

# Research on Rail Safety Security System

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**Abstract**—This paper analysis the integrated use of safety monitoring with the domestic and international latest research on rail safety protection system, and focus on the implementation of an organic whole system, with the monitoring and early warning, risk assessment, predictive control and emergency rescue system. The system framework, contents and system structure of Security system is proposed completely. It's pointed out that the Security system is a negative feedback system composed of by safety monitoring and warning system, risk assessment and emergency rescue system. Safety monitoring and warning system focus on the monitoring target monitoring, early warning, tracking, integration of decision-making, for objective and subjective risks factors. Risk assessment system analysis the occurrence of a major Security risk mechanism, determines the standard of the future short, medium and long term safety conditions, and give prop for development of safety indicators, accident analysis and safety standards. Emergency rescue system is with the goal of rapid and effective rescue work for accident, to minimize casualties and property losses.

**Keywords**—rail safety protection; monitoring and early warning; risk assessment; emergency rescue.

## I. INTRODUCTION

ALONG with the transportation develops towards high-speed, high-density, over loading, technique concentrated, complex of the technique systemic constitute, and the high linkage between business system, the safety Security work will face exceptional severe challenge. The objects related to safety Security consist of natural disasters, foundation devices and emergencies. Any local damage and un-control may evolve to a global damage and un-control during the subway is in motion and do business. However, now the question of safety Security system is that the apply and analysis on information of safety monitoring is on start-up period, the whole benefit of prediction control and emergency rescue by monitor data has not yet been fully developed, the primary cause of the problem is lack of systemic rail transportation Security Security system and technology criterion which is adaptive to the system and possess the industry characteristic. Following the development of the system on safety monitoring and early warning, it will accumulate a mass of Security monitoring data. If the data is effectively fusion, storage, and synthetically applied, the

hidden danger information related to safety which is contained in the data can be found and provides decision-making to the dispatch, protect and maintain, rescue and design of the technical equipment, then the Security Security will greatly average up.

Aim at the afore mentioned problem, this paper deeply researches the information fusion and predetermination method, uses the model of expert knowledge and intelligent analysis, analyzes and predeterminations the current Security tendency of the rail transportation system, which thereby supports the synthetic protect and maintain and the repair of operate facility, also supports the establish of relevance safety criterion rules and safety policy, based on which the systemic frame of the rail transportation safety Security Security is presented systematic, research is developed around a series applied theory and key technology of transportation safety, and it has far-researching signification on promoting the complete practice of safety Security systemic theory, improving standard of safety Security and management efficiency, Securitying life safety and decreasing the accident loss.

## II. STATUS QUO OF THE RESEARCH ON RAIL TRANSPORTATION SAFETY SECURITY

### A. Foreign status quo of the research on rail transportation safety Security

Co-relational research on rail transportation safety Security system is becoming highly valued step by step in recent years. Research on the theory and technology of rail transportation safety Security has bear fruit according to the literatures. Literature [1] described the depart control of rail transportation operating system and presented the optimal strategy and realize of depart intelligent decision support system based on Petri net. Literature [2] formally modeled definition, design and realization of the self-check function in automatic driving control software. Literature [3] had researched the analysis and design of the train strategic decision supporting system by using the method facing objects. Literature [4] optimized the train's initiative driving by using linear quadratic Gaussian (LQG) method and hereditary algorithm. Literature [5] presented and brought out the distributed strategy decision supporting system of the train station and train control along the line. Literature [6] researched the optimized operation of the train based on the neural networks. All of these achievements paved the path to build and improve the rail traffic safety Security system.

In Japan, experts started the research on the system frame of rail traffic intelligent transportation system Cyber-Rail, definite

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intelligent train control system and rail transportation scourges prevention facing the safety Security. It also invested abundant of labor power and financial resources to keep away and control the scourges, thereby the whole scourge early warning and monitor political system is formed. The system of scourge early warning used scientific early warning methods, gathered every kind of external data leading to scourge, advanced early warning to scourges such as flooded line and collapsed line, carried out responding scourge warning, formulated travelling regulation under scourges, which prevented the accidents of scourge and Securityd transportation safety. Scourge monitoring system directly monitored the scourges which are difficultly predicted, such as rolling stones, collapse, broken bridges, which ensured the running train can stop in time and transferred the information to any departments. The system frame of American rail traffic intelligent transportation system, which named IRS, contained system frame of proactive train controlling ( PTC ) system, which wan used to control train safety, reliable, punctual, effective operating, and by avoiding train colliding, decreasing the negligence of railroad workers, reducing facilities broken and over speed accidents.

