Application of Simulation Technologies in the Transport Information Field

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This paper outlines the application of simulation technologies to train operation and signaling systems. It describes the background and the development of simulators in each field. It also describes difficulties encountered with conventional simulators and recent developments aimed at resolving them. The new simulator can reflect interactions between passenger behavior, train movement and the conditions of signaling systems, to obtain more precise simulation results. Finally, it presents a combined technology using the new simulator and the communication network simulator for radio-based train control systems, and its application in the future.

**Keywords**: simulation, performance evaluation, transportation planning, train diagram, signaling systems

1. Introduction

Railway services must offer passengers a high level of convenience and should not be confusing when traffic is disrupted. For this reason, proper train time-tabling and scheduling of other related works is essential, as is rescheduling of traffic to reflect situations. In this regard, the design of signaling systems, including the block section lengths and safety speed profiles affects the minimum train headway which is one of the constraints faced when preparing train diagrams and recovery performance from a disrupted traffic.

As a consequence, it is preferable to study or evaluate the effectiveness of transportation planning, railway traffic rescheduling policy and design of signaling systems bearing the abovementioned points in mind. To conduct such a study or evaluation, it is necessary to consider the movements of many trains and passengers. However, tests using real trains and facilities are unrealistic. Simulation is a valid and essential means therefore to evaluate transportation planning and signaling systems. RTRI has already carried out work on the development of several simulators for different purposes. This article outlines work conducted to date to apply simulation technology with a view to evaluate train operations and discusses future possible applications and development.

2. Outline of Simulation Development and Application

2.1 Train operations and passenger flow simulator

Conventionally, train diagrams were evaluated using data such as estimated passenger volume or actual departure and arrival times recorded in operation control system after the time table have been implemented. This means that implementing a revised time table after evaluation takes approximately one year. In addition, this traditional revision process used data which was counted by a train, and did not take into account transfers or congestion that each passenger experienced. Moreover, railway operators themselves prefer to avoid an increase in boarding and alighting time caused by concentration of passengers and subsequent delay of trains. Consequently, in order to evaluate train timetables considering all these points, a “train operation and passenger flow simulator” [1] was developed, which makes it possible to predict individual passenger behavior according to train operation and level of congestion.

Figure 1 is a flow chart which illustrates the processes applied in the simulator. The OD (Origin-Destination) is collected from data at automatic ticket gates, and input into the simulator together with train timetables, and the simulator predicts passenger choice of trains, transfers and location on the train. Train operations are simulated on the basis of train timetables, estimated numbers of passengers and times for boarding and alighting at stations. Where delays occur due to increase of boarding or alighting time, passenger behavior can then be predicted depending on the train delay. The interaction between passenger behavior and train operations makes it possible to recreate a phenomenon whereby concentrations of passengers cause delays, which then lead to further concentration of passengers.

Figure 2 shows some examples of output screens. Figure 2 illustrates that it is possible to evaluate the situation from passenger point of view in terms of convenience, i.e. waiting times and degree of congestion, as well as from the train operating angle.

This simulator is not only used for railway operators to evaluate their timetables prior to their actual use but is...
also applied as a basic tool for research and development of evaluation methods for railway traffic rescheduling plans [2] and more precise evaluations described below in 3.1.

2.2 Signaling system evaluation simulation

The main purpose of signaling systems is to guarantee operational safety. In terms of efficiency however, signaling systems can be a constraint. For example, reducing block section length and increasing the number of signal aspects from 3 to 5 would enable shorter headways. Research and development into radio-based train control systems, to produce moving block systems, grew in Japan and elsewhere in the world in the 1990’s. This led to further work to modify or replace signaling systems in order to achieve even higher-density operations.

It was during this time that RTRI developed the simulator called Universal Train Simulator (UTRAS) [3] that simulates the running of trains according to the signaling system conditions, including the control logics for interlocking devices and the change-over times of switches. This simulator can evaluate automatic train control (ATC), radio-based train control systems and wayside signal systems. Train running can be simulated to train performance curve level, by calculating running states between stations in detail.

