platform, respectively responsible for information sharing to ministry, road-bureau and sub-bureau. The application service users extract data from the platform, and use data mining and intelligent technology to provide information and decision making service for inside-road and outside-road users.

The main function of universal technology platform is to extract data sharing from each sub-system, and take data fusion approach for multi-sourcing and different data, to finish organizations with multi-dynamic data, static data, time data and spatial data, and guarantee the accuracy and consistency of the relationship between data as well as avoid data redundancy. Moreover it also provides service for decision making support and information inquiry for the public. This platform is constituted of the following 4 platforms: data sharing platform, application service platform, network communication platform and safety management platform.

The data sharing platform is used to integrate different structures, different fields and separate data, and take into consideration management, searching and analysis, and then automatically send the result to the respective staff according to needs, purview and matters.

The application service platform provides information service and decision making support based on universal technology platform, which has enough openness and flexibility. It does not only provide information inquiry, navigation, assistant decision making support for passengers and consignor, but also provide decision making support and information service such as operation planning, dispatch command, passenger and freight marketing and traveling safety for inside-road users.

Furthermore, it is used to provide information transmission and interchange between moving objects, moving objects and fixed objects and fixed objects and every sub-system. Network communication platform holds all the information in RITS, including written information, video frequency image information, sound information and railway geography information. And this platform has large data transmission quantity, high requirement in real-time ability, safety and reliability, and it is the physical basis to realize RITS universal technology platform.

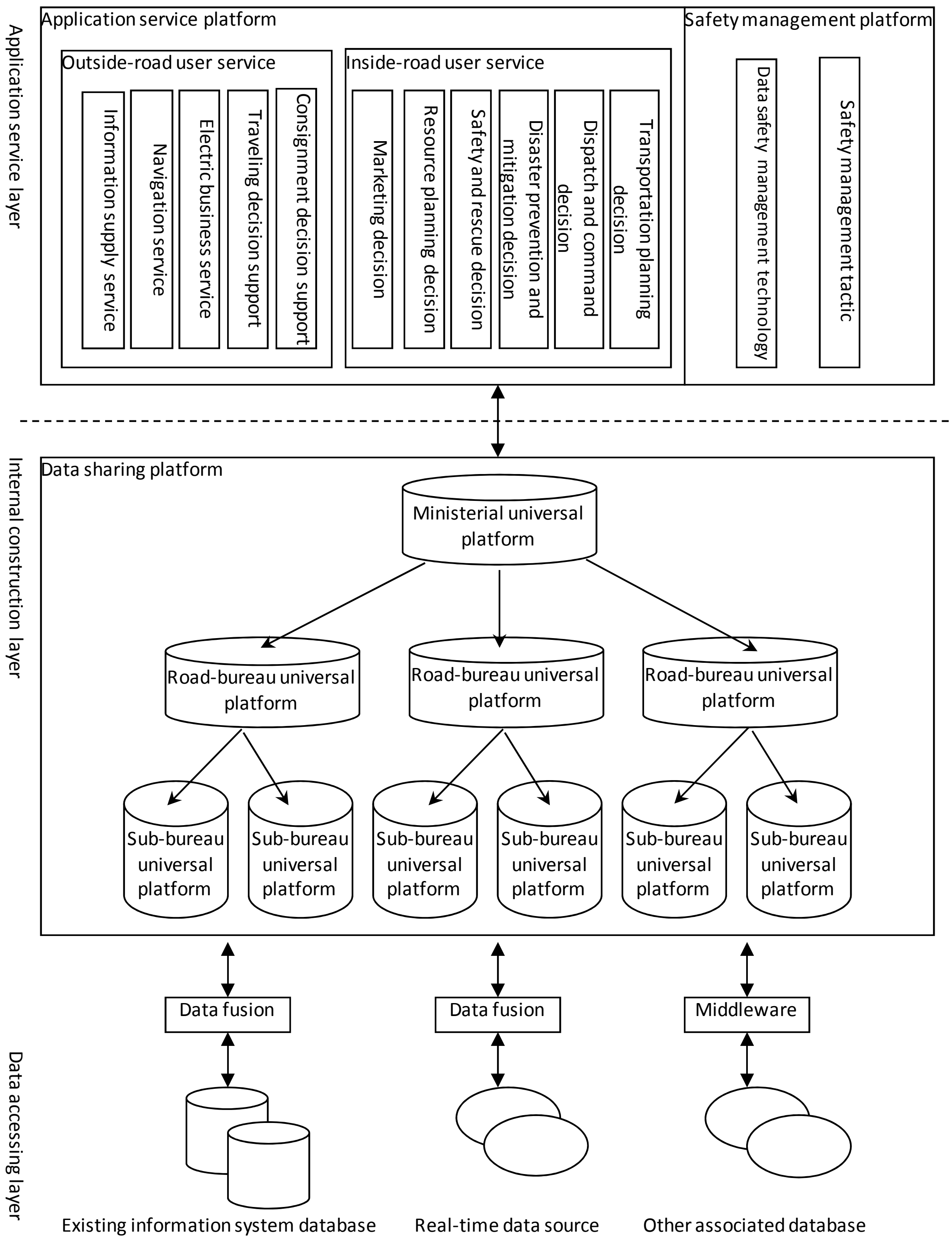


**Figure 2:** System construction of the RITS universal technology platform

The safety platform is the software and hardware system to ensure the system is running safety.

## KEY TECHNOLOGY INVOLVED IN RITS UNIVERSAL TECHNOLOGY PLATFORM

In order to successfully research RITS universal technology platform framework system, some key issues must be importantly solved, and the most important are train positioning technology, communication technology and data sharing technology (such as distributed mass spatial retrieve technology, intelligent space analysis and data mining technology and element data technology based on XML) [46].

## Train Positioning Technology

How to accurately inspect train position and control train operation is the core content of RITS, meanwhile, the data collection of the train position and speed is a very important link in universal technology platform. Consequently train positioning technology is undoubtedly a key technology in RITS. The introduction of this technology makes the intelligent and integrative traveling control and dispatch command possible, and more effectively improves traveling efficiency and safety. RITS requests the train positioning system to provide enough precision to distinguish train specific position like intersecting point, blocking section and signal device. Meanwhile, train positioning system must possess fine reliability, should work on all occasions and in trying circumstances conditions, and provide an alarm to users automatically and in a timely manner.

Currently often-used train positioning technology has the following several types:

### *Track Circuit Mode*

The track circuit mode is a commonly used mode for checking train position, its advantages are economic and convenient, and it can realize train positioning without large changes of existing equipments. Its positioning precision depends on the length of track circuit. In recent years, research on the track circuit positioning method has obtained new development: utilizing continuous moving frequency method, track circuit can also send position and speed-limit information.

### *Positioning Mode Based on Responder*

It is a widespread applied positioning method which can give the train positioning information dot-mode. The responder can work steadily under bad conditions, with low maintenance cost and long service life. Besides function of positioning, this method can also provide information like speed limitation and front route conditions. The responder-based positioning mode has very high positioning precision, and the positioning precision at the installing point is 1~2 meter, which depends on the effected scope of the search engine antenna. In the double-track railway, it can also effectively ascertain on which track the train is travelling. It is the characteristic not possessed by other positioning systems. At the same time, this type has high reliability, can work reliably in whatever whether and whatever position. Moreover, there are a series of advantages such as convenient maintenance and low operating cost and so on. But this mode can only furnish positioning information on the condition that the point installs the responder, and one-time investment to install responder will be large.

### *Inertia Navigation System*

The acceleration sensor (gyroscope) is used to measure the object acceleration in three-dimension space, and then calculate the mileage the object traveled through integral, without external signal and high positioning precision after calibration, about 20 meters. But with increasing traveling mileage, the accumulated error is very large, generally taking 0.25%~0.5% of traveling mileage. One possible method is to connect it with responder positioning method, to realize the train positioning.

### *Global Positioning System, GPS*

GPS is the positioning system belonging to the American military and is based on satellite transmission signal. The position checking theory is to install GPS receiver on trains, to receive signals from more than 4 satellites in space, and calculate absolute position and time of trains in three-dimensional space, according to the time delay and phase delay of these signals and in the signal transmission process. Global positioning system, which realizes the worldwide and all-day continuous real-time navigation and positioning, is conveniently operated and well anti-jammed, can finish the positioning and speed measuring works within 1 second or several seconds and continuously provide three-dimensional position, three-dimensional speed and time information of dynamic targets for users. Now, the main problem of GPS positioning lies in that GPS signals can be influenced by shrouded objects such as the line side buildings, high mountains and tunnels that the positioning ability will be lost when trains stop at stations or tunnels. In addition, usage of GPS positioning is easily affected by the American satellite policy.

