Recent Results and Prospects in Research and Development on Transport Planning

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Transport plans are essential to highly reliable and user-oriented railway services. In actual operation, plans may have to be changed dynamically when traffic is disrupted due to congestion, natural disaster and so on. In order to prepare suitable plans, having an evaluation method is important. This paper outlines recent research and development of transport planning evaluation methods. It describes results from the research and development of evaluation methods for basic transport plans, time tables and measures applicable to traffic operation. Finally, it describes the prospect of applying multi-data analysis and a new train control system based on radio communication, to transport planning.

Keywords: transport planning, time table, operation control, data analysis and evaluation techniques

1. Introduction

Railway transport is organized on the basis of a variety of plans such as basic plans for the number and types of train to be run, time tables, etc. Also, there may be cases where trains do not run as scheduled due to overcrowding, equipment failure, meteorological conditions, disasters, etc. In such cases, train operations may be adjusted by changing train arrival and departure times, train running order, through partial cancellation of train services, or changing destinations, etc. These measures may be considered to be equivalent to a rescheduling of the operational plan.

Techniques for planning train operations include estimation of demand for transport, evaluation of the transport network, inter alia. Evaluation techniques are important since they will ensure that time tables meet the demand for and conditions of the lines. Consequently, if effective evaluation methods are available to support operation control, including train rescheduling, it will be possible to apply the improved measures.

At the same time, recent years have seen a diversification of services in order to meet a growing variety of needs. As such, certain conditions, such as type of train, routes, etc. have added complexity to the situation, especially in metropolitan areas. Against this backdrop, the importance of having effective evaluation methods using simulation is increasing, in order to improve the quality of transport and minimize disruptions.

This paper describes recent progress in evaluation techniques designed for transport network and time tables, etc., which was achieved as part of the research and development program on transport planning. This paper also covers action taken to support planning, based on analyses which combine railway transport data with the socio-economic data inter alia, and future prospects.

2. Train operation and transport planning

Figure 1 shows the techniques for drawing up railway transport plans and operating trains in accordance with such plans, and the conceptual diagram of the related system. Among other things, the transport plans which are the subject of this paper are closely related to a higher layer than the operation control system indicated in the figure. As described in Chapter 1, this section discusses the evaluation techniques which are important for providing support in drawing up plans in accordance with the following classifications.

1. Convenience of transport networks and stations
   - Techniques providing support for drawing up policies, which are then used by railway operators to decide transport programs or draw up time tables by evaluating the transport network, and match the type and number of trains in accordance with required transport performance, demand forecast, etc.

2. Time tables
   - Techniques for evaluating time tables which set specific train operation schedule.

3. Operation control including train rescheduling
   - Techniques providing support to select train rescheduling methods used in response to disruptions and evaluating operational measures implemented in time of major disasters.

The signalling system indicated in the figure is not...
a system directly involved in transport planning but is a means to obtain operational information, such as train location, which is necessary for controlling train traffic. Systems based on data transmission between ground equipment and trains such as radio based train control systems [1] in particular, and which have been adopted in Japan and overseas in recent years, are able to collect information which is more detailed than ever before, and expected to provide unprecedented possibilities mainly in the field of train operation control.

3. Recent research achievements

3.1 Evaluation of convenience of transport networks and stations

3.1.1 Evaluation of transport networks

By focusing on the public transport networks such as airlines and main line buses as well as intercity railways, a method was developed for extracting and evaluating bottleneck stations [2]. Nationwide passenger flow performance data etc., were then entered into this method, to derive the best transport network using a multi-objective genetic algorithm. In this case, as shown in Fig. 2 (a), multiple solutions (i.e. there are no other solutions which are superior in all indicators) were found and the one which best suited the purpose in question was selected. Figure 2 (b) shows the relationship between the current number of passengers and the evaluation value for each station within the network (i.e. the difference between the best network and the current situation). For example, “stations requiring improvement” in the figure, are terminal stations located in local areas where passenger numbers are small, but in the figure appear to be those stations where bottlenecks may be occurring affecting the entire network.

Note that, in this case, the consumer surplus, which is found by converting the degree of improvement of convenience for passengers into a monetary value, and the environmental burden (i.e. CO₂ emissions) are shown as indicators. However, other indicators may be applied or added depending on the purpose of the exercise.

This method may be used to optimize the network by taking into account changes such as the opening of a new high speed line, the long-term suspension of train services due to disasters, the effect of population erosion, etc. in addition to extracting the bottleneck stations, as mentioned above.

3.1.2 Evaluation of train selection in urban rail traffic

Little research exists on methods to facilitate train selection on urban networks in cities, where a broad range of train types can be in operation on a single line (e.g. express trains, local trains, etc.). A method was therefore developed in response to this, to estimate train occupancy and the

![Fig. 2 Evaluation of the transport network](image-url)
number of passengers waiting at each station of such a train line [3].

A mathematical model of passengers’ train selection was designed, for cases where multiple train types have to run on a single line, as described above. OD (Origin-Destination) data for each time table and time band (i.e. volume of journeys between each arrival and departure point) were combined, and then the number of passengers on each train and number of passengers waiting at each station were estimated according to time series variation, as shown in Fig. 3.

3.1.3 Evaluation of user-friendliness of stations

Transport networks should be considered as a system, and therefore it is also important to evaluate how easy it is to transfer between transport modes in stations. Consequently, a method was developed to quantitatively evaluate passenger transfer resistance.

