Practical Macroscopic Evaluation and Comparison of Railway Timetables

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

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

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

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

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Comparing and Preferring Timetables

Belgian Infrastructure Management Company: Infrabel:

Compare 2 Timetables in terms of Expected Passenger Travel Time (includes: ride, dwell, transfer time and primary and secondary delays)

Note:

Including primary and secondary delays
$\Rightarrow$ evaluate efficiency & robustness

Specifics:

One Busy Day, Morning Peak Hour

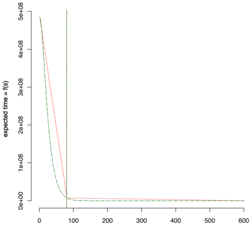
Result of Reflowing: Disc Area = Daily Flow

In-Time and Over-Time

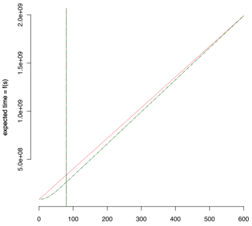
Table 1: In-Time and Over-Time Integrals when adding supplement D_0

	In-Time	Over-Time
probability	$\int_0^{D_0} p_a(x)dx$	$\int_{D_0}^{D_1} p_a(x)dx$
inc./dec. in D_0	inc.	dec.
expected time	$\int_0^{D_0} p_a(x)D_0 dx$	$\int_{D_0}^{D_1} p_a(x)D_1 dx$
inc./dec. in D_0	inc.	dec.
departing = ride' + dwell' + source		✓
through = ride + dwell	✓	
changing = ride + transfer	✓	✓
arriving = ride + sink	✓	

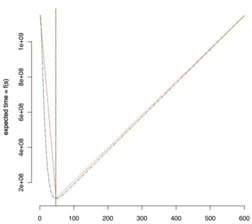
Cost curves of 4 Passenger Categories



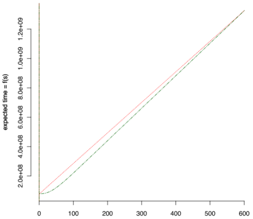
(a) departing=ride'+dwell' +source



(b) through=ride+dwell

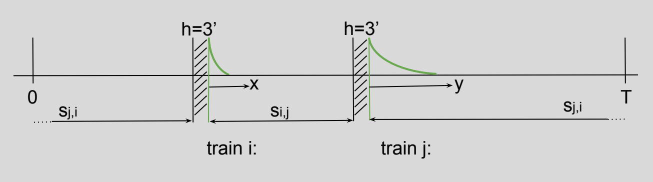


(c) changing=ride+transfer

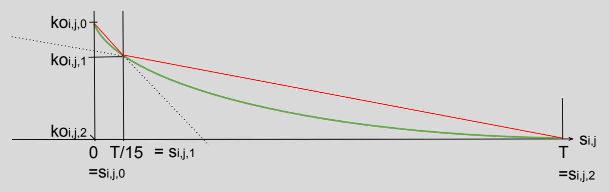


(d) arriving=ride+sink

All Knock-On Costs for $N(N-1)$ Trains on Same Resource: Formula



$$\forall R : pKO_R = \sum_{\substack{i,j \in I_R \\ i \neq j}} f_j \cdot \frac{a_j e^{-a_i s_{i,j}}}{a_i(a_i + a_j)}. \quad (1)$$



Results for Hard Constraints: Realisability?

Table 2: Realisability. Reduction of the number and size of minimum runtime violations from timetable T1 → T2.

timetable	distribution: # actions with a violation per size of violation in seconds										
	6s	12s	18s	24s	30s	36s	42s	48s	56s	60s	66s
T1	320	219	126	93	24	27	3	6	1	3	1
T2	277	155	84	37	11	2	2	2			

Table 3: Realisability. Reduction of total and average violation from timetable T1 → T2.

timetable	weighted sum (s)	tot.#	avg. (s)
T1	11454	823	13.9
T2	6504	570	11.4

Results for Hard Constraints: Minimum Run Time Violations.

From run time check table:

- Both T1 and T2 have minimum run time violations.
- So are not realisable.
- T2 has fewer and smaller run time violations than T1.

Results for Hard Constraints: Headway Conflicts?

