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Punctuality analysis using a microscopic simulation in which drivers' behaviour is considered

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ABSTRACT

One of the recent problems in urban railways in Japan is that small delays often happen during rush hours. Because trains are running very densely, even a small delay propagates to succeeding trains and the delay tends to expand. In order to precisely evaluate the robustness of a railway system, a detailed simulation so called microscopic simulation in which components of a railway system are modelled in detail is used. There exist a lot of research papers with regard to the microscopic simulation, but they have not explicitly dealt with the manipulation by the driver, which is yet crucial to obtain a realistic result of simulation. We have developed a microscopic simulator, in which drivers' manipulation is explicitly expressed. In the first part of this paper, we introduce how the simulator is constructed and in the second part, we show how the simulator was effective for punctuality analysis. In fact, a part of the tracks were relocated and because the distance between some stations was decreased at the same time, we were anxious about decrease of punctuality. We compared two plans by using the simulator. Then we proved that a plan which was expected better is not good at all if we consider the psychology of drivers and decided to choose a plan which at first looked not so good. We confirmed the choice was correct from the records of train operation after the track was actually relocated.

1. Introduction

In urban areas of Japan, there exist big demands for railway transportation. As a matter of fact, in Tokyo (the capital of Japan) area, about 38 million people in total use railways a day in average. In order to satisfy such a big demand, trains are operated very densely. In many railway lines in Tokyo, trains which consist of typically ten or sometimes even 15 cars which are 200 m–300 m long are running every two to three minutes per direction per track.

One of the recent problems in urban railways in Japan is that small delays often happen during rush hours. Even a small delay propagates to succeeding trains and the delay tends to expand to the whole railway network. Passengers complain even for delays of several minutes partly because they now use a transfer guidance system and if trains are delayed, they cannot catch the train indicated by the system. Another reason of their complaint is that if a train is delayed, this means transportation capacity is lost and the congestion of the trains increases. Thus, railway companies are now very keen to make the railway system more robust to reduce primary and secondary delays (Yamamura et al., 2013, 2014).

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A railway system should be regarded as a combination of various components, such as a timetable, rolling stock, tracks, signalling systems and operation. Passengers are also an important component of a railway system. We have to notice that there exists interaction among these components. For example, a train is compelled to stop outside a station if the track that the train is planned to use is still occupied by another train. Where the train should stop and how the driver drives the train to the station after it is allowed to restart are closely related with an increase/decrease of delays. The location where the train stops and the manipulation of the train etc. are closely related with the lengths of track circuits, aspects of the signals and so on. In order to improve robustness of a railway system, detailed analysis about the function of each component and the interrelationship among those components is indispensable.

In order to precisely evaluate robustness of a railway system, a detailed simulation so called microscopic simulation is useful. In the microscopic simulation, components of a railway system mentioned above are modelled in detail. Not only the events of arrival and departure of trains but also the trains' movement between stations considering signalling systems is also continuously simulated.

One of the key points when we apply the microscopic simulation to dense train traffic is that we need to simulate interaction among the components, especially the interaction between trains which run consecutively because trains' movement is influenced by the preceding train via the signalling system.

When we calculate the (technically) minimum running times of trains between stations, we use similar microscopic simulation but we consider only one train. We assume that the train can run without any influence by another train. In case of punctuality analysis, however, we usually need to simulate the situations when trains are slightly delayed. This means that we have to simulate a group of trains and consider the interrelationship among trains which run in sequence.

Another important point is that we need to explicitly consider the behaviour of drivers. In some railway lines, so called ATO – Automatic Train Operation - is already used. In those lines, drivers just need to push a button when they want to start the train and they usually do not need to manipulate the notch and the brake even when the train is stopping at a station. But in many railway lines, trains are still driven by drivers. Drivers try to drive the train as exactly as possible, namely so that the running time is as equal as the time prescribed in the timetable. If the train is delayed, they try to drive faster to restore the delay. Of course, they have to follow the constraints of the speed limits imposed by curves, signal aspects and so on. If we want to simulate train operation as realistically as possible, we should not assume that they drive the trains ideally as we do when we calculate the technically minimum running time. For example, they cannot run exactly at the same speed of the speed limit but the running speed might be a little less than the speed limit. In addition, the margin should be larger for a location with a steep down gradient because drivers are afraid that the running speed might increase and exceed the speed limit (in some cases, if the running speed exceeds the speed limit, an emergency brake applies). Thus, in order to get more realistic results of simulation, it is very important to explicitly consider the psychology and behaviour of drivers.

There exist a lot of research results concerning the microscopic simulation model. OpenTrack (Hürlimann and Nash, 2004; OpenTrack), RailSys (Radtke and Hauptmann, 2004; RailSys), Luks (Janecek and Weymann, 2010) and HERMES (HERMES) are widely used simulation tools and it is shown that microscopic simulation is shown to be an effective tool in timetabling (for example, see Čapek et al., 2012; Ercolani et al., 2014). Some of the simulators in the literature can explicitly express the existence of drivers, but as far as the authors know, none of them explicitly deals with the drivers' behaviour, which is influenced by their experience and psychological factors. Although the difference seems to be subtle, in railway lines where trains are running every couple of minutes, small difference in manipulation might cause a significant difference when we examine punctuality in these lines. This is because in such lines, train's operation is inevitably influenced by the preceding train and even a small difference of manipulation might cause a difference in the signal aspects the driver watches. Consequently, the running speeds and the headways become different, which are the very important factors when we examine punctuality.

In this paper, we introduce a microscopic simulator in which drivers' behaviour is explicitly considered. Behaviours might be different from one driver to another. But drivers in Japan are well trained and we have observed there does not exist a big difference in their behaviour especially in railway lines in urban areas where distances between stations are rather short. So, our current purpose is to simulate an “average” behaviour. Although we are interested in calibrating simulation results as shown in de Fabris et al. (2008) and de Fabris et al. (2011), we would like to put it off to the next step because we cannot get the detailed data about the running speeds or locations of trains at the moment.

Then, we show how we used the simulator to analyse the punctuality of trains in Odakyu Railway Company, which is one of the major private railway companies in Japan when some part of their track was relocated and decrease of punctuality was concerned about.

The rest of this paper comprises as follows: in Section 2, we show our approach to punctuality analysis together with our rules of train operation. In Section 3, we introduce our microscopic simulator in which drivers' behaviour is considered. We show the structure of our simulator, which is designed based on the object-oriented model. In Section 4, we show the results when we actually applied our simulator. We applied the simulator to a punctuality analysis when a part of the tracks were relocated and we are anxious if the robustness would decrease. We compared a couple of counter measures to reduce delays and based on the results we chose one of them. We confirmed the choice was correct from the records of train operation after the track was actually relocated.