PHD DEFENCE

Peter Sels

Large-Scale,
Passenger Oriented,
Cyclic TimeTabling &
Station Platforming and Routing

Sudoku

IS A FEASIBILITY PROBLEM

5	3			7				
6			1	9	5			
	9	8					6	
8				6				3
4			8		3			1
7				2				6
	6					2	8	
			4	1	9			5
				8			7	9

5	3	4	6	7	8	9	1	2
6	7	2	1	9	5	3	4	8
1	9	8	3	4	2	5	6	7
8	5	9	7	6	1	4	2	3
4	2	6	8	5	3	7	9	1
7	1	3	9	2	4	8	5	6
9	6	1	5	3	7	2	8	4
2	8	7	4	1	9	6	3	5
3	4	5	2	8	6	1	7	9

CONSTRAINTS

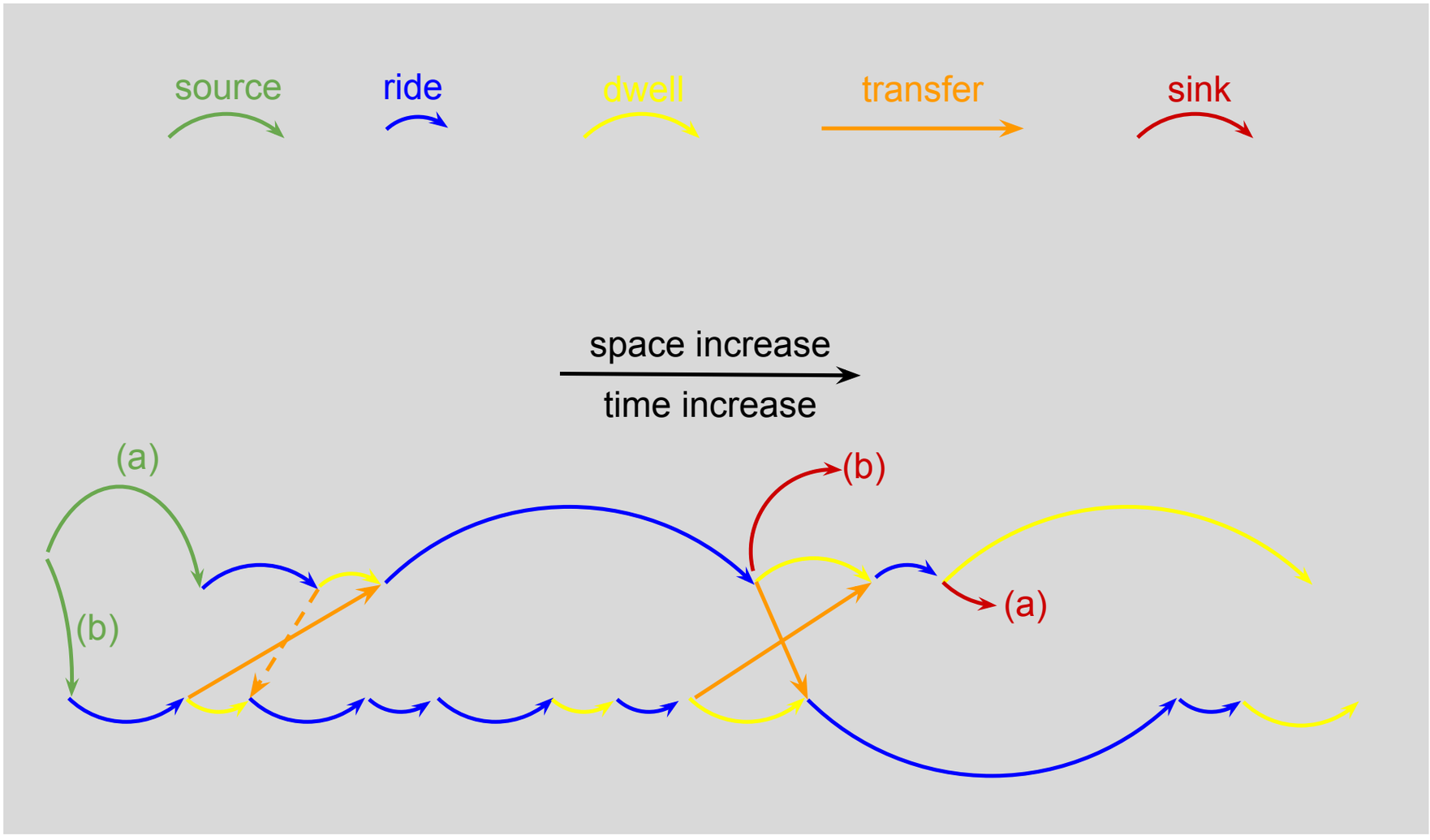
Scrabble

IS AN OPTIMISATION PROBLEM

CONSTRAINTS + OBJECTIVE (FUNCTION)

