Towards a Better Train Timetable for Denmark, Reducing Total Expected Passenger Time

Peter Sels[1,2,3], Dirk Cattrysse[2], Pieter Vansteenwegen[2]

[1]Logically Yours BVBA,
Plankenbergstraat 112 bus L7, 2100 Antwerp, Belgium
e-mail: sels.peter@gmail.com, corresponding author

[2]Katholieke Universiteit Leuven,
Leuven Mobility Research Centre, CIB,
Celestijnenlaan 300, 3001 Leuven, Belgium

[3]Infrabel, Traffic Management & Services,
Fonsnylaan 13, 1060 Brussels, Belgium

July 22nd 2015

Table of Contents

Challenge / Puzzle

Danish Infrastructure Management Company: Banedanmark:

Improve timetable in terms of *expected passenger travel time*
(includes: ride, dwell, transfer time and primary and secondary delays)

Fixed:

Infrastructure, train lines, halting pattern, primary delay distributions

Variable:

Timing: supplements times at every ride, dwell, transfer action,
$\Rightarrow$ variable inter-train heading times $\Rightarrow$ variable train orders

Note:

Includes primary and secondary delays $\Rightarrow$ opt. efficiency vs. robustness

Specifics:

One busy day, morning peak hour

Reflowing Results: via OD-Based Passenger Routing

Retiming Results for Hard Constraints: Minimum Run Time Violations?

Table 1: Realisability. Reduction of the number and size of minimum runtime violations from timetable Orig. → Opt.

time-	distribution: # actions with a violation per size of violation in seconds									
table:	6s	12s	18s	24s	30s	36s	42s	48s	56s	60s	66s
Orig.	107	88	44	22	6	6	5	0	3	1	0
	72s	78s	84s	90s	96s	102s	108s	114s	120s	126s	132s
Orig.	2	0	0	0	1	0	1	0	0	1	1

Table 2: Realisability. Reduction (elimination) of total and average violation from timetable Orig. → Opt.

timetable	weighted sum (s)	tot.#	avg. (s)
Orig.	4452	288	15.5
Opt.	0	0	0

Retiming Results for Hard Constraints: Realisability?

From headway histograms:

- Only Orig. has minimum run time violations.
- So Orig. is not realisable.
- Opt. is realisable.

Retiming Results for Hard Constraints: Headway Conflicts?

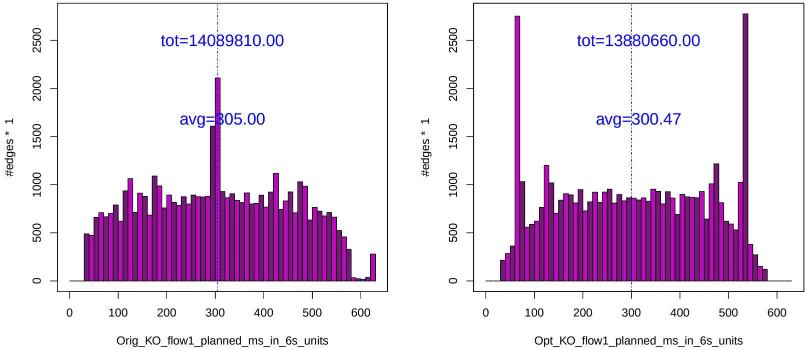

Figure 2: #Edges per Planned headway. $m + s < 3'$ and $T - 3' < m + s$, are problematic. Orig: NOK, Opt OK.

Retiming Results for Hard Constraints: Headway Conflicts?

