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## 1 Introduction

This paper deals with the coordinated train rerouting and rescheduling problem faced by railway infrastructure managers. Typically, the railway network is divided into non-overlapping control areas. Each control area is managed by a dispatcher, while control centers are in charge of coordinating the overall traffic. The rerouting and rescheduling problem arises when a perturbation occurs, i.e., when an unexpected event degrades operation. When this happens, the timetable cannot be operated as planned. Either timing or routes of trains have to be modified in order to minimize the impact of the perturbation and optimize a given objective, e.g., minimizing the total delay. This problem is known in the literature as real-time Railway Traffic Management Problem (rtRTMP) [3]. Several approaches have been proposed to deal with it [2]. Differently, only few papers focus on the coordination of traffic management across control areas. In particular, [1] proposes to use branch and bound to solve both the single dispatcher and the coordination problem at once, using bi-level optimization theory.

In this paper, we aim to propose a general coordination framework in which the single dispatcher problem can be solved through virtually any approach among those proposed in the literature. Only the addition of some constraints or the slight modification of the objective function is considered possible to achieve coordination. This generality has the advantage of allowing the use of the most suitable approach for each control area, for example considering a microscopic or mesoscopic representation of the infrastructure depending on the layouts.

## 2 Problem description

The railway network is subdivided into $m$ non-overlapping control areas which are traversed by a set of trains according to a given timetable. In each area a dispatcher manages schedule and routes of train movements. The borders between control areas represent the coordinator space. When movements traverse two or more control areas, the coordinator has direct decision-making power, or expresses preferences, on :

1. times at which trains leave or enter control areas ;
2. locations crossed to move from one area to the next one ;
3. precedence between trains entering or leaving areas.

Through these constraints and preferences, the coordinator aims to make dispatchers' decisions coherent. It can also compensate some time incoherences by controlling trains speed on the lines that join two adjacent but separated areas. It is assumed that the dispatchers, when they reroute and reschedule trains, collaborate with each other through the coordinator to reach a new schedule. In particular, they are required to find at least a feasible schedule for all trains, if it exists.

## 3 Logic-based Benders Decomposition

We propose to use Logic-based Benders Decomposition (LBBD) [4] to solve the problem of coordinating dispatchers' decisions. LBBD is a substantial generalization of classical Benders decomposition that, in principle, allows the slave problems to be any optimization problem rather than specifically a linear or nonlinear programming problem. LBBD provides a natural means to combine different kinds of problem formulations and solvers. In the proposed LBBD framework, we set the coordination problem as master problem and the dispatching problems as slave problems.

As in classical Benders decomposition, the output of the master problem is the input of the slave problems. Based on this input, the slave problems are solved. If all slave problems can be solved, that means the master problem generates a feasible schedule for all trains. If the objective value of the master problem is greater than or equal to the maximum objective value of the slave problems, the algorithm stops with the global optimality. If there is an infeasibility observed in some slave problem, we also need to add some constraints to the master to change its output. Otherwise, optimality constraints will be added to drive the master problem towards better and better solutions. Then, the process continues iteratively until a stopping criterion related to computational time or number of iterations is reached.

In our application, the coordinator problem is solved and train timings, border section crossings and passing sequences are passed to dispatchers. The latter solve the rtRTMP considering these inputs as (hard or soft) constraints and return the value of the objective function or the infeasibility of the instance. Consequently, cuts are added to the coordination problem, which is then is solved again to obtain a better solution.

Based on the preliminary test, the proposed approach seems promising for medium and large-size instances.

## Références


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