### *Doppler Radar Mode*

Measuring train speed according to Doppler theory and installing line side Doppler radar, when the section is used by trains, radar antenna will transmit ultra high frequency electromagnetic wave to moving trains and then the electromagnetic wave reflected by train body is accepted by the same antenna. The difference frequency of the transmitted electromagnetic wave and received reflected electromagnetic wave is taken out by the mixer. According to Doppler theory this difference in frequency is the directed ratio with the train traveling speed and through simulated or digital calculated the train speed and position information can be obtained. The weakness of this inspecting method is that it can easily generate accumulated error.

### *Wireless Distance Measuring Positioning System*

It installs spread spectrum radio wave on trains and line side, to realize train positioning by measuring radio wave propagation time of the train and track side equipments. Positioning precision is related with spread frequency signal, the higher the signal frequency, the higher is the positioning precision.. The advantage of wireless distance measuring positioning system is that strong communication anti-jamming capacity, high positioning precision, easy installment of line side equipments, and only antenna and on-board computer need to be installed on train. The wireless spread frequency equipment can be installed on the train head and tail, to which tracing positioning is made simultaneously [43].

## Communication Technology

Communication, as the interface of information interchanging between RITS universal technology platform and each sub-system in RITS, has functions as shown in (Fig. **3**). At first, in the internal universal technology platform, communication network collects information from all classes of management departments, to form a comprehensive, integrated and multi-functional RITS service information system, to provide information services of different levers for each RITS sub-system. Secondly, between the universal technology platform and each sub-system, RITS universal technology platform can utilize communication network to provide railway transportation related information for each RITS sub-system, and collect dynamic traffic information (such as running position of train group, speed, acceleration and so on) provided by sub-systems, - to timely update information in basic database, and better satisfy different needs of the sub-systems. Consequently, communication network is the assurance that RITS universal technology platform becomes a dynamic and useful information system.

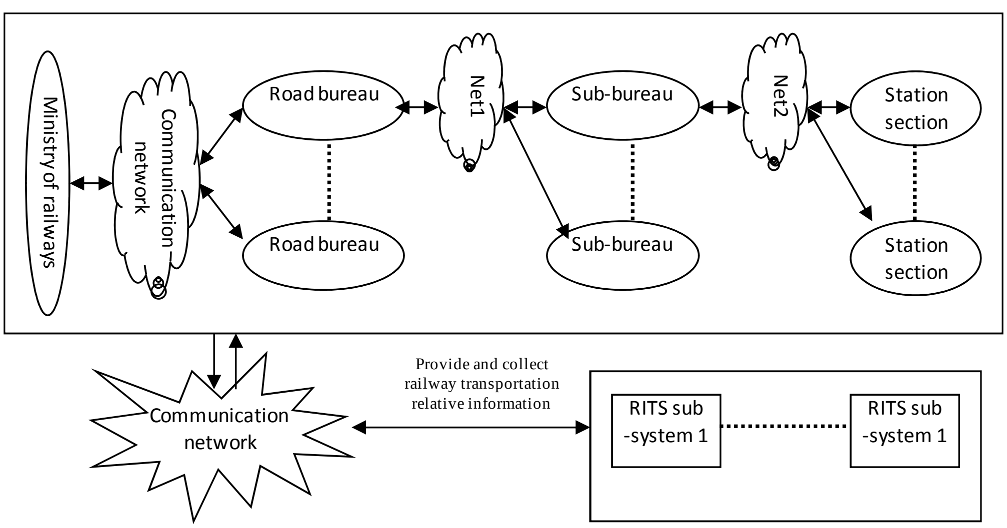


**Figure 3:** Information interchanging interface between RITS universal technology platform and each sub-system

### *Wireless Communication System*

In RITS, the station, dispatch department and operation management often need to interchange massive real-time information with traveling trains, such as train position, speed, acceleration, dispatch command, passenger stream information and emergency notice. Meanwhile, trains also need to interchange information with other trains. At this time, wireless communication technology must be adopted to realize information transmission from train to train, and train to ground, to finally realize intellectualization and integration of dispatch center, road and trains. Current wireless communication systems mainly contain the following types:

### *Global Mobile Communication System, GSM*

GSM is made up of network interchanging sub-system, base station sub-system and mobile table, and divides one service section into several wireless areas (cellular), and utilizes seamless covering mode to make up the network. Its frequency range is 905 ~ 915 MHz (upstream) and 950 ~ 960 MHz (downstream), adopting frequency division duplex (FDD) mode, with carrier spacing of 200 KHz, belonging to time division multi-address (TDMA) mode. As digital mobile communication system, GSM mainly relies on sound business, and can also transmit data business of 9.6kbit/s, and when applied in RITS, running trains can use GSM telephone business to keep in touch with the dispatch center, station and other trains. The GSM adopts circuit interchanging mode, consequently when transmit longer data files, it often needs to resend signals because of the signal decreasing and calling interruption. Moreover, every connection needs to occupy a signal tunnel independently, leading to low channel utilization.

### *Cellular Digital Packet Data System (CDPD)*

CDPD is made up of mobile data mediation system, mobile data base station system, mobile terminal system, network management system, mediation system, fix terminal and data transmission chain. Its frequency range is 824 ~ 849 MHz (upstream) and 869 ~ 894 MHz (downstream), with channel interval of 30 KHz. The signal tunnel occupancy mode is digital perception multiple access mode. And maximum speed rate of spatial signal tunnel is 19.2kbit/s. It provides support of Transmission Control Protocol/Internet Protocol (TCP/IP) and Connectionless Network Protocol (CLNP). If CDPD is applied in RITS, it can transmit medium and low speed data information whose speed is maintained to be lower than 19.2 kbit/s. Through CDPD, RITS can make traveling command, train supervision and emergency condition notice and so on. As CDPD system is based on packet switching, compared with GSM based on circuit interchange, the CDPD has advantages as high efficiency, economy, high reliability and low network operation cost, hence it is suitable for data communication of RITS. But, the signal tunnel bandwidth of CDPD system is too narrow to be not good at transmitting high-speed real-time data signal.

### *The Third Generation Mobile Communication System IMT-2000*

The public mobile communication system is rapidly developing towards the third generation IMT-2000, which is mainly composed of four functional sub-systems: core network, wireless accessing network, mobile platform and user identify modular. Our country has submitted the third generation mobile communication approach TD-SCDMA standard, which is suitable for our own national condition. This standard takes CDMA as the core technology. It utilizes intelligent antenna technology to realize SDMA and reduce background noise of CDMA system, utilizes TDD mode in order to form the intelligent antenna wave beam. In addition, the TD-SCDMA standard also organically fuses several advanced technologies such as Turbo coding, Rake receiving and software radio wave. The third generation mobile communication system can provide true-meaning worldwide covering, wider bandwidth and more flexible service business, and can make the terminal roam seamlessly in different networks. If the third generation mobile communication system is used in RITS, almost all communication demands of RITS can be met, because the third generation mobile communication system cannot only transmit sound information, but also the data information, with the data transmitting speed rate flexibly changing from several kbit/s to 2Mbit/s. So this system can transmit real-time operation information, real-time dispatch information, and locale video image information in emergent condition and so on for the RITS.

### *Wired Communication System*

Compared with the wireless communication technology, wired communication, is more mature and reliable in technology, with higher transmission speed rate and relative inexpensive communication cost, and is suitable for massive data transmission. In RITS, the wired communication is mainly used in the railway basic geography database and the distributed network among basic geography information processor, manager and users. Because the distributed area of railway road network is very large, wired communication technology suitable for RITS information transportation mainly contains the several following types:

- Ethernet

This protocol is the concentric cable protocol based on IEEE802.3 standard; Ethernet is the technology facing the local area network, providing transmission speed rate of 10Mb/s.

- Fiber distributed data interface (FDDI)

FDDI mainly deposits and draws protocol by supporting fiber mediation with transmission speed rate of 100Mbps, with annular logical structure, and also physically supports the star structure. FDDI mainly supports local area network or city network.

- Asynchronous transfer mode (ATM)

ATM, as an interchange transmission technology, can deal with all types of business re-used in the same network. In the ATM network, the bandwidth can be real-timely redistributed according to different businesses. ATM possesses huge flexibility, high resource usage rate and easily common used network, can reduce cost in operation, maintenance and management, as well as the transmission cost through statistic utilization, and can provide dynamic bandwidth distribution.

- Integrated services digital network (ISDN)

ISDN establishes the connection through interchange connection mode, with bit rate of 64kbps. The data transmitted in ISDN network is transparent for the net. The higher speed rate transmission can be realized through dividing data into several 64kbps bit rate signal tunnels.

