Improving the Train Diagram of the Tokaido Shinkansen
—Development of New Timetable Planning System

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1. Introduction

As the main artery of the Japanese railway network, the Tokaido Shinkansen, operated by Central Japan Railway Company (JR Central), links Japan’s principal metropolitan areas of Tokyo, Nagoya, and Osaka. The Tokaido Shinkansen is currently used by approximately 138 million passengers per year and has played an important role in Japanese economic, social and cultural development as a means of high speed and mass transport.

The Tokaido Shinkansen consists of three types of trains, all of which have different stopping patterns: from the fastest to the slowest, Nozomi, Hikari, and Kodama. The basic patterned schedule for an hour consists of nine Nozomi, two Hikari, and two Kodama, operating 400 trains a day during the peak period. In spite of complicated and densely scheduled train operation, the average delay time per train of the Tokaido Shinkansen is only 0.5 minutes (FY2009). One of the key factors to achieve this accurate transport service is traffic control system of Tokaido Shinkansen, called COMTRAC (Compute-Aided Traffic Control system), which includes timetable planning system.

To achieve a densely scheduled train operation, equipment conditions (wayside equipment arrangements, rolling stock performance and so on) have been improved continuously. To meet more increased passengers’ demand in the future, the train diagram should be more densely scheduled and equipment conditions also should be improved.

However, the equipment conditions improvements have been already made for number of years, and as a result further examination of equipment conditions, which enable even more densely scheduled train diagram, is becoming extremely difficult. To solve this problem, we have developed a new timetable planning system “Train Setting Simulation system”. This system enables JR Central to examine the equipment conditions exactly and efficiently, which satisfies the optimal train diagram.

2. Former process to make the train diagram

The process to make the train diagram before developing the system was as follows.
1. Using the Headway Calculating system, one of the COMTRAC subsystems, the station-to-station running times and the minimum headway times are calculated on the basis of equipment conditions.
2. Based on the calculated station-to-station running times and the minimum headway times, the basic train diagram will be made with assistance of Diagram Planning system.

By this process, a suitable train diagram with the present equipment conditions can be made, but it is not always the optimal train diagram. The optimal train diagram can be achieved by studying how to improve equipment conditions. However it is a very difficult task with the existing system. Indeed the following process should be done over and over: change the basic data of equipment conditions, calculate the minimum headway time and station-to-station running time, and check the available train diagrams. It is a very inefficient and time consuming process. Figure 1 shows the former process to make the train diagram without the Train Setting Simulation system.
### 3. New process using Train Setting Simulation system

To solve the problem above, we have developed a Train Setting Simulation system. This system allow user to easily examine the equipment conditions on the way to obtain optimal timetable. The new process to make the train diagram using this system is as follows. Figure 2 shows the new operation process.

1. Using the Diagram Planning system, the optimal train diagram, which reflects passenger's demand, is made without the restriction of present equipment conditions.
2. The Train Setting Simulation system acquires the train diagram from the Diagram Planning system.
3. The Train Setting Simulation system acquires the present equipment conditions from the Headway Calculating System.
4. The Train Setting Simulation system calculates the station-to-station running time and the minimum headway time based on the present equipment conditions.
5. Using the time calculated above, the train diagram is checked and the time-shortage points (for example headway shortage, running time-shortage) are extracted. If there is such time-shortage point, the optimal train diagram is not feasible. Figure 3 shows examination result screen in the format of train diagram with red text indicating time-shortage point.
6. If the operator clicks the time-shortage point in the examined result screen, the detailed examination screen appears. The detailed examination result of the extracted points is displayed as a running profile drawing and minimum headway drawing. By this screen, an operator can find out which signaling block causes the time-shortage point and can examine the solution (such as which boundary should change). Figure 4 shows the detailed examination result screen of minimum headway. In Figure 4, the yellow lines indicate the time-shortage points of headway, and red line indicates the worst time-shortage point of headway.
7. In order to eliminate the time-shortage points, equipment conditions. For example, headway shortage
might be eliminated by changing the signaling block boundary or speed limit. The operator sets the range of such equipment conditions' change, and within the range, the system calculates and proposes adjustments to the equipment conditions such that the time-shortage point will be eliminated.

8. From the proposed adjustments displayed by the system, the operator selects and inputs the best solution which eliminates the time-shortage point.