Timetabling

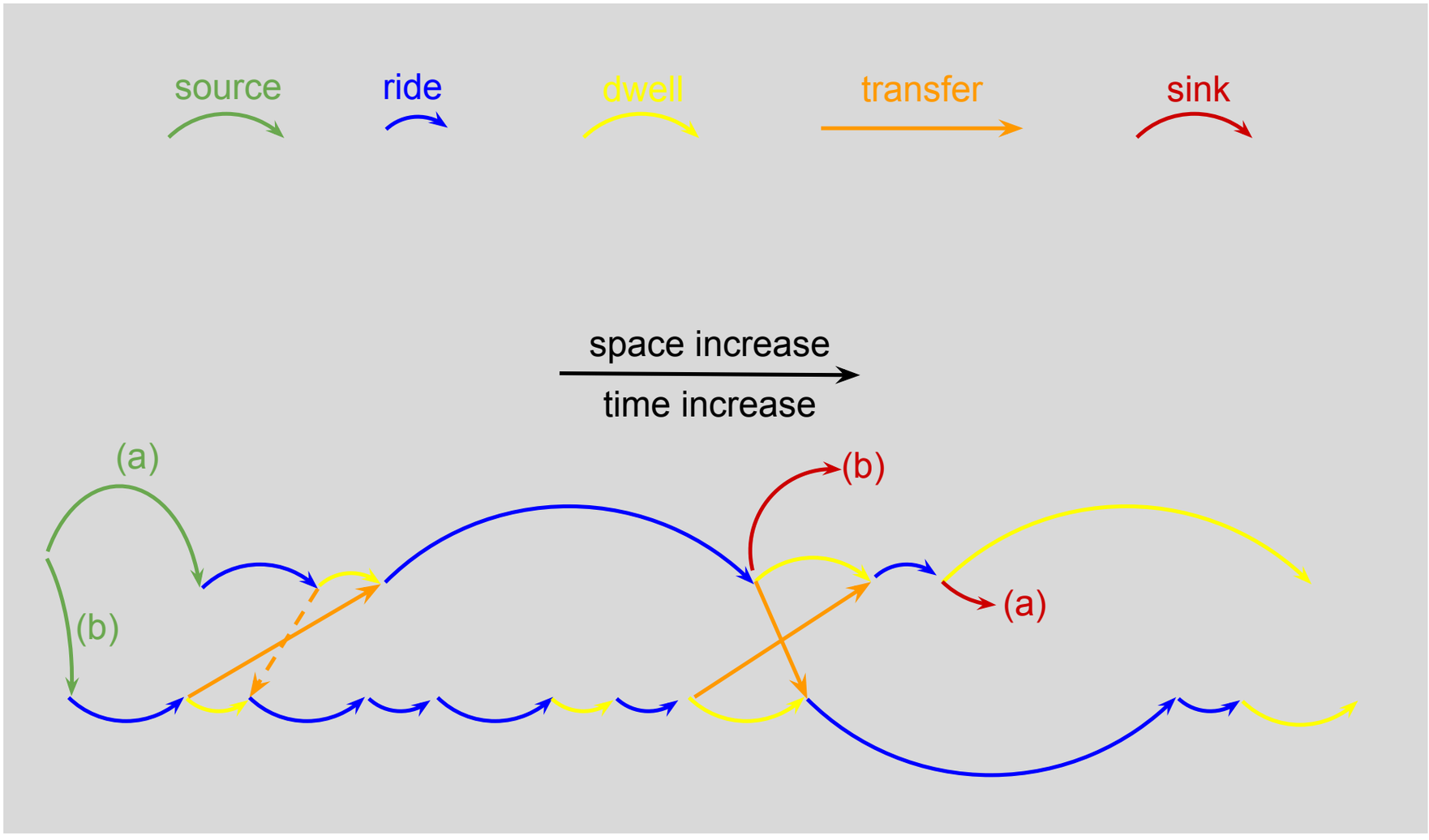
TRAIN NETWORK MODEL



EACH ARROW NEEDS: A NUMBER OF PASSENGERS & A DURATION

Timetabling

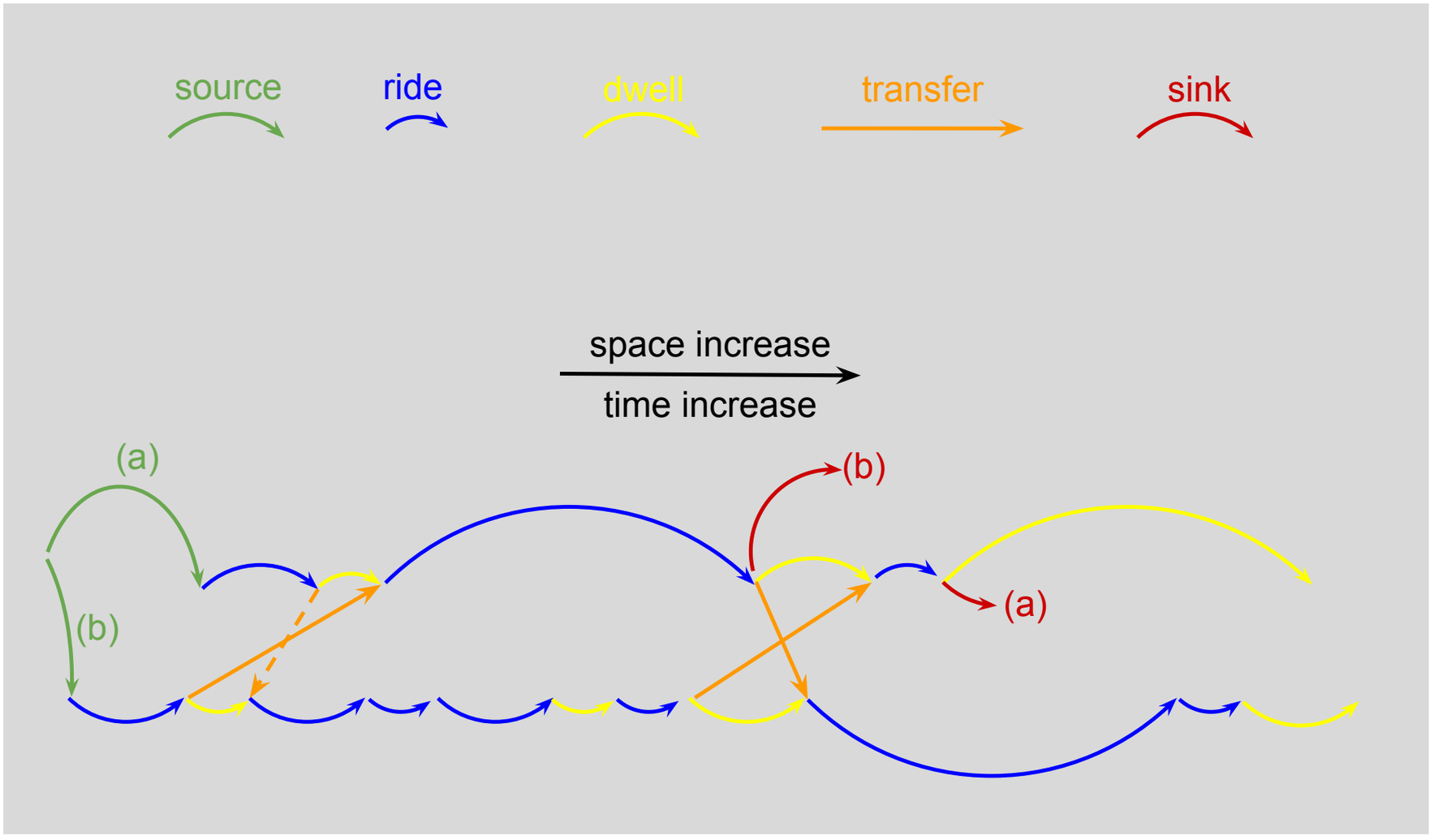
TRAIN NETWORK MODEL



ARROW WIDTH: NUMBER OF PASSENGERS: BY ROUTING

Timetabling

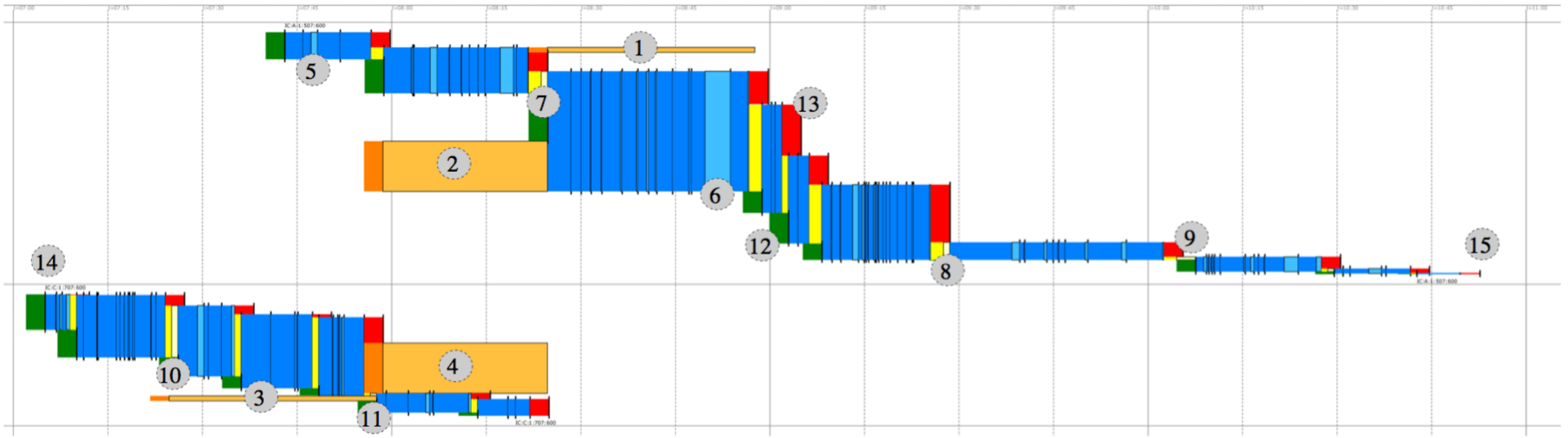
TRAIN NETWORK MODEL



ARROW LENGTH: DURATION: BY TIMETABLING

Timetabling

TRAIN NETWORK MODEL: OLD TIMETABLE

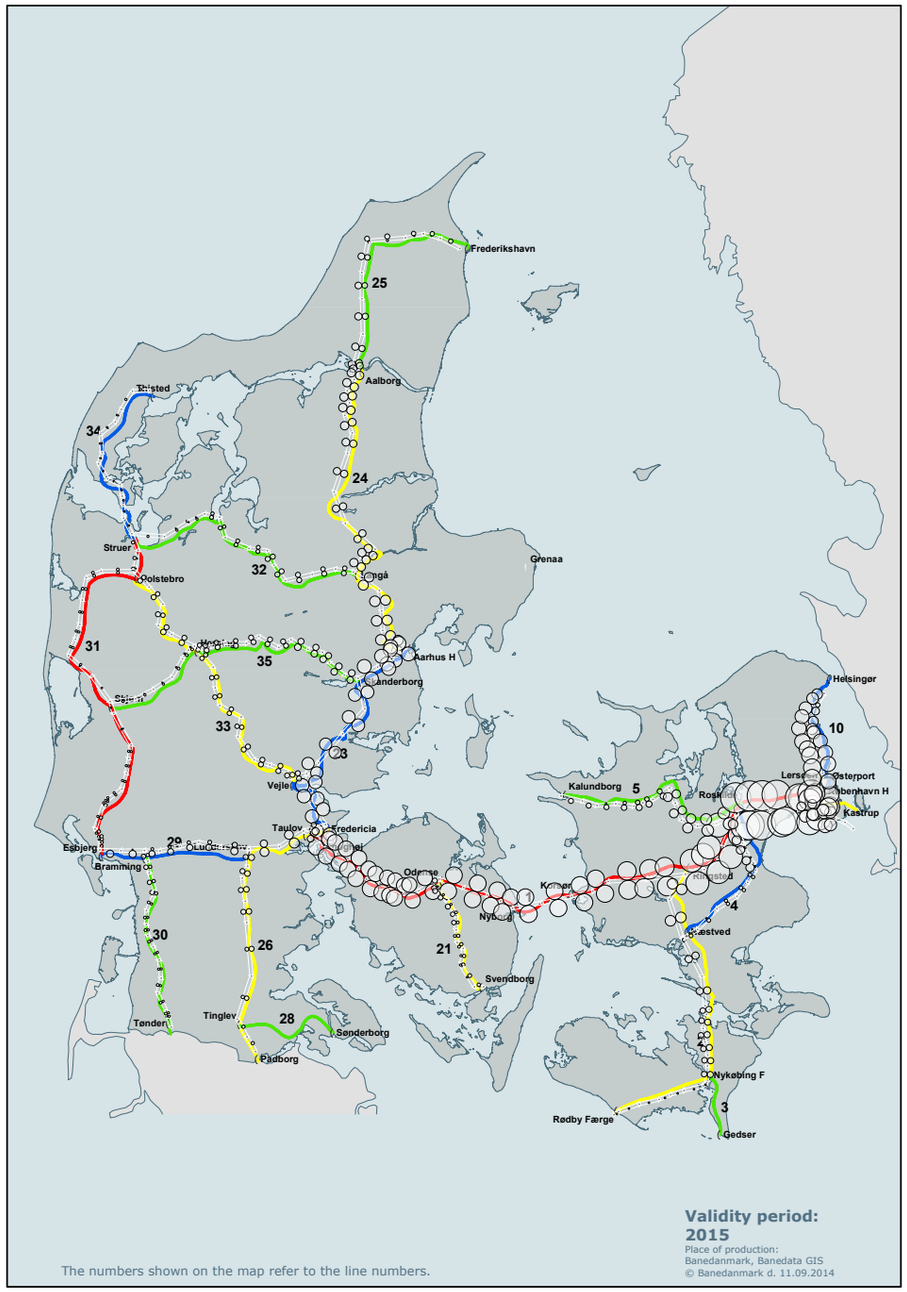


EACH ARROW HAD: A NUMBER OF PASSENGERS & AN OLD DURATION

Timetabling: Reflowing Phase: Belgium

