Development of a System to Utilize Tablets for Improved Response to Abnormal Situations




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In an effort to further improve transport quality by making use of ICT, we have developed functions to improve response to transport disorders by utilizing tablet PCs for train crews. The three developed functions that were added to the tablets are for “timetable transfer,” “computerization of rule books and manuals,” and “tablet location identification.” In the field tests, all crew members of the crew depot who participated in the tests carried a tablet, and they were able to smoothly use those functions without any serious problem. The transfer of timetables to the tablets in transport disorder enabled us to shorten the time to make necessary arrangements to resume train operation.

●Keywords: Tablet terminal, Timetable transfer, Computerization of manuals, Location identification

1 Introduction

Recent rapid advances in ICT have allowed easy use of the latest technologies through smartphones and tablets. Further improvement of quality of transport and service by use of ICT is thus demanded. At the same time, we at JR East still distribute timetables in case of transport disorder or other abnormal situation manually with hard copies by means such as fax. In some cases, such procedures take time and cause inconvenience to passengers.

In light of that situation, we have conducted technical development to improve response to abnormal situations by utilizing tablets for crews. In this development, we used general-purpose ICT as much as possible and focused on higher reliability, faster development, and cost reduction. The functions developed this time were as follows.

(1) Timetable transfer
(2) Computerization of rule books and manuals
(3) Tablet location identification

2 Functions Achieved Using Tablets

2.1 Timetable Transfer

In the event of transport disorder or other abnormal situation, dispatchers or other persons in charge at each crew depot promptly arrange crews based on an operation rescheduling plan set by the command center. Fig. 1 shows an image of the timetable distribution currently done and after the introduction of the function. When crew members are assigned to a train different from that which there were originally assigned to, they first need to receive the timetable for the train (except on some lines), sometimes causing time-consuming crew arrangement.

In light of that, we have developed a timetable transfer system, aiming at improving response to abnormal situations and thus transport quality, mainly for conventional lines. In this development, we created a function and a user interface whereby crew members can quickly and easily see on the tablet the timetable for the train they are assigned to. We then carried out field tests at an actual crew depot to check operability for crew members and pick up problems that will be faced at deployment. In that, we verified in usage scenes for conductors, drivers, and dispatchers.

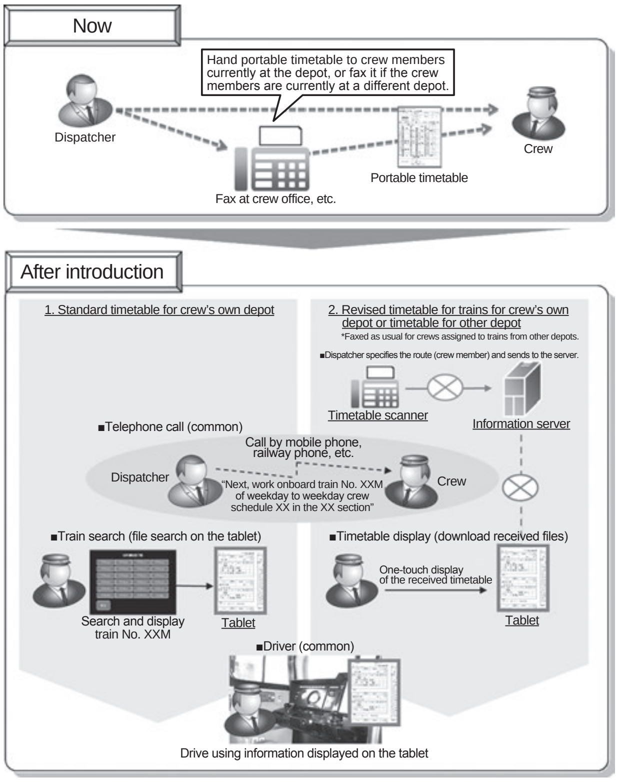

Fig. 1 Image of Current and Future Timetable Distribution

As shown in Fig. 1, this system is composed of tablets for crews, a timetable scanner, an information server and other components. For better operability by crews, the user interface of the application to be installed to the tablets was designed to be similar to the onboard monitor display they are accustomed to using.

