Train congestion has a significant impact on customer satisfaction, but current response in time of transport disorders is to select which train to cancel or adjust only based on delay information and experience of past accidents. In this study, we have developed a congestion level visualizing system for the dispatcher’s office to quantitatively identify congestion and delay of trains in real time that can be utilized in transport operation. Utilizing the system, dispatchers achieved a reduction in the maximum congestion rate by 31.4% and of the average congestion rate by 18.6% in some cases.

**Keywords:** Conventional line, Variable load, Visualization, Operation rescheduling

### 1 Introduction

In the event of a transport disorder, dispatchers in charge of train operation control decide on operation rescheduling taking into account various constantly changing parameters, such as delay time, train locations, and congestion level, to minimize impact of the transport disorder.

Of those parameters, real-time quantitative data on delay time and train locations is provided from existing transport management systems and the like. Congestion level, however, is often judged by individual dispatchers based on their own rules formed from past experience because there is no system that allows us to quantitatively identify congestion level.

On the other hand, a survey of customer satisfaction (CS) we carried out revealed the CS level regarding congestion level of trains in JR East’s operation area is low, greatly affecting total satisfaction with JR East. Train congestion level is thus positioned as an issue that needs prioritized improvement (Fig. 1).

In other words, if we provide an environment where dispatchers can make more proper operation rescheduling decisions based on qualitative congestion information, we can offer more flexible transport service that lowers congestion of trains. And that consequently will improve CS.

Reports of past research on information provision for train congestion include that on providing congestion information to passengers of streetcars by Tomoyuki Todoroki et al. and research on the effectiveness of modeling of train selection behavior of railway passengers when congestion information is given. However, there are no reports of research whereby congestion information is utilized for actual railway dispatch operation and the effectiveness of that is verified.

We therefore developed a prototype congestion visualization system for conventional line trains that allows us to identify train congestion level in real time quantitatively and that enables dispatchers to apply congestion level to operation rescheduling and information services for passengers. In this paper, we will report on the overall configuration of the system developed and the results of evaluation in proving tests of the system.
which are important indicators for train operation control, to enable three types of information (passenger load factor, train location, and delay time) to be visualized. Passenger load factor information only becomes useful for operation control when confirmed together with train location and delay time, so we arranged the data of congestion information, train location, and delay time on the same screen. If that data were provided from separate systems, dispatchers would have to read the information by viewing different systems.

The prototype system mainly consists of the following two components.

- Server for collecting information on the number of passengers onboard and ATOS information
- Congestion level visualizing terminal for dispatcher’s office

Next, we will explain the functions and features of the above two components.

2.1.1 Server for Collecting Information on Number of Passengers Onboard and ATOS Information

Fig. 3 shows the functional structure of the server for collecting information on the number of passengers onboard and ATOS information. The server every 30 seconds collects train locations and delay time from the ATOS information distribution system and train locations and numbers of passengers onboard from the passenger volume counting and searching system, and it combines that data and registers the combined data to the database as visualized data. Passenger capacity information for each car is registered to the database in advance.

The server transmits the data (real-time or past data) needed for data visualization as requested by the congestion level visualizing application (congestion level visualizing terminal).

2.1.2 Congestion Level Visualizing Terminal

A dedicated client application developed in this study (congestion level visualizing application) is installed to the congestion level visualizing terminal to be used in the dispatcher’s office. Congestion level is visualized for a total of 12 lines: Keihin-Tohoku/Negishi, Yamanote, Saikyo-Kawagoe/Yamanote freight, Joban, Joban local, Chuo/Sobu local, Chuo main, Yokosuka/Sobu rapid, Tokaido main, Utsunomiya, Takasaki, and Tohoku freight lines. On those lines, visualized congestion level information can be provided to dispatchers for identifying status in transport disorder, reviewing past operation rescheduling, information sharing, and the like. The congestion level visualizing terminal has the following functions.

(1) Display mode selection

The terminal has two modes: real-time display mode and past data display mode. In real-time display mode, the latest data of the day is displayed and updated at every 30 seconds. In past data display mode, users can also display animated data from the first train up to the time of the day data is requested.

(2) Display format

As mentioned above, this system has to visualize three different types of information (train location and delay time as well as passenger load factor) on the same screen, so effective use of icons colors and sizes and of text is needed. In development of the user interface (UI), we therefore adopted “agile software development” whereby we repeatedly interviewed dispatchers (users) to improve UI design.

Fig. 4 to 6 show the UI finally completed. It has two display modes: map display mode and a line occupation display mode. In the map display mode, users can change the viewpoint using a mouse and zoom in and out on the map. With a large area displayed, users can easily focus on congested trains and confirm locations of individual trains by zooming in as shown in Fig. 5. In the line occupation display mode, as shown in Fig. 6, users can display trains of multiple lines using a function that displays trains in a line.

