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Improvement of real-time traffic management by using optimization tools

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Abstract

Railway operation management must cope with failures of the railway system or external disturbances that may cause initial delays or so-called primary delays. In heavy traffic areas of rail networks, primary delays can quickly propagate and lead to the so-called secondary or knock-on delays. This paper describes the results of experiments done to evaluate railway traffic optimization tools that enable to decrease the secondary delays by selecting appropriate route settings and sequence of the train movements. These experiments are part of a task of the European FP7 project ON-TIME. The project aims to develop a prototype for a new generation of railway traffic management systems which will increase capacity and decrease delays for railway customers' satisfaction. The results of the project will be validated through system simulation and real-life case studies proposed by railway undertakings which are partners of the project. This paper focuses on the results achieved in one of the case studies of the ON-TIME project, through an algorithm which we developed. It consists of the solution of a mixed-integer linear programming formulation for a limited computation time: the best feasible solution found within this limited computation time is the final solution returned by the algorithm. The case study tackled here represents traffic in the Gonesse junction, in France. We assess the impact of including the optimization in a rolling-horizon framework. The results show that the optimization is quite robust to different settings of the rolling-horizon framework.

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Keywords: railway traffic management; routing; scheduling; mixed integer linear programming; rolling-horizon

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1. Introduction

Railway timetables are often designed to fully exploit the infrastructure capacity at peak hours. When an unexpected event perturbs traffic, even slight delays may have a major impact on operations due to the knock-on effect. Delays that are directly caused by unexpected events, as a temporary speed limit reduction due to maintenance works, are named primary delays. The only possibility for reducing them is linked to the use of buffer times possibly present in the timetable. Primary delays, though, imply that trains reach specific locations along their route at times which are different from the scheduled ones. This may cause the emergence of conflicts: two trains claim the same track section concurrently and one of them has to stop to wait for the other train to clear the track section itself. These delays caused by traffic congestion are named knock-on or secondary delays. To minimize these secondary delays, it is necessary to wisely manage traffic, that is, to properly decide train routing and scheduling in real-time to tackle a specific perturbation.

In Europe, traffic management aiming to minimize secondary delay is mostly performed by dispatchers without decision support tools. However, the importance of developing such a tool is quite unanimously recognized. Different research projects have been funded in recent years for proposing possible tools and assessing their potential impact on the railway service quality. In particular, the European Commission funded a project named ON-TIME (Optimal Networks for Train Integration Management across Europe) within its Framework Programme 7 (FP7). The aim of this project is a step-change in railway capacity by reducing delays and improving traffic fluidity. This will be achieved by a partnership between railway industry experts, system integrators, small dynamic knowledge led companies and academic researchers. Within this project, a work package is focused on the development of a traffic management system able to deal with traffic perturbations in real time. This system is intended to implement the decision of an optimization algorithm for minimizing secondary delay.

In the academic literature, several algorithms have been proposed to this aim. These algorithms can be grouped in terms of: train rerouting possibility (exclusion of train rerouting in, e.g., D'Ariano et al. (2007a) and Dessouky et al. (2006), consideration of train rerouting in, e.g., D'Ariano et al. (2008) and Törnquist Krasemann (2012)), speed variation dynamics consideration (fixed-speed model in, e.g., Corman et al. (2010) and Mazzarello and Ottaviani (2007), variable-speed model in, e.g., D'Ariano et al. (2007b) and Lusby et al. (2013)) and interlocking system representation (route-lock sectional-release in, e.g., Pellegrini et al. (2014) and Rodriguez (2007), route-lock route-release in, e.g., Caimi et al. (2012) and Törnquist and Persson (2007)).

Within the ON-TIME project, different of these algorithms will be tested and, in particular, an algorithm based on the mixed-integer linear programming (MILP) formulation by Pellegrini et al. (2014). It is based on the solution of the MILP formulation for a limited computation time: the solution returned by the so obtained heuristic algorithm is the incumbent solution after this time. In the following, we will refer to this algorithm as to the RECIFE-MILP heuristic.

In this paper, we propose an experimental analysis based on RECIFE-MILP applied to traffic perturbations in the infrastructure representing one of the case-studies considered in the ON-TIME project: the Gonesse junction in France. A junction is a portion of infrastructure in which multiple lines cross and in which the emergence of conflicts is quite frequent in case of traffic perturbation. The Gonesse junction is characterized by an intense traffic including conventional passenger, high-speed passenger and freight trains. In the experiments proposed in this paper, we include the optimization in a rolling horizon framework: several optimizations are performed sequentially considering the time evolution. For example, a first optimization is performed on the traffic which is present in the