The standard current situation of international standardization institution and each country safety Security system concerning is:

(1) UTC (Union International des Chemins defers, International Union of railways), UTC is the biggest international standardization institution of the world rail transportation. This organization is a non-government international rail transportation institute, which is subject of European rail transportation, and China is one member country in it. A set of standardizations related to safety Security system quickly developed for it.

(2) ISO, ISO related to the rail transportation standard is the 45 item-rail transportation projects. Although now the part of ISO rail transportation is emphasized on project material, but these standards are closely interrelated to transportation safety.

(3) IEEE(Institute of Electrical and Electronics Engineers ), IEEE standardization committee is responsible for the survey, impel, management of IEEE standard, pondering and proposing IEEE standard. For the past few years, IEEE standardization committee is very active in standardization research part of rail transportation information and control, closely follow after releasing many standards in this region, and some parts is related to transportation safety [7].

(4) ERRI(ERRI European Rail Research Institute) , ERRI is under the lead of UIC and it is a rail technical research institute which gathers rail traffic engineers in every country. Meanwhile, along with the typical RITS system-ERTMS continually deepens, ERRI plays a decisive role in the forming of the world rail traffic standard.

(5) JIS, section E in JIS standard object is directly related to rail transportation, including line general standard, locomotive signal, signal servicing installation, rail traffic vehicle general standard , high-speed train , passenger and freight vehicle, tight wire railway standard. JIS present standardization strategy of

every professional field in 2000, and it clearly points out in its rail traffic field. Because its standard is different from the international standard, it needs to build standard system. Therefore, it emphasizes the following standardization: amending the international standard to suitable for the native situation; corresponding standardization to advanced technologies, such as operating system, information transfer system between train and ground, communication signals, information service field; standardization problem corresponding to environmental protection, all of these standards directly ensure the rail traffic safety.

(6)ANSI(American National Standards Institute), standard related to rail transportation are mainly from American Association of railway(AAR), AAR distributes to unifying and control supervising on technical standard and the quality of rail traffic devices in American rail traffic. Because of ensuring rail traffic safety and improving quality of device, AAR specially sets up quality Security committee, which is responsible for the identification work of quality Security on rail traffic device.

#### *B. Current situation of domestic rail traffic safety protection*

In recent years the domestic rail traffic developed rapidly. Along with development of the tendency such as high-speed, high density and over loading transportation, safety protection system also had higher requirement, and safety protection technologies which was suitable to new circumstance, new situation were on the research. The newest correlated research result is as follow: literature [8] researched the institution of high speed rail traffic travelling safety protection system. Literature [9, 10] researched diagnosis and maintenance of intelligent train. Literature [11-13] researched intelligent travelling operating control system. Literature [14, 15] researched strategic decision supporting system of rail intelligent control. Literature [16] researched mathematical model of the train operating control system. Literature [17] researched intelligent integrative monitoring system and its key technology of city rail traffic.

### III. SYSTEM FRAME OF RAIL TRAFFIC SAFETY PROTECTION SYSTEM

Paper bases on the natural characters and total requirement of rail traffic safety protection system, presents a integrative system frame, and definite research content of the system including three parts: safety monitoring and early warning system, risk assessment system and emergency rescuing system. Safety monitoring and early warning system monitors subjective and objective hidden factors, researches safety early warning system; risk assessment system uses the accumulated safety monitoring information to safety risk assessment, build accident model analysis and safety standard system; emergency rescuing system formulates the scheme of emergency rescuing, performs rescue command.

#### *A. Substantive characteristics of safety protection system*

Safety protection system serves as a integrated complex macro system and possesses substantive characteristics as

follows:

(1) Integrated of systematic target

The global aims of the rail traffic safety protection are strengthening transportation safety operation and increasing transportation efficiency system. By means of monitoring, controlling and managing the safety Security facility, and integrating the objective of transportation safety information, technology, society, at last realizing a new higher safety Security system.

(2) Integration of system function

Integration of monitoring, controlling, overseeing, communicating, information processing, macrograph and micrograph decision supporting realizes the optimization of transportation safety and technical index.

