Interpretive article

Advancement and Issues of Transport Management and Signal/Train Control Systems

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Systemization of transport management and signal/train control systems advanced rapidly for the greater Tokyo area and the Shinkansen after the start of JR East in 1987. That allowed for things once unthought-of such as modernization of duties, improvement of safety and reliability and achievement of diverse customer services. Progress in systemization brought about such management-oriented benefits, but it also created risks. Those risks include difficulty of maintenance and expansion, increased costs and considerable impact on transport if a system malfunctions due to massive systems and complexity. This article will introduce the history of progress in systemization at JR East, issues faced, efforts in dealing with imminent replacement of those systems and more.

1 Introduction

Systemization for railways started in the pre-privatization era with efforts such as the COMputer aided TRAffic Control system (COMTRAC) for Shinkansen operation control and Multi Access Seat Reservation system (MARS) for automating reserved seat ticketing, and such systemization rapidly gained speed after the start of JR East in 1987. More than 20 years later, systemization has become indispensible in the JR East management strategy.

Especially in the areas of transport management, signaling safety and train control where high safety and reliability are demanded, there had been almost no systemization for a long time except for the Shinkansen and some conventional lines. Progress had thus not been made in modernization, creating a hindrance to business from not being able to deal with diversified customer needs. Large-scale systems with high safety and reliability became possible by utilizing ICT technologies that had rapidly advanced such as general use computer control and information communications. And that brought about rapid progress in systemization for those areas. This article will cover the history of such advance in systemization, current issues, and efforts for the future and more.

2 Transport Management System of the Greater Tokyo Area (ATOS*)

JR East's first large-scale system development in the area of transport management and signal/train control was the introduction of a transport management system for greater Tokyo area lines with ultra-high traffic density. Up until then, systemization was said to be impossible due to technical issues such as the lack of processing power of computers.

2.1 Overview of Systemization

To meet rapidly increasing demands after the start of JR East such as modernization of transport-related work, safe and stable transport and customer services, transport management duties that were previously handled mainly by the station were unified at the Train Control Center (CC). Systemization was achieved under the following four concepts.

(1) Transport management moved from mainly stations to CC
(2) Improvement of services to passengers
(3) Sharing of operation information at stations and crew offices
(4) Increased efficiency of maintenance work and improved safety

2.2 Concept of System Construction

Previous technical issues were overcome by introduction of the latest information technologies. System use thus gradually commenced, starting with the Chuo Line in 1996.

(1) Utilization of general purpose equipment
Systems were constructed based on general use computers that had seen rapid technical advances, allowing us to easily achieve high performance and high functionality. We also gained the ability to flexibly handle future system expansion and updates.

(2) Introduction of new electronic interlocking devices
New electronic interlocking devices using general use controllers were developed and introduced. Failsafe logic was achieved by 2 out of 3 majority decision logic and dedicated safety mechanisms.

(3) Achievement of automatic route control at lines with ultra-high traffic density and at large-scale stations
Prompt control was achieved to systematize lines with high train traffic density. And at large stations, route control for shunting became possible in addition to route control of main line trains.

(4) Adopting an autonomous decentralized system
The system covers a broad area, so the CC and stations are

*Autonomous Decentralized Transport Operation Control System connected by a 100 Mbps optical network. An autonomous decentralized transport control system was formed where malfunctions in some devices will not affect the overall system.

(5) Phased system construction

The system was made so it can be constructed in phases to allow systemization of a large number of lines and stations. Systemization is done by individual station for each line and operation of the overall system including the central unit starts by line after work for all stations is complete.

3 New Total System for the Shinkansen (COSMOS*)

The second large-scale transport control system development project at JR East was a system update for the Computer Aided Traffic Control System (COMTRAC), the operation control system for the Tohoku and Joetsu Shinkansen where systemization was relatively advanced even in the pre-privatization era. That development was conducted to smoothly deal with diversification of transport management such as expansion of lines for the Hokuriku Shinkansen and opening of the Akita Shinkansen.

3.1 Overview of Systemization

At the COMTRAC update, the following fundamental revision of work was done to make a new Shinkansen general system that can deal with diverse needs of the 21st century while making Shinkansen-related work more efficient and modernized. Use of that new system started in 1995 as the Computerized Safety, Maintenance and Operation Systems of Shinkansen (COSMOS).

