Train operation control system for high-speed railway

by YOSHIRO HAYASHI and SHIGEO YOKOTA
Japanese National Railways
Tokyo, Japan
and
TAIZO NAUCHI
Hitachi, Ltd. Head Office
Tokyo, Japan

INTRODUCTION

It was in 1964 that the Shinkansen made its debut between Tokyo and Shin Osaka. It was extended westward to Okayama in March 1972 and then on to Hakata in March 1975. It is now a more than 1,000-km long traffic artery of Japan and is functioning smoothly.

Constructed as a safety-performance high-speed means of passenger transport en masse in great comfort, the Shinkansen has proven its worthiness, playing a vital role in the economic and social growth of the nation. To have it play its part, the latest technical achievements are introduced to produce its rolling stock, track, electric facilities, etc. and control the operation of these aided by computer. It may be said that the Shinkansen is a typical modem railway operating under a total system.

In this paper, the conditions needed of the train operation control system for a high-speed mass-transport railway and how to meet these conditions will be explained.

DEVELOPMENT OF TRAIN OPERATION CONTROL SYSTEM

The Shinkansen calls for a train operation control system, vastly and basically different from that for conventional railways. One of the conditions attributable to the difference is the incomparable high speed. Here the conventional way of the driver operating his train by keeping his eyes on the wayside signal indications would never work. For this reason we employed the cab signal system together with, what is called, ATC (Automatic Train Control). To meet another condition of mass transport, there is CTC (Centralized Traffic Control) at work, though this is not entirely new. However, when it comes to a high-speed mass transport, like the Shinkansen, CTC has been proved to be an effective means of smooth dispatching and transportation. With the apparatus for these systems and the conventional interlocking device, the Tokaido Shinkansen was opened in 1964.

As the number of trains increased after 10 years, the CTC alone could not help the dispatches owing to a flood of information coming into the control center; therefore, CTC had to be backed up with computer. That is to have the computer do as much as possible to control train operation, collect data, classify these and do the transmission and to have the dispatchers devoting themselves to the job of making judgments by using the computer at will. To meet this demand, COMTRAC (Computer-aided Traffic Control System) was introduced.

OUTSTANDING FEATURES OF TRAIN OPERATION CONTROL SYSTEM

In order to operate high-speed trains in large numbers, safely, precisely and efficiently, the basic requirement for train operation control is to have all the elements of the system work together smoothly under prescribed plans (train diagram and working schedule).

With the trains that run on given rails, unlike any other modes of transport, it is clear that high efficiency can be obtained when they are operated under a meticulously planned diagram, instead of in a haphazard way. Even when confusion takes place for some reason, it is possible for all the elements of the control system to get down to work as a whole with the single purpose of "restoring the prescribed plan." One of the outstanding features of train operation is that it works as all planned out.

When train operation is disrupted seriously by a train accident or a natural disaster, it also is possible under the control system to command all its elements to partially change the plan.

Unlike other industries in general, train operation is a commodity that cannot be kept in stock. It has to be provided to suit the demand of the passengers. Overall revision of train diagram once in two to three years and quarterly minor revisions, therefore, are taken in as a matter of course. The train operation system with these features is shown in Figure 1, divided into three functions of Planning, Doing & Seeing.

1249

From the collection of the Computer History Museum (www.computerhistory.org)
COMTRAC

Basic concept of reliability design

Various functions shown in Figure 1, closely link themselves together to do the functions. When the reliability, data quality, massiveness of data handled and response time are arranged, we have Figure 2 (COMTRAC Reliability Characteristics). The whole Operation Control System is seen here in a stairway structure, the lower the step, the higher in reliability and the more real time-like. The higher the step, on the contrary, the higher in data accumulation and in judgment complication. Another point to be noted is that the Operation Control System is so made up that once the upper-step function fails out, a lower step fall-back part of the function has failed out.

With this adapted, the stairway structure is taken in the COMTRAC System. As higher reliability and response are demanded of lower functions and as higher-step functions demand more data accumulation and judgment complication, the functions of the system are divided into two groups according to the evaluation criteria. That is, into one group of those functions that strongly demand reliability and responsiveness to be accommodated in the route control system and the other group of functions demanding all sorts of data and others higher-level judgments in the operation adjustment system. As upper level functions call for more and more of those data that the computer is incapable of handling and more and more of human judgment, a man-machine system is needed, leaving the lower-level functions calling for less human intervention to be performed by an automatic system.

COMTRAC functions

A new train traffic control system with computer control is schematically shown in Figure 3. Among many functions necessary for the traffic control, COMTRAC is so designed...
that it can perform the following functions consisted of five subsystems.

1. Planning Subsystem that compiles the plan to implement train and rolling stock turnarounds in accord with the basic and extraordinary plans for train operation.

2. Dispatching Subsystem that monitors whether trains are being operated normally according to the train operation diagram prepared for the day by the Planning Subsystem. On detecting a diagram confusion, the computer automatically renders judgment, if the case is a simple one. If the confusion is serious, due to a train accident, for instance, the train diagram for four to five hours is predicated by simulation and the system prepares a train diagram thereafter and indicates it on GD (Graphic Display). Diagram modifications as decided through the computer are automatically transmitted from time to time to places concerned.

3. Route Control Subsystem that traces each train as diagrammed by the Planning and the Dispatching Subsystems and automatically sets its route. It also monitors the signals in all the stations.

4. The Subsystem to provide data for station announcements. Automation of route control enables the system to detect train positions and train delays, and the information is made use of in making station announcements. The train-to-leave signs on the platforms are automatically controlled, too.

