The train control and transport management systems of railways provide the essential structure and arrangements for safe and precise train operation. And it is important that such systems can be easily improved to allow for stable operation and better transport, to achieve further improvement and enhancement of the quality of transport service, which is required in the circumstances surrounding railways. Thus, we are making efforts to introduce the latest technologies related to train control and transport management, aiming at changing our system into the one that more easily brings about the feeling of security and reliability that customers demand and improvement of transport.

In this paper, I will explain the direction of our technical innovation in train control and transport management and introduce an overview of the related technical development.

1 Introduction

Train control and transport management systems have adopted safety measures by learning from actual accidents in the long history of railways. And they have developed by introducing and incorporating the technologies of the time in efforts to achieve transport improvement to meet social requirements.

But in the course of improvement, some troubles have occurred, such as train schedule disruption caused by faulty workmanship and inadequacy or defects in the systems or facilities of train control and transportation management.

Hence, JR East is making efforts for the improvement both physical and systematic aspects in the Committee for Improving Transport Stability for the greater Tokyo area and the Signal Innovation Project.

A promising permanent measure for improvement is changing systems by incorporating state-of-the-art technologies, based on the progress of information and communication technologies in recent years. So, we are proceeding with a range technical development related to train control and transport management. Since it is vital to identify the direction of technical innovation in the field of train control and transport management, we are seeking a good balance and optimization of the total system.

2 Past Improvement and Current Issues

2.1 Past Improvements in Train Control and Transport Management

Since its foundation, JR East has proceeded with introduction of new systems and computerization of devices in the field of train control and transport management as the technology advanced.

For example, a collision at Higashi-Nakano station which occurred just after the foundation of new JR East led to the establishment of Safety Research Laboratory and also accelerated the replacement of traditional ATS (Automatic Train Stop) devices with the ATS-P (Automatic Train Stop system Patten) that has higher functionality.

We introduced CTC (Centralized Traffic Control) and PRC (Programmed Route Control) to regional lines in the former Japan National Railways (JNR) era. But the innovation of operation management in the greater Tokyo area was delayed.

With the formation of JR East, we developed ATOS (Autonomous decentralized Transport Operation control System) in an effort at technical development. Additionally, we improved the operation management system for the Tohoku and Joetsu Shinkansen for compatibility with additional Shinkansen lines and through service between Shinkansen and conventional lines, and we introduced COSMOS (Computerized Safety, Maintenance and Operation Systems of Shinkansen) that has better coordination with other systems.

As for conventional ATC (Automatic Train Control) devices and train radio equipment, we developed and introduced new automatic train control devices (D-ATC for conventional lines, DS-ATC for Shinkansen) and digital train radio equipment both for Shinkansen and conventional lines by incorporating digital transmission technology (see Table 1).
2.2 Current Issues in Train Control and Transport Management

(1) Current Main Issues

Fig. 1 shows the overview and main issues of the train control and transport management system. The system consists of operations facilities such as on-train devices, signalling devices installed along tracks, stations and related facilities, dispatcher’s offices and crew offices, as well as the diversified transmission routes such as the communications network for transport management and signalling cables that connect those devices and facilities, and train radio equipment.

One of the issues that the train control and transport management system has is that the system needs a huge amount of signalling cables (most of those use multi-core copper cables) and lines and conduits that accommodate such cables along the routes connecting signal houses of each station and signalling facilities in stations and along the track. The other important issue is functional improvement to restore the train schedule quickly after disruption for more stable transport, falls under improvement of operation by staff, which is related to transport management. Accordingly, it would be reasonable to address each issue separately.

Table 1: Introduction History of New System and Equipment

<table>
<thead>
<tr>
<th>Year</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1989</td>
<td>ATS-P (Section between Ueno and Oku stations)</td>
</tr>
<tr>
<td>1992</td>
<td>RIOS (Integrated Railway Operation System: transmission of plans)</td>
</tr>
<tr>
<td>1996</td>
<td>COSMOS (Computerized Safety Maintenance and Operation Systems for Shinkansen)</td>
</tr>
<tr>
<td>1996</td>
<td>ATOS (Chuo line)</td>
</tr>
<tr>
<td>2002</td>
<td>Digital train radio for Shinkansen (Tohoku and Joetsu Shinkansen)</td>
</tr>
<tr>
<td>2002</td>
<td>Digital ATC for Shinkansen (Section between Minami-Urawa and Tsurumi stations)</td>
</tr>
<tr>
<td>2003</td>
<td>Digital ATC for conventional lines (Section between Hitomi and Tsuzuki stations)</td>
</tr>
<tr>
<td>2007</td>
<td>Digital train radio for conventional lines (Yamanote line)</td>
</tr>
</tbody>
</table>

