optimising railways

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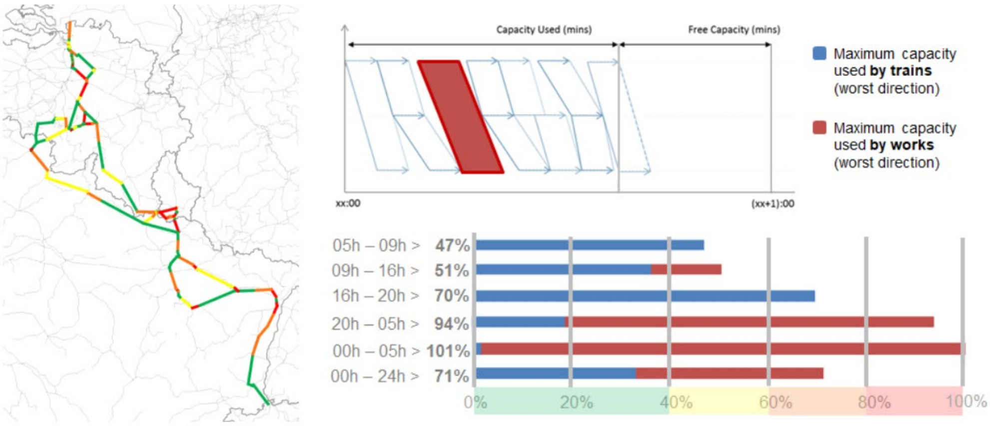
Calculation of Network Capacity Utilisation, including Engineering Possessions, for the European Rail Freight Corridor 2 with #OpenViriato

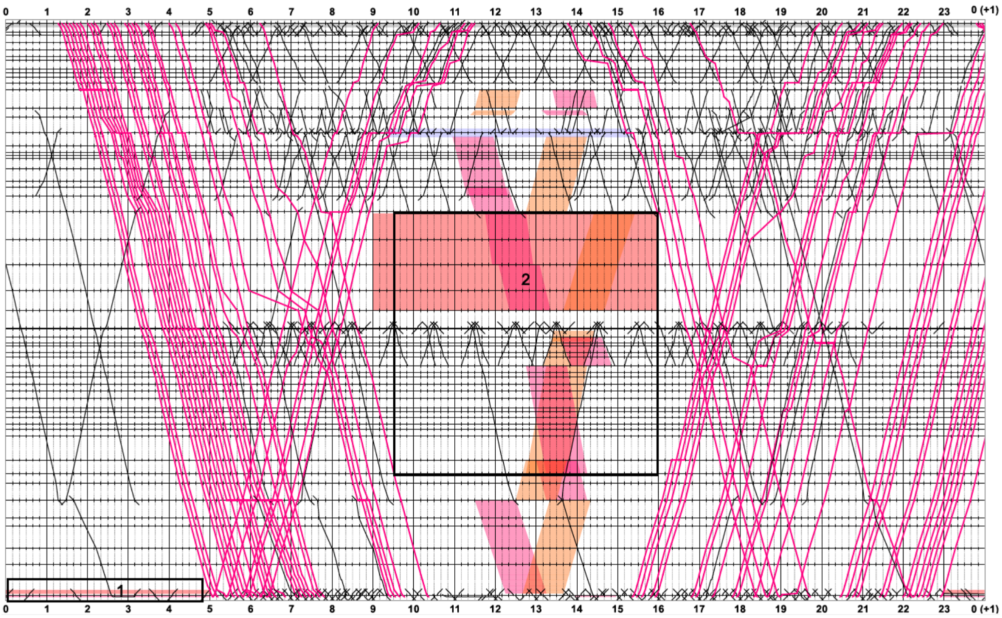
As part of a proof of concept project conducted for RFC North Sea – Mediterranean, one of the European Rail Freight Corridors, SMA has developed automated functions to evaluate capacity consumption and the residual capacity of international timetables considering both trains and temporary capacity restrictions (TCRs) for engineering works. Two algorithms have been used during this project with the Viriato Algorithm Platform: The first one determines capacity consumption by compressing the timetable and TCRs on each homogeneous section, junction and in stations. The second algorithm searches for available paths satisfying given constraints and performance goals in the input timetable and TCRs. Both algorithms have been tested on a complex and realistic example of an international network running from Antwerp (Belgium) to Saint-Louis (France). To the best of our knowledge, the algorithmic approach is novel and produces a broad variety of KPIs more efficiently than it would be possible to do manually, supporting the analyst by freeing them from monotonous work.