- CHINA digital data network (CHINADDN)

DDN network is all transparent net, using synchronous time division multiplexing mode, and provides permanent or semi-permanent digital special line connection for users, with the transmission speed rate of 2.4kbit/s-2Mbit/s. The transmission delay of the network terminal to terminal is very low.

- Public Packet Switched Network (CHINAPAC)

PAC which is based on CCITT X.25, can satisfy communication of different speed rates and different models, between terminal and terminal, terminal and computer, computer and computer and between local area networks, to realize data resource sharing.

## Data Sharing and Comprehensive Technology

### *Distributed Massive Spatial Data Inspection Technology*

The railway spatial data is a TB-class massive database with distributed characteristics. The conventional geography information system platform software often adopts file deposit and draw mode for the spatial data. Although it supports the spatial database deposit and draw mode, but makes low efficiency of the massive spatial data inspection. Index methods for attribute of conventional DBMS contain HASH, B-tree and B+-tree etc. Due to particularity and time dependence of spatial data, the spatial index not only involves static characteristics of spatial data, but also refers to the dynamic changing characteristics of spatial data. Now, most indexes to time and space are mainly based on conventional B+-tree and R-tree to make extendion and improvement. The spatial index arithmetic mainly contains index, four-branch tree, eight-branch tree, LSD-tree, Hilbert R tree and Cell tree etc. Then it can solve the problem of network massive spatial data inspection efficiency through using multilevel storage index arithmetic and distributed parallel calculation technology, and establish the software platform supporting the distributed spatial database deposit and draw.

### *Intelligent Space Analysis and Data Mining Technology*

The spatial data analysis and mining extracts the implied knowledge, spatial relationship or other modes without precise storage in spatial database. Because of the huge data quality of spatial data and complexity of spatial data type, spatial relationship and the spatial autocorrelation, extracting knowledge from spatial database will be much harder than extracting knowledge from conventional database. The main challenge of spatial data mining is the efficiency of the spatial data mining algorithmic. It can use advanced intelligent technology (fuzzy logic, neural network and evolutionary algorithm etc.) to strengthen efficiency and precision of conventional space analysis and data mining algorithm, including intelligent spatial data clustering, generalization and associative rule mining, etc., which is also research hotspot and direction of the existing spatial data analysis and mining algorithm.

### *Metadata Technology*

The metadata technology is an effective technology to realize and assort information resource sharing among different data departments. The spatial metadata is the descriptive information of the geography data and information resource. Though the description and introduction of the content, quality, condition and other features, people can effectively position, estimate, compare, obtain and utilize the geography related data. Presently, internationally the Federal Geographic Data Committee (FGDC), International Standardized Organization Geography Information/Global Information Technology Committee (ISO/TC211) and Opened GIS Coalition (OGC) respectively from different sides provide standards for spatial metadata content. Our own country has also brought several metadata standards in recent years, but these standards cannot absolutely be suitable for the railway application and need to make specialized railway geography information sharing metadata standard. Meanwhile, because these standards lack unified description, storage and transmission format in technology, the application has been greatly restricted. It must describe and transmit spatial metadata unified through adopting the newest Internet network information format and interchanging standard XML, and then makes the spatial data sharing and release based on metadata possible, and at the same time, together with the intelligent optimized technology to realize intelligent spatial data navigation function.

### *Middleware Technology*

RITS gathers databases and applications of different types, different operation platforms and different protocols. How to realize platform-crossed and transparent database sharing and communication in universal technology platform is the key to establish RITS, and the key to solve the mentioned-above problems is the adoption of middleware technology.

The middleware generally means software that can shield differences between operation systems and network protocols, and provide communication service between systems of different structures.

The middleware lies among hardware, operation system platform and applications, can satisfy massive applicant needs, operates in multiple types of hardware and operation system platform, supports distribution calculation, provides the transparent application and service alternation of network, hardware and operation system platform, and supports normal interface and protocol. The middleware is usually divided into 5 types:

- Remote Procedure Call, RPC: Make user terminal application call a process or service on remote platform
- Message Oriented Middleware, MOM: Use high-effective and reliable information sending mechanism to realize communication among different structure platforms
- Object Request Broker, ORB: Provide a communication mechanism, transparently send object request in the distributed calculation circumstance of different structures. These objects may stand on locale or remote machine, and the Client/Server role may be interchanged.
- Distributed Transaction Processing, DTP: Provide important distributed application service, effectively balance the network loading and host computer mission through affairs dealing supervision.
- Database Access Middleware, DA: Realize and deal with visits from different manufacturer databases. It provides a series of application interfaces API, through the middle layer but without consideration of operation system and network to visit databases.

## Railway Geographic Information System

The spatial distribution characteristic is the typical point of railway system data. According to the analysis and research to MIS system data structure that the present railway department usually used, about more than 90% data records contain fields that possess spatial position attribute such as “starting point mileage”, “ending point mileage”, “center point mileage” and “facility residence”. The information that people cannot convey intuitively in thousands of words will be vividly shown through maps, and this high-effective, intuitive and visible characteristic is another feature of railway system data. Information received by people from an image may not be conveyed in a thousand words. As same as all the spatial data, the railway spatial data is symbol record related to spatial position, special feature and time information. The spatial position, special feature and time are the three basic elements. But in contrast to common spatial data, the railway spatial data has following features: large data quality, railway distributed around the whole country; huge net work, with large data quality. The spatial objects are mainly line objects or point objects. Because the railway transportation production is generated on the railway road network line, the related operation and basic facility management are all distributed along the line side. The spatial distribution feature usually possessed by railway information and high efficiency and visibility of geography images conveying information ensures the railway information system has the ability of storing and dealing with spatial geography data.

According to purpose and source, railway spatial data can be divided into two types:

1. The railway basic spatial data is mainly the common used spatial information which is needed by the various railway business information systems of various-class scales and refers to country and railway road network; it contains the national basic geography element and the railway road network basic facility element data. Data of this part mainly provides macro decision-making information and basic background material, and is served as the basic carrier of the spatial positioning control, adjustment, display or drawing of the various special objects information. The confirmation of railway basic spatial data has great relationship with the demonstration ability of railway road network infrastructure under different scales.
2. The railway professional spatial data is mainly the special data of spatial position attribute possessed by the railway various professional systems contained in the large and middle sized scale or sketch map. The railway business, which refers to several professions containing vehicles, aircraft, engineering, electricity, transport, needs professional electronic map of relevant specialty and with detailed content. The data formula is more diverse. It not only refers to vector, grid and three-dimensional data in various type scales, and some data are stored as sketch map.
3. The multimedia data. The multimedia data contains the railway line side video recording, audio commentary and images, is used to provide information to the railway line side mileage, to learn surface feature and topography condition along the railway.

The main functions of the railway geography information system (RGIS) are: 1) having map navigation, 2) map edition and out put, 3) space analysis, 4) grip map processing, 5) bulk data input, 6) file exchange and e-mail exchange, 7) comprehensive information inquiry, 8) remote data calling, 9) decision making system, 10) application system interconnection.

After many years of information building, railway system has established several MIS systems, such as PMIS, TMIS (Integrated Transportation Management System), DMIS (Railway Dispatch Monitoring System), CMIS, PWMIS etc. But because of relative independence of the past various business departments and low development level of the computer technology, the existing MIS system still has weaknesses, shown as the following: 1) the existing MIS system mainly conveys information through text form, lack of visibility and ambience; 2) when the business departments built the MIS system, they are all just designed according to their own business, while the leading decision needs to grasp the overall situation, the existing MIS system needs to be effectively integrated; 3 the existing MIS system is lack of strong decision making supporting function.

With continuous deepening of the railway institution reform, the work of various departments also constantly changes.

### *The Combination of RGIS and the Transportation Information System*

At present, development and management of the TMIS, PMIS and DMIS all aim at the management to transportation objects, where the TMIS mainly aims at the freight transportation, and the PMIS aims at passenger transportation, the RGIS combines them, and through the realization of the information sharing of TMIS, PMIS and DMIS, using automatic identification technology, global positioning system (GPS) and wireless communication network technology, to realize the real-time supervision of the transportation object. Display of information of the transportation object position, distribution and static on the electronic map, realizes the combination of geography information and transportation objects.