(2) Points to be Considered in Addressing Issues

The issue of the huge amount of signalling cabling mentioned above relates to field facilities, so it is closely related to the category of railway train control. The other issue, functional improvement for more stable transport, falls under improvement of operation by staff, which is related to transport management. Accordingly, it would be reasonable to address each issue separately.

Therefore, our basic concept in addressing the issues is individual system changes, separating the category of train control and the category of transport management. As for train control, there are different ways of addressing issues depending on the signalling method, namely, the method using wayside signals (wayside signalling) and the method using the signals on the cab (cab signalling).

3 Addressing Issues According to Train Control Method

3.1 Wayside Signalling

3.1.1 Situation with Installation of Signal Cables

As shown in Photo 1, there is a huge volume of signalling cables to connect control devices such as interlocking equipment in the signal house of each station and signalling facilities in stations and along the track. The volume of that however, differs depending on the number of lines and platforms of each station.

So, when we replace equipment such as interlocking equipment due to aging or for improvement of station facilities, we have to install quite a lot of signalling cables which also entails several times more wiring of core wires than the number of cables themselves and carry out time-consuming connection tests to check wiring.

Any error or omission of such wiring or connection check could possibly cause transport disruption. Troubles that occurred in the continuous grade separation work between Mitaka and Tachikawa stations on the Chuo line is an example of an accident that provides a lesson and something to reflect on for us all concerned in railway signalling.

3.1.2 Measures for Solving Issue

The basic concept of the countermeasure is to shift from the current system where voltage or current via signalling cables controls interlocking equipments in the signal house and field signalling facilities (signals, markers, electric points etc.) to a system where data transmitted through optical fiber cables controls those devices and facilities (Fig. 3).
For the transmission units at both ends of optical fiber cables and the components for branching the fiber cores, we have decided to adopt universal technologies and arrange those to railway-specific requirements to incorporate those in our development.

We have also adopted IP (Internet Protocol) as the data transmission method, aiming to take advantage of universal technologies and to easily catch up with future technical advances.

We have named the new signalling system with these measures the “network-based signal control system”. Now we are making efforts for further technical development and practical application. As a matter of course, the network-based signal control system conforms to the specification to assure high safety and reliability as railway signals components ("failsafe", RAMS (IEC62278), etc.)

### 3.1.3 Current Status of Development and Future Outlook

1. **System in Actual Use**
   
   In order to test a station yard network-based signal control system, we made a test system consisting of a device for the signal house and a field controller(FC) to be installed in or to the field signal device. After the type approval test, we carried out a long-term field test at Tsuchiura Station on the Joban line.

   Photo 2 shows the appearance of the signal device that was installed with a FC inside and the device installed on the inner surface of the rear cover.

   Based on the development results after those tests, we started actual use of a station yard network-based signal control system at Ichikawa-Ono Station on the Musashino line in February 2007 when the relay interlocking equipment of that station was replaced.

2. **System Under Development**
   
   We are proceeding with the improvement of “the network-based signal control system between stations” for actual use, after carrying out field tests near Kitakogane Station on the Joban Rapid Service line.

   We are also addressing the development of the station yard logic device with an aim of centralizing logic devices in the signal house, simplified repair and maintenance of interlocking equipment and design support. And we are making technical reviews of the network control of the crossing protection devices between stations as well.

### 3.2 Cab Signal Method

#### 3.2.1 Technical Trends

The radio communication technology for mobile phones is shifting from first-generation analog to second- and third-generation digital. Railway train radios, too, are shifting from analog to digital both for Shinkansen and conventional lines.

As Fig. 4 shows, the technologies relating to automatic train control are also evolving from ATC analog type automatic train control system to digital type D-ATC/DS-ATC and the ATCS, a new radio train control system.

The largest difference between an analog system and a digital system is that the latter enables an overwhelming large amount of control data transmission. That brings about a big advantage of achieving highly functional automatic train control.

