Train Unit Shunting: Integrating rolling stock maintenance and capacity management in passenger railway stations

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1 Introduction

Rolling stock planning must take into account train units between an arriving trip and a departure trip in a station. Inside such station, train units are prepared for departure and possibly stored for several hours if they are not needed immediately. More precisely, they are cleaned and have maintenance checks. Train units can be coupled or uncoupled to match train configuration required for departure. This is done on siding tracks located around platform tracks. Parallel siding tracks form shunting yards. Some tracks have specific amenities such as train-wash for external cleaning or pits for maintenance checks. Train units need to be moved between platforms and shunting yards, and possibly between several shunting yards. Such movements are called shunting movements and must respect traffic safety rules imposed by signalling system and by ground-agents instructions. Indeed, shunting movements must not create conflicts with the rest of train traffic in the station.

Taking over train units between their arrival and their departure in a station constitutes shunting [1]. Shunting planning includes several decisions. First, arriving train units must be assigned to departures, it is a matching. Moreover, trains are parked at one or several shunting tracks according to amenities required by maintenance operations. Similarly, movements are set to achieve the parking plan. It is a route planning, since paths are assigned to train units and movements are scheduled based on running times and potential conflicts. Finally, depending on maintenance crews availability, maintenance operations are scheduled. Even if these decisions are often taken separately, they are usually strongly interdependent. The Generalized Train Unit Shunting problem (G-TUSP) is the problem of shunting operations planning.

The G-TUSP considers a station and a timetable with arriving and departing trains that need to be shunted. Each arriving train may need a specific maintenance which can be performed by specific crews. The problem is to assign arriving train units to departing train units, shunting tracks and paths, to schedule shunting movements and to assign crews to maintenance operations. These decisions are made to minimize departure delays, coupling and uncoupling operations and maintenance or departure cancellations. The G-TUSP includes specific constraints:

- When a train leaves a shunting track, it must not be blocked by another train parked in front of it. A constraint based on this requirement is called a crossing constraint.
- The length of trains parked on a shunting track does not exceed the track length. A constraint based on this requirement is called a length constraint.
A great part of the literature deals with combining matching and parking decisions. A contribution [3] gives an integrated ILP formulation. The same problem can be solved with column generation, greedy algorithms and a constraint programming method [2].

The aim of the paper is to provide an algorithmic approach for the G-TUSP. The contribution presents an integrated problem with a mixed-integer linear programming (MILP) formulation. The formulation is based on a microscopic model of the infrastructure and formal train units in order to consider coupling and uncoupling.

2 Formulation

In the paper, we propose an integrated formulation for G-TUSP, while literature tackles separately one or several sub-problems. The formulation is based on RECIFE-MILP [4] to model shunting movements scheduling.

In our formulation of the G-TUSP, three formal sets of trains are introduced to model the fact that train units can be coupled or uncoupled: arriving, intermediate and departing trains. Second, regarding the infrastructure, a microscopic representation is adopted. It is based on a track circuit-scale model. Thanks to this infrastructure model, detailed characteristics of interlocking systems are taken into account.

The proposed MILP formulation provides a model for planning and scheduling in the G-TUSP. The formulation includes binary variables for assignments (route choice of a train for example) or precedence between events. Continuous variables are used to decide event dates such as train arrival on a track circuit or the start of a maintenance operation. Then, inequalities model train matching, routing, parking and maintenance constraints. An objective function has to be minimized, including cost for possible departures cancellations and delays. Cost of operations canceling and cost of train unit coupling-uncoupling are also taken into account.

3 Experiments

The model is solved exactly using the commercial solver CPLEX. It is tested on instances based on Metz-Ville station in France. This station is a main regional hub which concentrates many starts and ends of train services. First, all the routes of the station control area and their corresponding track circuits are modeled. Instances are generated with real daily timetables. These timetables include trains to shunt and passing trains. Each instance contains an initial train matching plan, which can be modified if necessary.

The results are promising and show the suitability of the model. However, they show the limits of the exact solution of large instances, due to the unpractical computational times.

Références