### *The Combination Between RGIS and Transportation Equipments and Facilities*

The transportation equipments and facilities information is the basic information resource of the railway transportation, and is the important basis in essential decision making such as the technology reforming, traveling command, protecting traveling safety and accident emergency rescue. Now, all the departments have their own equipments and facilities management systems, and sufficient basic database, but equipments and facilities management systems of each department are basically at a discrete condition and cannot formulate comprehensive data. The data actually used in the locales are usually the comprehensive data of each department, for example, the ongoing line equipment reform to achieve the speed-increasing requirement, which refers to equipments of departments such as the engineering district, communication and signal district and station etc. Consequently, RGIS must translate the basic data of each specialty into data in spatial database, and combine geography information and transportation equipments and facilities organically, to actually realize the resource sharing. Through combination of the geography information and transportation objects and transportation equipments and facilities information, sufficient use of the GIS technology and computer network technology could realize the target that "thousands miles railway in the full view of eyes, the diagramed trains hold all views in sight". For example, power distribution networks of electrified railway-- geography information management system accessed by the net, management information system for productive electricity, railway water supply geography information system and railway gas supply geography information system etc. RGIS system provides scientific protection for increasing railway traveling safety, and provides the most effective scientific tools for the sufficient use of the railway resource, increasing the railway management level and management efficiency, and increasing railway traveling economic benefits.

### *The Combination Between RGIS and other Information Systems*

Besides the transportation objects and transportation equipments information, other information of railway is also very important, such as financial situation, personnel distribution, infrastructure, key protects, environmental protection facilities, sanitary condition, education level and project progress etc. The above information is indispensable for leading decision making. RGIS can use railway office information system (OMIS) to extract this type of information as the data in spatial database, to learn the distributed condition and static results of information more conveniently, more intuitively and more systematically [43].

## COMPREHENSIVE SAFETY MONITORING SYSTEM OF THE CHINESE QINGHAI-TIBET RAILWAY

### System Construction Background

With leapfrog development of our national railway, the railway transportation organization model has gradually shifted and developed in the direction of the command focusing, function integration, information sharing and high-degree autoimmunization. The urgent need of these technologies development and the railway transportation safety raises new challenges to railway traveling safety protection system. In order to be suitable for new needs of leapfrog development in our country railway, establishment of railway comprehensive operation safety supervision system based on high degree information sharing and traveling safety management system adapting to new situation has become the focus and the only way of establishment of the present railway traveling safety protection system. Presently, foreign developed countries (Japan, Germany, France, etc.) have equipped complete railway comprehensive operation safety supervision system and safety supervision dispatch table that are information integrated, function comprehensive and intelligent in high speed line, to take all-round supervision of the safety elements related with the whole-line "people, locomotive and rings", and effectively protect the railway traveling safety.

The special operation environment and the high centralized transportation organization mode of Qinghai-Tibet railway also provide urgent needs for the railway comprehensive operation safety supervision system. In the Qinghai-Tibet railway, the whole length of the Golmud-Lhasa section is 1142 kilometers, which is the world's highest plateau railway (the elevation of the highest point is 5072 meters high, and the length of the section above 4000 meters is 960 kilometers long) going through through the longest permafrost line (546.4 kilometers) and has the hardest nature condition. Three global challenges of permafrost, cold hypoxia and ecological fragility, take great difficulties to the Qinghai-Tibet railway establishment and operation. Closely around the target of the establishment of the world-class plateau railway, railway ministry implements the basic demand of "the train traveling time is the shortest, the equipments have high reliability and demand less maintenance, the line side basically realize unmanned management", and vigorously promotes the Qinghai-Tibet railway spirit of "challenge the limit, bravely create the first-class"; On July 1, 2006, this palatial project was initiated to be put into operation one year in advance.

The harsh natural environment of the Qinghai-Tibet Railway brings world-class challenge to the Qinghai-Tibet Railway construction, operation precision, high efficiency and safety. In order to realize world-class plateau railway transportation management level, it must adopt advanced and suitable information technology method to realize the whole-process supervision, pre-warning and unified coordinate command to Qinghai-Tibet Railway operation process, safety production and emergency accident dealing, to assure traveling safety, increase transportation efficiency and realize modern plateau railway operation management.

The Comprehensive Monitoring System of Railway Operation and Safety for Tibetian Line (CMSROS-QZ), as a comprehensive integrated system to protect the Qinghai-Tibet Railway safety operation, completely integrates the dynamic safety information of trains, locomotives, electric power, signal, line infrastructure and circumstances etc., and daily static information of passenger and freight transportation is the hub and "brain" of the Qinghai-Tibet Railway traveling safety protection system. It provides comprehensive, timely, accurate, precise and complete transportation safety production information and decision making support information for the Qinghai-Tibet Railway transportation command and safety management staff, and facilitates comprehensive supervision, pre-warning and safety management of the Qinghai-Tibet Railway traveling safety whole process [48].

**System Demand Analyses**

As a whole, the functioning needs of the Qinghai-Tibet railway operation and safety comprehensive supervision center system are mainly divided into four parts: hardware integration of operation and safety comprehensive supervision center; system maintenance and management; comprehensive supervision to Qinghai-Tibet railway operation process and operation safety; support to emergency rescue work in Qinghai-Tibet railway operation process. These demands respectively correspond to different professional departments and users.

The hardware integration of the operation and safety comprehensive supervision center aims to establish operation and safety comprehensive supervision center in Xi'ning, and to provide display screen, control platform and conference facilities for the daily management, management and software system. Hardware integration of operation and safety comprehensive supervision center provides basic work environment for Qinghai-Tibet railway operation and safety comprehensive supervision center system.

Main users of the system maintenance and management are the maintenance staff in Qinghai-Tibet railway operation and safety comprehensive supervision center. The system maintenance and management takes charge of management and allocation of the bases, the management and maintenance of the users and purview, the maintenance of the basic geography information etc.

Main users of comprehensive supervision of the Qinghai-Tibet railway operation process and operation safety are the daily duty staff of the operation and safety comprehensive supervision center, the Qinghai-Tibet railway safety supervision room duty staff and the Qinghai-Tibet railway dispatch staff. The system needs to take supervision of Qinghai-Tibet railway operation process and operation safety. The content contains: the train operation information, the train 5T safety information, the train operation wind power pre-warning information, railway line-side environmental information (including temperature, humidity, wind power, live video, etc.), the railway electric power remote dynamic supervision, the line signal condition, the freight operation process data, and the passenger operation process data.

Main users of the emergency rescue work supporting system during the Qinghai-Tibet railway operation process include Qinghai-Tibet railway safety supervision room staff, the emergency rescue command staff and the senior leadership of Qinghai-Tibet Railway Corporation when major accidents occur. The system has to support the emergency handling process, including the viewing of locale environment when emergency happens, the comprehensive inquiry of the geological and geographical condition; the equipment condition at the happening locale; the emergency happening; management, management after accident; the responsibility and damage confirmation; and emergency prediction [48].

**System Logical Structure**

The total logical structure of operation and safety comprehensive supervision center system is shown in (Fig. **4**), It is mainly divided into two parts; the server-side and client-side. The integrated application client-side is connected with the locale server-side to get related service. Through the interconnection with various operation management information systems such as the engineering district system, communication and signal district system and locomotive district, the GIS application server can obtain the real-time effective railway GIS professional spatial data. Through connection with every supervision system and the professional production system, the integrated application data input server can obtain real-time data needed by the comprehensive application and can get a display of the basic geography information system platform. The comprehensive application client-side centralizes the controlling content and the showing mode.