#### 3.2.2 Digital Automatic Train Control

1. **D-ATC for Conventional Lines**

   ATC is an automatic train control system where a train receives a current signal in the voice frequency band sent per designated speed to the track circuit, compares that current signal with the actual train speed, and makes automatic braking if the train speed is higher than the designation of the received signal. The analog type ATC is restricted in that there are limited signal frequency bands to which speed can be allocated. In contrast, D-ATC shown in Fig. 5 is a method to send digital signals by using higher frequency current on the track circuit.

   By replacing ATC with D-ATC, we could achieve improvement of train operation (higher riding quality and shorter traveling time) and simplification of wayside equipment (reduction of signalling cables).

   We started using D-ATC on the Keihin-Tohoku line (the section between Minami-Urawa and Tsurumi stations) in 2003. Then we introduced it to the Yamanote line, and now are carrying out installation work on the Keihin-Tohoku line and the Negishi line (between Omiya and Minami-Urawa stations and between Tsurumi and Ofuna stations respectively).
There are the following three main basic elements in train control.
* Train detection (positioning or detection of pass of cars)
* Route control (change over of in-station turnouts by points)
* Interval control (interval to other train, targets for stopping or speed limiting)

ATACS is the system whereby a train itself detects its position using the running distance information from its wheel rotation and the adjusted position information from transponders. In this way, ATACS enables train interval control other than by a fixed block system (that indicates signals for permitting or prohibiting entrance to protected sections and allowable speed by wayside or on-car indicators).

Since ATACS needs no track circuits for train detection, we are working for its introduction to achieve major reduction of wayside equipment.

4.1 Systems for Transport Management
(1) Transport Plan for Conventional Lines

The Comprehensive Management Information System that was built after the formation of JR East consists of main systems such as the income identification system, the expenditure identification system and the Integrated Railway Operation System. Among those, the Integrated Railway Operation System (IROS) has been developed to systemize the jobs relating to preparation and transmission of train schedules (Fig. 8).

The system has reformed the jobs for transport planning and train schedule management at branch offices and field offices (traditional hand-picking of train schedule information from received notices and hand-writing in the register).

4.2 Transport Management for Shinkansen

DS-ATC, an overview of which is shown in Fig. 6, is a digital automatic train control system for Shinkansen, and we introduced it at the start of operations at the Hachinohe section for the Tohoku Shinkansen (the section between Morioka and Hachinohe stations). Then we further introduced it to the section between Shin-Shirakawa and Morioka stations of the Tohoku Shinkansen. Now we are carrying out installation work on the section between Tokyo and Shin-Shirakawa stations of the Tohoku Shinkansen and on the Joetsu Shinkansen, with the opportunity provided by replacement of aged facilities for those.

3.2.3 ATACS (Advanced Train Administration and Communications System), a New Radio Train Control System

ATACS illustrated in Fig. 7 is a new train control system whereby a train itself detects its position on the line and sends and receives the positioning information over digital radio via wayside equipment from and to other train.

(2) Transport Management for Conventional Lines

JNR introduced Centralized Traffic Control (CTC) and Programmed Route Control (PRC) to local lines, but modernization of management jobs of train control for the lines in the greater Tokyo area was delayed. So, we introduced ATOS (Autonomous decentralized Transport Operation control System) that performs...
train operation management and maintenance work management for
those lines, when we moved and set up dispatcher’s offices (Fig. 9).

We started operation of ATOS first on the Chuo line in 1996. Now
we are expanding operation gradually to other lines in the Tokyo area.
(3) Transport Plan and Operation Management for Shinkansen
COSMOS is a system that adjusts COMTRAC, the operation manage-
ment system for the Tohoku and Joetsu Shinkansen, for compatibility
with additional Shinkansen lines and through service between
Shinkansen and conventional lines. It also centralizes systems dedicat-
ed to Shinkansen such as SMIS (Shinkansen Management Information
System), DECS (Denryoku-keito [power system] Control System),
and CTC as a total optimized system group (Fig. 10).

In COSMOS, the core system related to the transport planning and
operation management of the Shinkansen Transport Dept. and many
other systems for in-station work management, car management,
maintenance work management, power system control, central infor-
mation monitoring and facilities management work and operate
together in good coordination.

