Rescheduling of crew operation in case of disruption of the train schedule requires experience and unerring decision. Furthermore, it often takes time to identify the current position of each crew member and to give information and instructions. In order to support rescheduling of crew operation, we are developing a crew operation rescheduling support system that suggests operational change plans and enables distribution of operational change instructions to mobile information terminals for train crew (PDAs). In this paper, we will introduce the functions developed and the progress of the field tests.

**Keywords:** Rescheduling of crew operation, Algorithm, Mobile information terminal (PDA), location identification, Wireless LAN, PHS

**1 Introduction**

When the train schedule is disrupted, the crew operation schedule also is disrupted. So, crew offices make real-time rescheduling of crew operation according to the rescheduling of trains by dispatchers. Any error in location identification of the crew members concerned, in rescheduling or in delivery of information and instructions adversely may disrupt the train schedule more. There have been actual cases in the past of such troubles, in which location identification of some crew members and delivery of information and instructions took so much time that crew assignment could not be completed in time for rescheduled departure time of some trains. We should point out some reasons behind that are train radios and telephones being the only way of communication between crew offices and individual crew members and that rescheduling of crew operation is done manually relying only upon the attention and experience-based decision of the managers in charge. To address those problems, we have developed a system to support crew operation and are carrying out field tests now.

**2 System Configuration and Functions**

The system configuration and the information flow are as shown in Fig. 1.

2.1 Network Configuration

1) A server for total control of the system is located in the Tokyo General Dispatcher Office and is connected to ATOS (Autonomous decentralized Transport Operation control System)^1^ and IROS (Integrated Railway Operation System).^2^  
2) Universal antennas are installed in the crew cabins of trains, and wireless LAN access points, terminals for crew operation rescheduling and terminals for current location display and communication are placed in crew offices and depots.  
3) Each crew member carries a PDA and accesses the system server at times such as at the beginning and end of the job and when sending location information.

![Fig. 1: Network Configuration](image)

2.2 Information Flow

Information flow can be summarized as follows (Fig. 2).

1) The crew operation rescheduling support system server receives data on the train schedule and crew operation for the day from IROS at 3:00 am every day.  
2) The system server receives information on train delays and operation rescheduling by the dispatchers from ATOS as it is updated.  
3) The system server periodically receives information such as the
course number and the current location of each crew ID number from access points.

4) The terminals for crew operation rescheduling automatically suggest operation rescheduling plans, taking into account delays and cancellation of trains and the predicted train schedules. Upon approval by crew managers on duty, those terminals send out operational change instructions and time table data to each PDA.

5) The terminals for displaying current location show the list of collected current locations of crew members and make periodical updates to that list.

6) Each crew member boards the designated train and uploads the time table data received on his/her PDA to the cab monitor.

2.3 Functions in Detail

2.3.1 Location identification of Crew

We developed different methods to identify the current locations of each crew member. In the field test underway, the system carries out location detection by combining those methods. The details are as follows.

(1) Location Detection via Wireless LAN

PDAs for train crew have a wireless LAN transmission function. So, when a crew member comes near a wireless LAN access point in a crew office, a station office or a train crew cabin (to be installed in future), his/her PDA sends out and registers its MAC address (an ID number unique to each wireless LAN transmission unit) to the memory (an ARP table) of the access point. The system server periodically reads the table data for location identification of crew (Fig. 3).

Fig.3: Location Detection with Wireless LAN

The terminals for displaying current location at crew offices periodically obtain the current location data of crews from the server and displays those in a list. Specifically, it is possible to display the list of crews on trains in the order of their current stations on the line (inbound and outbound tracks separately) and the list of crews at crew offices and station offices. It is also possible to search any specific crew member in those lists (Fig. 4).

Fig.4: Display of Crew Member Location List

At the beginning of the field test, we used PDAs with the wireless LAN function always on. But, batteries of the PDAs actually worked for approx. eight hours only, and sometimes PDAs stopped before the end of the job. Accordingly, we introduced a mechanism to periodically turn the wireless LAN function of PDAs on and off to save power; and that successfully improved the life of batteries to ten and a half hours or more.

(2) Location Detection with Driver’s IC Cards

Since there are no wireless LAN access points on the cab at present, the system carries out location detection using driver’s IC cards. The actual process is as follows (Fig. 5).

* A driver inserts his/her IC card into the cab monitor of the train at the beginning of the job.

* During the job, the cab monitor combines information of the driver’s ID, train ID, car ID and the current location information, and periodically sends out that information to the server to identify the location of the driver.

Fig.5: Location Detection with Driver’s ID Card
(3) Location Detection by Input to PDA when Getting on and off Trains of Other Railways

Since trains of other railways do not have the detection systems described in either (1) or (2), it is impossible to detect the location of the crew when on board such trains. To solve this issue, we added PDAs with the function to input when getting on and off trains of other railways. PDAs send out to the system server information on getting on and off trains that was input by the crew member, and the server combines that with the train location information from ATOS. That allows continuous location detections of trains of other railways.

(4) Location Detection with PHS*

We developed a crew location detection system using PHSs that provides simple location detection (Fig. 7).