(1) Unification of transport planning duties and systemization of notification

(2) Support for train operation and decision-making by dispatchers of the CC and crew only

(3) Modernization of facility management duties and systemization of maintenance vehicle route control

(4) Unification of rolling stock management and automation of shunting control

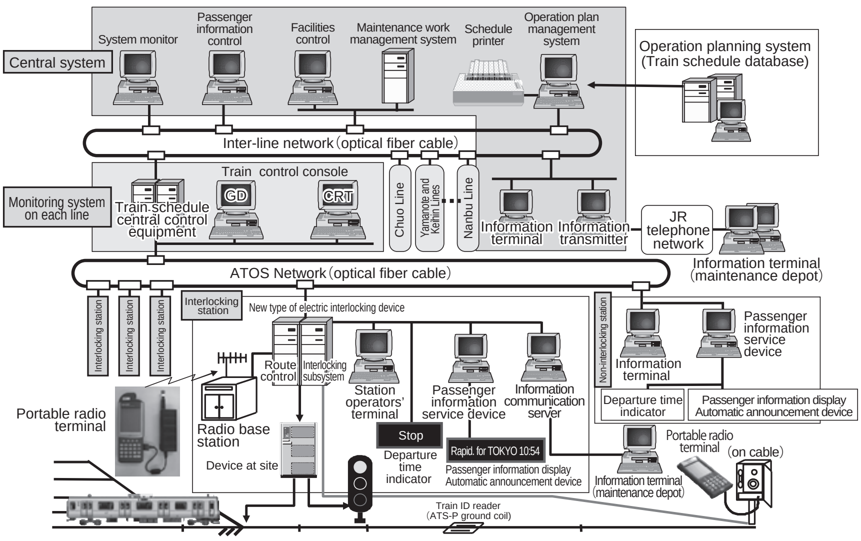

Fig. 1 Overview of the Autonomous Decentralized Transport Operation Control System (ATOS)

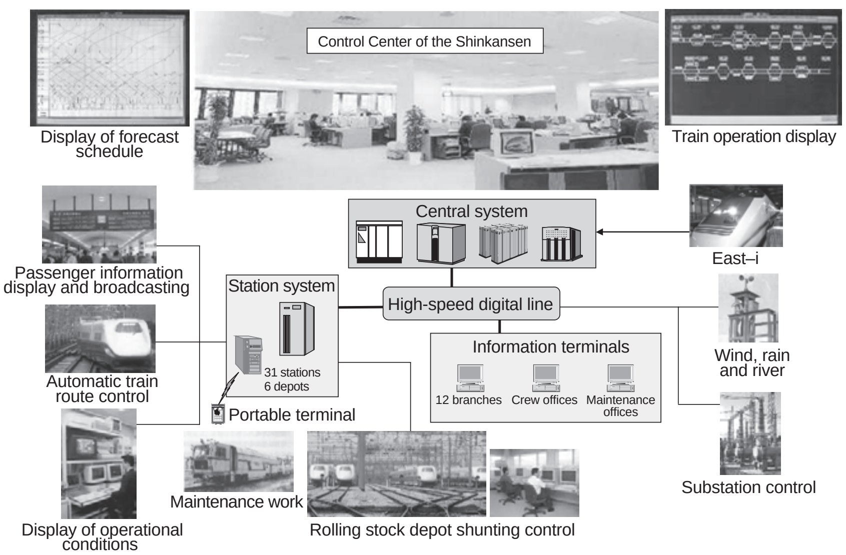

Fig. 2 Overview of Computerized Safety, Maintenance and Operation Systems of Shinkansen (COMTRAC)

*New Computerized Safety, Maintenance and Operation Systems of Shinkansen

3.2 Concept of System Construction

CC offices separated by duties were consolidated on one floor to enhance information sharing and coordination and to make work go faster. Radical revision was done without being limited to previous system concepts for a goal of a rational system configuration with division of duties by function.

(1) Coordination and information sharing between systems
A high-speed optical LAN network was built at the CC for information sharing and free exchange of information between systems such as transport management, power control, and centralized monitoring. That allowed for high-level control by coordination between systems such as automatic proposal of maintenance time slot, power transmission/interruption at set times and temporary speed control.