BY MIMICKING HOW PASSENGERS CHOOSE ROUTES

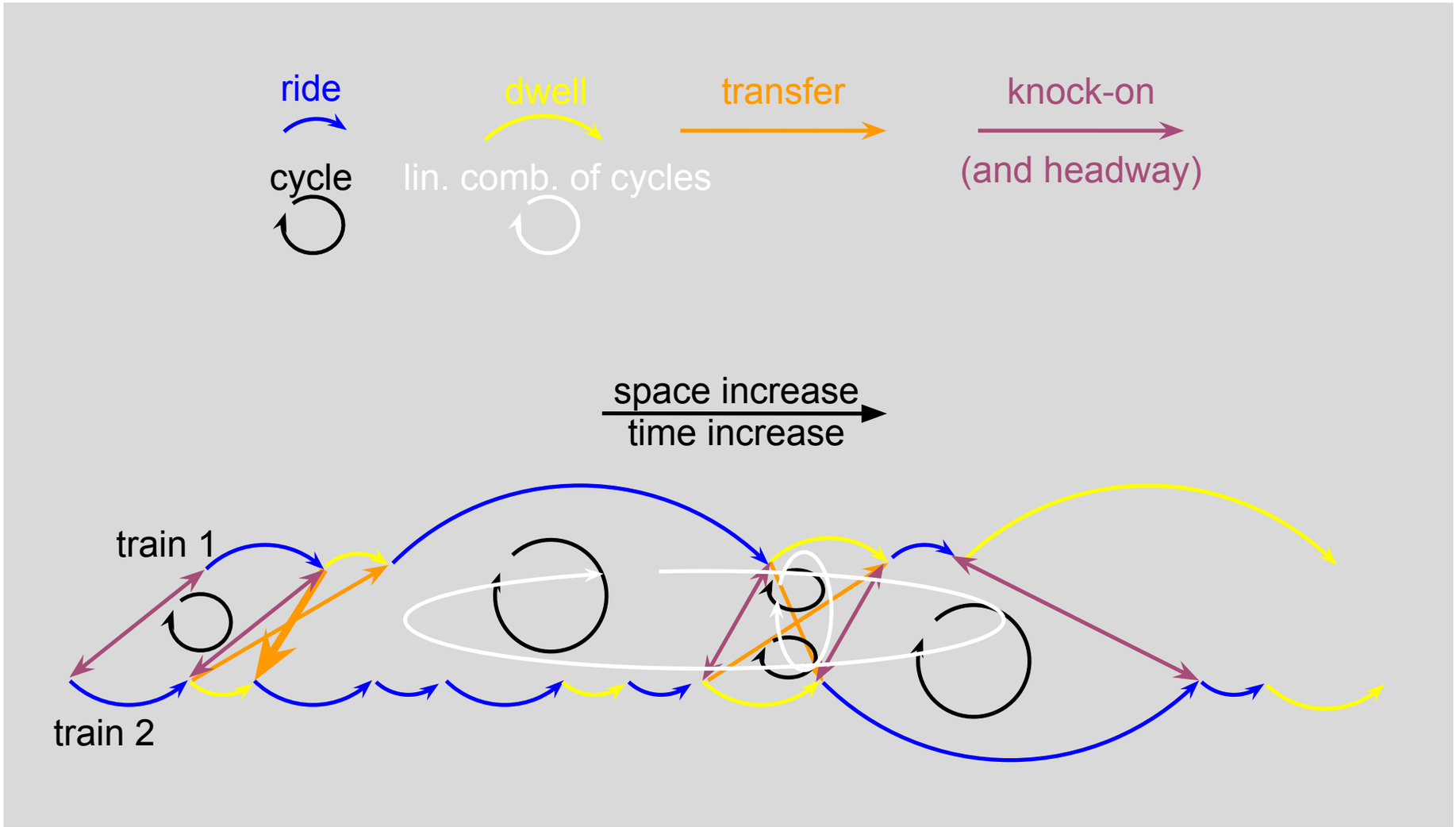
Timetabling: Reflowing Phase: Denmark



BY MIMICKING HOW PASSENGERS CHOOSE ROUTES

Timetabling: Retiming Phase: Constraints

VISUALLY IDENTIFYING CONSTRAINTS



FOR EACH ARROW
AT END OF ARROW TO BEGIN OF NEXT ARROW
IN CYCLES: (SMALL) BLACK AND (DEPENDENT) WHITE

Timetabling: Retiming Phase: Constraints

MATHEMATICALLY FORMULATING CONSTRAINTS

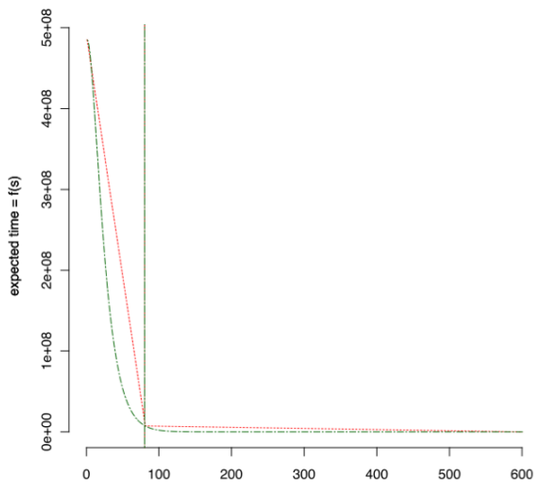
primary edges	secondary edges		cycles
ride dwell	transfer knock on turn around symmetry	symmetry	
