ROADEF/EURO 2014 Challenge
Trains don’t vanish!
Rolling stock unit management on railway sites

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EURO XXVI Conference – 1-4 July 2013 – ROME
SNCF Group: main figures

• Historically, French national railways company
• Today one of the leading group of sustainable mobility worldwide

250,000 employees in 120 countries.

€2.3 bn investment in 2012.

Revenue generated outside France.

24%

€33.8 bn revenue in 2012.

4 million passengers a day take our trains.
SNCF Group: 5 divisions

**SNCF INFRA**
- Renovation & construction
  - Includes Sferis and Eurailscout
- Projects and engineering
  - Systra
- Rail traffic
  - Direction de la Circulation Ferroviaire (DCF)

**SNCF PROXIMITÉS**
- TER (regional express transport by rail and road)
- Transilien (rail transport for Greater Paris)
- INTERCITÉS (standard medium and long-distance trains)
- Keolis (urban and suburban transport)

**SNCF VOYAGES**
- High-speed passenger rail operators
  - TGV
  - IDTGV
  - OUIGO
  - Eurostar
  - Thalys
  - TGV Lyria
  - DB/SNCF en coopération
  - NTV
  - Elipsos
  - TGV Italia
  - Westbahn
- Long-distance coach travel
  - iDBUS

**SNCF GÉODIS**
- Geodis
- STVA
- Rail freight (TFM)
  - Fret SNCF
  - Captrain
  - VFLI
  - VIHA
  - Multi-modal transport business
- Gestionnaires d'actifs
  - Ermenwa
  - Akiem

**GARES & CONNEXIONS**
- Station management & development in France
- Multi-disciplinary operations-building and outfitting facilities
  - AREP
  - Parvis
  - A2C

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Operations Research at SNCF

• Long story
  – First OR studies in the 60s

• A great variety of problems
  – Rolling stock unit rostering
  – Workforce scheduling
  – Maintenance optimization
  – ...

• Two dedicated teams
  – Innovation & Research
  – IT
Major train stations …

- 15 stations > 10 million passengers / year
  - 6 in Paris, others in large French cities
  - Gare du Nord: ~200 million / year
    - Highest traffic in Europ, 2\textsuperscript{nd} in the world

Source: wikipedia.org / Benjism89
... associated with major railway sites ...

• ... generally surrounded by maintenance facilities and yards
… close to saturation

- Traffic increased significantly in recent years
  - Projections forecast further increase

- Some tracks are closed in urban areas
  - Industrial areas converted into new constructions

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And NOW

The problem itself!
Overview of the problem

• Resources: tracks within a local perimeter
  – Train station
  – Maintenance facilities
  – Yards
  – Tracks (moves, parking)

• Trains
  – Entering the system (Arrivals)
  – Exiting (Departures)
Overview of the problem

• Maintenance
  – Distance / time before maintenance of each arriving train
  – Requirements (distance / time) for each departure
  – Maintenance operations
    • Type D or T
    • Can be performed only on maintenance facilities

• Joint-arrival and joint-departures
  – Assembled trains coming / leaving together
  – Junction and disjunction operations to assemble and disassemble trains
Transitions between resources

• Tracks are linear resources
  – Two sides: A and B

• Gates to enter/exit a resource
  – At most one on each side for “individual” tracks
    • $A1 ; B1$
  – No restriction for yards and track groups
    • As many gates as tracks: $A1, \ldots, An ; B1, \ldots, Bm$
    • One gate to be chosen among all possibilities
  – Ordered on each side of the resource
    • Physical position of tracks
Different types of resources

• **Platform**
  – Tracks in train station
  – Required for arrival and departures
    • Boarding / unboarding of passengers
  – At most one entry point on each side
Different types of resources

• Maintenance facility
  – Track dedicated to operations either on distance or on time
  – At most one entry point on each side
Different types of resources

• Single track
  – Track outside station with no particular dedication
  – May be used for parking or to perform some moves
  – At most one entry point on each side
Different types of resources

• Yard
  – Set of tracks dedicated to storage of trains
  – Potentially a few entry points on each side
  – Capacity: number of trains
  – No internal details provided

Source: maps.google.fr
Different types of resources

• Track group
  – Set of tracks dedicated to train moves
  – Potentially a few entry points on each side
  – No internal detail provided
  – Fixed travel time
  – Headway time: minimum time between two trains on intersecting paths
  – No reverse allowed
System: composed of all types of resources
Expected solutions

• Over a $n$-day horizon (up to 2 weeks)
• Propose a schedule for each train
  – Train: visit in the system of a rolling stock unit
  – Either linked with an arrival
  – Or initially in the system

• Schedule of $t$
  – List of events associated with $t$
    • Enter/exit system
    • Enter/exit resource
    • Begin/end operation
### Example: Schedule of Train 1

