Train timetable rearrangement facing infrastructure maintenance activities

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1 Introduction

The performance of railway infrastructure maintenance activities (MAs) consumes an important part of the railway capacity of a network. Indeed, MAs directly or indirectly affect the circulations of trains in the network, either by banning or by restraining them in some locations, i.e., MAs are infrastructure capacity consumers. To optimize the capacity exploitation, an efficient coordination between MAs and trains is required [1, 2].

In general, the MAs plan is considered during the timetable design. However, unforeseen MAs may emerge at any time, e.g., due to a device malfunction or an accident. When an unforeseen MA is introduced, the timetable may need to be adapted.

A typical example consists on the performance of a MA in a track segment of a double-track line connecting two stations. Train circulations are not allowed in the track where the MA takes place, while the adjacent track can be used for traffic in both directions provided that a temporal speed limitation is respected. A common approach applied in practice to overcome this situation is the use of a train batteries. In essence, this approach forms several groups of trains travelling in the same direction, which are called batteries. Then batteries use the available adjacent track in turns, one per direction. This straightforward approach allows a more efficient capacity exploitation than a first-come first-serve strategy which is still employed in several railway systems.

2 Problem Formulation

To tackle the problem of rearranging a timetable to cope with infrastructure maintenance activities, we present RECIFE-MAINT, a MILP formulation based on a microscopic representation of the infrastructure. Trains are allowed to be rerouted and rescheduled to cope with MAs. However, trains can not be advanced or cancelled because this problem occurs in a pre-operational level, i.e., the timetable is already published. Moreover, we consider the planning of maintenance trains and the temporary speed limitations imposed by the MAs.

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. More specifically, the objective is: Find a new timetable that is compatible with all MAs and minimizes the weighted sum of arrival time delays. This objective is formalized in (Equation 1). Here, T is the set of trains, S_t is the set of intermediate stops of train t, $\delta_{t,s}$ is the arrival time delay of t at intermediate stop s, and $w_{t,s}$ is the weight associated to a late arrival of t to s.

We propose an algorithm implementing RECIF-MAINT which is used for our experiments. Moreover, we propose another algorithm which emulates the batteries approach to compare the quality of the solutions obtained by RECIFE-MAINT with respect to the current practice.

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

3 Experimental Results

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. We define 5 initially unplanned MAs: MA_01 to MA_05, with an approximate length of 11, 0.5, 12, 0.5 and 1 Km, respectively. We define 3 possible durations for each MA: 60, 90 and 120 minutes. In total, we tackle 150 instances, 10 instances per combination MA-duration. Our algorithms are implemented in C++ and use CPLEX 12.6 solver. The computational time limit is set to 1 hour. The results, summarized in Table (1), show that our algorithm obtains at least a feasible solution for all the tacked instances. Moreover, 75% of these solutions are proven optimal.

Class	Trains	% Feas.	% Opt.	% Impr.
MA_01	44	100	60	16
MA_02	48	100	100	91
MA_03	48	100	20	12
MA_04	50	100	97	49
MA_05	46	100	97	69
All	47	100	75	47

TAB. 1 – Experimental results (Trains: median number of trains. % Feas.: Median Percentage of feasible solutions. % Opt.: Percentage of optimal solutions. % Impr.: Mean solution improvement percentage with respect to the emulation of the current practice.)

4 Conclusion and Perspectives

We introduce RECIFE-MAINT, a MILP formulation to tackle the problem of timetable rearrangement to cope with MAs. We consider specific aspects of the problem that are often disregarded: the planning of maintenance trains and the temporary speed limitations.

The results presented show that our algorithm implementing RECIFE-MAINT obtains good quality solutions in a practical computational time. Moreover, the solutions proposed are in mean 47% better, in terms of accumulated trains' delay, than the solutions obtained by the algorithm emulating the current practice.

Perspectives of future work include the exploration of other methods to reduce the computational time, e.g., hybrid meta-heuristics. Furthermore, we aim to study the possibility of MA rescheduling, which may lead to a better capacity exploitation: MAs may be scheduled in a time period which minimizes the impacts on train circulations.

Références

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