b + m + s = e	b + m + s + (d * T) = e	e = T - b or e = T/2 - b or ...	sum_e_in_cycle : sign_e_in_cycle * (m_e + s_e + (d_e * T)) = 0

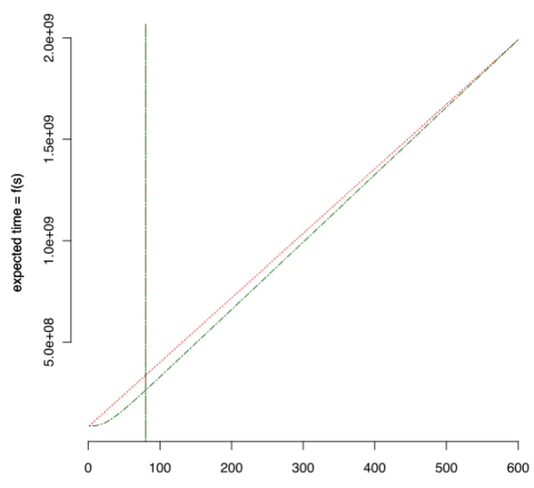
b(egin), m(inimum), s(upplement), e(nd), d(integer), T(period)
constants: m, T
variables: b, s, e, d

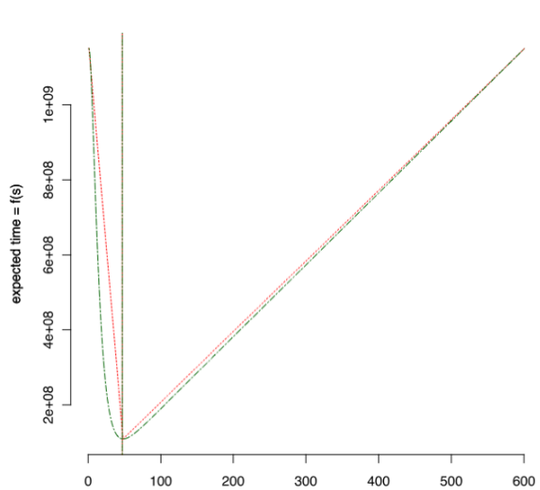
BEGIN + DURATION = END
EACH END = NEW BEGIN
BY KIRCHHOFF VOLTAGE LAWS IN BASIC (BLACK) AND EXTRA (WHITE) CYCLES

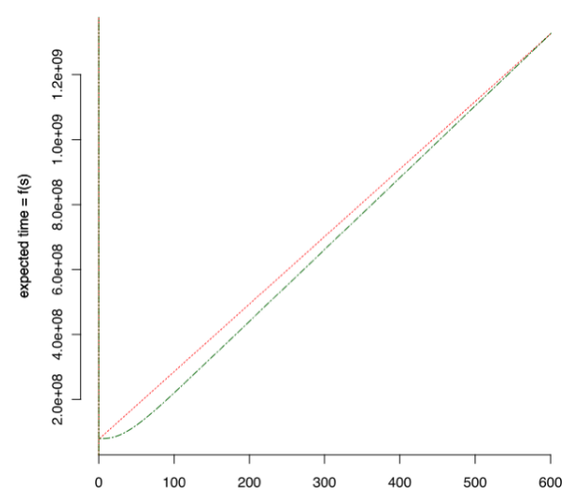
Timetabling: Retiming Phase: Objective

DURATION = MIN + SUPPLEMENT. SUPPLEMENTS: HOW DETERMINED?