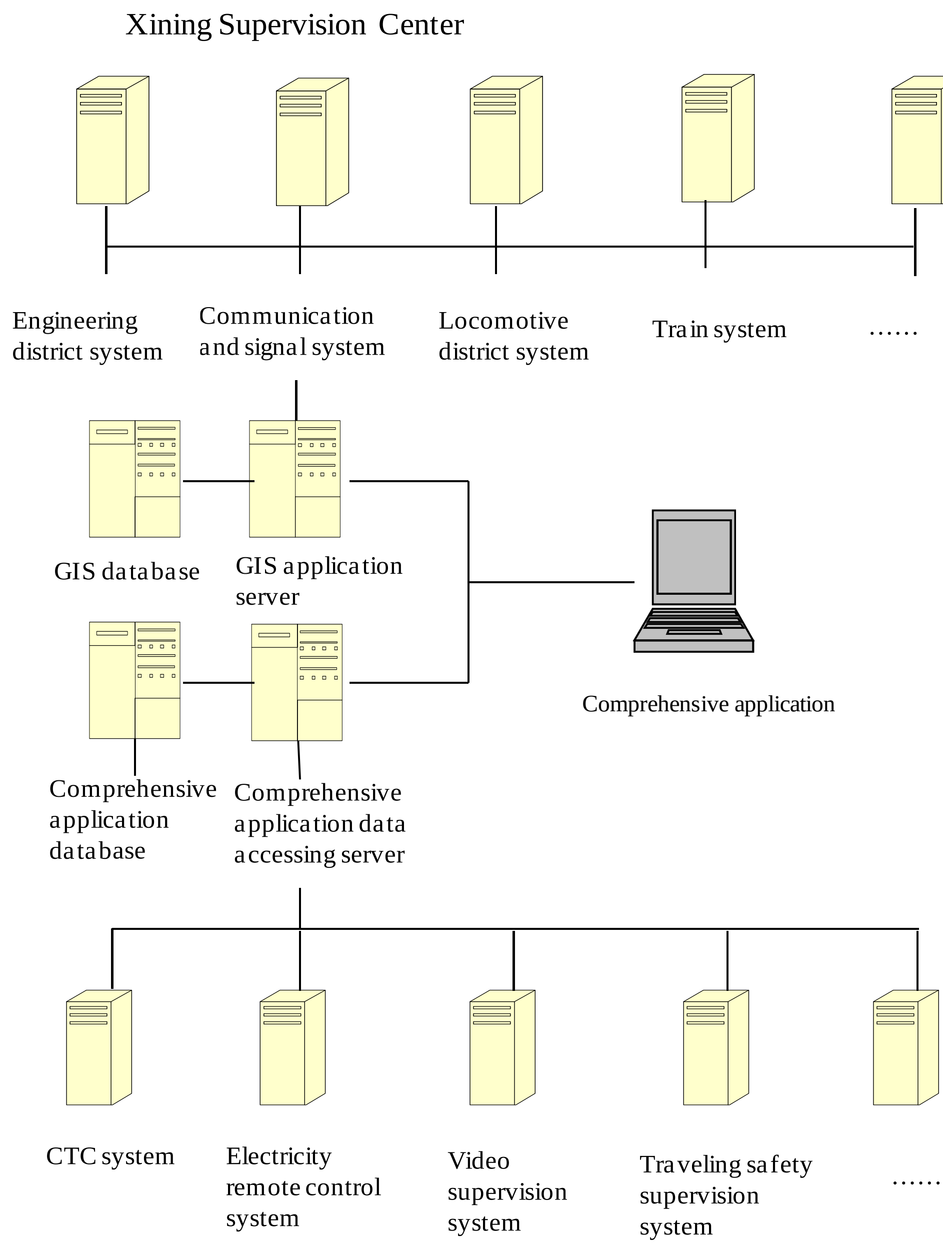


**Figure 4:** Logical structure of the comprehensive operation safety supervision center

### System Physical Structure

From demands and actual conditions of Qinghai-Tibet railway comprehensive operation safety supervision center, structural design of Qinghai-Tibet railway comprehensive operation safety supervision center system network and physical equipment is shown as the (Fig. **5**).

The independent servers, storage and LAN systems established in Xi'ning are used to store all the transmitted professional information and the local geography information, and simultaneously can operate the locale video equipment etc.

The development and setting of information sharing platform in Xi'ning comprehensive operation safety supervision center, are used at the real time information interchange of comprehensive supervision system and each professional information system. The information sharing platform, in hardware, has to satisfy the various types of professional information system physical input and the demands of the information exchange speed and efficiency, and in software, it needs to be compatible with various types of modes for the professional information system sending information.

The video information and geographic information is operated and displayed on the same display screen. Communication can be under taken between geographic information and video information dispatch control system, to facilitate synchronized display of the geographic information and video information, arriving at a more intuitive and more visual effect.

The comprehensive operation safety supervision center in Xi'ning consists of supervision terminal and servers; servers mainly include the GIS data server of Qinghai-Tibet line geographic information system, comprehensive application server that supports the comprehensive operation safety supervision center system function and the data accessing server that interchanges with business information system. The supervision terminal realizes functions like the comprehensive supervision, the locale video equipment and displaying screen control, and can switch various types of information display to big screen. It can also provide the telephone communication function between locale and related business head department.

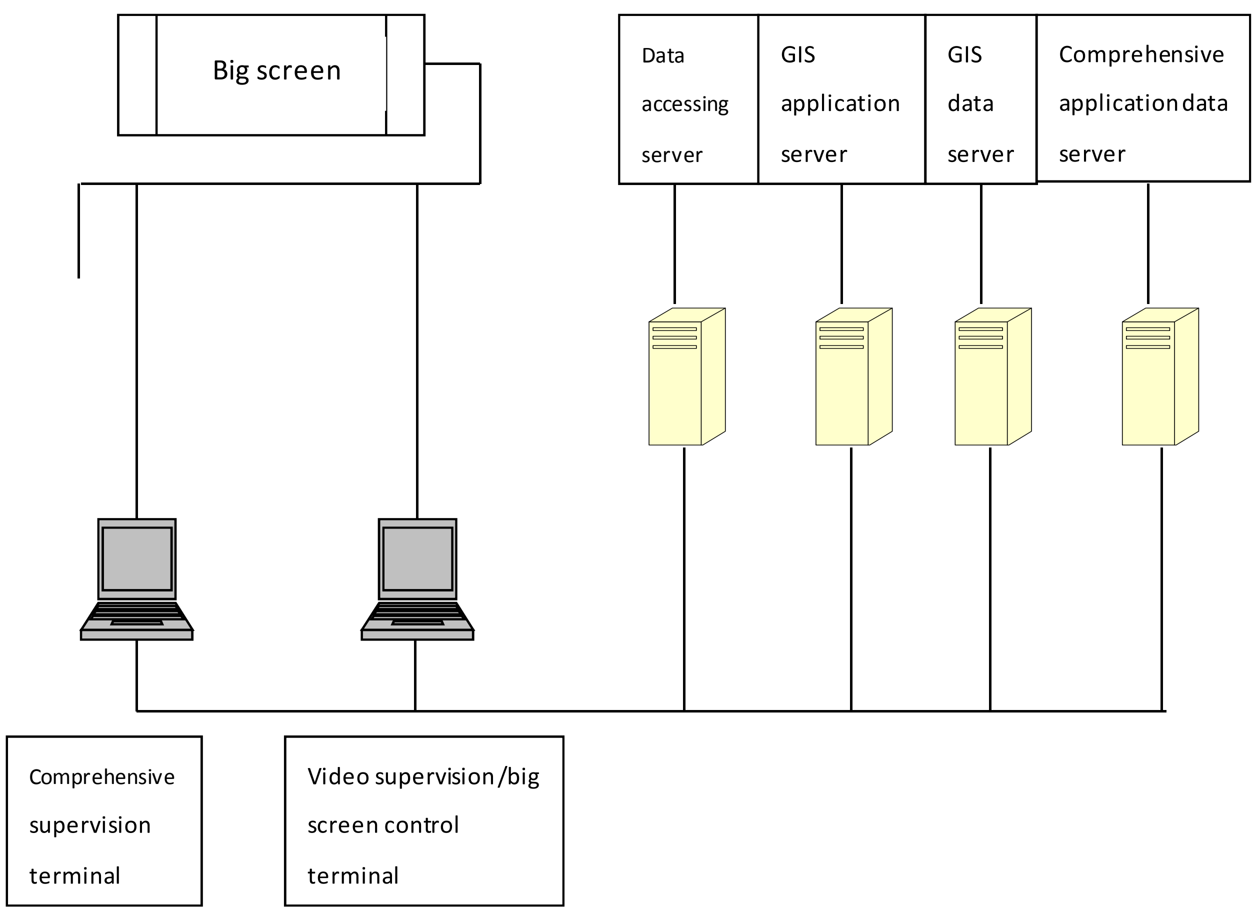


**Figure 5:** Physical structure image of the Xi'ning comprehensive operation safety supervision center

# CHAPTER 6

# Chinese RITS in Development

**Abstract:** This chapter describes RITS structure model in three levels that acquirement and recognition needed by users, the realization of demand, all types of resources support for demand realization, and gives the location of existing information systems in the future RITS. And many Chinese RITS system in construction are introduced in this chapter either, such as: Qinhai-Tibet Line Emergency Rescue institutions and Emergency Rescue Command Information System; Geographic Information System of Qinhai-Tibet Line; and Comprehensive Monitoring System of Railway Operational Safety for Qinhai-Tibet Line etc. Finally RITS development strategy and vision analysis are introduced.

## DEVELOPMENT FRAMEWORK FOR RITS

### RITS Structural Model

As mentioned above, railway information construction is the foundation of RITS development, while RITS is the senior development stage of railway information; it is basically the guidance of railway information from a higher level. RITS should be composed of two parts: one part is to execute integration and optimization on existing railway information system, under the guidance of the new framework system, and the other part is a fire-new component element that is not involved in railway information and have features of Intelligent Transport System. Railway transport system identifies user needs. and develops appropriate plans to make full use and deployment of related resources to meet users needs Its logical structure is correspondingly divided into three levels that are requirements acquisition and recognition layer, and requirements implementation layer, requirements implementation supporting layer. This paper describes RITS structure model in three levels, such as acquirement and recognition needed by users, the realization of demand, all types of resources support demand realization as shown in (Fig. **1**). The non-shadow box (such as passenger transport management, etc.) is the field with certain research and development basis after railway information construction and the box with shadow (such as mobile resource management system, passenger e-commerce, etc.) represents new areas having no corresponding research base with an urgent need for study.