(3) Display delay

The prototype system developed this time displays the data from two existing different systems: the ATOS information distribution system and the passenger volume counting and searching system. The data of numbers of passengers onboard is obtained with a delay of approx. 3 minutes because the data comes through many different systems, while the data of train locations and delay time from the ATOS information distribution system is obtained...
within a 30 to 40 second time lag. Furthermore, the server for collecting information on the number of passengers onboard and ATOS information needs to execute processes of combining that data from the two systems and registering it to the database.

For that reason, in the real-time display mode of the congestion level visualizing application for dispatchers, data of three to four minutes before the current time is displayed.

3 Evaluation of the Developed Prototype System

In order to evaluate the congestion level visualizing system for the dispatcher’s office, we installed the developed congestion level visualizing terminal in the Tokyo general dispatcher’s office, which controls operation on major lines in JR East’s operation area in the greater Tokyo area, and carried out proving tests. The effects found in the tests and the issues to be overcome for practical use found in the proving tests are shown in (1) and (2), below.

(1) Effect on alleviation of congestion level in transport disorder

The number of train runs was reduced on September 10, 2015 (Thu.) because speed control was implemented from the first train of the day between Mamada and Oyama stations on the Utsunomiya line due to heavy rain. The developed system showed that inbound morning commuter trains (heading toward Ueno) between Utsunomiya and Omiya stations were constantly congested. The dispatcher’s office thus adjusted the number of train runs the next day, September 11 (Fri.), to alleviate the congestion.

Table 1 shows the change in congestion alleviation rate after the above-mentioned operation rescheduling. The congestion alleviation rate was calculated by the following formula.

\[
\text{Congestion alleviation rate } \rho = \left(1 - \frac{\text{passenger load factor of given train}}{\text{passenger load factor of train to be compared with}}\right) \times 100
\]

With the inbound trains between Kuki and Omiya stations (heading toward Ueno) on September 11 (Fri.), the congestion alleviation rate of the train with the highest passenger load factor in the period from the first train of the day to 10:00 am was 31.4%, and the average congestion alleviation rate of the period was 18.6% when compared with the rate of the previous day (September 10 (Thu.)). This proved that adjusting the number of trains and the like referring to this system could alleviate congestion level of trains in transport disorder.

(2) Results of questionnaire to dispatchers

Responses to a questionnaire to dispatchers revealed that approx. 90% of the dispatchers referred to the system for operation rescheduling by delaying trains (intentionally delaying previous trains when train intervals become large due to transport disorder and the like for the purpose of preventing longer delay due to train congestion).

<table>
<thead>
<tr>
<th>Between stations</th>
<th>Congestion alleviation rate on Sep. 11 (Fri.) compared with the same time slot on the previous day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Departure</td>
<td>Arrival</td>
</tr>
<tr>
<td>Kuki</td>
<td>Shin-Shiraoka</td>
</tr>
<tr>
<td>Shin-Shiraoka</td>
<td>Shiraoka</td>
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<tr>
<td>Shiraoka</td>
<td>Hasuda</td>
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<tr>
<td>Hasuda</td>
<td>Higashi-Omiya</td>
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<tr>
<td>Higashi-Omiya</td>
<td>Toro</td>
</tr>
<tr>
<td>Toro</td>
<td>Omiya</td>
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<tr>
<td>Average</td>
<td></td>
</tr>
</tbody>
</table>
The major basis for deciding delaying trains is passenger load rate and train interval. We assume that dispatchers refer to the system often because it is the only system that simultaneously provides that data.

Dispatchers also began utilizing the system for other diverse purposes. For example, they reviewed transport arrangements in transport disorders using the past data display mode and referred to it for future operation rescheduling.

Meanwhile, responses to the questionnaire clarified the following issues and points to be improved.

(a) Dispatchers have no time to refer to the system to make arrangements in large-scale transport disorders.
(b) By shortening display delay, accuracy of arrangements such as delaying trains could be improved.
(c) The system needs to be able to display out-of-service trains and freight trains the dispatchers take into account in operation rescheduling.
(d) If kilometerage were displayed, dispatchers could identify the order of priority for restoring operation of trains in a disaster or other transport disorder.
(e) By making the terminal portable, persons other than the designated dispatchers could view the information, expanding utilization of the system.

4 Conclusion

In this research and development, we were able to design a system that front-line dispatchers could utilize sufficiently for their work by adopting the agile method in the development process, even though the system is still a prototype.

Utilizing the developed system for work of dispatchers demonstrated that the system can be effectively used for operation rescheduling (delaying trains in particular) because the system can quantitatively identify congestion level of trains and delay time. In the transport disorder due to heavy rain during the proving tests, the information of the system was used as the basis for decision-making, resulting in considerable alleviation of congestion.

In light of those results, we believe that the system will be indispensable for achieving the customer-oriented flexible transport service JR East aims for. Visualization of information on congestion level of trains may help not only dispatchers, but station personnel as well, in providing appropriate customer guidance.

Furthermore, spreading the service to direct distribution of congestion information by means of passengers’ mobile information terminals and the like will improve CS. That will also allow passengers to avoid congested trains themselves, thus leveling overall congestion level of railways.

We will continue working on improvement and verification of functions in order to overcome the issues found in this study, and we will search for ways to expand utilization of the system.

Reference: