A mixed-integer linear program for the real-time railway traffic management problem:quantification of the impact of a priori platform assignment

Paola Pellegrini, Grégory Marliere, Joaquin Rodriguez

A mixed-integer linear program for the real-time railway traffic management problem: Quantification of the impact of a priori platform assignment

Paola Pellegrini, Grégory Marlière and Joaquin Rodriguez

Ifsttar – ESTAS, Univ. Lille Nord de France
rue Élisée Reclus 20, 59666 Villeneuve d'Ascq, Lille, France
{paola.pellegrini, gregory.marliere, joaquin.rodriguez}@ifsttar.fr

Mots-clés : *real-time railway traffic management problem, mixed-integer linear programming, track-circuit, complex junction*

1 Motivation of the study and current practice

At peak hours, railway timetables extensively exploit the infrastructure for accommodating traffic. This extensive exploitation often translates into many trains traveling through critical junctions within short time horizons, where junctions are physical areas in which multiple lines cross. In these areas, unexpected events, even of apparently negligible entity, may cause a relevant deviation with respect to the scheduled timetable. In fact, according to the timetable, trains may be scheduled to traverse the same track section at a very short time distance. If one of them is delayed due to an unexpected event, conflicts may emerge, i. e., multiple trains may claim the same track section concurrently : in this case trains may have to stop or slow-down for ensuring safety. As a consequence, conflicts may generate a severe delay propagation.

In the practice, conflicts are often solved in a first-come-first-served manner : the first train claiming a track section is allowed to use it first. This is of course a sub-optimal scheduling strategy, but dispatchers in charge of managing traffic in a control area typically do not dispose of automatic tools for selecting a better one. As an additional degree of freedom for dispatchers, typically multiple routes can be used for traversing a junction, going from an origin to a destination location. In principle, the exploitation of these multiple routes may increase the efficiency of the system, but, as in the case of train scheduling, few automatic tools are available for selecting an effective rerouting. As a consequence, the decrease of delay propagation by concurrently rerouting multiple trains is a hardly achievable goal for dispatchers.

2 The model proposed

The selection of the train routing and scheduling for minimizing delay propagation has been formalized as the real-time Railway Traffic Management Problem (rtRTMP) [5]. In this study, we propose a fixed-speed mixed-integer linear programming formulation for optimally solving the rtRTMP, which we shortly introduced in [5]. We model the infrastructure in terms of track-circuits, which are the basic components for train detection. Thanks to this detection, the signaling system imposes the suitable headway distance between consecutive trains. This headway must always be at least equal to the train braking distance : it is achieved by combining sequences of track-circuits into block sections, and protecting them through signals. While directing trains along track-circuits, our formulation assesses all possible alternatives for train rerouting in the infrastructure and all rescheduling alternatives for trains along these routes. To the best of our knowledge, we present and assess the first formulation that solves this problem to optimality. Most of the models proposed in the literature limit the representation to block sections [2, 3, 4, 7], imposing an artificial restriction to junction capacity. The others either consider heuristic solution approaches [6] or restrict a priori the possibilities to be taken into account for rerouting or rescheduling trains [1].

3 Experimental analysis

In a thorough experimental analysis, we test our formulation on perturbations of a real instance representing traffic in the control area including the main station of Lille in the North of France, i. e., the Lille-Flandres station. In particular, we considered a one-day timetable including 589 trains. All rolling stocks are used for both an arriving and a departing train, but for what concerns the first trains departing in the morning and the last ones arriving at night. Besides 259 turnarounds, the timetable contains 8 joins and 10 splits. Starting from the original timetable, we impose a delay to 20% of trains that do not represent shunting movements : we randomly select the trains to be delayed and we randomly draw their delay in the interval between 5 and 15 minutes. Moreover, we consider different scenarios for what concerns the infrastructure, forbidding the use of different number of track-circuits, and hence of different numbers of routes.

4 Conclusions

This analysis allows the quantification of the improvement, in terms of reduction of delay propagation, that can be achieved by allowing the platform assignment to be different from the one defined in the timetable. Our results show that such an additional degree of freedom may allow a reduction of delay propagation that is both non-negligible and statistically significant. This might appear as a trivial result, since the relaxation of the constraints of platform pre-assignment cannot imply a solution worsening. Yet it has an undeniable practical impact : our experiments show that such a relaxation deserves being seriously considered in the practice, because eliminating the platform pre-assignment may actually allow the reduction of delay propagation.

Références

[1] G. Caimi, M. Fuchsberger, M. Laumanns, and M. Lüthi. A model predictive control approach for descrete-time rescheduling in complex central railway station approach. *Computers & Operations Research*, 39 :2578–2593, 2012.

[2] F. Corman, A. D'Ariano, D. Pacciarelli, and M. Pranzo. A tabu search algorithm for rerouting trains during rail operations. *Transportation Research Part B*, 44 :175–192, 2010.

[3] A. D'Ariano, D. Pacciarelli, and M. Pranzo. A branch and bound algorithm for scheduling trains in a railway network. *European Journal of Operational Research*, 183 :643–657, 2007.

[4] M. Mazzarello and E. Ottaviani. A traffic management system for real-time traffic optimisation in railways. *Transportation Research Part B*, 41 :246–274, 2007.

[5] P. Pellegrini, G. Marlière, and J. Rodriguez. Real Time Railway Traffic Management Modeling Track-Circuits. In Delling D. and Liberti L., editors, *12th Workshop on Algorithmic Approaches for Transportation Modelling, Optimization, and Systems*, volume 25 of *OpenAccess Series in Informatics (OASIcs)*, pages 23–34, Dagstuhl, Germany, 2012. Schloss Dagstuhl–Leibniz-Zentrum fuer Informatik.

[6] J. Rodriguez. A constraint programming model for real-time train scheduling at junctions. *Transportation Research Part B*, 41 :231–245, 2007.

[7] J. Törnquist Krasemann. Design of an effective algorithm for fast response to re-scheduling of railway traffic during disturbances. *Transportation Research Part C*, 20 :62–78, 2012.