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Automated platforming & routing of trains in all Belgian railway stations

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A B S T R A C T

Automatically generating train to platform assignments has been an active research area for some time, but systems implementing this research are still not readily available to practitioners. However, now, our train platforming model has been implemented as the tool *Leopard* inside Infrabel, the Belgian railway infrastructure manager. In practice, initial macroscopic timetables are often not yet feasible inside stations on the microscopic level. This means that a platforming tool must be able to handle cases where not all trains can be platformed or routed. Our model provides a platforming and routing plan for as many trains as possible and puts the remaining trains on a fictive platform. Contrary to the manually made platforming plans, the optimised platforming plans have no platform conflicts nor routing conflicts. Our model assigns as much trains as possible, given the timetable and the available infrastructure. Our tool can solve the platforming problems for all 530 stations in Belgium together in about 10 min. This means (i) it saves many man months of planning time compared to the still common manual practice to platforming and (ii) it achieves higher quality results leading to significantly less in-station train delays in practice.

1. Introduction and state of the art

In railway operations, planning all operations accurately and reliably is important since train passengers rely on the timetable to plan their journeys. A sequence of four main planning stages is identified (Cordeau, Toth, & Vigo, 1998; Lusby, Larsen, Ehrgott, & Ryan, 2011; Zwaneveld et al., 1996). Firstly, train lines with certain frequencies and stopping patterns are decided upon. Secondly, train arrival and departure times are fixed for each train in each station and for each train, platforms and routes are also determined. Thirdly, train material is assigned to the lines and lastly, crew rostering is performed. This paper focusses on the platforming and routing of trains in stations. Narayanaswami and Rangaraj (2014) mention that problems occurring in railway planning typically contain complex interdependencies between multiple components and are operationally critical and that human resolutions of these problems are inconsistent, scale inefficient, and potentially infeasible. These are the reasons why we look for computer assisted resolutions.

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1.1. Decomposition into timetabling and platform planning

The train platforming problem (TPP) is essentially a vehicle routing problem that includes timing constraints. Vehicle routing problems are usually solved using local search, possibly augmented with techniques to escape from local minima like meta-heuristics (Barbucha, 2012). However, the subcategory of TPP has attracted special attention and different versions resulted in dedicated solution approaches. Quite some research papers discuss the problem of train platforming (TPP) as the problem of trying to fit all trains on platforms and decide on routings while also allowing to change arrival and departure times (Caprara, Galli, & Toth, 2011; Caprara, Kroon, Monaci, Peeters, & Toth, 2007; Carey, 1994a; 1994b; Carey & Carville, 2000; 2003; Dewilde, Sels, Cattrysse, & Vansteenwegen, 2013; Zwaneveld, 1997; Zwaneveld et al., 1996). While this solves the problem for one station, any changed arrival or departure time for a certain train in the considered station will require changes to train times in the previous and next station as well if not enough ride time buffer is present between these stations to absorb that change. This means that platform models with variable train arrival and departure times cannot be solved independently from the platforming problems of neigbouring stations. This is why the problem of solving platforming and timetabling of corridors of stations or small networks of neighbouring stations has been addressed by, amongst others, Carey and Crawford (2005) and Bešinović et al. (2015). These publications present examples of solutions for corridors of stations or small research networks of stations but do not report studies nor results for entire countries. We built an expert system to assist Infrabel in platforming all 530 stations of Belgium.

1.2. Improving the platforming approach

We believe our approach of platforming optimisation is an improvement to the current practice in railway planning, where we think platforming does not get the right amount of attention. We explain this by contrasting the current approaches to plaforming in Section 1.2.1 and our approach in Section 1.2.2.

1.2.1. The conflict detection and train delay simulation approach

To the best of our knowledge, *no commercially available tool* exists for the *automatic generation* of optimal platforming solutions. Infrabel possesses the tool Artemis which can *check* existing platforming solutions on the signal and block section level. However, Artemis cannot generate a platforming solution by itself. The situation at railway infrastructure companies in most other countries is not better. Goverde and Hansen (2013) mention that in France and Italy in 2013, a timetable was constructed, but no platform nor routing choices were made in the planning phase. This makes it impossible to know if two trains will be simultaneously present on the same platform or on the same or crossing routes until this happens in practice. Most countries choose a platform track and route for every train during the planning stage, so that they can detect conflicts as well as simulate the effect of these choices on the total network behaviour before the plans are put in practice. RMCon's RailSys and ViaCon's LUKS used in Germany and elsewhere (Rail Management Consultants GmbH (RMCon), 2016; ViaCon GmbH, 2008b) and OpenTrack used in Switzerland and many other countries (OpenTrack Railway Technology Ltd., 2012) are microscopic simulators that are used to evaluate a timetable - including the chosen platforms and routes in stations - with respect to total propagated train delay. A LUKS user can indicate chosen platform tracks along with routes (ViaCon GmbH, 2008a). However, currently, automatic platform and route plan generation is not possible with any of these simulators. Also, the routes indicated can only depend on the line a train entering a station comes from and the line a train leaving the station goes to. In busy traffic, other platform tracks than the default ones may have to be considered to be able to platform all trains.