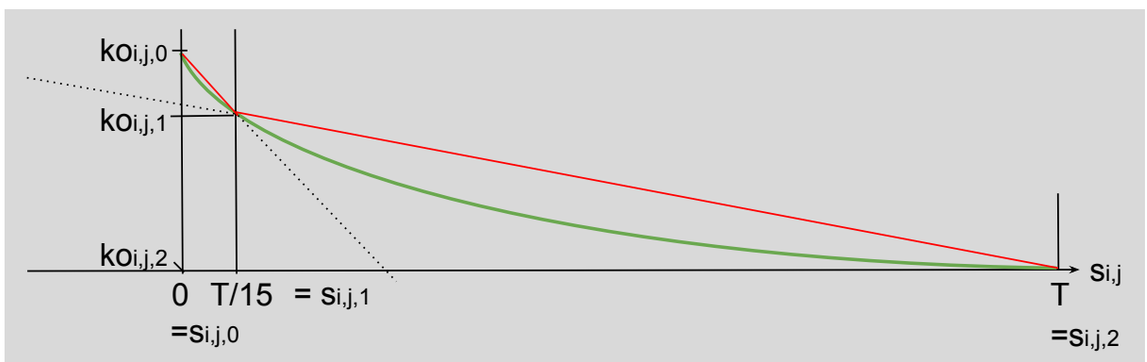








DEPARTING THROUGH TRANSFER ARRIVING

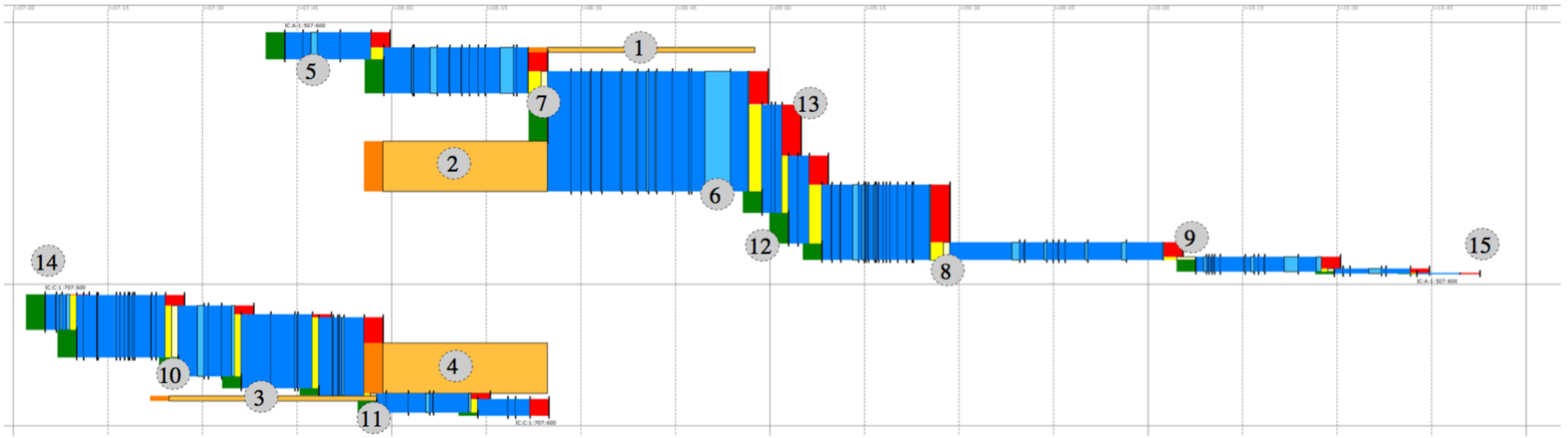


KNOCK-ON DELAY

BY LOCAL COST FUNCTIONS: REPRESENTING LOCAL PLANNED TIME
TOTAL OBJECTIVE = SUM OF LOCAL OBJECTIVE => SUPPLEMENTS COMPETE

Timetabling

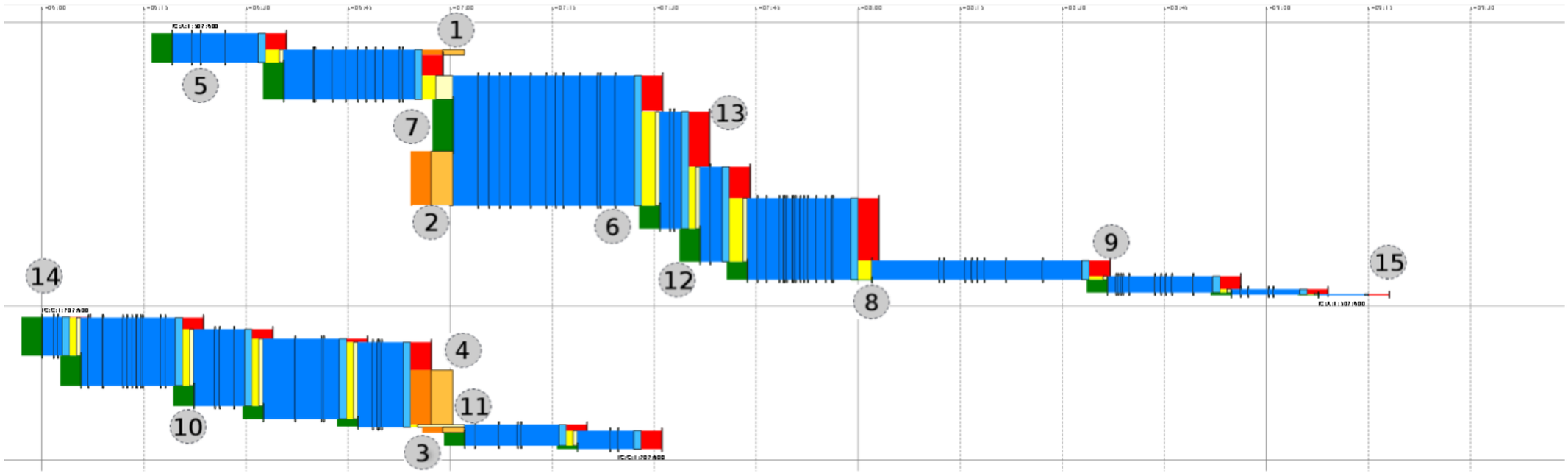
TRAIN NETWORK MODEL: OLD TIMETABLE



EACH ARROW HAD: A NUMBER OF PASSENGERS & AN OLD DURATION

Timetabling: Retiming Phase

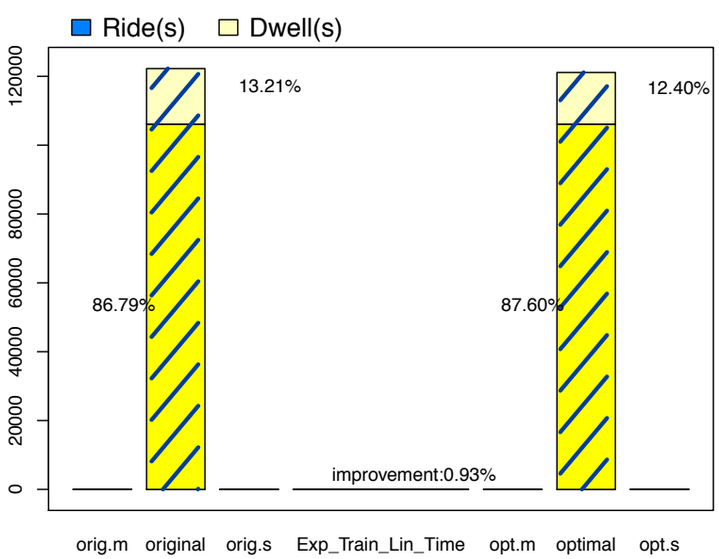
TRAIN NETWORK MODEL: NEW TIMETABLE

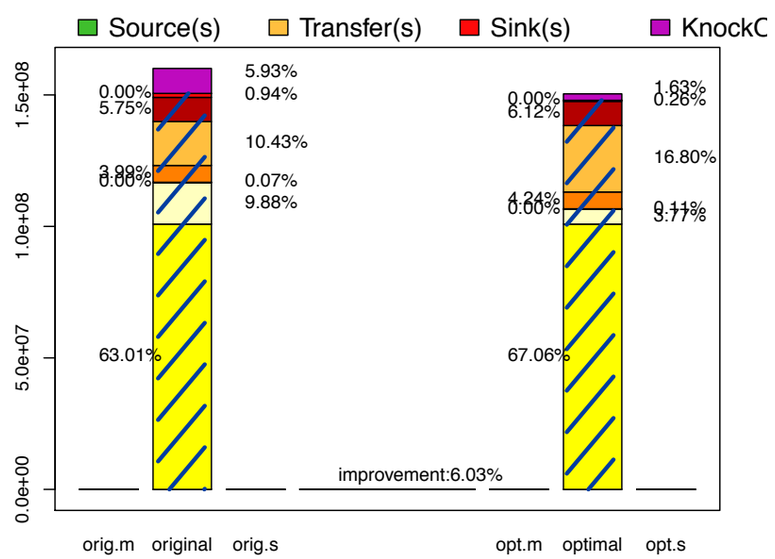


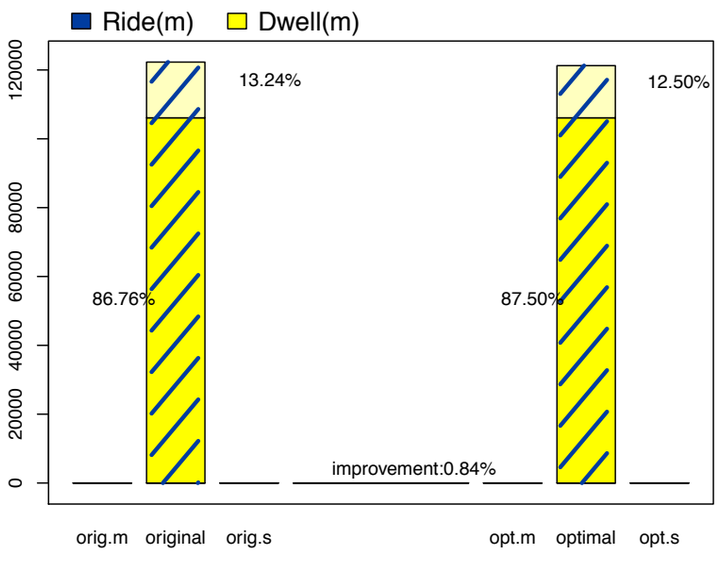
EACH ARROW HAS: A NUMBER OF PASSENGERS & A NEW DURATION
NOTE COMPRESSION, BUT NOT TOTALLY => EFFICIENT YET ROBUST