9. Until entire time-shortage points are solved, the operations from step 4 to step 8 will be repeated. And finally the improvement plan of equipment conditions which satisfy the optimal train diagram will be acquired. Figure 5 shows the process of eliminating time-shortage points by repeating equipment conditions' change.

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**System**

1. **Diagram planning system**

   - 1. Making the train diagram
   - 2. Input the equipment conditions
   - 3. Check the time-shortage points
   - 4. Verify the detailed information. Set the conditions and execute automated proposal
   - 5. Verify the proposed results and decide the final result
   - 6. Verify details
   - 7. Automated proposal
   - 8. Select from the proposals which improve equipment conditions (plural proposal)
   - 9. Results of equipment conditions

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**Operation**

1. The optimal train diagram

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**Data**

- A: Station and route
- B: Way-side equipments
- C: Rolling stock performance and so on.
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Figure 2: New operation flow
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Figure 3: Examination result screen of train diagram

Figure 4: Detailed examination result screen of minimum headway
4. The development of Train Setting Simulation system

Train Setting Simulation system has been developed as a subsystem of the traffic control system of Tokaido Shinkansen which is called COMTRAC. Therefore this system is able to obtain fundamental data such as train diagram and equipment conditions from other subsystem of COMTRAC.

To make the Train Setting Simulation system easy to use, we worked in the following improvements.

1. Speed up the calculation times

   If the system calculates the train running profile and minimum headway of all trains in the train diagram, it will take too much time. To solve this problem, the system analyzes the train diagram before calculation. Figure 6 shows the example of picking up the same pattern. If following conditions are realized, the system judges that train 3A & 5A and train19A & 21A from station A to station C have the same pattern.

   1. Train 3A and train 19A have the same stopping pattern, platform and rolling stock performance.
   2. Train 5A and train 21A have also the same stopping pattern, platform and rolling stock performance.

   Trains with same pattern will be calculated just once. In the case of Figure 6, only train 3A & 5A will be calculated. By this process, the quantity of calculation diminishes and calculation times are reduced.

   For example, the calculation time of all trains from Tokyo to Osaka all day long (about 400 trains) is about 37 minutes 40 seconds without the above method. With the above method, the calculation time goes down...
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to 4 minutes 10 seconds. (The computer of this system has dual core 2.8GHz CPU, and 8G RAM.)

(2) Automated proposal function
When the operator tries to revise the improved equipment conditions, there are too many combinations of equipment conditions, and it is almost impossible to input various combinations.
If there are time-shortage points of minimum headway, there are some methods to shorten the headway as below.
1. Change boundary of signaling block or increase the signaling block
2. Change performance of rolling stock such as acceleration and deceleration
3. Change speed and the extent of the speed limit
Taking into account of above changes, there will be many combinations, and it takes too much time if the operator changes data and calculates over and over.
To solve this problem, we have developed an automated proposal function. In this function, the operator sets maximum ranges of change to the equipment conditions such as maximum range of change to the boundary of signaling block. With the entered conditions, all patterns of station-to-station running time and minimum headway are calculated, and the function proposes the solution. The operator selects the optimal one from proposed solutions and the entire train diagram is checked again to find out whether the other time-shortage points are solved. Figure 7 shows an example of automated proposal function, and Figure 8 shows the sample of automated proposal screen.
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All patterns are calculated

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Figure 7: Example of automated proposal function
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Figure 8: Automated proposal screen

(3) User friendly man-machine interface

There are various equipment conditions in this system and it is difficult to input the data of all equipment conditions correctly. To solve the problem, we have developed a data input function which supports the input of equipment conditions’ data visually. If the operator wants to change the data of equipment conditions, this function changes the data of related equipment conditions at the same time. Figure 9 shows the sample of wayside equipment editing screen, which enables mouse operation if operator wants to change the equipment parameters.

Figure 9: Wayside equipment editing screen

5. Conclusions

The Tokaido Shinkansen is the most densely scheduled high-speed railway in the world and so it is almost impossible to increase the frequency without improving the equipment conditions. However, equipment conditions improvements and the frequency increase have been done in past years and its examination is becoming very difficult and time consuming. Train Setting Simulation system has been used since 2008, and the new process of examining the Tokaido Shinkansen train diagram has begun. By developing Train Setting Simulation system, wide range of equipment conditions’ improvements can be examined, and as a result the examination of the optimal train diagram can be realized.

We should continuously serve the needs of passengers and improve the typical service level of the train diagram. By providing the optimal train diagram examined by this system, we can contribute to improve the service level of the Tokaido Shinkansen.

References