(2) Dispatch human-machine interface improvement, anticipated schedule display on operation rescheduling screen
The latest general use workstations have been adopted for dispatch screens. Those allowed for quick display and operation and a high level of visibility. They also achieved a system that displays the anticipated schedule on the operation rescheduling screen and conducts high-level operation rescheduling and route control that reflects situations such as train delays.

(3) Adoption of an autonomous decentralized method
An autonomous decentralized method was adopted for work such as route control so as to handle the high-speed and high-density traffic operation of Shinkansen trains. That allowed us to achieve both high response and high reliability.

(4) Secured system maintainability and expandability
System maintainability and expandability were secured by means such as adopting remote maintenance functions and development practice functions that allow for flexible handling of work such as system modification spanning a broad area.

4 Digital ATC Systems (D-ATC, DS-ATC)

Technical innovation in transport management systems such as ATOS and COSMOS resulted in advances for train control such as ATC and ATS-P and for field signal control such as network signal systems. It was in such advances that technical innovation in ATC updates was made.

4.1 Overview of Systemization

ATC up to now has been old, pre-privatization era design, resulting in problems such as poor ride comfort due to brakes being applied with force multiple times before stopping and wayside equipment being massive. We thus developed digital ATC where information on the section where the train should stop is transmitted by digital signal from wayside to onboard equipment. Based on speed information from a tachometer generator from the train, the train's location and speed are constantly monitored, and optimal brake control is done autonomously mainly on the train based on that information. The following effects were gained by digital ATC.

(1) Reduction in train service interval and travel time
(2) Improved ride comfort and ease of driving
(3) Cost reduction from simplified wayside devices
(4) Improved maintainability and quicker recovery from disruptions

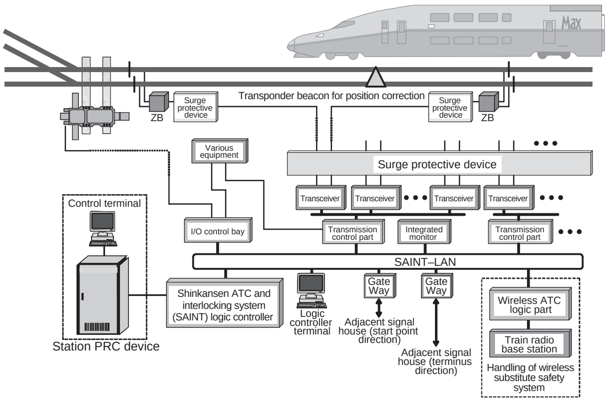

Fig. 3 Overview of Digital ATC System (DS-ATC)

4.2 Concept of System Construction

We developed and introduced the Tohoku/Joetsu Shinkansen Digital ATC System (DS-ATC) ahead of opening of the Tohoku Shinkansen between Morioka and Hachinohe in December 2002 and the Yamanote/Keihin-Tohoku Line Digital ATC System (D-ATC) starting in December 2003. That was done gradually under the following concepts.

(1) Simplifying of wayside equipment
D-ATC wayside devices have a distributed configuration with the logic controller set up at major stations and transmission/reception unit set up at individual stations connected in a LAN network by optical cables for which we worked to reduce the amount of signal cable laid. DS-ATC has an even more simplified configuration with interlocking devices and ATC devices unified in the Shinkansen ATC and Interlocking system (SAINT).

(2) Train detection and control by digital signals
We adopted digital signals with a large information capacity for train detection and control in an attempt to secure high functionality, safety and reliability.

(3) Advance preparation of speed check patterns for brake control
Speed check patterns are prepared using an onboard database that has information such as curves and gradient added in advance instead of through on the fly calculation. We used that method to be able to confirm patterns in advance and lighten the processing load of onboard devices.

(4) Failsafe system configuration compliant with international standards
We have adopted a failsafe system configuration compliant with international standards such as RAMS. By making onboard devices and the logic controller of wayside devices failsafe, we have been able to adopt general-purpose equipment for the intermediate transmission part.

(5) Utilization of assurance technology
Utilizing assurance technology allows both old and new ATC devices to work simultaneously. Switchover and testing at replacement to digital ATC and automatic switching with

through service between digital ATC and conventional ATC sections can thus be done safely and certainly.