2.3.2 Warning of Non-allocation and Operation Rescheduling Plan

When a train is delayed or canceled and operation is rescheduled on ATOS, the crew operation rescheduling support system makes prediction of a new train schedule. After such prediction, the system checks data such as any trains not allocated with crew and the limit of continuous working hours of each crew member, and displays warning messages if there are any problems (Fig. 8). When the system makes out the operation rescheduling plan to solve such problems, it selects one of the following two algorithms according to the situation.

(1) Algorithm for Local Suggestions

The algorithm for local suggestions is mainly used when dispatchers reschedule operation. With this algorithm, the system makes local,
time-series rescheduling of crew operation by substituting with crew members who are on break or with backup crew members (Fig. 9).

In this case, the system also considers the following conditions to secure enough crew.

- Allocating crew instructors
- Continuing work by the crew members who are scheduled to be relieved
- Adding work by crew members who have ended their jobs

(2) Algorithm for Global Suggestions

Global suggestion means the work to return crew to their originally designated courses using the algorithm for global suggestions after completing operation rescheduling by dispatchers. With this algorithm, the crew operation rescheduling support system withdraws scheduled courses of all crew members on and after the current time, and recombines those to return the total crew operation to normal (Fig. 10).

As with the algorithm for local suggestions, the system allocates crew members to each course in the order of priorities in the allocation rules with this algorithm. The order of priorities can be changed as desired. The reasons of selection of algorithms are as follows.

- With the algorithm for local suggestions only, warnings can not be canceled in some cases.
- With the algorithm for global suggestions only, if a train cancellation etc. occurs just after the recombination of all courses and crew members from the start, the system has to recombine courses and crew members again and issue operational change instructions to the crew members concerned. That may cause confusion at the worksite. Either algorithm gives the first priority to suggestions to returning the crew operation to normal, considering restrictions such as the work area of each crew member.

2.3.3 Information Transmission to Crew

In the following cases, the system sends mass e-mail of crew operational change instructions etc. to the PDAs of the crew members concerned.

- When either of the above-mentioned algorithms creates an operation rescheduling plan, and on-site operators in charge make approval inputs
- When on-site operators in charge prepare individual operational notices on the terminals for location display and transmit those notices

Upon receiving such information, crew members have to input reception confirmation. Whether reception confirmation was input or not is sent back to the system server, and the original transmitters can check that on the screens of terminals for location display (Fig. 11).

3 Field Test

3.1 Location Identification and Information Transmission

We conducted field tests on functionality of location identification and information transmission, having all drivers of the Chuo Sobu line carry a PDA (Fig. 12).
In those field tests, we confirmed the effectiveness of method of...
-2.3.1 (1) Location detection with wireless LAN
-2.3.1 (2) Location detection with driver’s IC cards
-2.3.1 (3) Location detection of input to PDAs when getting on and off trains of other railways

We also confirmed the effectiveness of information transmission. In particular, these location identification methods were actually used in train schedule disruption due to an earthquake, and those location identification functions received praise from worksite staff.

For 2.3.1 (4) Location Detection with PHSs, we conducted a survey of the condition of PHS signals along the applicable lines and accuracy of location detection, and the survey results demonstrated that positioning by station is generally feasible (Fig. 13). This method is particularly promising for use on lines not under the control of ATOS.

3.2 Function for Suggesting Operation Rescheduling Plan

In order to verify the algorithms for suggestion, verification has to be repeatedly carried out in many different patterns of train schedule disruption. Based on an instance of actual disruption, we verified the algorithm for local suggestions with worksite staff (Fig. 14).

The verification indicated that the algorithm could perform almost continuous operation rescheduling from the start to the resolution of disruption in the above-mentioned instance.

And we further found the following issues from the test results.

(1) Addressing warnings issued just before rescheduling
Due to the timing of the information reception from ATOS etc., sometimes warnings of non-allocation with crew are suddenly issued. In such a case, there is a possibility that the system operation by operators might not be able to keep up and crew cannot be allocated in time for departure of some trains.

(2) Addressing incidents that the system does not consider
Since the system does not consider sex of crew members, not enough bedrooms for female crew may be available, when the places where the crew stays overnight are changed due to the train schedule disruption just before the last train of the day.

And, since the system does not consider the train schedule of lines other than the Chuo Sobu line, it cannot make reasonable and practical plan suggestions in some scenarios, such as a suggestion to have crews that have finished their work ride along on the trains of the Chuo Rapid Service line that runs parallel with the Chuo Sobu line.

As we received requests such as for improvement of operability of the system, we will continue the field test for practical implementation.

For future practical implementation of the system, we should consider that verification of the suggestion function of the system is not yet complete from the perspective of the absolute number of verified instances and issues not yet solved. So, further monitoring tests are required. And we wish to put the system to practical use as early as possible by overcoming those.

4 Conclusion

For future practical implementation of the system, we should consider that verification of the suggestion function of the system is not yet complete from the perspective of the absolute number of verified instances and issues not-yet solved. So, further monitoring tests are required. And we wish to put the system to practical use as early as possible by overcoming those.

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