



# Strategic assessment of capacity consumption in railway networks: Framework and model



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## ABSTRACT

In this paper, we develop a new framework for strategic planning purposes to calculate railway infrastructure occupation and capacity consumption in networks, independent of a timetable. Furthermore, a model implementing the framework is presented. In this model different train sequences are generated and assessed to obtain timetable independence. A stochastic simulation of delays is used to obtain the capacity consumption. The model is tested on a case network where four different infrastructure scenarios are considered. Both infrastructure occupation and capacity consumption results are obtained efficiently with little input. The case illustrates the model's ability to quantify the capacity gain from infrastructure scenario to infrastructure scenario which can be used to increase the number of trains or improve the robustness of the system.

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## 1. Introduction

With an ever increasing demand for transport, knowledge of railway capacity is crucial for the railway industry to efficiently utilise and manage the available resources in the best way possible (Abril et al., 2008). However, the capacity of a railway system is not easily determined. This is especially the case because capacity cannot be defined in a simple way since it depends not only on the infrastructure, but also on operational constraints, the rolling stock used, and the order of trains if operating speeds are different (UIC, 1996).

As a consequence, the capacity of a railway system cannot be assessed with traditional methods without a predefined timetable. For strategic capacity planning this is not desirable, as the process of producing a timetable can be very time-consuming. And even if a timetable has been produced, it is uncertain if it will be put into operation due to the long time horizon. Furthermore, to reduce the work-load in the planning process only smaller parts of the network are usually considered (as in (UIC, 2004, 2013)), thus neglecting constraints induced by other parts of the network.

In this paper, we therefore develop a framework that can be used to determine the capacity consumed by a set of trains traversing a specific network, independent of a predefined timetable, while taking measures into account to obtain a robust capacity utilisation.

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<sup>1</sup> In memoriam of Leo G. Kroon who passed away on September 14th 2016.

Specifically, the framework extends and improves the UIC 406 method (UIC, 2004, 2013) to be used in strategic capacity planning with the following properties:

- No predefined timetable is needed, only service intentions.
- Networks can be handled, not just lines or line sections.
- Estimation of buffer times to absorb delays and thus to achieve a robust capacity utilisation.

Several methods exist to estimate the capacity consumed by a set of trains. However, none of these methods have all of the properties listed above. Thus this paper contributes to the area of railway capacity research by developing a framework that has all the three properties. In addition to this, we give an implementation of the framework.

The framework is especially useful for assessing different infrastructure scenarios as the capability of the infrastructure to support different timetables can be analysed easily. Furthermore, the ability to handle networks makes it possible to assess the impact on network capacity from different upgrades, and thus which upgrades has the highest capacity benefit.

The paper is organised as follows. In Section 2, we conduct a literature review of methods related to assessment of capacity. In Section 3, we describe the developed framework in detail. Section 4 describes our implementation of the framework. In Section 5, our framework and the implementation of it are applied on a network in Southwestern Denmark for four different infrastructure scenarios. Main findings are summarised in Section 6.

## 2. Literature review

In the following sections, we review methods that are related to strategic capacity assessment.

Several methods related to the area of capacity research exist, spanning over various analytical methods (Sections 2.1 and 2.2), optimisation models (Section 2.3), and simulation (Section 2.4). In our review, we focus on the ability to assess capacity (consumption) which ensures an operation that is robust against delays in networks. We consider a strategic context where only sparse data is available and independence of a predefined timetable is therefore desirable or even necessary. The literature review is shortly summarised in Section 2.5 and Table 1.

### 2.1. UIC 406 and related approaches

A widely used method to assess capacity is defined by UIC (International Union of Railways) in their leaflet 406 (UIC, 2004, 2013). The leaflet describes how to assess the percentual capacity consumed on a piece of infrastructure based on a given timetable using timetable compression (described in detail in Section 3.1).

In the UIC 406 method the network in question is decomposed into line sections for easier manageability. However, one of the shortcomings of this is that different network decompositions will lead to different results. Especially shorter line sections are a problem in the method (e.g. see Landex, 2008). However, in the latest version of the UIC 406 method from 2013 (UIC, 2013), it is recommended to look at entire routes without decomposition when assessing long-distance services.

Robustness is handled by the UIC in the form of six (four unique) thresholds for the infrastructure occupation rate, based on the type of operation, see UIC (2004, 2013). The threshold categories for the infrastructure occupation rate only provide a guideline due to the broad categorisation, as similar types of operation might differ in the characteristics and behaviour of infrastructure, rolling stock and passengers.

To negate this effect, Goverde et al. (2013) extend the compression method to obtain the dynamic infrastructure occupation under disturbances, contrary to the scheduled infrastructure occupation.

As described in Section 1, the capacity depends on the order of trains and thus on the timetable in networks with heterogeneous train types. To deal with this issue of heterogeneous train types Lai et al. (2015) use a standardized unit to denote base train equivalents (BTE) and base train units (BTU) to define capacity on lines.

**Table 1**

Summary of approaches related to capacity assessment and their ability to assess capacity (denoted by •) in networks, independent of the timetable, and by including the aspect of robust capacity utilisation. Parentheses imply that only some methods within each group of methods have the ability specified, or that the ability specified is only partially obtained. See table notes for more.

Method (type)	Timetable independent	Network assessment	Robustness
UIC 406			(•) <sup>a</sup>
Capacity optimisation	• <sup>b</sup>	•	(•) <sup>c</sup>
Queuing models	•		(•) <sup>d</sup>
Simulation	(•) <sup>e</sup>	•	•
Others	(•)	(•)	(•)

<sup>a</sup> Not handled directly, but through recommended thresholds of maximum occupation rate.

<sup>b</sup> All reviewed are timetable independent, but only Burdett and Kozan (2006) take train heterogeneity into account.

<sup>c</sup> de Kort et al. (2003) and Mussone and Wolfer Calvo (2013) can handle knock-on delays in a simple way.

<sup>d</sup> Only for non-timetabled operation (as the structure of a timetable cannot be included).

<sup>e</sup> RTC has the possibility to make train departures flexible (Sogin et al., 2013).

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