(3) Opening systemic structure

It interconnects various kinds of safety Security devices which faces safety controlling, command system which faces to operation and the basic operating system which faces on-site operation system. The structure efficiently coordinates an entirety of stabilize devices, moving devices and maintenance devices. It also should have sufficient system of flexibility and expansibility, which can adapt to changes in the external and internal environment, especially with other transportation safety information sharing and exchange with the structure of the system and openness.

(4) Wide application of intelligent technology

It means that making full use of modern high science and technology development, closely tracking the achievement of the latest progress of technology and intelligent, constantly absorbing new technologies, enriching technical support system, realizing improvement and perfection of the whole function. The new generation rail transportation Security system consistent of operation system, whose main technical support business system are intelligent control technology, such as fuzzy control, expert system and evolutionary algorithm. They are: the intelligent monitoring system, intelligent traffic control and scheduling system, intelligent safety resource management system, intelligent risk control system, intelligent emergency rescue system. These systems are interconnection, sharing information highly, integrating an organic integrity based on intelligent technology platforms and forming an intelligent rail traffic safety Security system.

### B. The framework of safety Security system

The framework of rail traffic safety Security system contains:

- (1) The overall demand,
- (2) Physical structure,
- (3) Logic structure,
- (4) Function structure,
- (5) Information flow,
- (6) Internal interaction standard,
- (7) External interaction standard,
- (8) Functions and standard of each functional subsystem,
- (9) Communication system structure,
- (10) Application interconnection standards,

(11) Implementation strategy,

(12) Related standards,

(13) Related product evaluation system,

(14) Monitoring system,

(15) Risk assessment system,

(16) Information fusion system.

The framework of rail traffic safety system can be realized by negative-feedback system, which is shown in figure 1.

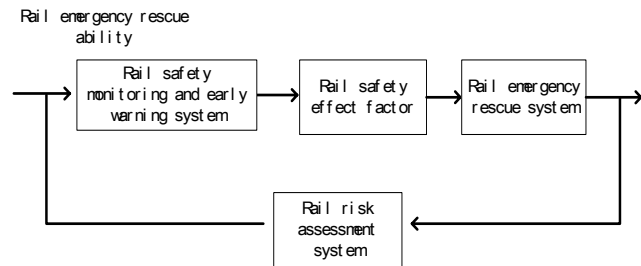


Fig.1 The framework of safety Security system

Rail traffic safety system is composed of three parts: the safety monitoring and early warning system, risk assessment system and emergency rescue system. Emergency rescue system is center, safety monitoring and early warning and risk assessment system is the means. In this system, safety monitoring warning system is controller and transportation safety factors is the object; the input is a closed-loop system of emergency rescue level. Among them, safety factors are generalized concepts, including not only individual subjective and objective factors which lead to the danger, but also the relationship between factors and combination.

### C. Safety monitoring and early warning system

Rail traffic safety monitoring and early warning system is aiming at subjective and hidden danger factors. Monitoring network is composed by monitoring stations, and observing monitoring target, tracking, early warning, recognizing, monitoring and reporting the development state. The monitoring content is composed of operation action of person in key position, the running condition of vehicle, the vehicle loading condition and infrastructure condition; transportation safety synthetical monitoring information base is formed by information fusion, providing timely information to prevention, predicting of hidden danger and emergency rescue.

Safety monitoring and early warning system uses distributed network monitoring stations to monitor, track the safety status of targets. Monitoring network has following advantages:

- (1) expanding space coverage area: many stations coverage the same area, avoid the blind zone of covering area, strengthen the smooth of the space transition;
- (2) expanding the time coverage area: teamwork of many stations improves the reliability of monitoring;
- (3) improve the performance of monitoring: the fusion of many stations monitoring information improves the effectiveness of monitoring [19].

## i. System interface of monitoring and early warning

The key technology of rail traffic safety monitoring and early warning system is system interface. System interface contains not only integration technology of site safety monitoring system, but also information exchange technology of safety subsystems interconnection or integration. The contents include the classification of the interface, form of structure and realization.

According to the technical content and layer of structure, system interface is divided into: system interface and monitoring level interface. System interface: system interface refers to the safety monitoring system and the interface of each safety subsystem. System interface integrates and plans subsystem information base on the aspects of system interconnection, part function, characteristic and structure, builds uniform standard information storage structure, organization structure, circulation mechanism, Monitoring level interface: monitoring level is that safety subsystem interface processes the data collection and forms standardized interface. Monitoring level interface is related to their own function features of safety device.