Fig. 2 shows an image of screen transition when inputting a crew schedule. Crew members at the depot can register the necessary information to the information server by inputting the number of the crew schedule they are assigned that day to the tablets they receive from the dispatcher.

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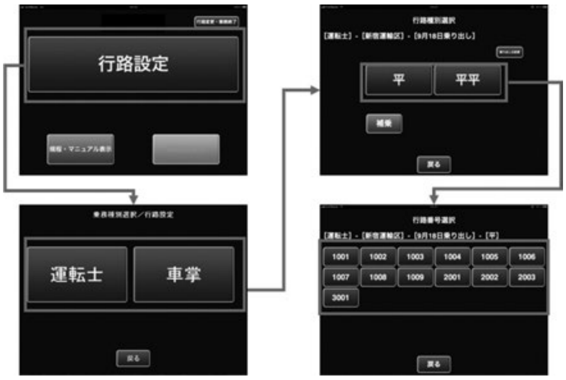


Fig. 2 Screen Transition when Registering Crew Schedule

In the event of a transport disorder etc. and the crew is assigned to a train other than originally assigned, the crew members have to receive the timetable of the train they are newly assigned to (except on some lines). They may receive either of the following two types of timetables.

(1) Standard timetable of the depot normally assigned to
(2) Revised timetable of the depot normally assigned to and timetable of another depot

Fig. 3 shows an image of the timetable screen displayed when on a tablet by a crew member. Fig. 4 is the screen transition when the dispatcher transmits a timetable to the information server.

(1) Standard timetable (2) Revised timetable and timetables of other depots

Fig. 3 Timetable Display Control Screen

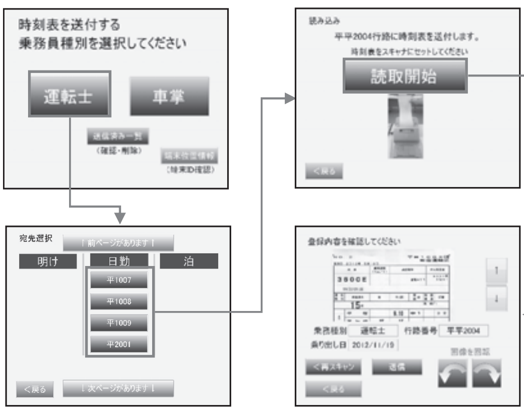


Fig. 4 Timetable Scanner Screen Transition

With timetable (1), all timetables of the depot are stored in the tablets at each timetable revision. In the event of an abnormal situation, crew members choose the timetable of the train they are assigned to and display it on the tablet to be able to operate the new train.

With timetable (2), dispatchers distribute hard copies of the timetables. Next, they specify the route the timetable should be sent to, scanning and transferring the timetable to the information server. Then, crew members access to the information server with a tablet to download the timetable of the train assigned to as instructed by the dispatcher, displaying the required timetable on the tablet. Crew member carries out duties on the train according to the downloaded timetable.

2.2 Computerization of Rule Books and Manuals

Crew members have to carry a variety of rule books and manuals when working aboard trains, including operation guidelines. Drivers also carry a train trouble emergency measures manual, and conductors carry pattern lists for alternative methods of transport. The total weight of those manuals is sometimes as heavy as approx. 2 kg. No matter how many of those manuals are computerized and stored to the tablet, it will not exceed approx. 0.8 kg, the weight of the tablet we used this time. Much materials for passenger service and guidance and for quick recovery from abnormal situations can also be stored. Fig. 5 shows an image of the screen transition when searching rule books and manuals.