5 Newly Occurring Issues with Progress in Systemization

Management benefits such as modernization of duties and achievement of high-level services have been brought about with the introduction of ATOS and other large-scale systems. On the other hand, it has created issues such as the following.

5.1 Handling of System Function Upgrades, Equipment Renovation, Etc.

Introduction of high-level systems has brought about demands such as more new services and function upgrades. And systems frequently needed modification along with signal equipment upgrades in large-scale project construction such as terminal station renovation. The range of modification became broad with system expansion, and much labor and expenditures came to be needed for design and construction.

5.2 Handling of System Maintenance, System Updates, Etc.

Securing parts for system maintenance and modification is becoming difficult due to reasons such as those parts no longer being in production. Also, maintenance expenses for work such as overhauls are increasing, and issues such as device failure due to aging are occurring. In the future, updates of large-scale systems introduced early in systems such as the Chuo Line ATOS will start, and switchovers at system updates need to go on safely and certainly without affecting train operation.

5.3 Occurrence of System Disruptions with Major Effects on Trains

With systems becoming large in scale and complex, disruptions that are hard to identify the cause of and to recover from have come to occur. Major system disruptions that have occurred at JR East are as follows.

5.3.1 Chuo Line ATOS Network Disruptions

On February 4, 1998, operation of electronic interlocking and completion of rail maintenance work could not be done at all stations on the Chuo Line from Tokyo to Kofu, resulting in inability to control station signals. Investigation showed that failure of a communications controller at Saruhashi Station on the Chuo Line caused inappropriate data to flow on the ATOS network, resulting in inability to do operations such as route control at all stations. A total of 291 runs were canceled, and 258 were delayed.

On August 31, 1999, failure of communications controllers at Fujino Station caused inappropriate data to flow into the ATOS network, resulting in inability to input changes from the CC. A total of 142 runs were canceled, and 122 were delayed.

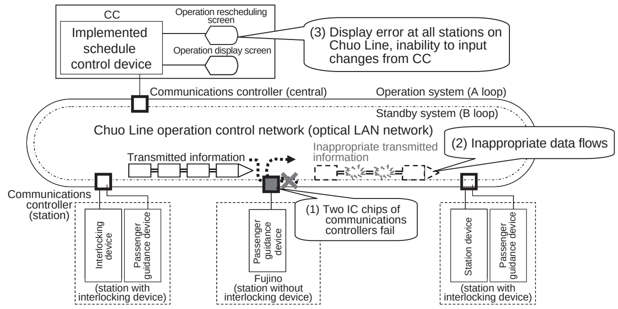

Fig. 4 ATOS Network Communications Disruption at Fujino Station on the Chuo Line

5.3.2 Shinkansen COSMOS Transport Disruption

During operation rescheduling at a three-hour power outage between Omiya and Kumagaya on the Joetsu Shinkanen on November 16, 1997, the anticipated schedule display function of the COSMOS operation rescheduling screen went blank due to an inconsistency in the system and the actual starting order of trains departing the depot. While the function was restored once, the problem occurred again right away, and the anticipated schedule could not be displayed on the operation rescheduling screen all day. Operation rescheduling by dispatchers also could not keep up and trains were delayed even further, creating a large volume of plan change data for the day and resulting in transport planning computer processing ability being exceeded. Due to that, COSMOS date switchover processing did not work, and the anticipation function did not recover on the 17th, the next day, either. Transport was thus in disarray for two days. A total of 229 runs were canceled, and 267 were delayed.

5.3.3 Signal Malfunction Between Kamata and Tsurumi on the Keihin-Tohoku Line

D-ATC device failure on the Keihin-Tohoku Line between Kamata and Tsurumi in the morning of May 11, 2005 caused abnormal signals to continuously flow between devices, resulting in successive track circuit outages and inability to conduct train control. About three hours later, system 2 of the connection of the ATC interface and D-ATC devices (dual) was isolated, and recovery from the failure was made. A total of 230 runs were canceled, and 30 were delayed.