After this simulator was developed, a modified system was used to conduct a study with a railway operator to evaluate the effectiveness of improvements to its signaling systems. The simulator was also used as a research and development tool for new train control systems, such as prediction control [4] as shown in Fig. 3. An output example of the results is shown in Fig. 4.

2.3 Conventional issues

As described above, simulators with different purposes were developed and applied to studies conducted with railway operators and used for RTRI research and development. When using the simulator mainly to evaluate transportation planning and railway traffic rescheduling methods, as mentioned in 2.1, train runs between stations were estimated based on arrival and departure times to and from the stations, which does not reflect the train movements between stations in as much detail as in 2.2. On the other hand, when using the simulator to evaluate signaling systems as stated in 2.2, passenger movement was not reflected, and therefore, fixed values or occasionally previously established delay time values, were used for train stopping times in stations.

These simulations are sufficient to evaluate the basic performance of each factor. However, in order to have a more precise evaluation or an evaluation including factors such as energy consumption for train operation, it is necessary to consider both train operation including signaling conditions and passenger behavior. In order to study train control systems with a view to flexible control assuming high-density operation, such as the previously described prediction control, it is necessary to forecast train stopping times in stations as accurately as possible while also considering passenger behavior.
3. Upgrading and application of simulation

3.1 Train operation simulation at train performance curve level

Requirements in transportation planning have become increasingly diversified in recent years, and include demands for economic performance and energy saving performance in addition to punctuality. It is thus necessary to evaluate planning from these angles. In high-density sections of metropolitan areas, small-scale delays occur easily due to congestion on trains or in stations, especially during morning rush hours. Trains are thus often compelled to slow down, because of signaling, which prevents them from running according to their normal performance curve, and these circumstances need to be taken into consideration. A simulator was therefore developed which includes interaction of various factors such as passenger behavior, train congestion and successive train runs, reproducing in detail train running conditions between stations while also taking signaling into account, on the basis of the "train operation and passenger flow simulator", described above in 2.1 [5]. This simulator is able to calculate runs between stations in consideration of signaling conditions, departure delays due to concentration of passengers, energy consumption during power running by trains, as well as passenger behavior. As the result, operational plans can be evaluated from the point of view of convenience to the passenger, railway operator business management, and impact on the society, as shown in Fig. 5.

This simulator needs to be further modified and functionally upgraded, including more accurate calculation of regenerative and other electric power consumption and in order to be able to work with other signaling systems. The simulator, however, resolves the issues described above in 2.3 and is thus expected to be more widely used in the future.

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3.2 Application to radio-based train control systems

Radio-based train control systems such as Advanced Train Administration and Communications System (ATACS) have over recent years become increasingly deployed for operational use and are expected to be introduced widely in the future. Safety side controls are usually built into these systems, therefore when an anomaly occurs, such as interruption of radio communication, the train will be stopped automatically. The number of trains that can communicate with certain radio-base station is limited in the case of some radio systems, such as time-division multiple access. As a result, in case of the interruption of radio communication or traffic congestion, it might impact on train operation in for example large stations.

RTRI developed a simulator system to evaluate the communication performance of radio-based train control systems including a ground network, that can be used to help more efficient design of radio networks [6][7]. Linking this system to the simulator described above in 3.1, it can then be used for designing the location of base stations for radio-based train control systems taking into account the effects on train operation.

4. Future development

The development of the simulator stated above in 3.1 has made it possible to create simulations incorporating interactions between passenger behavior, train congestion and train running. Currently, development of certain functions has begun to link communication network simulators for radio-based train control systems and enable incorporation of feeding systems and detailed vehicle performance, as shown in Fig. 6. This further development is expected to be applied for predicting the effect of the system design on train operations or vice-versa, in order to help define system design specifications suited to the required train operations. Besides, more precise estimation and evaluation of power consumptions can be expected.
5. Conclusion

This paper summarizes the development background and sets out prospective use of simulation technologies aimed at evaluating train operations. Precision and functionality are not always enough for simulation. Simulation tools need to be built and selected appropriately according to each purpose. This research will therefore continue in order to fine-tune the simulation system to optimize its suitability for constantly changing requirements, while proposing new solutions to improve convenience to passengers and railway safety.

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