Requirements acquisition and recognition layer, through providing users with information navigation, e-commerce, integrated transport services etc, continually acquire and identify requirements of railway transport from passengers, shippers, manufacturers, circulation (transportation), retailers, financial institutions, road transport department, water management department, aviation management etc., and simultaneously transmit downward the demand to the requirements implementation layer.

In accordance with ever-changing user requirements provided by the requirements acquisition and recognition layer, requirements implementation layer dynamically establishes intelligent traffic control system and integrated dispatching system corresponding to user needs. Intelligent traffic control system is a fire-new model system, formulated after effective integration and optimization of ATC, ATP and ATS, which could automatically operate with less human intervention or even no intervention. Integrated dispatching system comprehensively optimizes and upgrades the existing traffic scheduling, locomotives scheduling, and power supply systems, which are carried out by the separation, and the ultimately formulated scheduling system will achieve optimization and integrating of resources utilization.

Based on intelligent traffic control systems and dispatching systems, we establish integrated operation management system and emergency rescue and safety system. Integrated operation management system is optimization and integration of existing passenger and freight transport, package, and container, and adds the new content passenger and cargo marketing to realize integration and efficiency of rail operation. Based on existing driving safety monitoring system and emergency rescue system, emergency rescue and safety system add a comprehensive disaster prevention system, and executes comprehensive integration from the angel of system, to fully ensure the safety of railway traffic.

On the basis of integrated operation management system and emergency rescue and safety system, we established the entire road transport resource management system, which consists of mobile resource management system, fixed resource management system, financial resources management system, maintenance decision support system, to effectuate unified

**Wang Zhuo and Jia Li-min**

management on the status of the various railway resources, and according to intelligent decision-making techniques to provide decision-making support and assessment suggestions for maintenance, purchase, use, security and so on of all road various facilities. At the same time, requirements implementation layer transmits foundational resource requirements needed for realizing users demand for requirements implementation supporting layer [43].

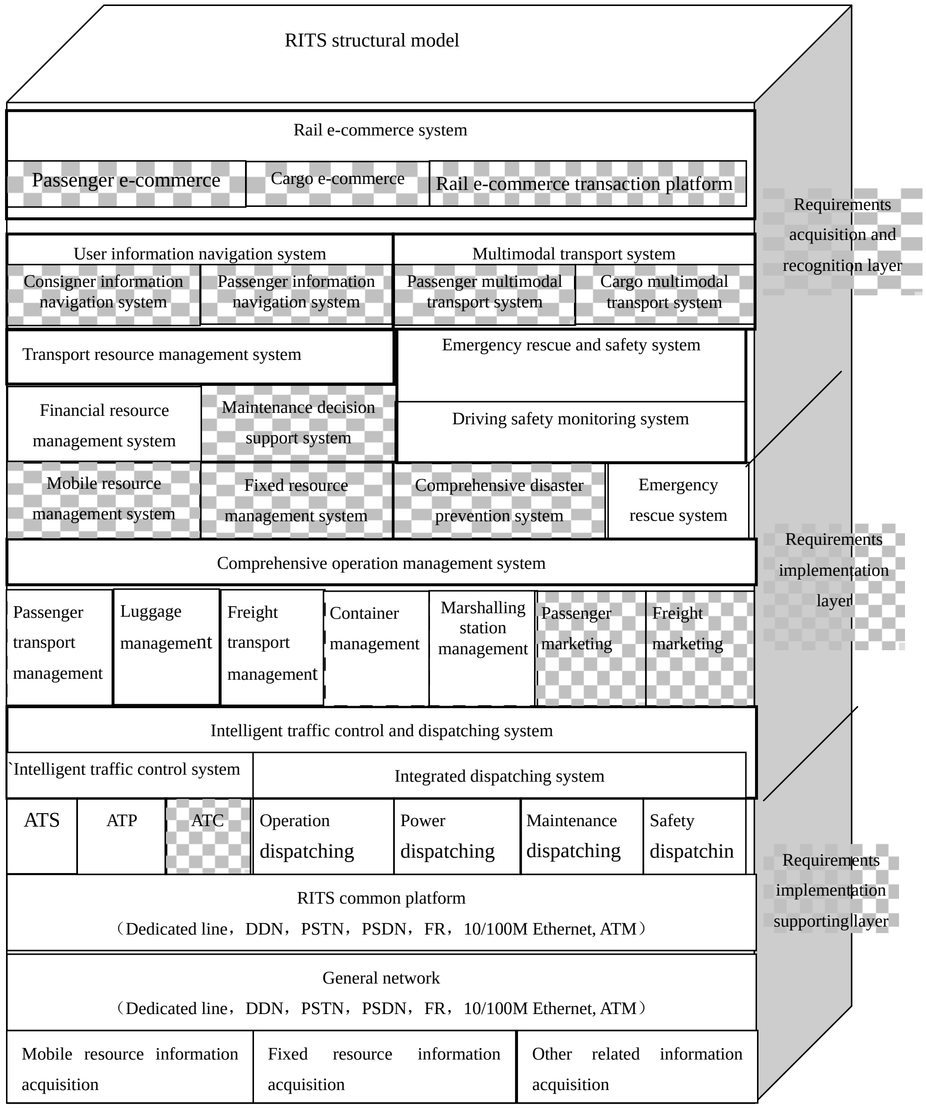


**Figure 1:** RITS structure model

According to resource requirements proposed by requirements implementation layer, requirements implementation supporting layer adopts information from mobile resource, fixed resource and other aspects, to achieve resources sharing by RITS rail common platform.

In addition to the vertical relations at various levels mentioned above, between various levels there is still great dynamic information exchange and feedback in RITS, and (Fig. **2**) describes the interaction relations between three levels which consist RITS. On the whole, the total input of system is users needs for RITS. The total output is the realized demand by RITS. According to the continuous dynamic optimization of requirements acquisition and recognition layer, requirements implementation layer, requirements implementation supporting layer mentioned above, based on RITS continuous optimization of their resources allocation and operational management, it makes the realized user needs closely approach to the users requirements, providing a fundamental guarantee for the achievement of the "high-efficiency, high security, high-quality service" rail transport. Interactive relationship between the various levels is as follows:

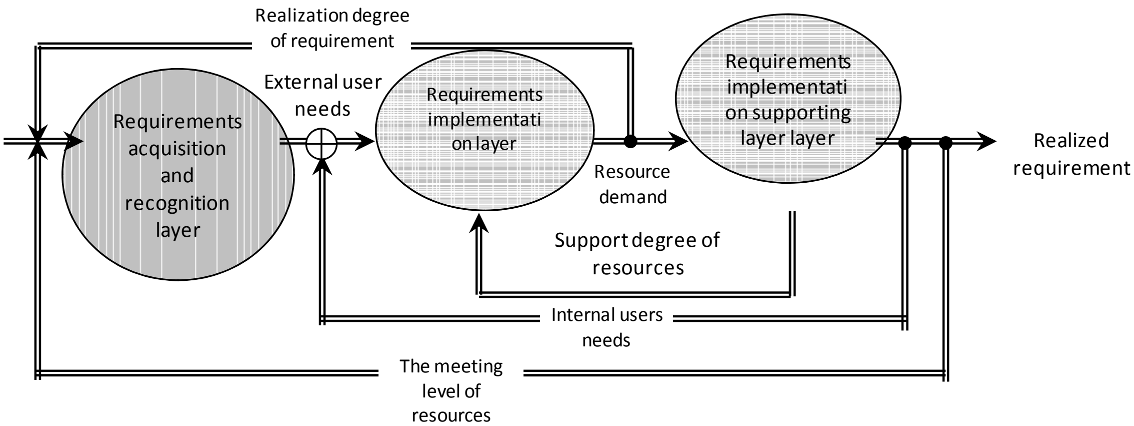


**Figure 2:** Interactive relationship between levels of RITS structural model

Requirements acquisition and recognition layer corresponds to railway external service. In accordance with the users demand, its main function lies in comprehensively considering user demand degree achieved by current railway operation management and level that the rail transport resources meet user demands. From the user's original demands, identifying the demand should be realized under constraints of current railway operation management and allocation of transport resources, and should be confirmed as external user demands.

Requirements implementation layer corresponds to the railway organization and management functions Its main task is to achieve users' demands under constraints of resources support degree. The demand here includes not only the user's needs away from the road, but also the users' needs on the road, such as the preparation of train operation plans and adjustment programs based on actual demand of passenger traveling plans, driving safety monitoring according to railway safety departments, integrated dispatching in accordance with requirements of the railway scheduling departments etc.