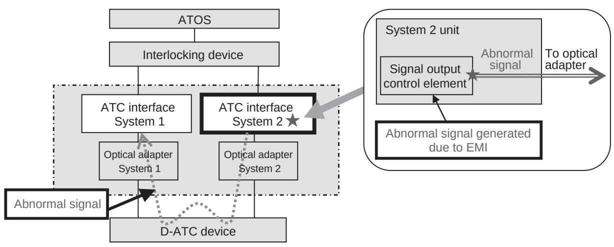

Fig. 5 Signal Trouble Between Kamata and Tsurumi on Keihin-Tohoku Line

5.4 Maintaining and Educating about Know-how and Technical Ability Concerning Systems

High-level specialized knowledge on systems is needed for work such as system upgrade, maintenance and operation. Tasks such as educating about systems and handling disruptions have thus become difficult. In large-scale systems in particular, system function management and technical management have become difficult.

6 Future Direction of Transport Management and Signal/Train Control Systems

High-level systemization that creates services with high added value is becoming more and more important for railways to maintain a competitive advantage over other means of transport while dealing with changes in the social environment such as an aging population with fewer children and reducing the burden placed on the global environment. Strategic efforts need to be made while dealing with new issues created by introduction of large-scale systems.

6.1 Improving System Reliability and Curtailing Expense Increases

In order to prevent system failure that leads directly to large-scale transport disruption for systems that are constantly introducing the latest technologies, being upgraded and expanding, remote monitoring and upgrading need to be put in place to allow quick and accurate system upgrading and handling of issues such as system failure. Also, efforts must be taken for continuously improving quality and toughness such as conducting reviews related to major failures. Furthermore, we need to work to secure stable operation and minimize maintenance costs by efforts such as securing part compatibility and reducing maintenance expenditures as systems age.

6.2 Construction of an Architecture that Allows Easy System Modification

Assurance technology must be used for safe and certain implementation of future Chuo Line ATOS system updates. It is important to construct an architecture for easy handling of new needs and large-scale projects. That includes rethinking unnecessary functions and wasteful system configurations to make the system more integrated and simplified (including by station yard LCs etc.), making design and installation work easier and refurbishing broadband communications networks that incorporate the technical innovations.

6.3 Overall Optimization of Coordination and Division of Functions Between Systems

New services and the like are being achieved by coordination with systems such as notice transmitting systems and ATACS that have newly included rolling stock for transport management and signal/train control systems which had developed independently. In the future, high functionality, improved reliability, cost reduction and more need to be achieved by means such as utilizing the latest technologies including broadband communications for further enhancement of coordination between systems, overall optimization of division of functions and simplification of wayside equipment.

6.4 System Construction and Technical Development Based Primarily on Needs

Accurate and strategic handling is needed for changes such as transport needs including expanded through service on lines like the Shonan-Shinjuku Line trains, new customer needs such as those related to popularization of smartphones, video and other content distribution, IPv6 and ubiquitous communications, services and technologies. And sustainable efforts are needed for preventing system obsolescence and maximizing performance and availability. It is thus important to continuously conduct technical development with strategic goals for issues such as new needs and to reflect results in systems such as the next-generation ATOS.

6.5 Maintaining and Improving Know-how and Technical Abilities Regarding Systems

We need to work to maintain employee technical abilities and know-how so that they can accurately deal with system failures and the like on the chance that those occur. And that must be done while proceeding with a variety of enhancements to handle new needs related to transport management and signal/train control systems and expanding coordination including rolling stock. Such important skill-up work includes training of competent employees in a planned manner and coordinating with manufacturers for highly specialized system technology development, designing, constructing, maintenance, system operation and other jobs.

7 Efforts for the Future

JR East is currently studying ways to direct measures for rolling stock, transport management and signal/train control systems in the greater Tokyo area that will be approaching their update periods in the future so next-generation system framing can be done in a coordinated manner. Our R&D center will thus continue to conduct R&D so we will be able to meet the needs of next generation railway systems in a strategic manner with the direction for those systems in mind. Examples include practical deployment of network signal systems and station yard LC, function development for the next-generation ATOS, function development for introducing the greater Tokyo area ATACS and development of the INTEROS next-generation rolling stock control system.

Reference:

1) Hiroshi Miyajima, "Unko-kanri System no Henkaku [in Japanese]," *JR East Technical Review* No. 5 (Autumn 2003)

2) Tsuyoshi Suzuki, "Digital ATC no Kaihatsu to Donyu [in Japanese]," *JR East Technical Review* No. 20 (Summer 2007)