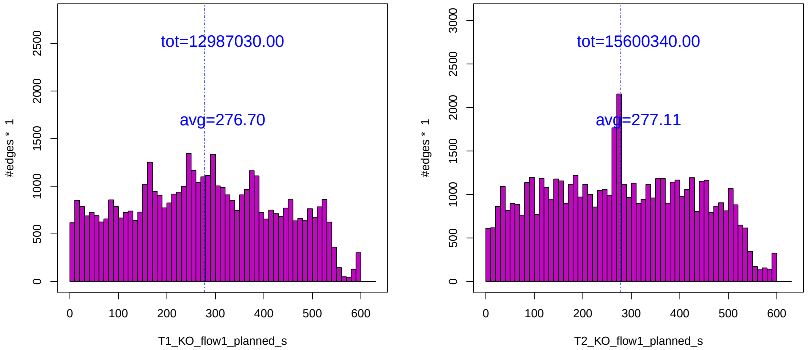


Figure 1: Planned headway supplements, in T1 and T2 of: $T - 3' \leq s < T$, are problematic.

Results for Hard Constraints: Headway Conflicts.

From headway histograms:

- Both T1 and T2 have minimum headway time violations.
- So are not feasible = not conflict-less.

Results in the Planned Train Time Domain

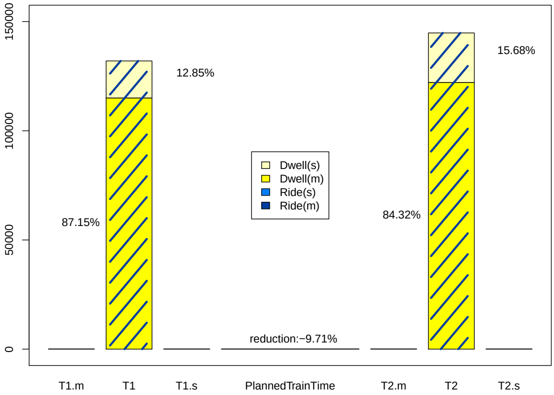


Figure 2: Increase of 9.71% f total planned train time from T1 to T2. All time units are in 6 second multiples.

Results in the Planned Train Time Domain

Bargraphs show: T1 $\rightarrow$ T2

- more planned train minimum ride + dwell time:
  - due to some extra trains in T2 compared to T1,
  - effectiveness for passenger service of this is to be judged in expected passenger time domain.
- (relatively) more planned train ride + dwell supplement time:
  - efficiency versus robustness of this is to be judged in expected passenger time domain.

Results in the Expected Passenger Time Domain

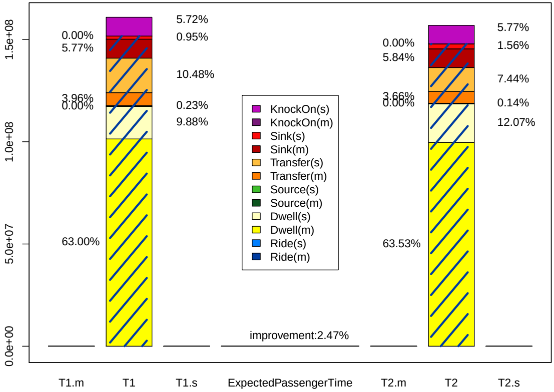


Figure 3: Reduction of 2.47% of total expected passenger time from T1 to T2. All time units are in 6 second multiples.

Results in the Expected Passenger Time Domain

Bargraphs show: T1 $\rightarrow$ T2

- $+$ less (expected) minimum ride $+$ dwell time due to:
  - faster trains and/or
  - more effective direct connections (for big passenger OD pairs) (different line planning)
- - more expected ride $+$ dwell supplement time $\rightarrow$ less efficient
- $=$ similar expected knock-on delay $\rightarrow$ similar robustness
- $+$ significantly reduced expected transfer time due to:
  - more effective transfers (for big passenger OD pairs)
- $+$ overall reduction of 2.47% in expected passenger time
- $+$ average probability of missing a transfer is reduced from 14.41% for T1 to 5.51% for T2.

International Comparison

Table 4: Current Quality Levels of some European Railway Timetables

Level	realisable	conflictless	robust	resilient	Country
	no min. run/dwell violations	no min. headway violations			
	feasible				
	deterministic		stochastic		
0					FR, IT, BE, DK
1	v				NL, UK
2	v	v			DE
3	v	v	v		CH, SE, BE'^{*}, DK'^{*}
4	v	v	v	v	

- All text in black above is due to [Goverde and Hansen(2013)]
- [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]
- *Note: Our optimized timetables: BE',DK'are stable, *have no 'macroscopic conflicts'* and are robust.

Conclusions

- practical method to evaluate and compare timetables
- objective = evaluation function = minimal expected passenger time
- showed T1 $\rightarrow$ T2 reduction of 2.47% in exp. passenger. time
- evaluation reports on hard constraints, deterministic
  - realisability (ride & dwell & transfers)
  - conflict freeness (headways)
  - stability (cycles)
- evaluation reports on soft constraints, stochastic
  - efficiency
  - robustness
  - (resilience)

Future Work

- evaluate over only real transfers ← 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

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

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.

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