Journal of Rail Transport Planning & Management 7 (2017) 207–223

Contents lists available at ScienceDirect

Journal of Rail Transport Planning & Management

journal homepage: www.elsevier.com/locate/jrtpm

A microscopic evaluation of railway timetable robustness and critical points

Emma Solinen [a, b, *], Gemma Nicholson [c], Anders Peterson [b]

[a] Trafikverket, SE-172 90 Sundbyberg, Sweden
[b] Department of Science and Technology, Linköping University, SE-601 74 Norrköping, Sweden
[c] Birmingham Centre for Railway Research and Education, University of Birmingham, Edgbaston, Birmingham, B15 2TT, UK

ARTICLE INFO

Article history:
Received 26 May 2017
Received in revised form 10 August 2017
Accepted 28 August 2017
Available online 1 September 2017

This paper is based on the manuscript "A Microscopic Evaluation of Robustness in Critical Points" by E. Solinen, G. Nicholson and A. Peterson, presented at the 7th International Conference on Railway Operations Modelling and Analysis, RailLille 2017.

Keywords:
Railway timetabling
Robustness
Microscopic simulation
Key performance indicators

ABSTRACT

One method to increase the quality of railway traffic flow is to construct a more robust timetable in which trains are able both to recover from delays and the delays are prevented from propagating. Previous research results show that the indicator Robustness in Critical Points (RCP) can be used to increase timetable robustness. In this paper we present the use of a method for RCP optimization: how it can be assessed ex-post via microscopic simulation. From the evaluation we learn more about how increased RCP values influence a timetable's performance. The aim is to understand more about RCP increase at a localised level within a timetable in terms of effects to the pairs of trains that are part of the indicator. We present a case study where an initial timetable and a timetable with increased RCP values are evaluated. The ex-post evaluation includes the quantification of measures concerning train-borne delay and robustness of operations, as well as measures capturing the subsequent quality of service experienced by passengers to assess the broader effects of improved robustness. The result shows that it is necessary to use several key performance indicators (KPIs) to evaluate the effects of an RCP increase. The robustness increases at a localised level, but the results also indicate that there is a need to analyse the relationship between ex-post measures and RCP further, to improve the method used to increase RCP and thus its overall effect on timetable robustness.

1. Introduction

The idealised railway runs its trains as specified in a pre-defined timetable; however, inevitable day-to-day disturbances mean that trains cannot meet their planned times of arrival at stations and other timing points and times for departure from stations. More severe disruptions lead to trains not being able to run in their planned timeslots and/or the propagation of delay from one train to others in the network.

One method to increase the quality of railway traffic flow is to construct a more robust timetable, i.e. a timetable in which trains are able to keep their originally planned slots despite small disturbances and without causing unrecoverable delays to other trains. A robust timetable should also be able to recover from small delays. With a more robust timetable railway traffic delays can be reduced and punctuality can be improved.

* Corresponding author. Trafikverket, SE-172 90 Sundbyberg, Sweden.
E-mail address: emma.solinen@trafikverket.se (E. Solinen).

http://dx.doi.org/10.1016/j.jrtpm.2017.08.005
2210-9706/

Previous research results presented in Andersson et al. (2013, 2015) show that the concept of critical points and the related ex-ante indicator Robustness in Critical Points (RCP) can be used to increase timetable robustness in a satisfying way. The general idea is that if the robustness in some points that are particularly sensitive to disturbances can be improved, the whole timetable will have an improved capability to recover from delay and provide a better quality of service.

Performance measurements are essential for railway operations: the capture, processing and reporting of performance measures is a regulatory requirement of most established railway systems worldwide. There is an ongoing necessity to improve the quantity and quality of railway services to meet the demands of customers; this needs objective measurement.

Across Europe a widely-used measure of operational performance is that of punctuality of trains arriving at their final destination. Some tolerance is given; in Sweden, for example, trains arriving at their destination station within 5 min of the timetabled time are considered to be punctual. In the UK a 5 min threshold is also used, except for long distance services where the requirement is relaxed to a 10 min threshold.

However, such punctuality measures do not give an assessment of performance at intermediate stations and do not necessarily capture well the degree of delay propagation, especially in timetables where journeys are padded with most of their running time supplements towards the destination stations. This is connected to the experience of passengers not being well reflected by such punctuality measures. Passengers making journeys between intermediate stations are not interested in punctuality of the train itself, but rather in the reliability of their journey. They may miss connections at intermediate stations without this fact being reported and measured.

Ensuring a high quality of service provision requires monitoring with a wide-ranging evaluation using KPIs (key performance indicators) considering the goals of both operators and passengers to check that improvement in one aspect of performance is not being made to the detriment of other important considerations, such as improvement in punctuality at destination stations at the expense of missed connections for passengers at intermediate stations.

Methods to improve robustness of timetables are usually assessed using microscopic, i.e. detailed, simulation. Typically, ex-ante indicators of robustness, based on, for example, traffic heterogeneity and speed, time supplements and buffers, are optimized and the resulting level of performance is assessed through simulation. Together with a balanced and thorough evaluation of performance using ex-post performance measures, micro simulation can give a precise assessment of changes in performance. However, this type of simulation is time-consuming and complex. Understanding the link between ex-ante robustness indicators and actual resultant performance may lead to improved ability to optimize operational performance and a reduced requirement for exhaustive micro simulation in the future.

In this paper we address the relationship between ex-ante indicators and ex-post measures by evaluating a timetable improved with the use of the ex-ante robustness indicator RCP. We present the first steps towards an implementation of an RCP optimization model in reality, where a macroscopically generated improved timetable is assessed via microscopic simulation. It is adjusted to run without conflict, i.e. to become feasible, at the microscopic level and subsequently evaluated with several performance measures.

The aim is to understand more about RCP increase at a localised level within a timetable in terms of the effects on the pairs of trains that are part of the indicator. We combine the information in the RCP indicator with knowledge of the current punctuality in the initial timetable and with other ex-post measures to gain a deeper knowledge of when and how to apply an increase in RCP. The main contributions of this paper are furthering knowledge of how RCP optimization can be used in reality, and of the problems that may occur when transferring a macroscopically generated timetable into a microscopic environment. The microscopic evaluation also gives us insights into when and how to apply an increase in RCP and hints at what can be improved in the optimization model so that it smooths the implementation process, and results in better performing timetable. Understanding more about the relationship between ex-ante indicators and ex-post measures is another important contribution.

The paper is structured in the following way. First a review of related research is given in Section 2 and then a description of the macro to micro transformation made in this study is presented in Section 3. Section 4 includes the analysis of a real-world case study, followed by the evaluation results in Section 5. In Section 6 the results are discussed and finally, in Section 7, the main findings are summarized and directions for future research are given.

2. Related work

Several aspects of railway timetable robustness have been assessed and analysed in previous research. The definition of a robust timetable is, however, ambiguous. In this paper we refer to a timetable as robust when trains are able to keep their originally planned slots despite small delays and without causing unrecoverable delays to other trains. In a robust timetable, we also require that trains have the capability to recover from small delays and that the delays are kept from propagating over the network.

Measures of robustness can be categorised in different ways, e.g. ex-ante and ex-post, by level of detail (macroscopic and microscopic), stage of planning, or train- or passenger-focussed, in the aspects of robustness that they assess.

2.1. Ex-post robustness measures

The most commonly used timetable robustness measures are ex-post measures, i.e. measures that are based on performance, typically of traffic. These measures cannot be calculated unless the timetable has been executed, either in real life or in