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# Timetable Optimization to cope with Railway Infrastructure Maintenance

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## 1 Introduction

Maintenance Activities (MA's) are necessary to sustain the state and functionality of the railway infrastructure. However, MA's directly or indirectly affect the circulations of trains in the network, either by banning or by restraining them in some locations. Therefore, an efficient coordination between MA's and train circulations is necessary to optimize the railway capacity utilization [1, 2].

In the first part of this work, we present a MILP formulation for rescheduling and rerouting trains that are directly or indirectly affected by MA's. This formulation can be used to validate or to optimize the train schedules and routes with great precision, since a microscopic perspective of the infrastructure and rolling stock is considered. In the second part, we discuss some experimental results obtained with our formulation in a real-world case study in the French railway network. Finally, we present our conclusions and perspectives.

## 2 Problem Description

A timetable defines the schedule and routes of trains circulating in a given railway infrastructure. Typically, the timetable is elaborated considering the disruptions caused by the planned MA's. However, these considerations are not often accurate. Moreover, in other cases, unplanned MA's need to be coped with.

When optimizing a timetable to cope with MA's several characteristics of a train journeys must be considered : origin, destination, running times, arrival, departure and dwelling times at intermediate stops, connections, etc. Additionally, safety and capacity constraints need to be always respected.

A MA can be defined as a set of tracks that can not be used by any train during a given time period. Because of safety issues, adjacent tracks may also be affected by the MA : a Temporary Speed Limitation (TSL) for trains may be imposed on these tracks.

Trains can be rescheduled and rerouted to cope with MA's. Rescheduled trains can depart from their intermediate stops after the planned time, but not before.

### 2.1 Objective

As trains are rescheduled and rerouted, delays may be introduced. The objective of the problem is to minimize the overall delay suffered by all trains. In some cases, it is preferable

to delay some trains over others, the same may hold for delay at different stations. In our formulation this implies the assignment of a possibly different weight for every intermediate stop of each train.

Formally, the objective is : Find a train schedule and a routing plan that are compatible with all MA's and minimize the weighted sum of arrival time delays (Equation 1).

$$\min \sum_{t \in T} \sum_{s \in S^t} \delta_{t,s} \cdot w_{t,s} \quad (1)$$

Here,  $T$  is the set of trains in the timetable,  $S^t$  is the set of intermediate stops of train  $t$ ,  $\delta_{t,s}$  is the arrival time delay of train  $t$  at intermediate stop  $s$ , and  $w_{t,s}$  is the weight associated to said intermediate stop.

### 3 Experimental Analysis

We model approximately 70 km of the French railway infrastructure (between Rosny-sur-Seine and Saint-Etienne-du-Rouvray). This line segment contains 10 stations. An initially unplanned MA is defined between Bonnières and Vernon (about 12 km). The duration of the MA is set to 1h30 (8h45-10h15), which corresponds to the typical inspection-type MA in this line. We consider several time horizons. The results are summarized in Table 1. We implement our model in C++ and solve it using CPLEX 12.6 solver. The experimentations are performed in a 2.9GHz i7 laptop, with 12 GB of RAM.

Horizon		Trains		Computational	
Start	End	All	Dir. Aff. by MA	Total Delay (s)	Time (s)
9h00	10h00	10	5	911	51
8h45	10h15	17	6	1307	547
8h30	10h30	24	6	1307	1272
8h15	10h45	33	7	2308	5595
8h00	11h00	41	7	2308	5797

TAB. 1 – Experimental results

### 4 Conclusions and Perspectives

We presented a MILP formulation that can effectively reschedule and reroute trains that are directly or indirectly affected by MA's.

The proposed formulation can be used as a tool to allow rail planners to validate or to obtain more efficient timetables coping with MA's in short computational time.

Future works include : First, to perform comprehensive experimentations with larger horizons, denser traffic and multiple MA's. Second, to develop some performance boosting methods to reduce the computational time. And finally, to add the possibility of rescheduling MA's as well as trains.

### Références

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