5. Statistics Analyzing Subsystem that prepares all sorts of reports on trains operated and compiles reference materials for administration.

In producing a computerized system for the functions explained earlier, the degree of reliability and the response time demanded of each function should be clarified and the unique characteristic of each function need be taken fully into consideration.

The route control system that is directly concerned with train operation is completely a process-control system, setting train routes by the data gathered in the Center by CTC and in accord with the train diagram. It being the last output part of COMTRAC, the highest reliability is demanded of it and the data handled here also must be high in reliability.

The Dispatching System detects diagram confusion by tracing each train with the data provided by the Route Control System and then it really starts displaying its function. As the automatic judgment portion of it is considered to be similar to the monitoring function in the case of train operation, we thought it be better performed under the Route Control System and set one minute as the target for the response time for the diagram simulation function. As for the data transmission function, we thought it hardly matters if acknowledgment of its receipt is made of a change in the plan within several minutes at the worst after the change is decided upon.

The Dispatching System is to be made up as man-machine system as stated before, with man-machine interface centering around GD (Graphic Display) for complicated judgment simulation and around CD (Character Display) for simple item simulation. It is made up as a multicomputer system with two divisions, one a highly reliable system, centering around route control and the other a data processing system centering around train operation adjustment with man-machine equipment included and the fall-back idea partly taken in, as is shown in Figure 4.
TABLE IV.—Availability

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>System</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>99.93</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>99.99</td>
</tr>
<tr>
<td>Availability</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dual</td>
<td>99.89</td>
<td>100</td>
<td>100</td>
<td>99.85</td>
<td>99.96</td>
<td>99.84</td>
<td>100</td>
<td>99.90</td>
<td>99.69</td>
<td>99.97</td>
<td>99.92</td>
<td>99.92</td>
<td>99.92</td>
</tr>
<tr>
<td>Availability</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of system down cases</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

(Remark: The one case of system-down was due to software bug)

With this make-up, the Route Control System is as reliable as CTC with the target of 99.99 percent set for the working efficiency, and the Train Dispatching System, also with the target of 99.9 percent, downtime within 10 minutes.

To attain these targets, a 2-out-of-3 computer system was developed for the Route Control System, and a DSC (Dual System Controller) for the Train Operation Control.

As the Train Dispatching System handles a great number of data for many hours, two large-sized computers are introduced for duplex operation.

EFFECTS OF SYSTEM INTRODUCTION & WORKING COEFFICIENCY

In carrying on high-speed mass transport the best way to secure efficiency, safety and preciseness is to perform all the jobs concerned under single command, based on the diagram prepared by the Train Diagram Planning System.

Thus, when a computer system takes care of diagram planning with infallible data, the following effects can be expected:

(1) Infallible train control is possible (Prevention of route missetting)—Prevention of such accidents as train collision to preserve safety is ensured by ATC and interlocking device on the spot. However, missetting of routes for high-speed mass transporting trains gives rise to train diagram confusion; hence missetting is regarded as a serious accident in train operation administration. Although there are no detailed records of route missetting before COMTRAC was introduced, such cases appear to have taken place several times a month. For the large number of various types of trains operating the Shinkansen today, with the stopping station pattern as it is, it surely would be impossible to set routes by human hand without COMTRAC at work, even if the number of dispatchers were increased. After the introduction of COMTRAC, there were three cases of route missetting—two cases, programming misses, and one, an input miss by dispatcher due to man-machine trouble.

(2) Control of trains diversifying in type to meet the demand is possible—Users’ demands on the Shinkansen, the main traffic artery in Japan and long in operating section, change from season to season and diverse types of train are operated to meet their demands. Introduction of COMTRAC has thus brought forth a complicated transport form of operating diverse types of train to meet the users’ demands. In Table I, the diversification of train types is shown.

(3) The growing number of dispatchers checked by automation of route setting—The number of dispatchers before and after COMTRAC is shown in Table II. Under Ph-1 System, data transmission and rolling stock turnaround control were not performed but the system had the effect of checking the growing number of dispatchers. The systematization also had a notable effect in changing the dispatchers’ work from lever handling for route setting to their primary job (train operation adjustment, for instance). With the introduction of Ph-2 System, data transmission and rolling stock turnaround control were performed and the effect of checking the growing number of dispatchers has grown all the more.

(4) It is possible to cope with the demand for high-speed mass transport—The growth of the number of trains and the route setting frequencies are shown in Table III. The route setting by lever operation before COMTRAC averaged once in every one to two minutes. At the time of opening the Shin Osaka-Okayama Section it grew to once in every 30 sec to one minute and then to once in every 10 sec to 20 sec when the Okayama-Hakata Section was opened. It is impossible for man to handle the lever for route setting at such a frequency. The System is presently working nicely with the target reliability value attained. There has been only one case of system-down during the year from April 1976 to March 1977 and this was due to software logic bug. (Refer to Table III.)
FUTURE OF COMTRAC

JNR has two other Shinkansen lines, Tohoku and Joetsu, scheduled for opening within several years and is planning to form a nationwide Shinkansen network. COMTRAC will then be indispensable, as more and more diverse types of high-speed mass transporting trains have to be operated within the network. To be ready for it, COMTRAC will have to expand its scope of control, improve its functions to the infallible extent and grow not only into a train operation control system but also into a traffic control system, as well as to have it linked to MARS (Seat reservation system), Rolling Stock Control System and Management Information System, so that it can provide service more commensurate with the transport demands.