Requirements implementation support layer is also known as resources layer, it corresponds to railway fixed resources, mobile resources, information resources, and its main task is to provide the appropriate resources support according to resource requirements needed by requirements implementation layer, such as providing locomotives, vehicles and other resources support, in accordance with the demand of trains running plans in the requirements implementation layer.

## RITS Core Technology

Since the end of "Ninth Five-Year Plan" period, with the boom of world ITS research and application, Chinese railways also strongly carried out RITS foundation and application research. In fact, after nearly 20 years' development, Chinese RITS infrastructure and related technique systems have been well established. Currently, railway information construction being vigorously carried out will provide unprecedented opportunity and huge driving force for the ultimate Chinese RITS system.

Most critical research and development work of China's RITS development will be carried out around the following aspects. They are:

(1) Research of national RITS architecture framework,

(2) Railway mobile and fixed infrastructure all-in-one security detection systems,

(3) National rail transportation security system and related core technologies,

(4) Distributed National Railways security data center system construction,

(5) High-speed broadband bi-directional data accessing system technology,

(6) Interconnection of railway existing business system and information sharing technology,

(7) All-in-one high-speed railway communications signal system,

(8) Train running control and operation assurance integrated technologies in special areas,

(9) National Railway Geographic Information System,

(10) Train scheduling and command system based on wireless and satellite navigation GPS,

(11) GPS-based logistics monitoring and tracking system,

(12) Digital train system based on train bus-line.

Research and development of above-mentioned technology and related systems, are the key of RITS system to constitute our country's integration. Research of national RITS framework architecture is the foundation and starting point for the whole RITS development framework.

Research purpose of national RITS framework architecture is to provide dependencies and guidance for planning, design, implementation, standards and management of China's RITS development. The RITS framework architecture in China has to formulate specifications and definition in accordance with national conditions to the following contents, which are:

(1) RITS overall demand,

(2) RITS physical structure,

(3) RITS logical structure,

(4) RITS function structure,

(5) RITS data streams,

(6) RITS internal interactive standards,

(7) RITS function and standards of each functional subsystem,

(8) RITS communication system architecture,

(9) RITS application interactive standards,

(10) RITS implementation strategy,

(11) RITS-related standards,

(12) RITS assessment methods,

(13) RITS operation theory,

(14) RITS external interactive standards,

(15) RITS related technique systems,

(16) RITS technique selection criteria,

(17) RITS service model,

(18) RITS related products evaluation system,

(19) RITS risk analysis,

(20) RITS related benefit analysis methods,

(21) RITS information integration rules,

**RITS Development Model**

The principles to develop RITS are of enhancing transport efficiency, improving the transport services, and enhancing transportation safety. Besides tracking and adoption of modern intelligent technology, it combines the foundation of existing internal information establishment, under the unified framework guidance, and focuses on integrating resources and advantages of information construction. At the same time, it concentrates on tackling key problem and demonstrates application of key technologies, strives for a leap in realization technology, to continuously improve intelligence level of the whole China's railway transportation system and provide technical support for Chinese railway to market and international competitiveness.

On foundation of single model, it constantly completes and attains perfections, and ultimately formulates comprehensive RITS integrated system. (Figs. **3** and **4**) are a brief description of processes mentioned above.

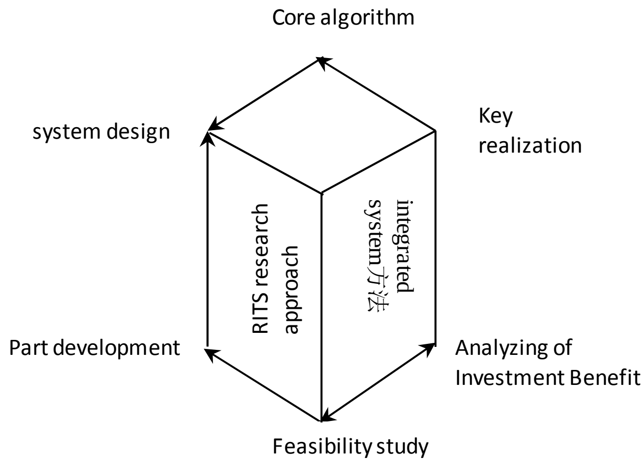


**Figure 3:** Method abided by RITS research: integration system method

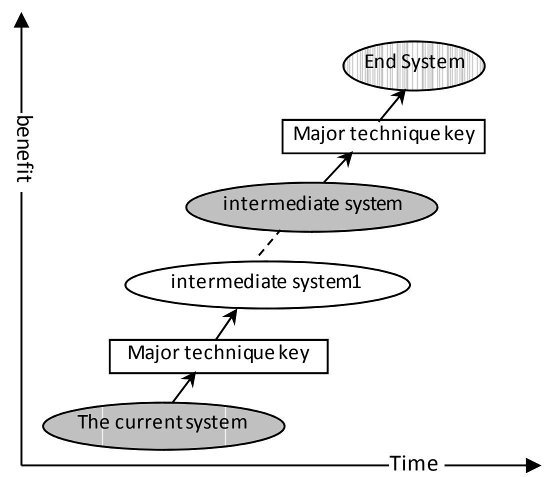


**Figure 4:** Entire process of RITS system development and application: the process of incremental transformation

## CHINESE RITS SYSTEM IN CONSTRUCTION

### Qinhai-Tibet Line Emergency Rescue and Emergency Rescue Command Information System

Railway emergency rescue command institutions and the system is the important safeguard for effective management of emergency resources. Orderly, rapid and efficient implementation of emergency rescue is the key to achieve railways harmony and science. Emergency rescue needs under the special operating environment of Qinhai-Tibet Line, around the Qinhai-Tibet Line emergency rescue command institutions and system, this system carried out the research on system theory and key technology, presented the evaluation index system for Qinhai-Tibet Line Emergency Rescue System and preplans as well as the corresponding assessment method, developed the Qinhai-Tibet Line emergency rescue command information system, and effectively improved the scientific decision-making level and rapid response capability of Qinhai-Tibet Line emergency rescue command.

Main research contents:

1) Evaluation index system and assessment methods for emergency rescue capabilities and emergency preplan,

2) Mobile Emergency Response objects auto-tracking technology,
3) Automatic generation technology for emergency preplan process,
4) Interoperability model dynamic trust management techniques,
5) Emergency resource optimization allocation techniques.

The system has three support functions including emergency preplan and resource management, emergency command and aid in decision making, emergency incident management, builds a fully-featured safety emergency management platform with security information, security technologies, monitoring and forewarning, rescue command, training and education etc., and forms the basis of accurate and efficient emergency messaging, emergency response, emergency processing, emergency rescue and predicted forewarning mechanism, to prevent the occurrence of catastrophic incidents and impact spreading. It achieves command and management of emergency rescue scene, emergency rescue preplan management, incident management, decision support management, rescue resource management, system maintenance, exchange and sharing of information and data, emergency drills management, and has therefore obtained the practical application in the Qinhai-Tibet Line. The system achieves the purposes that utilize first-class information technology tools to protect the first-class plateau railway operating, and has significant social and indirect economic benefit.

Successful implementation of this system provided a show-how for design, development, deployment, application and maintenance of emergency rescue command system in railway and related industries. Through its construction, it provided a standard model of reference and implementation for building of the existing lines, new lines, as well as passenger line emergency rescue command system, formulated emergency rescue command system which faces the field of railway emergency rescue and gives demonstrations, and has reference meaning and practical application value for construction of railway bureau-level emergency rescue system and development of the system.

**Geographic Information System of Qinhai-Tibet Line**

To support the urgent construction requirements from sharing railway information resources at this stage, exertion of overall information efficiency and formulation of management decision support system, RGIS has become the core of research and application. Especially for the Qinhai-Tibet Line, its special operation and management mode put forward higher requirements in these areas. Qinghai-Tibet RGIS provides a unified visual location-based service based on electronic map for Qinhai-Tibet Line traffic command, security, emergency rescue and management of the business system, which greatly facilitated the level of sharing of Qinhai-Tibet Line information resources, comprehensive utilization and transport management scientific decision-making support.

The system covers the whole process of the Qinhai-Tibet Line spatial data collection, processing, application and management maintenance, and its main contents include the following four aspects: (1) The Qinhai-Tibet Line spatial data collection, processing and management maintenance: to study the Qinhai-Tibet Line spatial data efficient collection, unified registration processing and management of maintenance techniques spatial database, (2) sharing and exchange of the Qinhai-Tibet Line Geographic Information: under the control of unified security permissions, to study the railway spatial data real-time access, transmission, and network information publishing technology, (3) comprehensive application and integration of Qinhai-Tibet Line Geographic Information: to study fusion and integration technology of Qinhai-Tibet Line geographic information and the data businesses, providing electronic maps spatial information services of different application models for the driving command, security, emergency rescue and business management, and (4) Qinhai-Tibet Line three-dimensional virtual reality: to study the technology to establish Qinhai-Tibet Line three-dimensional Geographic Information System, and provide fundamental platform for comprehensive digital Qinhai-Tibet Line.