After the digitalization of the train radio system for the Tohoku and
Joetsu Shinkansen, we started practical use of the Shinkansen dis-
patch transmission system in 2004. With this system, we edit infor-
mation on train schedule changes and slowdown data in COSMOS
as dispatch transmission information, and then send the edited infor-
mation to the crew of the affected trains via that system. Such infor-
mation, which was traditionally sent and repeated to confirm by
voice through the train radio, is now indicated on the monitors in
the dispatcher’s office and train cabs, and that has achieved quick dis-
patch transmission (actions required to receive) and information
transmission (no action required to receive).

4.2 Addressing Issues Related to Transport Management
(1) Basics of Addressing Issues to Transport Management for
Conventional Lines
As the history of introducing new systems and equipment in Table 1
of section 2.1 shows, the transport management system, the digital
ATC, the digital train radio system and other new systems and func-
tions have introduced into actual use for the Shinkansen earlier than
conventional lines.

The reason is that there are a limited number Shinkansen lines; so,
their technical environment and conditions of facilities are easier to
apply new methods. In this context, it is reasonable to seek a way to
address the issues of conventional lines by adding the particular pur-
pose, facilities and restrictions of conventional lines in consideration
of the practical application and status of new methods for the
Shinkansen. In this way, we can find the themes of the issues and
improvement measures of the transport management for conven-
tional lines as shown on the right of Fig. 11.

In this paper, I am introducing a general overview of the system
change of train control and transport management; and each of the
following development projects on those themes will be explained in
detail later.

* Development of an operation rescheduling system (new algo-
rithms, etc.)
* Development of a locomotive operation rescheduling and sup-
port system
* Verification test of the crew operation rescheduling support sys-
tem
* Development of the crew management support system
* Development and introduction of a digital train radio system
for conventional lines
* Development of a notification system for local lines

(2) Train Diagram and Car and Crew Allocation Management
Since the traffic demand of passengers of each line and section varies
by season, day of the week and time of day, we make transport plans
as comprehensive as possible, and IROS creates and transmits the
daily train schedule based on that plan in advance. In the train operation schedule, usually called the "train diagram", the schedules and routes of trains are indicated with different patterns and figures according to their purpose. What is fundamental in railway transport management is to make the best allocation of sets of cars and crew (drivers and conductors) based on that train diagram and the timetable of each train. In other words, what is essential in transport management is to arrange train operation to recover to the regular schedule as early as possible in case of any disruption.

When the train diagram is changed for some reason, the scheduled plan for the train sets and crew allocation, as well as duties, is also changed. It is the mission for us all involved in train operation to achieve a system and organization that enables the optimization of the train diagram and the operation of cars and crew in good coordination even in any unpredictable situation, whilst minimizing the total influence to transport capacity (the traffic demand of passengers).

We are now proceeding with the development of a system that incorporates a new algorithm to rescheduling operation upon consideration of the effect on transport capacity and works in liaison and coordination with vehicle and crew operation rescheduling support (the improvement of the location identification function shown in Fig. 12).

(3) Efforts for Transport Management and Total Optimization

Achieving the functions explained in the previous paragraph in the next transport management system is the system change for transport management shown in Fig. 2; so, we are making efforts in that direction. Transport management requires each of train crew, dispatchers and workers at stations and offices to conduct their jobs appropriately, because every job is related to train operation in the end. Therefore, it is important to address the following challenges and have them catch on in the best way;

* Education and training of employees concerned in train operation and definition of their roles
* Improvement of functions of transport management systems (both hardware and software)
* Notification of and conformance to rules of train operation

Conclusion

In Japanese society with its falling birthrate and aging population, we cannot expect an increase in customers of our railway business. Our company’s operating environment will be ever more difficult due to that and issues such as more intensified competition in the transportation market. And demands from our customers are more and more refined and diverse.

In such a perspective, New Frontier 2008, the medium-term business plan of JR East Group, states "the JR East Group must offer enhanced services to be chosen by customers", with "emphasis on research and development" as one of six important challenges in basic business operation.

The train control and transport management system of railways provides the essential structure and arrangements for safe and accurate train operation; so, we are required to make further improvement of transport services, while ensuring safe and stable transport. Accordingly, it is important to change the system for railways to enable easy improvement for better transport. And innovation of train control and transport management systems should be achieved for that purpose.

We will contribute to "Further Creation and Evolution" by carrying out research and development along the management policy. JR East will remain a future-oriented, dynamic corporate group, consolidating our internal wisdom and expertise, aiming to be ahead of the times, and keep striving to meet our customers’ expectations.

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