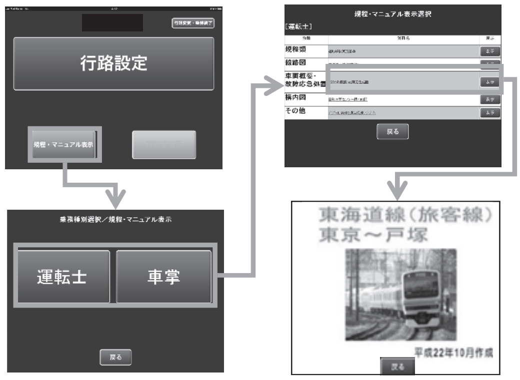


Fig. 5 Electronic Manual Search Screen

2.3 Tablet Location Identification

In the Great East Japan Earthquake on March 11, 2011, we faced serious difficulty in getting in contact with crews to confirm their safety. And if the locations of crew members cannot be accurately identified in the confusion of abnormal situations such as transport disorder, it is difficult for dispatchers to assign duties to crew members quickly.

Many tablets have a GPS function whereby we can identify the location of the tablet in terms of latitude and longitude. Fig. 6 shows the configuration of the tablet location identification system. The location of the tablet is identified based on the latitude and longitude the tablet itself detects and the kilometerage information of the track and railway facilities. Such determination of location is done with the information server used for timetable transfer.

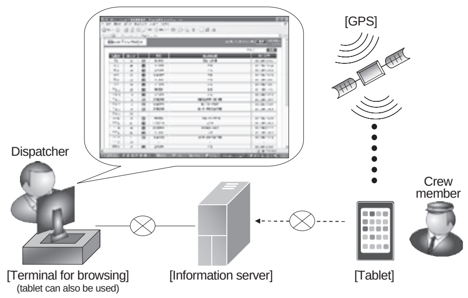


Fig. 6 Tablet Location Identification System Configuration

The procedure of identifying the tablet location is as follows.

(1) The tablet sends its location information (in latitude and longitude) by polling to the information server at a predetermined distance interval or a time interval. Fig. 7 shows an image of location information transmission.

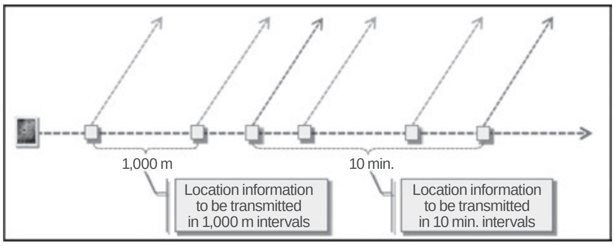


Fig. 7 Image of Location Information Transmission

(2) The information server converts the tablet location into kilometerage of the nearest line. For the conversion, the information server calculates the distance between the tablet location and the line kilometerage, both in latitude and longitude, and determines the kilometerage with the shortest distance to be the tablet kilometerage. Fig. 8 shows the image of the kilometerage conversion.

(3) The line and kilometerage information of individual railway facilities (between stations or within the stations) is registered in advance. The information server checks whether the tablet kilometerage determined in (2) is included on the line to determine whether the tablet location is between stations or within the station.

A possible measure to improve accuracy of tablet location identification is increasing the frequency at which the tablet sends its current location information to the server by reducing the predetermined distance or time interval. The tablet, however, consumes battery power every time it transmits data to the server, so battery power consumption of the tablet increases as the number of transmission increases. We thus worked to verify the optimal value for the interval at which the accuracy of tablet location identification can be improved while keeping battery power consumption in check.