## ii. Early warning decision-making of monitoring network

The same major safety monitoring system in monitoring network which deployed at the site is independence. Because of the monitoring results are influenced by many random factors, the single point estimation judgment may not be necessarily accurate in monitoring and warning, which means false alarm and leakage alarm(false alarm is that target under monitoring system is out of action, but it actual trouble-free. False alarm rate is in a period, the number of fault alarm displaying contrast to the total alarm displaying). Therefore, the result of judgment will objective, when the monitoring network stations increase a participant of fusion judgment node, judge monitoring system become integrated, the participants with the determination results objectively.

The monitoring network system containing several stations and a decision fusion monitoring network system can be divided into two kinds of structure, figure 2 shows a kind of monitoring and early warning decision-making model which composes by many stations and a fusion center, called MDOF (Multi Detection One Fusion) model.

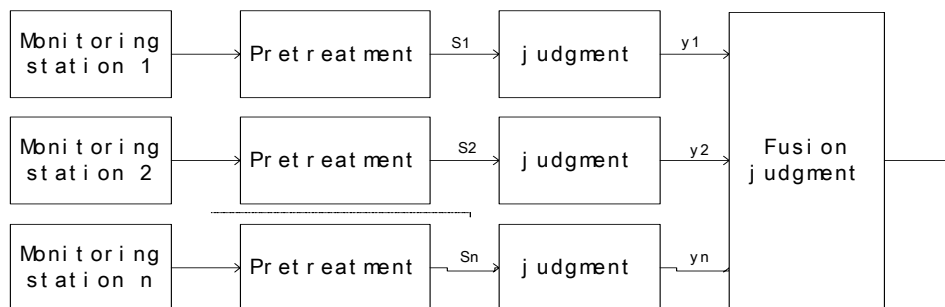


Fig. 2 Monitoring and early warning decision-making model of multi-station and one fusion center

$S_i$ : detection vector of monitoring station;  $y_i$ : judgment on station level

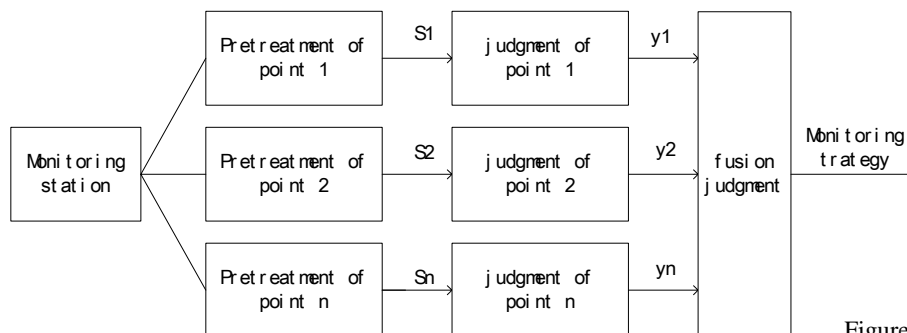


Fig.3 Monitoring and early warning decision-making model of one station and one fusion center

$S_i$ : detection vector of monitoring station;  $y_i$ : judgment on station level

Figure 3 shows a monitoring

and early warning decision-making model which composes by a monitoring station with several monitoring information and an information fusion center ODOF(One Detection and One Fusion)

Each station bases on their local detection results independently and completes the same decision task, these local decision-making (not their monitoring vector) is transferred to the fusion center and forms a detection vector in fusion center:

$$Y = (Y_1, Y_2, \dots, Y_n) \quad (1)$$

The fusion center gets the global judge decision based on Y. The fusion center is based on global judge decision.

#### *D. Rail traffic risk assessment system*

Rail transit risk assessment system is for the purpose to realize transportation safety transportation. By using the theory of system engineering, it identifies, analyzes and evaluates the risk source, namely, the hidden danger, studies major safety mechanism, judgment criteria, effective operation scheme of operation procedure, the preventive measures and emergency remedial measures for safety index decision, accident analysis and improvement of safety codes.

Rail traffic system is composed of three parts: the risk analysis, risk assessment and risk management. Risk analysis analyzes and researches risk source quantitatively, risk assessment evaluates risk itself, and risk management monitors and manages specific risk.