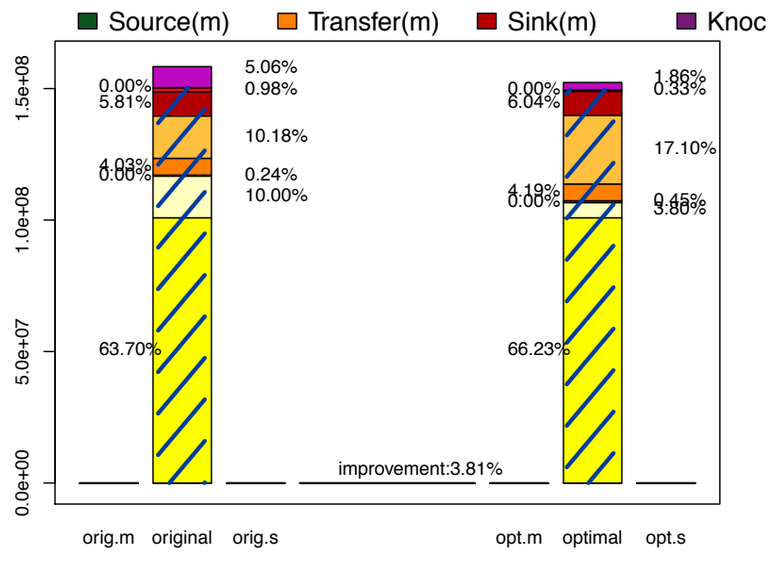
Timetabling

RESULTS FOR PASSENGERS: BELGIUM







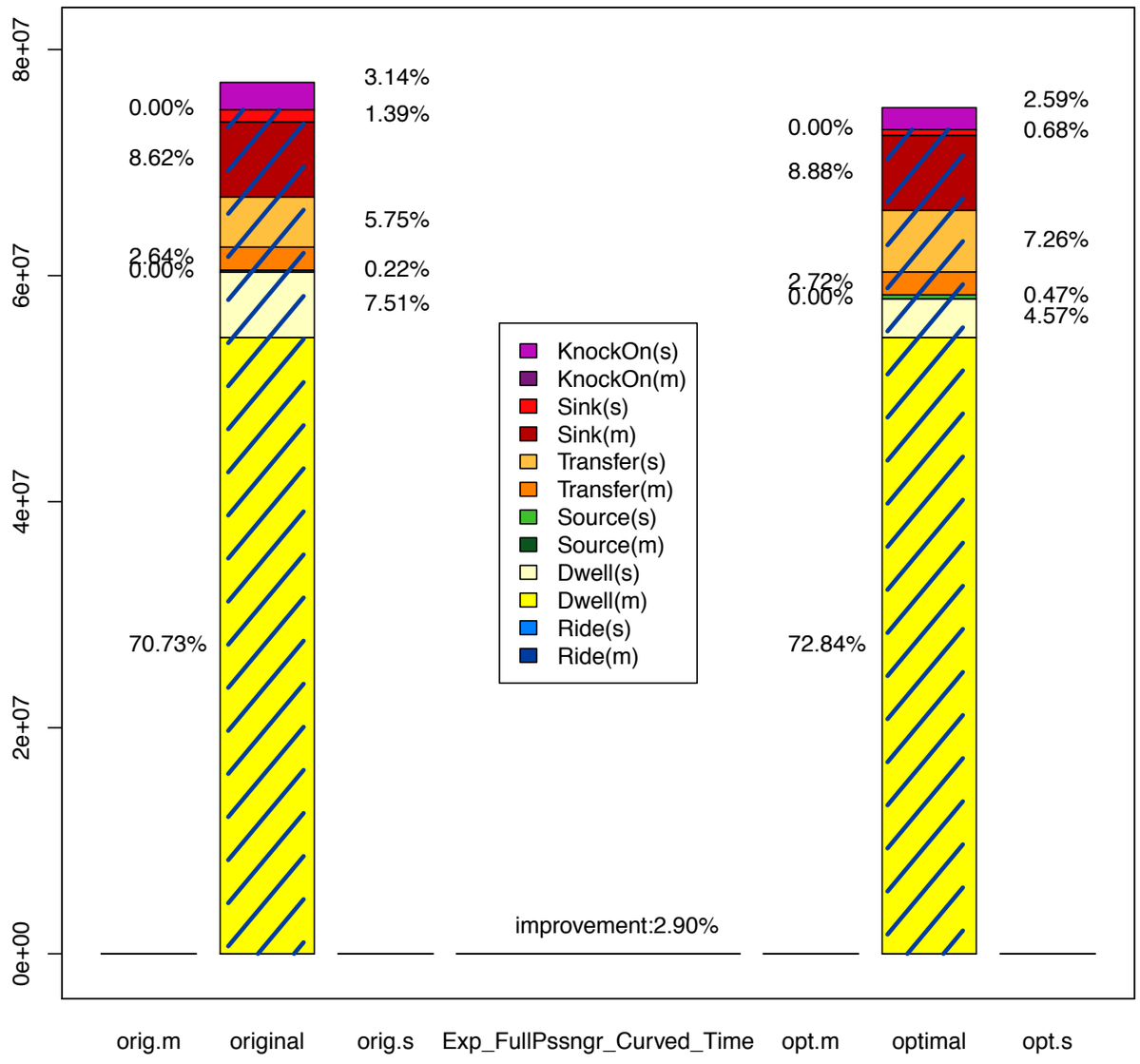


SMALL PLANNED TRAIN SUPPLEMENT REDUCTION

3.8% LESS PASSENGER TIME IN PRACTICE

Timetabling

RESULTS FOR PASSENGERS: DENMARK



SMALL PLANNED TRAIN SUPPLEMENT INCREASE 2.9% LESS PASSENGER TIME IN PRACTICE

Timetabling

RESULTS FOR TRAINS: PUNCTUALITY

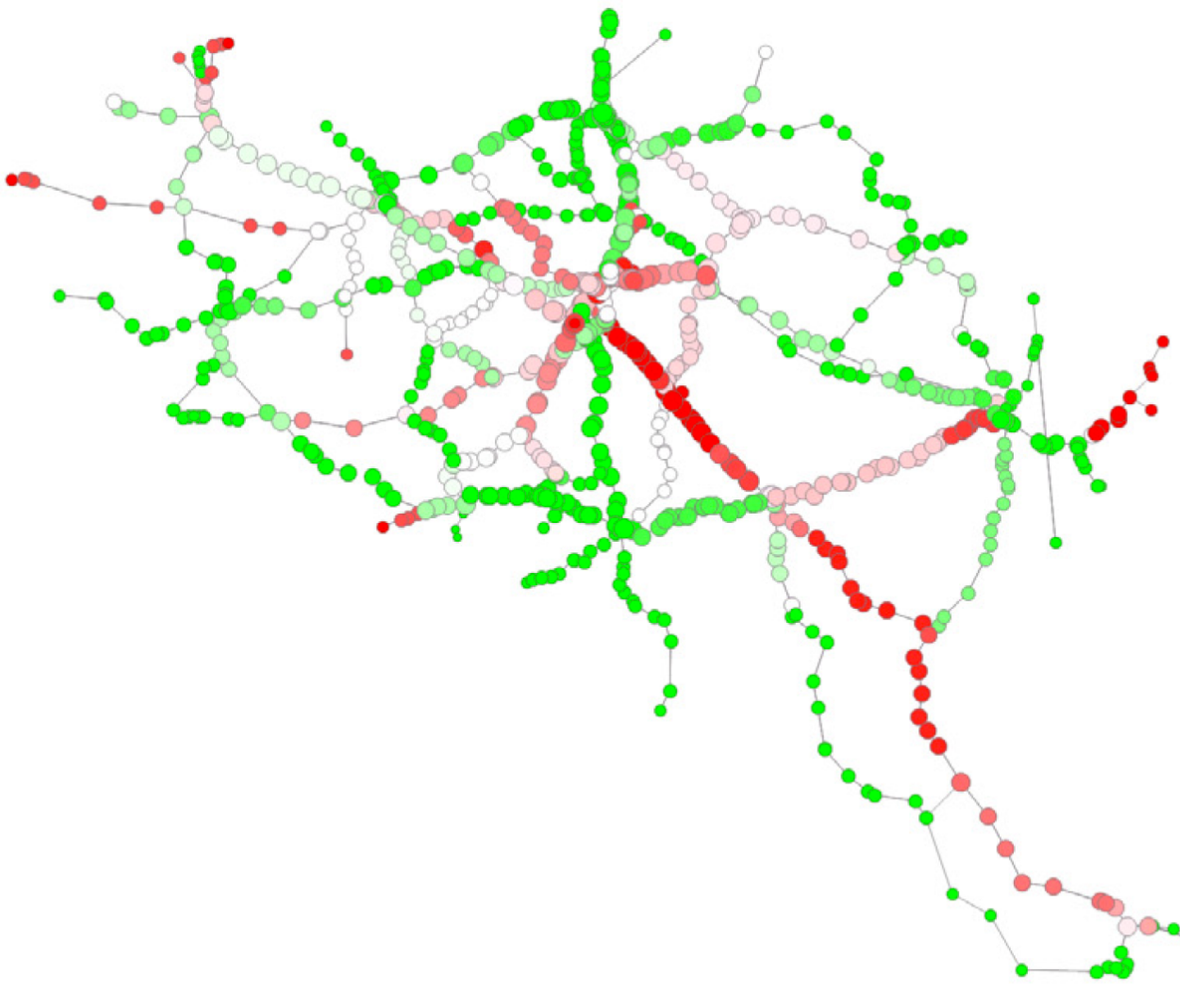
(a) Orig. tt, 0':00" late probability, red/green 50%