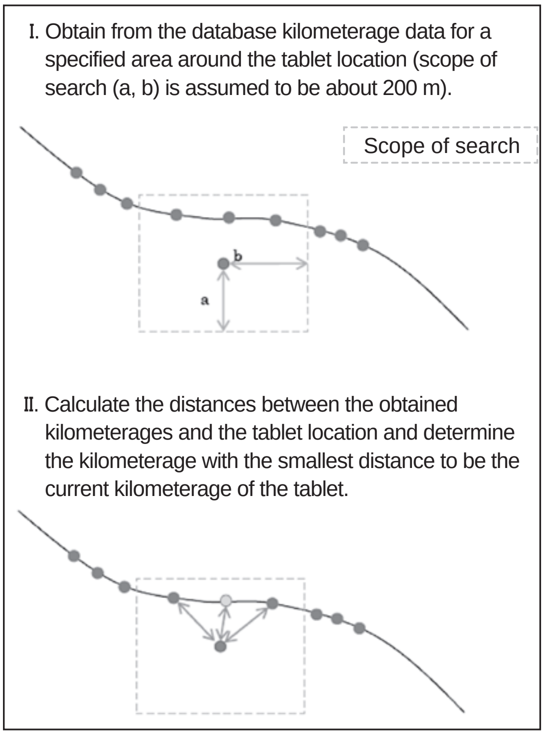


Fig. 8 Image of Kilometerage Conversion

Table 1 shows the battery power consumption when the predetermined time interval parameter was set to 15 seconds. As the tablet cover is closed while not being used in actual operation, we measured the battery power consumption with the tablet cover closed.

Table 1 Battery Consumption

Elapsed time (min.)	Charge level at start (%)	Charge level at finish (%)	Consumption (%)	Elapsed time per one percent of consumption (min.)
150	60	52	8	18.75
150	72	64	8	18.75

From the results above, we predicted that the battery level falls to zero after approx. 31 hours when a tablet with a fully charged battery transmits its location at a time interval of 15 seconds. With such location information transmission at 15-second intervals, the tablet quickly consumes its battery power, and thus there are concerns that the battery might run down when the crew is still on duty, taking into account crew schedules where crew members are on duty for more than 24 hours on some overnight routes. The parameter value that controls the transmission interval therefore needs to be adjusted to the minimum necessary interval.

In light of that, we assumed that a tablet location could be roughly identified by transmitting location information at a 1,000-meter interval while in motion (on duty) and at a 10-minute interval when the crew is off duty at the office. Table 2 shows the conditions of the field tests.

Table 2 Location Information Transmission Setting Conditions

Item	Description
Predetermined distance interval	1,000 m
Predetermined time interval	10 min.

Kilometerage information used for matching was existing data of facilities and tracks for stations and between stations, but we set the kilometerage information of crew offices for the first time. We first set the value for a 20-meter radius, taking the dimensions of crew office buildings into account, and carried out preliminary verification of detection accuracy. The positioning results included some errors due to GPS positioning error or inaccuracy due to base station positioning. For example, we observed a case where a tablet location was identified as being outside, even though it was actually located in the crew office. This was due to the crew office being indoors and high-rise buildings being located around the crew office. However, checking the positioning errors, we confirmed that even the maximum error was within a 200 m radius. As a tablet does not need to be located with pinpoint accuracy, but to be only roughly identified in actual duties, we carried out measurement and result verification again with the value of the crew office area magnified to a 200 m radius. As a result, we confirmed that the tablet location was for the most part correctly matched with the kilometerage information.

Fig. 9 shows an image of the tablet location identification screen. The location information can be viewed on Joi-Net (JR East intranet) terminals and on tablets. We configured the screen to show almost all necessary information on one screen and to enable information updating and narrowing down on the same screen. That way, the dispatcher can easily identify the estimated tablet location in abnormal situations. The screen information is automatically updated every 60 seconds and can be manually updated as well. For quick information search, the displayed information also can be sorted by crew schedule number.

Fig. 9 Tablet Location Identification Screen

3 Field Tests

After the development of the aforementioned three functions, we carried out field tests under the conditions shown in Table 3.

Table 3 Field Test Items

Item	Description
Test period	October 23, 2012 - January 31, 2013
Test details	Step 1: Training in normal situation (with designated trains only) Step 2: Train operation using both tablet and fax transmission in abnormal situation Step 3: Train operation using tablet only in abnormal situation
Test place	Shinjuku crew depot, Tokyo Branch
Test participants	All conductors and drivers of the crew depot
Terminals tested	85 Apple iPads (iPad mini for some routes)

4 Test Results and Analysis

4.1 Timetable Transfer

In the field test period, every crew member carried a tablet, and we were able to obtain relatively good results. The detailed test results are as follows.