##### *i. Risk analysis*

The goal of risk analysis is to study how the adverse consequences happened, why it happened. Actually it refers to the classification and model of risk source, it manages risk, reduces or controls risk through mastering the state of the risk source. Risk analysis contains two links.

Main task of Risk source analysis is studying the risk source components - risk source factor of probability or return period. Any risk source factor need three parameters to completely depict characterization, time, space and intensity.

Time: time of risk source factor appears or acts (time or period);

Space: the location of risk source factor (may be a operation interval);

Intensity: intensity of risk source, such as vehicle shaking intensity.

##### *ii. Risk assessment*

The purpose of risk assessment is to recognize and describe the characteristics of risk source. It formulates the system frame according to various risk models to evaluate the risk influent style and tendency, avoids and controls risks. Main models related are risk source factor model, destroy model and lose model:

##### *(1) Risk source factor model*

Risk source factor model can be showed by probability formula: Prob (T, G, I), namely at T or a period, the probability of risk source in the regional G with intensity I. However, many

risk source factor contained uncertainty component, and the uncertain factors modeling method based on fuzzy set theory is research hotspot.

##### *(2) Damage model*

Damage model is used to describe function relationship between risk source factor intensity and accident damage. This relationship is hard to find in practice, so damage model mainly use accident simulation, it looks for approximate function by historical data statistic method.

##### *(3) Loss model*

Loss model contains economic loss model and personnel loss model, it is mainly obtained by the history statistical method.

#### *iii. Risk management*

Risk management is developing risk resource monitoring strategies and management mechanisms to eliminate or inhibit the risk source, to avoid risks based on risk assessment.

Risk management contains: design management scheme; selection and implementation management systems; monitoring and verifying.

Proceeding from monitoring the objective and subjective factors of risk, it composed of monitoring operation behavior of key post; monitoring the vehicles running status, vehicles loading condition, dangerous material long-distance transport process.

#### *E. Rail traffic emergency rescue system*

Rail traffic emergency rescue system's goal is quickly and effectively organizes the work of rescue incidents, minimize casualties and property losses.

This system takes rail traffic safety Security and early warning system and rail traffic risk assessment system as a foundation, takes pronunciation, data, static and dynamic image transmission system as the information support, takes GPS/GIS as localization method, it provides the synthesis knowledge and the consummation information service for the safe rescue groups and gives the Security situation assessment result and the emergency plan, the instruction coordinated specialized department operation flow, the formulation emergency rescue plan, exercises the rescue direction. This system includes emergency rescue plan and emergency rescue system.

The emergency rescue plan is mainly composed of 4 parts as following:

(1) Action guide. According to the identified dangerous formulation, we formulate the organization, duties and division of labor. The guide describes the constituents and the main functions of the command structure, such as the timely release and removes emergency rescue plans command; take emergency measures, train relevant personnel and so on.

(2) Emergency guide. According to the dangerous target simulation accident condition, we draw up each kind of heavy accident's handling plan and the disposal procedure. such as Communications, emergency rescue, medical aid, and so on.

(3) Disposal procedure guide. The stipulation motion observes procedure, such as an accident what to do first, then what do

next.

(4) Accident report and responsibility investigation. Description of the accident content and responsibility investigation system.

The emergency rescue system is mainly composed of 4 parts as following:

- (1) Independent emergency command system platform;
- (2) With platform integration Security information and control system;
- (3) With foundation equipment integration information and control system;
- (4) personnel use individual equipment information and control system;
- (5) Safety education and training information and control systems.

#### IV. CONCLUSION

The paper based on analyzing and summarizing co-relational research results of rail traffic safety Security, and it presents systematically the traffic safety Security system which should be served as a unity including safety monitoring and early warning system, risk evaluation system and emergency rescuing system. It realizes information fusion, information sharing and technical standardization. In the paper, rail traffic safety management system and Security management system is proposed and founded to adapt to the new features nowadays. After minutely stating the detailed technical frame design of safety monitoring and early warning system, risk evaluation system and emergency rescuing system, the paper integrally presents the system frame, research contents and system constitute of safety Security system. Synthetic safety Security system can develop synthetically monitoring, forecasting, early warning, disaster prevention and rescuing strategy service function, make that it can cohere with the work of some department, such as safety operating, infrastructure maintenance, quick emergency, and give full play to the function of Security safety devices and safety monitoring system.

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