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The train platforming problem: The infrastructure management company perspective

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ABSTRACT

If railway companies ask for station capacity numbers, their underlying question is in fact one about the platformability of extra trains. Train platformability depends not only on the infrastructure, buffer times, and the desired departure and arrival times of the trains, but also on route durations, which depend on train speeds and lengths, as well as on conflicts between routes at any given time. We consider all these factors in this paper. We assume a current train set and a future one, where the second is based on the expected traffic increase through the station considered. The platforming problem is about assigning a platform to each train, together with suitable in- and out-routes. Route choices lead to different route durations and imply different in-route-begin and out-route-end times. Our module platforms the maximum possible weighted sum of trains in the current and future train set. The resulting number of trains can be seen as the *realistic capacity consumption* of the schedule. Our goal function allows for current trains to be preferably allocated to their current platforms.

Our module is able to deal with real stations and train sets in a few seconds and has been fully integrated by Infrabel, the Belgian Infrastructure Management Company, in their application called Ocapi, which is now used to platform existing and projected train sets and to determine the capacity consumption.

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1. Introduction

Over the years, train operator companies require more and more trains to be added on the existing infrastructure. For infrastructure management companies, it is essential to determine a feasible platforming plan for all stations and junctions. Each of these train platforming problems (TPPs) deals with assigning all trains in a station to the available platforms, in a way to avoid conflicts on the platforms as well as on the routes from an incoming and to an outgoing line. Often, this platforming process is still done manually. This means it is error prone, takes a lot of time and the result is not optimal. At Infrabel, the Belgian Railway Infrastructure Manager, both cases of wrongly judging two routes as being in conflict and cases of wrongly considering two routes as not being in conflict, have been noted. De Luca Cardillo (1998) illustrates how in a particular case, platforming 242 trains in a station with 16 platforms requires 15 working days for an expert planner. In order to perform this platforming task better as well as faster, we want to develop software to automate this process.

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In this paper, we focus on automatically platforming as many trains as possible from two train sets: an already operational set (current set) and a future set, based on the expected traffic increase. The way that infrastructure management companies work today, is that they first construct a timetable and then try to platform all planned trains in the stations they visit, respecting the planned platform time. So, for our platforming problem, we consider the timetable to be given. We do not allow automatic changes in platform arrival and departure times. Trains that cannot be platformed will be put on a *fictive platform* and arrive or depart from there via *fictive routes*.

Our platforming solution is a Mixed Integer Linear Programming MILP model that extends the model of Billionnet (2003) with consideration of route duration differences, as well as with the fictive route concept. Thanks to the MILP method, the fictive platform concept and our simple goal function, (i) our model always returns a usable solution, (ii) we can and do list which trains cannot be platformed, and (iii) the gap also tells us how far our solution is removed from the optimal one, in meaningful units of number of trains that could not be platformed. Moreover, for realistic traffic, we obtain the optimal solution in very low solver times and our system is integrated and used at Infrabel. Also, our goal function can be tuned to prefer a solution close to the current one or otherwise optimize more progressively.

In the next section we summarize the existing literature about the train platforming problem. In Section 3, we first situate our own TPP version amongst the TPP in the literature. Our detailed Mixed Integer Linear Programming (MILP) model is described in Section 4. The last sections discuss the results, summarize the conclusions and hint at some further work.

2. Literature review

We refer to Caprara et al. (2007, 2011b,a) and Lusby et al. (2011a) for some recent surveys about the train platforming problem (TPP). An earlier survey, with a larger scope of problems, but also describing train platforming problems, is due to Cordeau et al. (1998).

An important categorization mentioned by Zwaneveld et al. (1996), Cordeau et al. (1998) and Lusby et al. (2011a) is whether the TPP considers a system which is intended for use at the strategic (S), tactical (T) or operational (O) level. The strategic level is concerned with platforming and possibly also routes for capacity estimation. At this level, one should evaluate the platform feasibility for a range of potential timetables and possibly also infrastructure change options. The tactical level of the TPP tries to determine platforms for the timetable that is already decided. The importance of deciding on routes becomes bigger here. The operational level TPP decides on platforms and routes in real time.

2.1. Strategic level TPP

Zwaneveld et al. (1996), Zwaneveld (1997, 2001) and Kroon et al. (1997) consider the strategic level TPP where they allow multiple route variants for each direction-platform pair. They use as input, the current timetable with a set of possible time shifts in minutes on arrival and departure time couples. They construct triplets, each consisting of a train-platform, a time interval with a time shift and each dominating route (inbound, outbound or complete (for passing trains)). They precalculate if pairs of the mentioned triplets conflict with each other or not. The result is a MILP model representing a *node packing problem*. Reformulating some constraints as clique inequalities, they significantly reduce the number of constraints and also solution time. The goal is to maximize the number of trains platformed. All platforming experiments for the timetable without time shift variations could be solved in at most 85 s. Experiments including time shift variations required at most 400 s on a 1996 SUN LX workstation running CPLEX 2.1. The system was integrated in STATIONS, software used at the Dutch railways for timetable evaluation and capacity estimation. Some variants of the problem solved in Zwaneveld et al. (1996) are reformulated in Kroon et al. (1997) as fixed interval scheduling problems.

Delorme et al. (2001) use *constraint programming* and its constraint propagation technique to calculate the capacity of a railway subnetwork. The area studied is the Pierrefitte-Gonesse area north of Paris. Four combinations of mixed speed, high speed, IC and freight train traffic are generated and their effect on capacity consumption is reported. Even though calculation times, for the junction described, are in between 1000 and 10,000 s, this approach is integrated into the capacity evaluation tool RECIFE at Sociéte Nationale des Chemins de fers Français (SNCF).

2.2. Tactical level TPP

De Luca Cardillo (1998) used a graph coloring formulation and an efficient heuristic they call *Conflict-Direct Backtracking*, to quickly solve the feasibility problem at the tactical level. Between two endpoints, only a single route variant is considered. Additionally, a list of incompatible routes is used. They solve 5 out of the 6 real stations considered, in less than a second, one in 115 s.

Billionnet (2003) uses integer programming to first solve the same problem as De Luca Cardillo (1998), but also considers various goal functions, like maximum use of some platforms. He uses 20 randomly generated station infrastructure graphs and train sets. Solving times on these instances are from below one second to 80 s and one case had no solution in 1200 s. These are further reduced by an alternative model formulation and the addition of clique cuts. For the one reported real station of Abatone, with 5 platforms and 41 trains to platform, he obtains a very low solver time of 0.01 up to 0.03 s.

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