In step 1, we carried out a questionnaire survey for the crew after onboard duties on whether or not they got used to tablet operation, and we tallied the survey results per day. The number of the respondents who replied that they got used to operation was about a half in the first week of the field test, but it reached approx. 70% in the last week.

In step 3, we actually transferred timetables to tablets in abnormal situations and the like and used them for driving trains. Particularly, in the case of transport disorder due to heavy snow on January 14 and 15, 2013, we sent train timetables and other data for 30 trains to the crew (22 timetables for trains with changed crew assignments, 8 operation rescheduling plans from the command center). We achieved reductions of the time required for rescheduling in comparison to time with the conventional manner of timetable distribution.

On the other hand, we found the following problems too.

(1) Hard copy timetables are scanned and displayed as image data on the tablet without modifications. So, for some routes with many stations, it is difficult to display the whole timetable on one screen. The tablet cannot display the part of the timetable at the top of the screen with information such as the train number and the number of cars in the train set when the user scrolls the timetable screen to the data for the final destination. Furthermore, unintentionally touching and moving a finger on the tablet display can scroll the screen away from the data the user wants to view.

We thus added a timetable splitting function and timetable locking function in the field test period. With the timetable splitting function, information at the top of the timetable such as the train number is displayed at the same time as information of the stations on the route. With the timetable locking function, the screen is locked to prevent unintentional screen scrolling even if touching the screen. Fig. 10 shows the timetable splitting and the timetable locking functions.

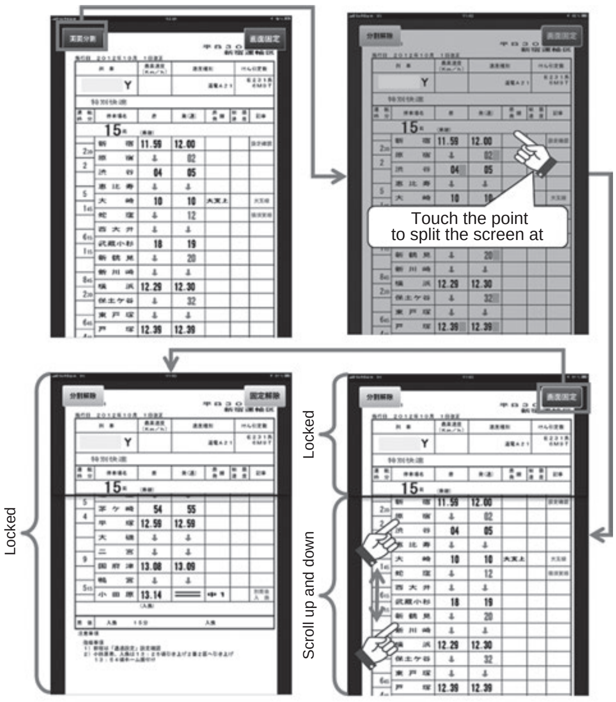


Fig. 10 Timetable Screen Splitting and Locking Functions

(2) Many respondents commented that they had a hard time finding an appropriate space in the cab to place the tablet. For example, drivers replied that they often placed the tablet in locations such as in front of the monitor because the current timetable holder cannot hold the tablet due to the size difference. But when pointing and verbally confirming, that tablet position made for a greater range of eye movement needed compared to with the specified position.

Ahead of practical deployment, we also have to consider modification of the timetable holder to make it compatible with multiple models of tablets or select a tablet of a size the current timetable holder can hold.

4.2 Computerization of Rule Books and Manuals

In the field tests, finally approx. 200 rule books and manuals were stored in the tablet, considerably reducing the weight the crew members had to carry.

Some crew members replied that they could effectively use the computerized rule books and manuals. Such actual comments included "It was useful for immediately checking things I wanted to find out," "I could use it for showing tariffs and the like to customers," and "I was able to study documents and broadcast manuals while in training."