(b) Opt. tt, 0':00" late probability, red/green 50%

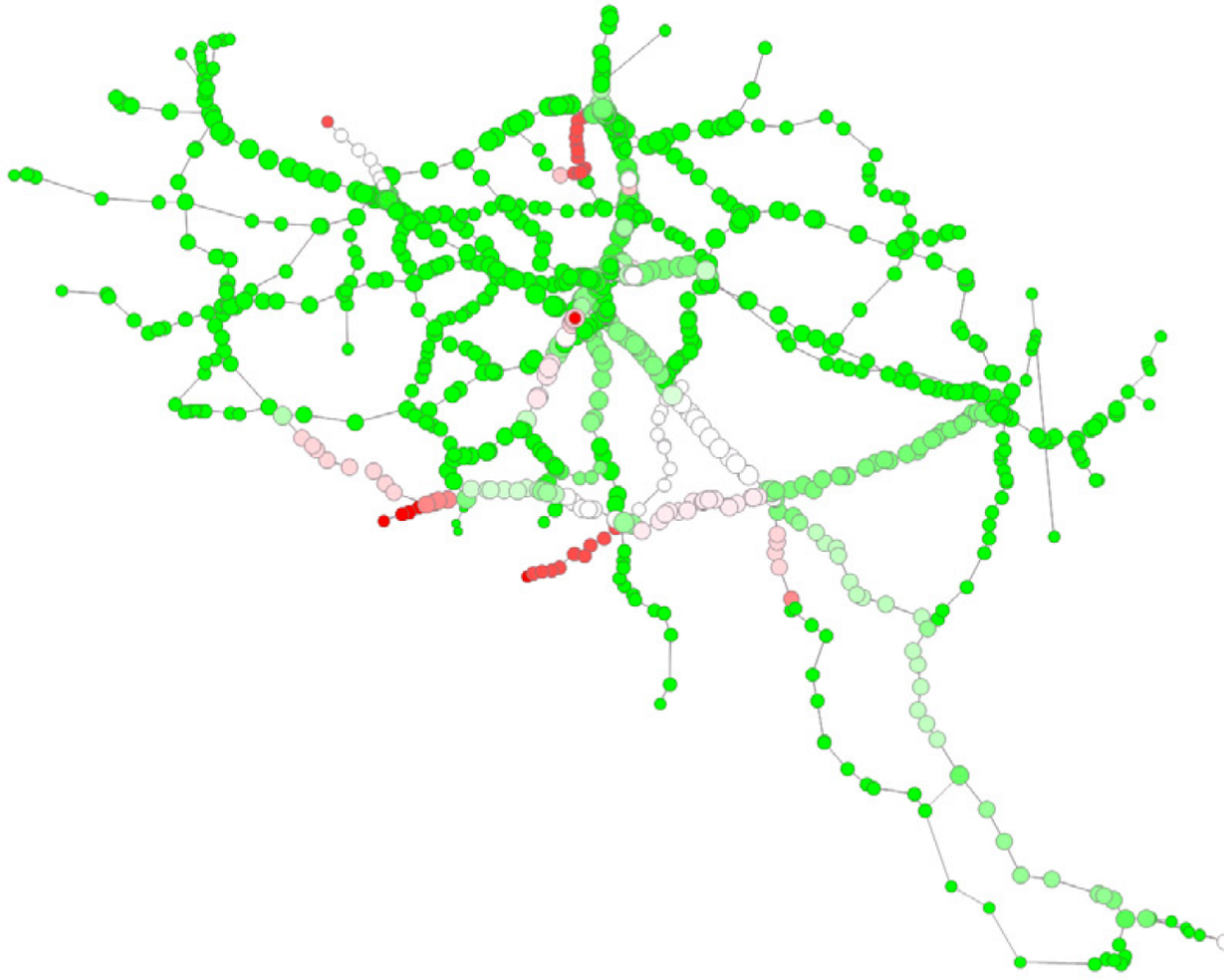
ALSO BETTER TRAIN PUNCTUALITY

Timetabling

RESULTS FOR TRAINS: PUNCTUALITY



(c) Orig. tt, 0':00" late probability, red/green 80%

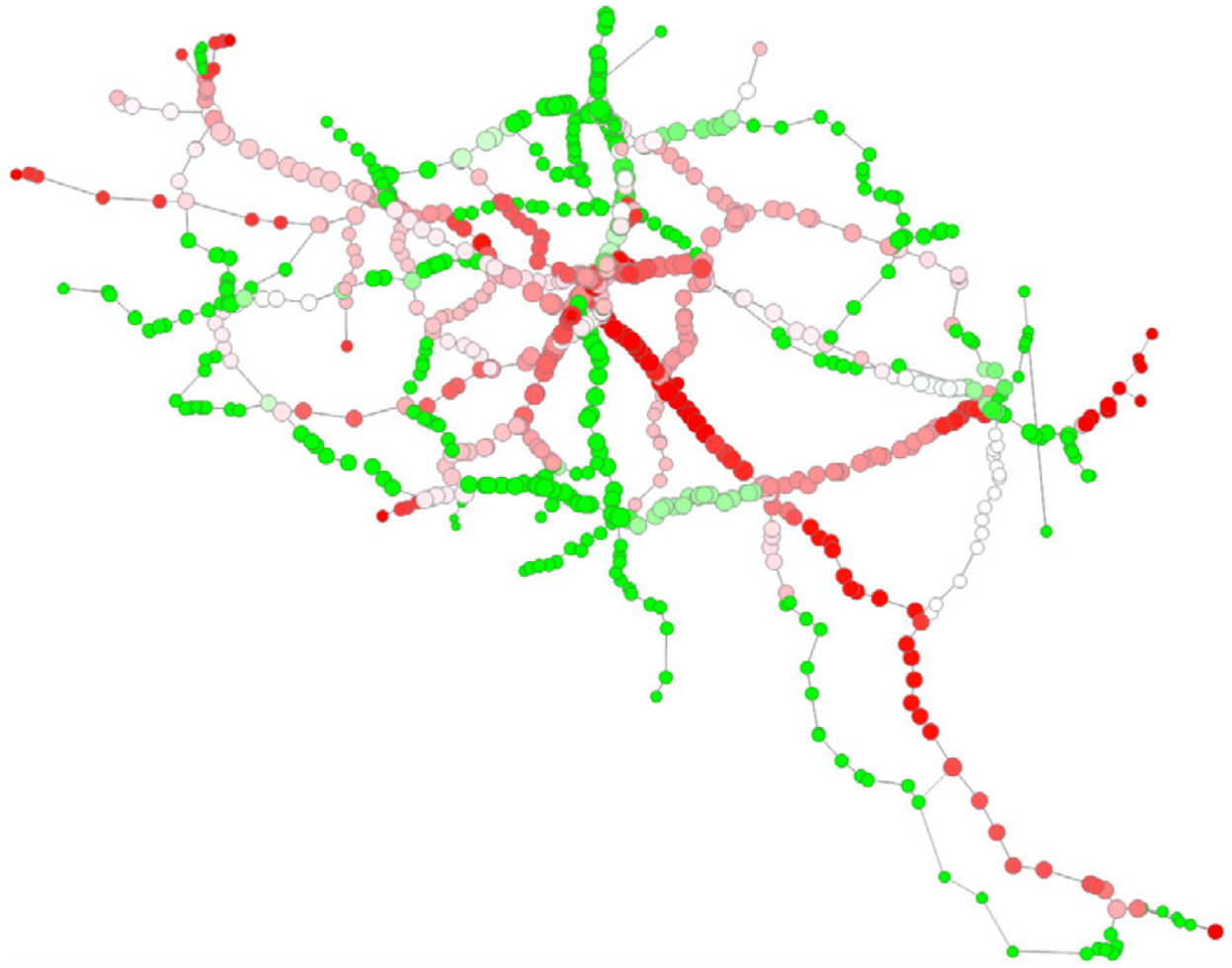


