Automatically and Quickly Planning Platform and Route of Trains in Railway Stations

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March 23, 2015
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Automatically and Quickly Planning Platform and Route of Trains in Railway Stations

Business Problem

Task

Belgian Infrastructure Management Company: Infrabel:

"Train Platforming Problem (TPP): platform and route as many trains as possible"

Objectives:

no conflicts in planning in stations, check robustness

Fixed:

infrastructure, train lines, halting pattern, arrival & departure times

Specifics:

- one busy day, morning peak hours, periodic/non-periodic
- (check current platforming +) create new ('optimised') one
Platforming = Mapping Trains on Infrastructure
In objective function:

- Minimize penalties
  - of assigning to fictive a platform and
  - of moving assignment from preferred (real) to non-preferred (real) platforms,

for both initial $O_{INI}$ and for supplementary $O_{SUP}$ train sets

$$g(op_o,p) = \sum_{o \in O_{INI}} CF_{INI} \cdot f_o + CR_{INI} \cdot cr_o$$
$$+ \sum_{o \in O_{SUP}} CF_{SUP} \cdot f_o + CR_{SUP} \cdot cr_o. \tag{1}$$

where

$$\forall o \in O : f_o \equiv (o2p_o,p = pFICT)$$
$$\forall o \in O : cr_o \equiv (o2p_o,p \neq pORIG_o)$$

- uses fictive platform at a higher cost than real platform
- conservative optimisation $(CF_{INI}, CF_{SUP}, CR_{INI}, CR_{SUP}) = (8, 4, 2, 1)$
- progressive optimisation $(CF_{INI}, CF_{SUP}, CR_{INI}, CR_{SUP}) = (1, 1, 0, 0)$
Not in objective function:

- weighting of trains by importance (e.g. #passengers)
- important (e.g. #passengers) transfer concerns, placing two trains close together
- robustness against delays
Definitions: Movement & Occupation

Movement Definition:
- Train ‘IN/OUT movement’ specifies:
  - IN/OUT line
  - platform arrival time
  - platform departure time
- IN route: connects IN line to platform,
- OUT route: connects platform to OUT line.

Occupation Definition:
- platform ‘occupation’ specifies (bundles):
  - (list of) IN movement(s)
  - (list of) OUT movement(s)
- e.g.: 1 IN movement, 2 OUT movements = train split
- e.g.: 2 IN movements, 1 OUT movement = train merge
## In / Not In Variability

### In Variability:
- per occupation
  - one platform choice
- per movement
  - one route choice
  - (indirectly) one platform choice

### Not in Variability:
- per line-platform combination: only 1 *default* routing allowed for now
- only fixed platform arrival/departure times
Automatic and Quickly Planning Platform and Route of Trains in Railway Stations

Model

Constraints

Constraints Requiring total Assignment

Per-Movement, Per-Occupation and Compatibility Constraints:

- For each occupation, exactly one platform has to be chosen:
  \[ \forall o \in O : \sum_{p \in P} op_{o,p} = 1 \]  (2)

- For each movement, exactly one route has to be chosen:
  \[ \forall o \in O : \forall m \in M_o : \sum_{r \in R} mr_{o,m,r} = 1 \]  (3)

- All movements in 1 occupation need to come together on 1 platform track
  \[ \forall o \in O : \forall m \in M_o : mr_{o,m,r} \implies op_{m2o_m,r2p_r} \]  (4)

- Via \(m2o_m\) function, movement-occupation membership is respected
- Via \(r2p_r\) function, route-platform connectivity is respected
## Inter-Occupation Constraints:

- no 2 extended occupations use *equal* platform tracks at any time

\[
\forall \ o_0 \prec o_1 : \forall p_0 = p_1 (p_0, p_1) \in (P_{o_0}, P_{o_1}) :
\]

\[
o_{o_0, p_0} \land o_{o_1, p_1} \implies osep_{o_0, o_1}
\]  

(5)