<table>
<thead>
<tr>
<th>Event type</th>
<th>Time</th>
<th>Resource</th>
<th>Gate</th>
<th>Complement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Departure</td>
<td>07:35</td>
<td>Yard5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EnterResource</td>
<td>07:35</td>
<td>TrGroup7</td>
<td>A3</td>
<td></td>
</tr>
<tr>
<td>BegJunction</td>
<td>07:38</td>
<td>Yard5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EndJunction</td>
<td>07:38</td>
<td>Yard5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ExitResource</td>
<td>07:40</td>
<td>TrGroup7</td>
<td>B3</td>
<td></td>
</tr>
<tr>
<td>EnterResource</td>
<td>07:40</td>
<td>TrGroup7</td>
<td>A2</td>
<td></td>
</tr>
<tr>
<td>EnterResource</td>
<td>07:42</td>
<td>TrGroup8</td>
<td>B2</td>
<td></td>
</tr>
<tr>
<td>EnterResource</td>
<td>07:45</td>
<td>Facility1</td>
<td>A1</td>
<td></td>
</tr>
<tr>
<td>ExitResource</td>
<td>07:45</td>
<td>Facility1</td>
<td>A1</td>
<td></td>
</tr>
<tr>
<td>BeginMaintenance</td>
<td>07:45</td>
<td>Facility1</td>
<td>A1</td>
<td></td>
</tr>
<tr>
<td>EndMaintenance</td>
<td>07:45</td>
<td>Facility1</td>
<td>A1</td>
<td></td>
</tr>
</tbody>
</table>

**Input data**

- Train 1
- Train 1 + Train 9 + Train 12

**Decisions**

- Departure 34
- Departure 35
- Departure 36

**Joint-Departure (from input data)**

- "D"
- "D"
Main decisions to make

• Assign
  – A platform for each arrival/departure
  – A train for each departure
  – A suitable resource for each operation (maintenance, junction/disjonction)

• Operations performed by trains
  – Maintenance
  – Junction/disjunction

• At which time
  – Trains move from one resource to another one
  – Trains start operations
Objectives

- Lexicographic multi-objective evaluation
  1. Min number of uncovered departures
  2. Min number of conflicts and yard overload
  3. Min operational cost
     - Over-maintenance cost
     - Junction/disjunction cost
     - Platform usage
     - Non-satisfied preferred platform assignment cost
     - Non-satisfied train reuse cost
Main types of constraints

• Schedule properties
  – Enter/exit resources, transitions between resources
  – Duration of operations

• Assignment
  – Trains to departures
  – Maintenance requirements for departures

• Resource usage
  – Limited capacities / length of tracks
  – Train order

• Assembled trains
  – Train position on platform
Conflicts between two moves

• No conflict if paths do not intersect
  – E.g.: A1-B1 and A6-B3 can be performed simultaneously

• Otherwise, conflicts detected in 2 cases:
  – Moves in same direction, headway not satisfied
    • \(| h1 - h2 | < H\)
  – Moves in opposite direction, headway not satisfied
    • \(| h1 - h2 | < T + H\)
Track groups

• Conflict detection: simplified model
  – No internal representation
    • Number of tracks, location of switches, signaling…
  – No perfect correspondence with conflicts that occur in practice
    • Only estimation of situations to avoid
    • Some situations with conflicts could be feasible in practice
    • Absence of conflicts does not mean 100% of moves are feasible
Position of trains on individual tracks

- Order of enter/exit of trains must be consistent
Your software, in practice

• Input: each instance composed of several csv files
  – Arrivals
  – Departures
  – Resource description
  – Compatibilities
  – Preferences
  – General parameters (costs, horizon)
  – …

• Output: one csv file
  – Schedules of all trains
  – Sorted by train, then by event time
Typical volume of data

- Number of days in the horizon: 1 to 14.
- Initial trains: 10 to 100.
- Arrivals: 50 to 500 per day.
- Departures: 50 to 500 per day.
- Train categories: 1 to 10.
- Single tracks: 0 to 50.
- Platforms: 10 to 50.
- Maintenance facilities: 5 to 50.
- Track groups: 5 to 20.
- Yards: 1 to 5.
Your software, in practice

- Allowed computation time: 10 mn
  - From executable launch to output file generation
- Checker can be used to evaluate solutions
  - Provided early September
  - Evaluates
    - Feasibility of solutions
    - Objective functions
- Open Source
  - Evaluation made transparent
  - Inconsistancies between problem description and checker (if any) can be detected and reported to SNCF via the forum dedicated to this challenge
Conclusion

• Industrial problem with real issues to solve
  – Integrated approach
  – Rich model, broad range of possibilities
  – Nasty constraints: be smart!

• Prospective approach
  – In practice, problem divided into many sub-problems, solved sequentially (and mostly manually) at SNCF
  – No internal tool to compare with
  – Analysis of solutions by experts: changes might be introduced at the end of qualification