"Business Intelligence is the process of collecting, analysing and effectively presenting business data in order to make informed decisions. The RFC North Sea - Med handles capacity data, so why not develop a Capacity Intelligence approach? SMA perfectly understood our ambition, and their team combining timetabling, software and algorithmic expertise had the profile to match our expectations. The results of a Proof of Concept for Antwerp - Basel, one of our main routes, were extremely powerful and open up exciting opportunities for the creation of an international database of train paths and works, as well as for the visualisation of factual and objective capacity KPIs." - Yann Le Floch, Managing Director, Rail Freight Corridor North Sea - Mediterranean

The capacity consumption algorithm uses a timetable compression methodology derived from the UIC406 method but applied at a macroscopic level. It automatically computes the optimal network decomposition with the longest possible homogeneous sections (i.e. where no trains converge, diverge, start or terminate), then compresses the timetable while respecting the train path durations, formal headway and separation times and the location of any TCRs. The user may perform the compression on the given input timetable (with fixed train order) or on any permutation of the train order for the same service volume in order to compare the capacity consumption rates of the given timetable with the lowest or highest possible capacity utilisation of any timetable. The results are compared using standard thresholds to identify sections, junctions or stations subject to major capacity constraints. This algorithm has been used successfully on the whole study area for an entire 24-hour timetable (comprising approximately 6800 trains and 200 TCRs) using datasets provided by three different infrastructure managers, which were merged into a common database. Similar analyses on sub-periods (with durations from 4 to 9 hours) illustrated the evolution of capacity consumption due to trains and TCRs during the day. As the algorithm is designed to work on timetables at an early point in the planning process, or even using service intentions considering only train paths and their sequence, it is able to handle coarsely planned timetables, potentially containing conflicts. This allows an initial overview of capacity consumption to be obtained regardless of the input data quality. The figure below shows a schematic input network and an indicative visualisation of some test data.



The path search algorithm finds and inserts new paths in a given timetable until no commercially efficient capacity remains based on a template train and its performance requirements. Using the existing timetable and a saturation scenario, which comprises a list of template trains to be inserted, the algorithm builds a mixed-integer linear programming formulation of the problem (MILP) according to the geographic boundaries and the time window of the train network area to analyse. Multiple saturation runs are carried out until the scenario thresholds are satisfied and/or no more trains can be added. Once the maximum number of trains has been reached, an optimised timetable is created so the inserted trains can be saved back into Viriato and analysed by the user with Viriato's visualisation functions. The algorithm respects the infrastructure definition and the conflict model of Viriato (runtimes, headway times, separation times on stations and junctions, etc.) but also allows the user to selectively ignore some conflicts in the base timetable to enable saturation analyses on input timetables which still contain conflicts and other construction issues. Using this algorithm, it was possible to successfully search for paths on a 300-km long cross-border corridor for a 6-hour long time window (around 200 trains in the base timetable and dozens of TCRs), and to then saturate the network to full capacity for the entire 24-hour timetable with around 100 inserted trains (in both directions) as shown in the figure below.



The illustration highlights how the location of small works around stations (1) and in line (2) affect the usable capacity of the whole corridor even in time windows which are otherwise only lightly utilised. This proof of concept has shown us the exact limits research encounters in practice: consistency of the provided input data and scalability of the analysis for large geographical boundaries and time windows. Solving a MILP requires a careful and consistent definition of planning constraints so that the inserted trains are viable according to the base timetable. Although this necessarily precise input state can be an advantage in some cases, saturation analyses are also worth undertaking on rough timetables where some trains are still planned in conflict with others. We can already ignore some of these conflicts, and implementing ways to ignore other base conflicts in the timetable will solve the remaining issues. It was not yet possible to undertake a full saturation analysis on the whole corridor or for the whole 24-hour timetable window due to the computational complexity of such a MILP formulation. Temporarily ignoring some constraints (such as large stations) has already shown potential in preventing out-of-memory situations and calculation time limits for such analyses, but heuristic extensions (e.g. an automatic decomposition of long time window into shorter sub-periods, etc.) could help to enhance the scalability of the algorithm. Overall, the path search algorithm has provided good quality results and gave valuable insights as soon as the data quality was sufficiently high and the geographical limits were carefully defined.