In this method, the resistance coefficients of certain factors, such as the need to use stairs, escalators and crosswalks, etc., which were determined by assuming a perceived resistance, for example, time on a crosswalk of 1 second would be “1,” are added together to calculate the total transfer resistance. Figure 4 shows an example of the calculation to show the change brought about when a stairway is replaced with an escalator. This example illustrates how places needing improvement can be picked out to reduce the transfer resistance and how improvements can be evaluated quantitatively.

3.1.4 Evaluation of freight transfer

The role to be played by railway operators to rationalize freight transport as a whole and reduce the environmental burden is large. For this reason, a method is being developed to gain a clearer picture and facilitate the evaluation of freight transport. A set of indicators for evaluating and modeling freight transport has already been designed [4], and a system has been developed to display the evaluation results on a map.

3.2 Time table evaluation

3.2.1 Evaluation from various viewpoints

Conventionally, time tables are evaluated by examining arrival and departure times at each station, whereas the detailed movement of trains between stations and impact of signal are not generally considered enough. In practice however, there are multiple factors that come into play, such as passenger behavior, train congestion, train movement, signalling, etc. By simulating these conditions as faithfully as possible, time tables can be evaluated more accurately from multiple angles. As such, a simulator was developed which is able to evaluate the time table from a train operator management point of view take into consideration other factors such as customer experience, energy consumption, etc. based on the “train operation and passenger behavior simulator [5].”

3.2.2 Evaluation of influence on passenger flows in stations

Stations in metropolitan areas can become overcrowded as passengers transfer between trains. A method was developed to design and evaluate measures which can mitigate overcrowding and improve passenger flows, through better time tabling.

Figure 5 is an example comparing time tables where the arrival and departure times of trains were overlapping at a certain station and were then shifted by 3 minutes. Where the times overlapped passengers spent 2.3 times more time on the stairs in case of a delay. After the 3-min-
ute shift in times, passenger spent slightly longer waiting during normal traffic operation, but only had to spend 1.6 times more time on the stairs if there was a delay. This demonstrates that the influence of a change in the time table on passenger flows at a certain station can be evaluated quantitatively.

3.3 Evaluation of operation control including train rescheduling

This section describes the method for evaluating policies applied to resume services when train services are suspended for long periods due to a major disaster. The plan for resuming services and restrictions on the entry of passengers into the station, and the data on passenger transfers are input into the simulator, and the transport volume and number of passengers in the station are calculated. If the number of passengers waiting in the station is excessively large, a simulation is made of the train not stopping there, and where passengers cannot alight. This makes it possible to check whether stopping services can be avoided if entry of passengers into the station is restricted.

The next step in this work will be to design a procedure for inputting data and devising possible policy scenarios.

4. Utilization of the data for transport planning

The past few years have seen big data being used as a basis to propose new services and to organize maintenance of facilities. Transport data is also being used for railway transport planning. However, improvements can be made to this planning process, to take into account changes in society, economic trends, and interfaces with other transport modes, etc. For this reason, work was launched to build a model for forecasting daily demand and transport demand per time band during the day, by factoring in the results of analyses of these other influences, such as economic trends, to the existing demand forecasting method and the transport network evaluation technique mentioned in 3.1.1. This model can then form the basis for another method to support basic transport planning, which considers seasonal changes in demand and interfaces with other transport modes (Fig. 6).

The purpose of this work will be to propose a method to effectively analyze data on the use of railways. Furthermore, through other research on visualization of analytical results, other more effective methods can be proposed for optimized train rescheduling, and optimized time tabling to avoid delays or mitigate the consequences of delays.
5. Interface between train operation control and signalling systems

As described in Chapter 2, the signalling system is a essential source of information required for train operation control. While conventional signalling systems have contributed significantly to safer train operations, on many conventional lines, the presence of a train is only indicated by an occupied/unoccupied signal from each track circuit. Other information about the train is also limited as train numbers are collected indirectly. In contrast, with radio-based train control systems, trains can be identified directly by checking the ID of relevant onboard equipment, etc., providing location, speed, etc. continuously. Given that acquiring detailed train information is now a reality, it is necessary to rethink train operation control. As such, the Railway Technical Research Institute has just launched research and development into a new system [6] which integrates train operation control and signalling system functions.

6. Conclusion

This paper describes recent research achievements centering on railway transport planning evaluation techniques. It is expected that further progress will be built upon these achievements and the new sets of values established, to make the railways even more user-friendly.

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References

[1] Sato, S., “Radio-Communication Based Moving Block Signalling System “ATACS”,” Japanese Railway Engineering, Vol.53, No.4, pp.2-5, 2013.
[2] Watanabe, T., Shibata M. and Suzuki, T., “Method for Identifying “Bottleneck” Stations on the Inter-regional Public Transportation Network,” Quarterly Report of RTRI, Vol.57, No.1, pp.15-21, 2016.
[3] Fukasawa, N. and Shibata M., “A Study on Passengers’ Train Choice Model in Urban Railways,” Quarterly Report of RTRI, Vol.57, No.1, pp.29-35, 2016.
[4] Li, G., “A Systematic Methodology to Evaluate the Door to Door Intermodal Freight Transports,” Proceedings of 11th WCRR 2016, 2016.
[5] Takeuchi, Y., Sakaguchi, T., Kumazawa, K., Kunimatsu, T. and Sato, K., “Improvement of Train Operation and Passenger Flow Simulator for Detailed Estimation of Train Movement on High Frequency Railway Lines,” Quarterly Report of RTRI, Vol.56, No.1, pp.39-44, 2015.
[6] Hiraguri, H., “Recent Research and Development of Signalling and Telecommunications Technologies,” Quarterly Report of RTRI, Vol.57, No.4, pp.252-255, 2016.

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