Railway freight node capacity evaluation: a timetable-saturation approach and its application to the Novara freight terminal

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Abstract

This paper presents a timetable-based approach to assess the capacity of a railway freight node, based on the microscopic simulation and saturation of the timetable. Saturation is done by scheduling additional saturation train paths without introducing any traffic conflict, while respecting the required technical and operational constraints, until no more paths can be added. The approach is applied to analyze the potential effects on capacity of some infrastructure improvements planned by Rete Ferroviaria Italiana (RFI) for the rail freight node of Novara, Italy. The capacity (theoretical or practical, depending on the presence of buffer times) is evaluated by means of two KPIs computed on saturated timetables: the number of daily pairs of saturation freight trains and the infrastructure Occupancy Time Rate (OTR) computed by the UIC 406R compression method. For the analysis, we use SASTRE, an analysis environment for railway systems developed at Politecnico di Torino, which combines a MILP formulation for the timetable saturation problem with a saturation strategy layer. The saturation strategy considers a given set of priorities between the different network areas and the train types to be used during the saturation process. The results reveal that using a microscopic model to schedule traffic flows on a railway node allows for a good accuracy of the timetable, but at a high computational cost.

Keywords: Railway Capacity; Train Timetable; Freight Trains; Saturation; Mixed-Integer Linear Program (MILP).

The rail market liberalization has led to a steady increase of the demand for rail freight transport in recent decades. This encourages European Infrastructure Managers to improve the capacity of railway systems. One way to achieve this objective is to expand the rail infrastructure. However, given the high cost of building new infrastructures, the application of advanced methods for capacity assessment is an alternative or at least complementary key action to pursue. This paper presents a timetable-based approach to assess the capacity of a railway freight node, based on the microscopic simulation and saturation of train timetables. The proposed approach is applied to analyze the potential effects of some infrastructure improvements planned by Rete Ferroviaria Italiana (RFI) on the node of Novara, Italy.

We define railway capacity as the maximum number of trains which can be operated on a given infrastructure within a certain time window and for a given set of operational constraints (Abril et al., 2008). The majority of European Infrastructure Managers (RFI included) uses techniques for railway capacity evaluation based on the UIC 406R analytical method of timetable compression (Goverde, et al., 2013). Such a method can be used to calculate the capacity consumption of pre-determined timetables or to schedule trains as close as possible to each other. The latter is called timetable-saturation if the scheduling exploits all the available capacity (Delorme, et al., 2001).

A saturated timetable permits to estimate the maximum system capacity in terms of number and type of scheduled trains. Several approaches have been pursued to solve the timetable saturation problem, see e.g. the literature reviewed by Cacchiani, et al. (2016) and Coviello, et al. (2017). Although some of the approaches in the literature are suitable for large instances or for freight traffic (Cacchiani, et al., 2010), they do not take into account rail operations interactions in highly interconnected freight nodes. In these cases, additional technical and operational constraints have
to be satisfied, which are not normally present in corridors or passenger nodes, and a reciprocal interdependence between alternatives routes has to be considered.

Our work extends a microscopic method introduced for lines to jointly manage freight nodes and lines. We integrate a general timetabling saturation algorithm with a saturation strategy layer, which considers priorities between the different network areas and the train types to be used during the saturation process. When saturation is performed without such priorities, some areas of the system may be saturated before others, and eventually block their access.

Capacity is evaluated by means of two KPIs, computed on saturated timetables: the number of daily pairs of saturating freight trains (a pair is composed by an arriving train and by the corresponding departing one) and the infrastructure Occupancy Time Rate (OTR). The first KPI is directly obtained from the timetable and represents an absolute estimation of the capacity (theoretical or practical, depending on the presence of buffer times). Instead, the OTR is computed by the UIC 406R compression method (UIC, 2013) and it is used to identify local bottlenecks.

The proposed approach is implemented in SASTRE, an analysis environment for railway systems proposed by Coviello (2018). For the timetable saturation problem, SASTRE combines a MILP formulation, based on one recently proposed by (Pellegrini, et al., 2017), and the blocking time theory (Hansen & Pachl, 2014). With respect to Pellegrini et al. (2017) formulation, we introduce station routing and scheduling flexibility of the saturating train paths (i.e., the entry time of each train into the railway system and its dwell time in each station can be modified). Our mathematical formulation also considers rolling stock re-utilization to model turn-around operations and shunting movements in rail terminals. The saturation is performed in a time window of 24 hours and by using freight trains only. This is achieved by setting the passenger timetable as a fixed constraint. The objective function of the MILP formulation is the maximization of the saturating train paths inserted in the timetable. The MILP is solved with GUROBI 8.1.

We apply the proposed methodology to the Novara freight node, which includes the two major railway stations of Novara Centrale (the passenger terminal) and Novara Boschetto (the freight yard, linked to an intermodal and a rolling highway terminals), plus two 20-km sections of the north-bound railway, with some minor stations. To analyze the improvements planned by RFI in this area, two infrastructure configurations are considered. However, the same infrastructure can be operated by different timetable patterns, resulting in a different number of train paths obtained with saturation. We thus saturate a given infrastructure scenario with different operational sub-scenarios.

The analysis highlights that the capacity of the studied node is only modestly increased by the considered interventions and the bottleneck of the whole system lies in the switch areas of Novara Boschetto yard. The RFI managers recognized that the proposed timetable-based saturation approach can quantitatively support this conclusion. Despite the good accuracy of the solution computed by the proposed method, the microscopic simulation of such a complex railway node requires several hours of computation. To reduce the time dedicated to simulations, future research should be focused on reducing the number of evaluated alternative train routes for each saturating train path.

In the full paper, we aim to investigate more extensively: how to design the saturation method, and how the saturation strategy layer should be involved in the saturation process. We will also present the computational results about the real case application in the different operational sub-scenarios tested.

References