Geographic Information System of Qinhai-Tibet Line has been applied to integrated applications, such asQinhai-Tibet Line driving safety monitoring, power monitoring, wind environment monitoring, emergency rescue command and public works, electricity services management and other business information systems, and is playing a role in the new Comprehensive Monitoring System of Railway Operational Safety for Qinhai-Tibet Line, video monitoring system along the route, while it has now been extended to other existing railway lines.

### Comprehensive Monitoring System of Railway Operational Safety for Qinhai-Tibet Line

Comprehensive Monitoring System of Railway Operation and Safety for Qinhai-Tibet Line (CMSROS-QZ) is a comprehensive integrated system to ensure the safe operation of Qinhai-Tibet Line, which fully integrates the trains, locomotives, vehicles, electricity, signal, line infrastructure, environment and other aspects of dynamical security information, as well as the daily passenger and freight statistics, and is the center and "brain" for Qinhai-Tibet Line traffic security guarantee system. It intensively provides comprehensive, timely, accurate and complete information on transportation safety production and decision-support for transportation command and safety management officers of Qinhai-Tibet Line, and realizes comprehensive monitoring, early warning and security management for the Qinhai-Tibet Line traffic safety process.

Main research contents:

1. Fully integrate transport processes and safe production dynamic information related to Qinhai-Tibet Line operations management,
2. Realize information sharing and integrated applications based on visual rail geographic information system platform,
3. Achieve monitoring, early warning and coordination command for the whole process of Qinhai-Tibet Line operational process and safe production,
4. Realize tracking and monitoring of the whole handling process of Qinhai-Tibet Line emergencies, as well as decision-making support to corresponding emergency rescue command,
5. Achieve unified and coordinated command for trans-departmental, multi-disciplinary transportation within the jurisdiction of the Qinhai-Tibet Line.

Research, development and deployment of CMSROS-QZ is a systematic information system engineering. It collects all kinds of operations and security dynamic information in real time through the computer network from various types operating facilities, operational regions and external environments of the Qinhai-Tibet Line, carries on centralized management of computer to Qinhai-Tibet Line operations and security state to build the omnibearing driving safety system facing Qinghai-Tibet line [48].

## RITS DEVELOPMENT STRATEGY

Core technology of RITS is intelligence technology, and the so-called intelligence refers to the ability to effectively access, treat, regenerate and utilize information, to achieve the intended target in any given environment. At the same time, the intelligence itself has different levels and grades. Low-level intelligence performs as sensing environment, making initial decision-making control act accordingly. Higher-level intelligence performs as having judgment ability, identifying object, expressing knowledge of the environment model, and could make planning and reasoning for the future. High-level intelligence performs with understanding capacity, and can make successful decision-making in complex environment. Accordingly, RITS is also divided into the following three levels as shown in (Fig. **5**):

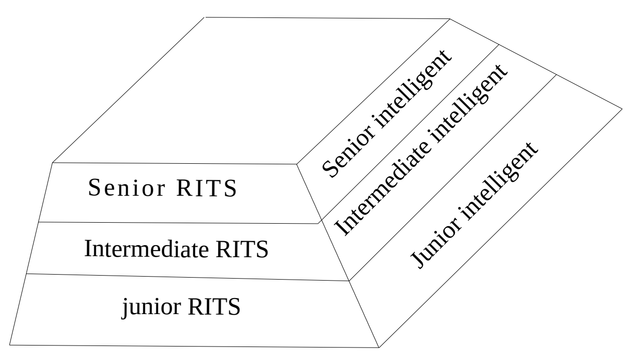


**Figure 5:** Division of RITS development stage

**Primary RITS**

With the application of computer technology, information processing technology, geographic information technology, data communications technology etc., the system collects, transmits and shares all types of information from rail transport environment, and in accordance with the above-mentioned information carries out initial decision-making and control, with the existing TMIS, DMIS, ATIS, PMIS etc., as well as the railway geographic information systems being actively studied.

**Senior RITS**

With the application of system identification, pattern recognition technology etc., the system establishes mathematical mode to determine environment, so as to make planning and reasoning for future, such as: preparation of train schedules based on operations research model, marshalling station shunting operation automation systems, train speed intelligent control etc.

**Senior RITS**

Besides application of mathematical model for modeling of determined environment, simultaneously the system cites knowledge model for modeling of non-identified object, in order to simulate human understanding capacity, and accomplish decision-making under complex environment, such as integrated scheduling system, comprehensive operation management system, and automatic train operation system etc.

As mentioned above, China's railway is currently in its infancy and is at an advanced RITS development stage, with partial achievement of task in initial stage, and many issues waiting to be resolved in further advanced stage. In view of this status quo, we developed RITS recent and long-term development goals as follows :

Short-term objective (until 2007) of RITS development is the mission-critical for the completion of primary and higher RITS stage, including:

1. Formulate overall planning and framework for RITS development, to provide basis of design, implementation, standards and management for China's RITS development.
2. Bring to perfection and integrate existing information establishment technology outcome, initially build all-route sharing platform based on geographic information system, and realize unified management to transport resources;
3. Build high-speed vehicle-road two-way data accessing system, to provide assurance for data communications between vehicle and road;
4. Initially build entire-route traffic safety monitoring system, to provide assurance for railway safety operation;
5. Initially build user service system based on Internet and handheld device, to provide users with high-quality services;
6. Initially build train scheduling and command system, logistics monitoring and tracking system, based on wireless and advanced localization technologies;
7. Build RITS model application systems;

Long-term objective (by 2020) for RITS development is:

1. Build advanced entire-route sharing data platform based on GIS, to formulate entire-route sharing transport resource management system, emergency incidents and security information systems etc;
2. Establish perfect service system and e-commerce systems, in various ways to provide passengers or cargo owners with high-quality, full range services;
3. Build integrated scheduling system which covers passenger scheduling, cargo scheduling, special scheduling and other scheduling etc, to improve scientific and rationality of scheduling command;
4. Build integrated operation management system including passenger, cargo, containers, shunting management, to improve the efficiency of rail transport;

5. Build automatic control loop, to realize automatic operation, under less or no human intervention
6. Provide ITS interface with other transport modes;
7. Build modern management mechanism adapting to railway intelligent strategy.

**Vision Analysis of RITS Development**

The most fundamental significance of RITS development is to provide a fire-new transport mode with high security, high efficiency and high service quality. So that China railway cannot only win the domestic market by virtue of good service and safety, but can also win international market by virtue of excellent efficiency to reply WTO challenges. Simultaneously as a fire-new rail transport mode, RITS will perform entirely different characteristic from traditional rail transport modes in service, security, and efficiency etc, mainly reflected in:

In services, RITS will provide detailed information and electronic secretary function for passengers and shippers. While pre-rip or pre-shipment, passengers and cargo could timely find out various services and corresponding provisions provided by railway via the Internet, inquiry train schedules, fares, schedules and fares when changing other transportation modes at destination etc.Personalized service information (such as through mobile phone messages to remind visitors of departure time, the train's late notice, station navigation, etc.) can be customized. While in travel or shipment consignment, the cargo owners could track and query location and status of the goods. Passengers can obtain information that navigation, train speed, location, sooner or later, weather and so on. When emergency accident occurs, the system electronic secretary may provide passengers or cargo with decision support of transfer; incidents rescue information etc, to help passengers reach their destinations as soon as possible.

In terms of efficiency, construction of railway geographic information system will provide a comprehensive sharing platform for railway transport sub-systems, for centralized management of all relevant information, in order to improve the overall efficiency, and ensure the coordination operation of sub-systems. Based on this sharing platform, intelligent integrated scheduling system and integrated operating management system based on the wireless communication technology could be built, in order to make efficient use of rail mobile resources, fixed resources, human resources etc., achieve high-density high-speed rail transport, and further excavate railway potential of scale economies. At the same time marshalling yard integrated information management and automation systems are built, to achieve efficient and safe decomposition and marshalling of trains.

In terms of security, through establishment of all-road driving safety monitoring system and safety assessment decision-making system based on expert knowledge, to monitor state of entire-route resources. At the same time, the system could execute real-time monitoring on entire-route natural disasters, to formulate entire-road disaster prevention, rescue, decision-making and command information system. So the system fully ensures train operation safety.

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