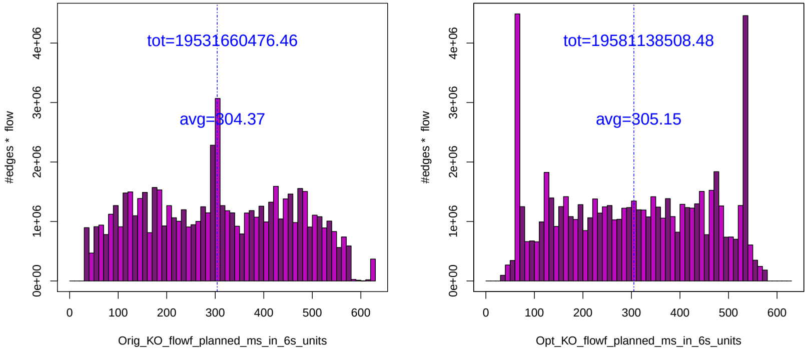

Figure 3: #Passengers per Planned headway. $m + s < 3'$ and $T - 3' < m + s$, are problematic. Orig: NOK, Opt OK.

Retiming Results for Hard Constraints: *Macroscopically* Feasible?

From headway histograms:

- Only Orig. has minimum headway time violations.
- So Orig. is not *macroscopically* feasible = not conflict-less.
- Opt. is *macroscopically* feasible = conflict-less.

Retiming Results in the Planned Train Time Domain

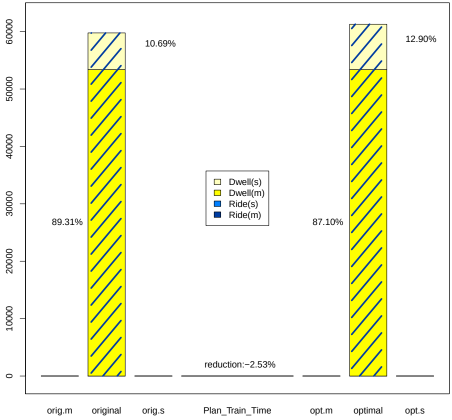

Figure 4: Increase of 2.53% of total planned train time from Orig. to Opt.

Retiming Results in the Planned Train Time Domain

Bargraphs show: Orig. $\rightarrow$ Opt.

- Same planned train minimum ride + dwell time:
  - due to same number of trains and same minima in Orig. and Opt. timetables,
- (relatively) more planned train ride + dwell supplement time:
  - steered by objective function trading off efficiency with robustness,
  - effectiveness for passenger service of this is to be judged in expected passenger time domain.

Results in the Expected Passenger Time Domain

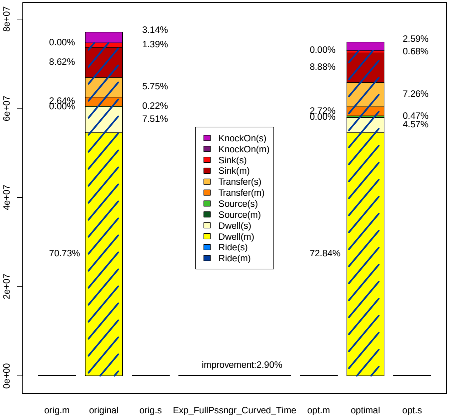

Figure 5: Reduction by 2.90% of total exp. passenger time from Orig. to Opt.

Results in the Expected Passenger Time Domain

Bargraphs show: Orig. $\rightarrow$ Opt.

- $=$ same (expected) minimum ride $+$ dwell time due to:
  - same train line plan
  - passengers (still) taking same routes
- $+$ less expected ride $+$ dwell supplement time $\rightarrow$ more efficient
- $+$ lowered expected knock-on delay $\rightarrow$ better robustness
- - increased expected transfer time due to:
  - difficulty for solver to plan many transfers with few passengers
- $+$ overall reduction of 2.90% in expected passenger time

Reduction of missed transfer probability from 11.34% to 2.45%

Conclusions

- practical method to optimise timetables (in 65 minutes)
- objective = minimal expected passenger time
- showed Orig. → Opt. reduction of 2.90% in exp. passenger. time
- evaluation reports on hard constraints, deterministic
  - stability (ride & dwell & transfers)
  - feasibility = conflict freeness (headways)
- evaluation reports on soft constraints, stochastic
  - efficiency versus robustness
  - does not consider resilience