4.3 Tablet Location Identification

We obtained the battery consumption information for a single onboard duty period from the log information at start and finish of onboard duty, and we verified the effects of location information transmission setting conditions shown in Table 2 have on battery consumption. Of the collected log information, we omitted records such as those for onboard duties that finished within an hour of starting and those where the tablet had less than 20% battery level at the start of the onboard duties.

Fig. 11 shows a graph of battery consumption in relation to time of onboard duties. The horizontal axis is time from start to the finish of onboard duties (hours), and the vertical axis is battery consumption shown as the battery level at the start of onboard duties minus the battery level at the end of onboard duties (%). The average battery consumption for 24 hours of onboard duties (overnight crew schedules) was approx. 30%. There were only two cases where the remaining tablet battery charge reached zero at the finish of onboard duties. In one case, the battery level at the start of onboard duties was as low at 40%, and in the other case, the onboard duties continued more than 22 hours and the tablet was often used during that time.

Based on those verification results of battery consumption in usage similar to that of actual duties, we concluded that the setting of the location information transmission interval in the field tests was appropriate for actual operation.

Next, we analyzed and verified the data in the field test period regarding accuracy of tablet location identification. Checking the positioning of tablets of the Shinjuku crew office, we found tablets were often detected as being near the border of the crew office detection scope, and the detected information included location information of tablets in a status other than being within the crew office. For example, the information had tablets in motion on the Shinjuku station platform.

To exclude information of tablets in a different status such

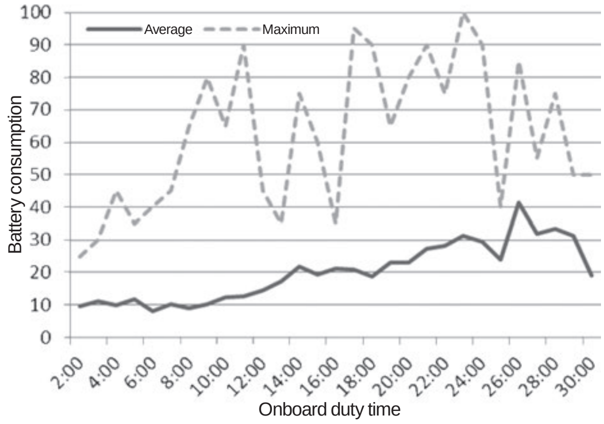


Fig. 11 Battery Consumption and Onboard Duty Time

as being carried on the platform, the crew office detection scope should be narrowed down. But the preliminary test results suggest that narrowing the crew office detection scope down will lower detection accuracy. Thus, in actual deployment, the tablet should be provided with processing where the location is identified taking into account movement to improve accuracy in determining whether the carrier of the tablet is moving or staying in the crew office. More specifically, the processing should check not only the current location of the tablet, but also the movement history. For example, the tablet location will move when the tablet carrier moves on the platform, while the tablet location will probably stay at the same point when the tablet carrier is on a break in the crew office.

Other problems found out in the field test are as follows.

(1) It is difficult to receive GPS signals in underground sections such as between Tokyo and Shinagawa on the Yokosuka Line and in the Tokyo station underground crew office. So, tablet location identification and consequent matching with the line was wrong, and the tablet location screen displayed the tablet as being on the wrong line, such as "between Tokyo and Shinagawa on the Tokaido Main Line." For such locations including underground crew offices where receiving GPS signals is difficult, we need to consider introducing detection using RFID tags and the like for actual deployment.