## Inter-Movement Constraints:

- no 2 extended movements use *dependent* (equal or crossing) routings at any time

\[
\forall \ m_0 \prec m_1 : \forall dep_{r_0, r_1} (r_0, r_1) \in (R_{m_0}, R_{m_1}) :
\]

\[
m_{r_{o_0, m_0, r_0}} \land m_{r_{o_1, m_1, r_1}} \implies msep_{m_0, m_1}
\]  

(6)
Separation boolean definitions

**Occupation Separation boolean definition:**

\[
\forall \ (o_0 \prec o_1) \ni \begin{align*}
[otLoLbC_{o_0},otHiUbC_{o_0}] \cap [otLoLbC_{o_1},otHiUbC_{o_1}] & \neq \emptyset
\end{align*}
\]

\[
o_0, o_1 \in O : 
obe_{o_0,o_1} \equiv (otHiV_{o_0} + dt_s \leq otLoV_{o_1}) \tag{7}
\]

\[
o_{sep}_{o_0,o_1} \equiv (obe_{o_0,o_1} \lor obe_{o_1,o_0}).
\]

**Movement separation boolean definition:**

\[
\forall \ (m_0 \prec m_1) \ni \begin{align*}
[mtLoLbC_{m_0},mtHiUbC_{m_0}] \cap [mtLoLbC_{m_1},mtHiUbC_{m_1}] & \neq \emptyset
\end{align*}
\]

\[
m_0, m_1 \in M : 
m_{bef}_{m_0,m_1} \equiv (mtHiV_{m_0} + dt_s \leq mtLoV_{m_1})
\]

\[
m_{sep}_{m_0,m_1} \equiv (m_{bef}_{m_0,m_1} \lor m_{bef}_{m_1,m_0}) \tag{8}
\]
User Interface Parameters

Figure: Leopard GUI and parameters
### Table: Solver running times on a Xeon CPU E31240 Quad Core 3.3 GHz, comparing CPLEX v12.5.0.0 32 bit, XPRESS BCL v4.6.1 64 bit and Gurobi v5.6.3 64 bit

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Figure: Antwerp-Central original Assignment: 3 levels, some conflicts
Automatically and Quickly Planning Platform and Route of Trains in Railway Stations

Results

Antwerp-Central Optimised, Non-Periodic

Optimised Assignment, Non-Periodic

**Figure:** Antwerp-Central Opt. assignment, non-periodic: no conflicts, some unplaced trains
Automatically and Quickly Planning Platform and Route of Trains in Railway Stations

Results

Antwerp-Central Optimised, Periodic

Optimised Assignment, Periodic

Figure: Antwerp-Central Opt. assignment, periodic: no conflicts, some unplaced trains
Both Assignments, Non-Periodic

**Figure:** Antwerp-Central: comparing original and optimised assignments
Antwerp Station

Figure: Antwerp Station
Results

Ghent Sint-Pieters Original

Original Assignment

Figure: Ghent Sint-Pieters original Assignment: some conflicts
Figure: Ghent Sint-Pieters Opt. assignment, non-periodic: no conflicts, some unplaced trains
Both Assignments, Non-Periodic

**Figure:** Ghent Sint-Pieters: comparing original and optimised assignments
# Comparing Original and Optimised Assignment KPIs

## Results

### Comparative Overview

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<th>#platform</th>
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<th>#OptLine</th>
<th>#darkOrq</th>
<th>#lightOrq</th>
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### Example Data

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## TPP Research and Integration

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**Table:** Comparing TPP Research & Integration
Conclusions & Future Work

- Conclusions
  - Leopard usable as check of current platform assignment
    - indicates all conflicts
    - indicates all robustness issues
  - Leopard usable as generator of correct platform assignment
    - guarantees no conflicts
    - can have robustness issues, indicates them
  - fast as a Leopard

- Further Work
  - roll-out with Infrabel planners
  - avoid robustness issues
  - weight trains per # passengers
  - allow some variability of platform times
  - allow multiple routes per line-platform combination
Questions

- Questions?
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- www.LogicallyYours.com/Company/