The mentioned simulators propagate train delays through a train network model. These simulators detect platform and routing conflicts and robustness issues that result from a given planned timetable that includes default or explicitly chosen platform tracks and routings. The simulators can indicate these conflicts by writing out a list of conflicts. Also, in their simulations, these conflicts and robustness issues cause train delays which are then propagated through the train network in the calculations. As such, a simulator user can evaluate whether one timetable causes more total propagated delay than another. This approach of conflict detection and simulation which was not preceded by a phase of optimal platform assignment that guarantees conflict avoidance has two major drawbacks. Firstly, there is no back-annotation from the resulting train delays to what they were caused by. So, it remains difficult to know how much of this total delay is caused by the macroscopic timetable itself and how much is caused by any of the platform and route choices of any of the trains in the system. As a consequence, it is sheer impossible to know how to 'repair' the timetable or platforming plan to avoid or reduce total train delays, should they be considered too high. Secondly, these microscopic simulations take a lot of computer time. At Infrabel, the use of LUKS on the complete Belgian train network is considered impractical. As a consequence, simulations are restricted to subareas of about a tenth of the country. Obviously, these simulations could ignore some important dependencies between these subareas.

1.2.2. The conflict avoidance by optimisation approach

Practice shows that manually constructed platform plans sometimes still possess train conflicts and robustness issues. Conflict detection tools and train delay simulation tools indicate these problems but do not tell a planner how to fix these issues. Solving one issue can be easy, but coming up with a platform plan that solves all issues simultaneously can be a large combinatorial problem that is hard to solve for human planners. We consider it more efficient to directly try to construct timetables and platforming plans that are guaranteed to be conflict free. Conflict detection and train delay propagation can and should still be performed afterwards, but the whole process will then have to be iterated over less often. This should save a lot of time in the total timetabling and platforming process.

For this to work, macroscopic timetabling should guarantee the absence of 'macroscopic conflicts' and platforming should avoid all platform and routing conflicts inside stations. In earlier research (Sels, Dewilde, Cattrysse, & Vansteenwegen, 2016), we constructed a method for macroscopic timetabling that produces timetables without these 'macroscopic conflicts', assuming headways of at least 3 min are feasible and assuming that the number of trains on each track section does not exceed capacity constraints. In this paper, we test our platforming method that plans trains on routes and platforms without generating conflicts inside stations. By adopting our two step method, we believe better timetabling and platforming plans would be more quickly obtained and, as a consequence, a lot of conflict detection and simulation time of 'wrong' timetable or platforming plans would be saved.

This idea is not new. The Dutch Railways (NS) possess a platforming tool called STATIONS (Zwaneveld, 1997; Zwaneveld et al., 1996) that does allow generation of platforming and routing solutions. STATIONS even allows some shifts on train arrival and departure times. When NS produces a new timetable, STATIONS is used on checking feasibility of platforming and routing in the larger stations. The French railway operator SNCF (Société National de Chemins de Fer) together with IFSTTAR (Institut Français des Sciences et Technologies des Transports, de l'Aménagement et des Réseaux) have developed a platforming solution called RECIFE (Delorme, Rodriguez, & Gandibleux, 2001). RECIFE has mainly been used on the Pierrefitte-Gonesse junction near Paris and the Lille-Flandres station. None of these tools is commercially available. Infrabel also believes that even after negotiation about adopting these solutions and in the case of a positive outcome, too much adapting and integration work would have to be carried out. This means a new platform plan generating tool had to be developed.

1.3. Time constraints of a platform plan: fixed versus variable arrival and departure times

Because no expert systems exist yet that solve countrywide timetabling and platforming for all stations at once, Infrabel, like many other railway companies, prefers to decompose the planning work sequentially into macroscopic timetabling and train platforming in stations. This means that for the platforming problem, train arrival and departure times are supposed to be fixed. So, we take the following approach. Firstly, the nationwide macroscopic timetable is automatically constructed, taking care that all minimal ride times, dwell times and headway times are respected. This work was described in Sels, Dewilde, Cattrysse, and Vansteenwegen (2013, 2016). In the second phase, the construction of the platform plan is performed for each station separately, with arrival