Railway Timetable Performance Indicators

Table 3: Railway Timetable Performance Indicators

deterministic		stochastic	
stable	feasible	robust	resilient
property in realised domain			
timetable-internal delays settle	no timetable-internal delays	timetable absorbs common prim. & sec. delays	timetable allows dispatching to absorb more rare delays
cause or measure taken in planned domain			
some supplements can be negative but some are *compensatingly* positive	no supplements are negative	supplements are *sufficiently* large	timetable-tuned dispatching measures

International Comparison

Table 4: Current Quality Levels of some European Railway Timetables

	deterministic			stochastic		
Level	stable	...............feasible............... realisable	no μ-HW-conflicts	robust	resilient	Country
0						FR,IT,BE,DK
1	v					NL,UK
2	v	v	v			DE
3	v	v	v	v		CH,SE
4	v	v	v	v	v	
	stable	realisable	no 3´HW-conflicts	robust	resilient	Country
?,?	v,v	v,v	v,v	v,v		*BE′**, *DK′**

- Black text above [Goverde and Hansen(2013)], based on inquiries and timetable process descriptions of 2013, may be incorrect.
- [Sels et al.(2015a)Sels, Cattrysse, and Vansteenwegen]
- [Sels et al.(2015b)Sels, Dewilde, Cattrysse, and Vansteenwegen]
- [Sels et al.(2015c)Sels, Dewilde, Cattrysse, and Vansteenwegen]
- μ-HW = microscopically calculated min. headway times.
- 3´HW = 3 minute macroscopically assumed min. headway times.

Future Work

- evaluate over only real transfers $\leftarrow$ data?
- vary parameter 'a' value: 1% .. 5%
- add parameter 'r'
  - r% of passengers benefit from temporal spreading of trains
- parameter 'r' value: 0% .. 100%

Questions / Next Steps

- Your questions?
  - here and now, or ...
  - sels.peter@gmail.com
  - www.LogicallyYours.com/research/

Results in all Time Domains

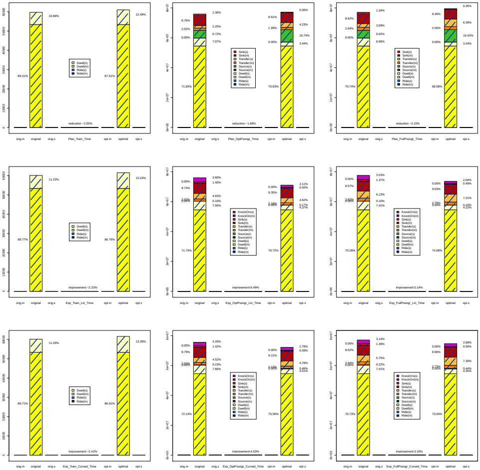

Figure 6: Reduction by 3.16% of total exp. passenger time from Orig. to Opt.

- Goverde, R., Hansen, I., 2013. Performance indicators for railway timetables. Proceedings of IEEE International Conference on Intelligent Rail Transportation: ICIRT2013, August 30-September 1, 2013, Beijing, China., 301–306.
- Sels, P., Cattrysse, D., Vansteenwegen, P., Jul. 2015a. Practical Macroscopic Evaluation and Comparison of Railway Timetables. Proceedings of the 18th Euro Working Group on transportation (EWGT2015), 14-16 July 2015, Delft, The Netherlands. URL `http://4c4u.com/ED2015.pdf`.
- Sels, P., Dewilde, T., Cattrysse, D., Vansteenwegen, P., 2015b. Reducing the Passenger Travel Time in Practice by the Automated Construction of a Robust Railway Timetable. submitted to Transportation Research Part B URL `http://4c4u.com/TRB2015.pdf`.
- Sels, P., Dewilde, T., Cattrysse, D., Vansteenwegen, P., Jul. 2015c. Towards a Better Train Timetable for Denmark, Reducing Total Expected Passenger Time. Proceedings of the 13th Conference on Advanced Systems in Public Transport (CASPT2015), 19-23 July 2015, Rotterdam, The Netherlands. URL `http://4c4u.com/CR2015.pdf`.