Railway transportation planning optimization

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1 Introduction

Our work addresses the problem of railroad transportation planning optimization. SNCF typically faces this problem when a new high-speed line is created: the objective is to redefine the conveyance service for the travelers on the concerned area, which may be wide. Indeed, the decrease of the train travel duration on the new line section significantly modifies, for each of the many origin-destination demands (*OD*) :

- the number and characteristics of the required conveyance possibilities (*frequencies*),
- the passenger traffic prevision and its time repartition through a specific day of study.

We have developed a software tool for these case studies, that provides a relevant transportation supply and thus the future operating and investment costs, according to a set of traffic prevision parameters (*scenario*). This tool implements operational research techniques (see [1,2]), to deal with the complex (and heterogeneous) constraints and optimization criteria of the model.

2 Definition of the problem

The problem to be solved consists in a set of constraints that have to be strictly respected (*hard constraints*), a set of constraints that have to be respected at best (*soft constraints*), and optimization criteria. The hard constraints in the construction of the aimed transportation plan are of different kinds :

- the structural constraints on the **trains**: their possible routings, stops, and composition (number of high-speed units composing each train, eventually from different rolling stock series such as *TGV-Réseau*, *TGV-Duplex* or *TGV-Atlantique*);
- the network **infrastructure capacity** constraints: different types of bounds on the number of circulations, on the sections of the studied line and in the railway nodes (stations or bifurcations);
- the constraints associated to **passengers assignment**: bounds on the train capacity, on the traffic prevision for each OD, passenger behaviour in front of a current transportation supply, and other commercial rules;
- the constraints associated to the **rolling stock planning**: spatio-temporal linking between two trains, cycling of the planning, respect of the maintenance frequency.

Other traffic prevision constraints are depicted as soft constraints, according to respectively:

- the target number of customers to convey on each OD;
- the target number and characteristics of the frequencies of each OD;
- the target characteristics on the stops in each station.

The objective here is thus to minimize a weighted violation of these soft constraints, and in parallel to maximize the global passenger conveyance. The number of rolling stock units that are involved in the roster plan is also minimized.

3 Solving method

The problem depicted above integrates several subproblems that can be found separately in the accompanying literature: calculation of the most relevant conveyance service [6], calculation of the feasible train timetable [3], and calculation of the roster plan [5].

Whereas the model is highly complex, the objective function of this optimisation problem is itself quite long to evaluate (in particular the number of customers of each OD in each step of each train). Thus the proposed algorithm is incremental and explores at each iteration the neighbourhood of the current solution, with the aim to increase its quality. To do so, it involves a functional decomposition:

- the evaluation of the conveyed passengers, mentioned above. This is done by a dispatching of the potential customers in the different frequencies, respecting the corresponding constraints. Algorithmically, a flow-based model is implemented and solved by a greedy algorithm;

- the neighbourhood operator consists in inserting (resp. in removing) a train in the current solution. As the evaluation process is time consuming, a heuristic permits to identify and to select the most promising trains to insert (resp. to remove), with regards to the soft constraints. In the case of an insertion, the train is set at a relevant hour of the day, regarding the not yet conveyed passengers;
- the scheduling of all trains on the network ensures the respect of the line capacity constraints. The algorithm used for that is derived from a list algorithm issued from the flowshop scheduling problem literature.

This iterative phase is performed to provide a feasible and optimized schedule of the commercial trains. The building of the rolling stock roster plan is post-processed by the solving of a flow-based mixed integer **linear programming** model [4]. This model integrates, in addition to the commercial trains, non-commercial circulations (empty trains defining new circulations or coupled to commercial trains) and maintenance operations.

Results and perspectives

This software has been validated on a large set of test scenarios and is currently being used by SNCF on different real-life case studies for the development of the transportation supply corresponding to future new French high speed lines (conclusions on these experiments during Summer 2012). Improvements on the evaluation method of the conveyed passengers and on the rolling stock assignment (composition and series of the trains) method are expected in parallel, thanks to a new linear programming approach. The neighbourhood operator could also be enhanced in a near future.

In the longer term, the study of a more complex version of the problem, that specifically integrates the optimization of both operating and investment costs in the process, is planned.

References

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