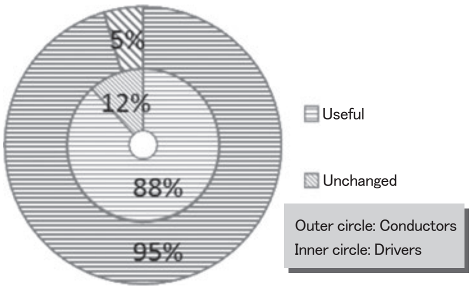
(2) In sections with parallel lines, matching of the line the tablet was on sometimes was incorrect. For example, the Tokaido Line and the Tokaido Freight Line run parallel between Ofuna and Odawara. The matching result is based on the latitude and longitude identified by GPS, so the tablet location identification screen in some cases indicates the line as being the Tokaido Line and in other cases as the Tokaido Freight Line. As there are many other sections with lines in parallel, processing to narrow down the line based on the route at matching has to be added in actual deployment.

5 Questionnaire Results

We carried out a questionnaire survey for all crew members (conductors and drivers) and dispatchers of the Shinjuku crew depot after the field tests.

(1) Compared with traditional hard copy based timetable distribution, do you find the timetable transfer function more useful in abnormal situations?

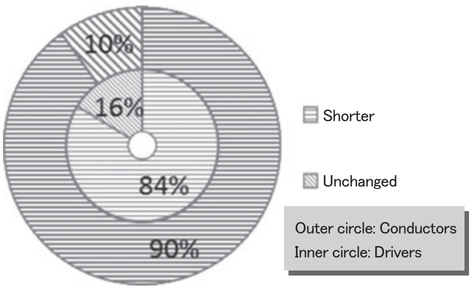
(Reply options: useful, unchanged, not useful)



Many conductors and drivers replied that the function is "useful," and all of seven dispatchers replied so too.

(2) Compared with traditional hard copy based timetable distribution, was the time it took you to receive the timetable shorter?

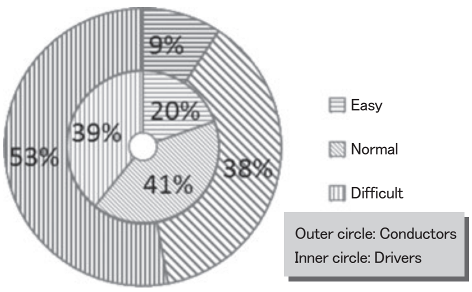
(Reply options: shorter, unchanged, longer)



Many conductors and drivers replied that the time required was "shorter," and four out of the seven dispatchers replied "shorter" and two "unchanged." A dispatcher also requested a function be added to the timetable scanner to allow the crew members to know when the transferred timetable is received by the tablet. Adding this reception check function for crews will facilitate smoother timetable transfer in actual deployment.

(3) Could you easily find the necessary manual or other document?

(Reply options: easy, normal, difficult)



Many conductors and drivers replied that it was "difficult." In the field tests, users had to choose the manual etc. from the index because the tablet did not have a keyword search or other search functions. As more manuals are stored, even longer time is needed to find the desired one. The necessary manual must be found quickly in abnormal situations or when giving guidance to passengers, so we have to improve the search function in actual deployment.

6 Future Issues

As many crew members will carry and use tablets at work in the future, the following issues have to be studied.

(1) Battery level

Tablets are very useful from a perspective of work improvement and information sharing, so a variety of applications will need to be installed. With more applications and longer use time, the battery level of the tablet will naturally decrease, possibly leading to it not being usable in case of emergency. We thus need to verify the most efficient way to secure tablet battery capacity. Examples of such methods include reducing battery consumption by individual applications and utilizing innovations such as wireless battery charging.

(2) Terminal management (security)

As more applications are installed, the probability of important data concerning train operation being stored in the tablet increases. In the future, terminal management will become more important. For example, if a tablet is lost, the data needs to be deleted by remote wipe or similar function before the data can be leaked.

7 Conclusion

We have developed and tested three functions to be provided to tablets to improve response in abnormal situations, and we obtained mostly favorable results. Incorporating the findings of development and testing, we are planning for all crew members (conductors and drivers) to carry tablets for use in case of transport disorders, for use as computerized manuals and rule books, and to improve service quality such as when providing guidance.

Into the future, we will further improve response to abnormal situations so as to quickly resume operations by utilizing the latest technologies such as tablets. And to accomplish that, we will speed up development for improving transport and service quality.