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The use of railway simulation as an input to economic assessment of timetables

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ABSTRACT

Assessment of capacity for highly-used railways is an important and challenging task. This paper describes a method for evaluation of timetables based on capacity and economic assessment. Common methods from both fields are combined. For developing and analysing purposes, the model is first tested with historical delay data for express trains on a double-track line with dense, mixed traffic in Sweden. An assessment aiming to compare the departures is made by combining common weights for different variables. Differences in the results based on the model structure are discussed. In the second step, microscopic simulation is used to reveal delay characteristics of timetable alternatives that are then compared and discussed in a similar way to step 1.

The presented method using simulation makes it possible to reveal and evaluate characteristics that are important for both timetable planning and economic analysis, for example evaluation of strategies. Timetable and delay times are important input variables that affect the travellers' choice. Using simulation and other methods from capacity planning gives the opportunity to find characteristics for analysing alternatives and improve economic evaluation, at the same time as the use of economic parameters provides more possibilities to make a relevant capacity analysis.

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1. Introduction

Service reliability has always been an important topic in railway traffic contexts as low punctuality and long delays make people choose other means of travel or transporting their goods, thus lowering the service demand.

Time savings and passenger valuations are a cornerstone in evaluating capacity usage and socio-economic benefits to achieve a cost-efficient and well-functioning system. However, capacity analyses rarely contain economic approaches. On the other hand, capacity characteristics are hardly ever included in economic assessments although they can affect the results significantly and their importance is highlighted in many economic studies and guidelines. Choosing and measuring the right parameters for these assessments can be difficult, especially if changes are to be analysed and input data difficult to estimate.

The main purpose of this article is to introduce a method for evaluating different timetable alternatives based on capacity and passenger valuations. Unlike in previous research on economic evaluation of capacity, the method uses microscopic simulation to retrieve input data. Advantages and experiences from both fields are combined. In the paper, characteristics of delays and ways to include these and other measurements for describing capacity will be demonstrated and analysed. For this

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purpose, timetable data, delay statistics and simulation data for the Swedish Western Main Line, an important, highly-used double-track line in Sweden, are used. With the help of commonly used variables and valuation parameters for describing capacity, alternatives are compared and the choice and combination of parameters and variables for the model discussed. The purpose is to develop a method that combines economics and capacity and can easily be applied for timetable and capacity planning but also supports processes where decisions are based on economic evaluation. Focus is on reliability and travel time, but the possibility for extending the model with other variables as for example frequency is prepared. This paper describes a novel method for including capacity parameters in an economic model, thus making it possible to estimate the effect of changes in a timetable. In the first part, statistics are used, while the second part contributes a model application where simulation is used to reveal characteristics that are used for evaluating alternatives. This is a new approach and combines capacity and economics.

The article begins with a short description of common practice in capacity analysis, transportation and cost benefit analysis and how they are connected. The introduction closes with a description of capacity measurements and recommendations for valuation. The model is then presented. Different input combinations are tested for statistical and simulated data. Finally, results and model structure as well as the need for further work are discussed.

2. Capacity and transport economics

2.1. Capacity analysis

Capacity analysis aims to estimate the maximum number of trains that can use an infrastructure during a time period without exceeding given circumstances (Abril et al., 2008). Variables influencing capacity are divided into infrastructure, traffic and operation. Block and signalling system, single/double track, definition of lines/routes, network effect, track structure/speed limits and lengths of subdivisions are pointed out for the infrastructure. Regarding the traffic parameters, new/existing lines, train mix, regularity of timetables, traffic peaking factor and priority were included. Track interruptions, train stop time, maximum trip time threshold, time window and quality of service/reliability/robustness were chosen as operational characteristics. The goal of a capacity analysis can also be to determine the properties of an infrastructure and timetable as a baseline for reducing delays by using the existing capacity in a better way (Goverde et al., 2013). Often, the relationship between key factors, such as train homogeneity or number of trains on a line, and their impact on delays is analysed (see e.g. Lindfeldt, 2015) and trade-offs between conflicting aims have to be made. Several methods and tools have been developed to improve the way of analysing capacity. Vromans et al. (2006) describe different kinds of analytical and stochastic models and railway simulation. Abril et al. (2008) also mention optimisation and recommend a combination using an analytical method before optimising and finally simulating. Nicholson et al. (2015) describe an evaluation framework for comparison and evaluation of timetables and control methods that includes several important KPIs such as punctuality, the delay at selected stations as well as the recovery time, maximum delay and delay area. Further, Andersson et al. (2013) quantify timetable robustness by considering critical points. An approach for calibration of simulation disturbance parameters can be found in Cui et al. (2016). Pouryousef and Lautala (2015) use a hybrid approach to improve level of service parameters (maximum, total, average and standard deviation of dwell time, and timetable duration).

2.2. Transportation cost and benefit analysis

In order to make decisions, cost and benefit analysis is used to evaluate advantages and disadvantages for different alternatives. As for capacity analysis, many different objectives have to be balanced in order to find the most efficient solution.

The value of travel time savings (VTTS) is a crucial measurement in transport economics and transport policy. The theory about allocating time based on income initiated by Becker (1965) has been redefined by many authors and also adjusted for use in transport economics. The VTTS is often used in combination with costs in order to evaluate alternatives using the parametric utility function

$$Utility\ u = \alpha c + \beta t \tag{1}$$

where c stands for cost and t for time, while α and β are parameters to be estimated. Assuming the parameters to be constant, a change in travel time or cost would affect the utility. The consumer surplus describing the customers' willingness to pay can be calculated by converting the utility to a monetary value. If we know the parameters, the travellers' monetary value of time (in money/time) can be expressed as

$$Value\ of\ travel\ time\ VOT_t = \frac{\beta}{\alpha} \tag{2}$$

The resulting consumer surplus for existing travellers can be calculated as

$$Consumer\ surplus\ CS = VOT_t * \Delta t \tag{3}$$

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