(d) Opt. tt, 0':00" late probability, red/green 80%

ALSO BETTER TRAIN PUNCTUALITY

Timetabling

RESULTS FOR TRAINS: PUNCTUALITY



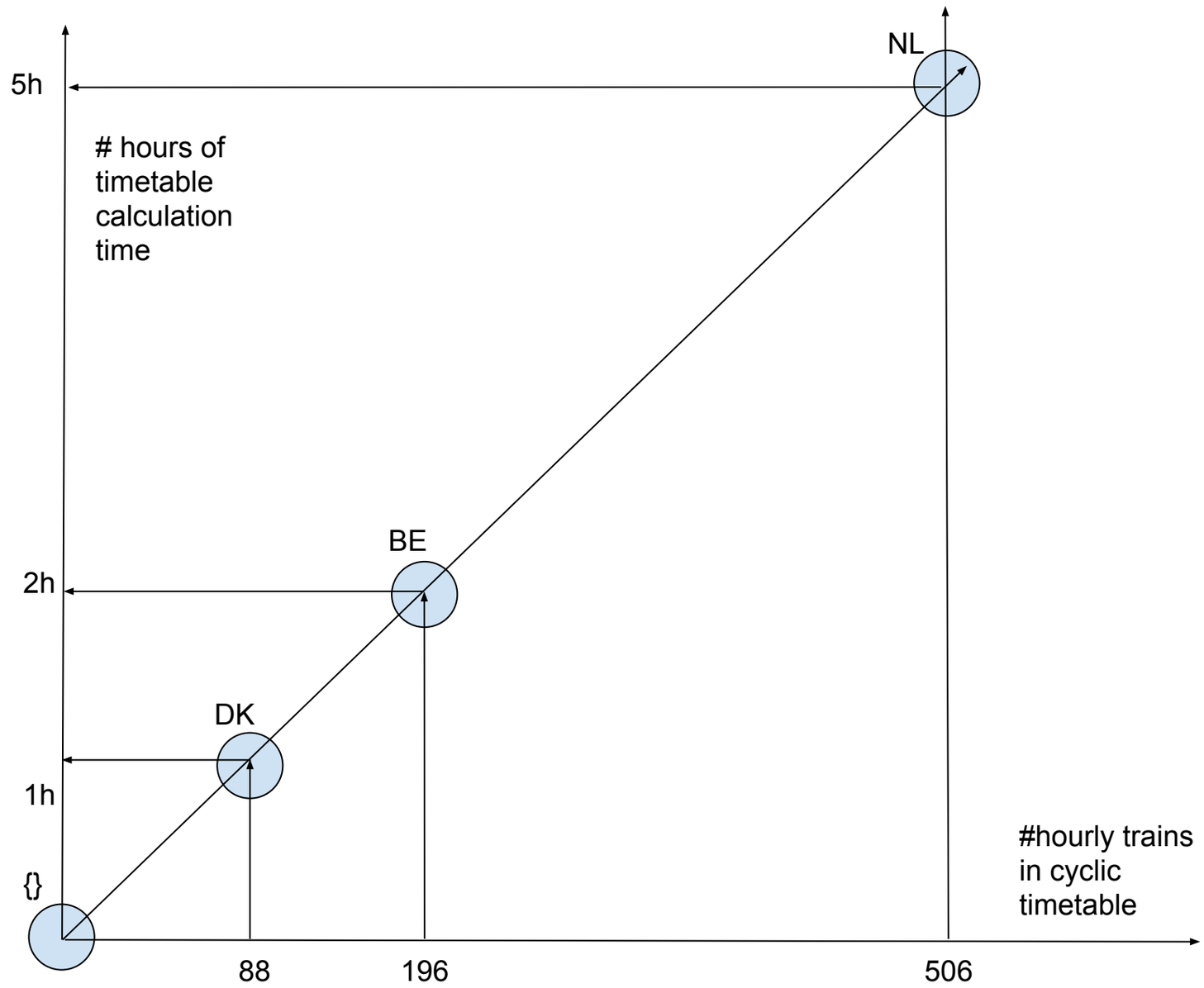
(e) Orig. tt, 0':00" late probability, red/green 90%

(f) Opt. tt, 0':00" late probability, red/green 90%

ALSO BETTER TRAIN PUNCTUALITY

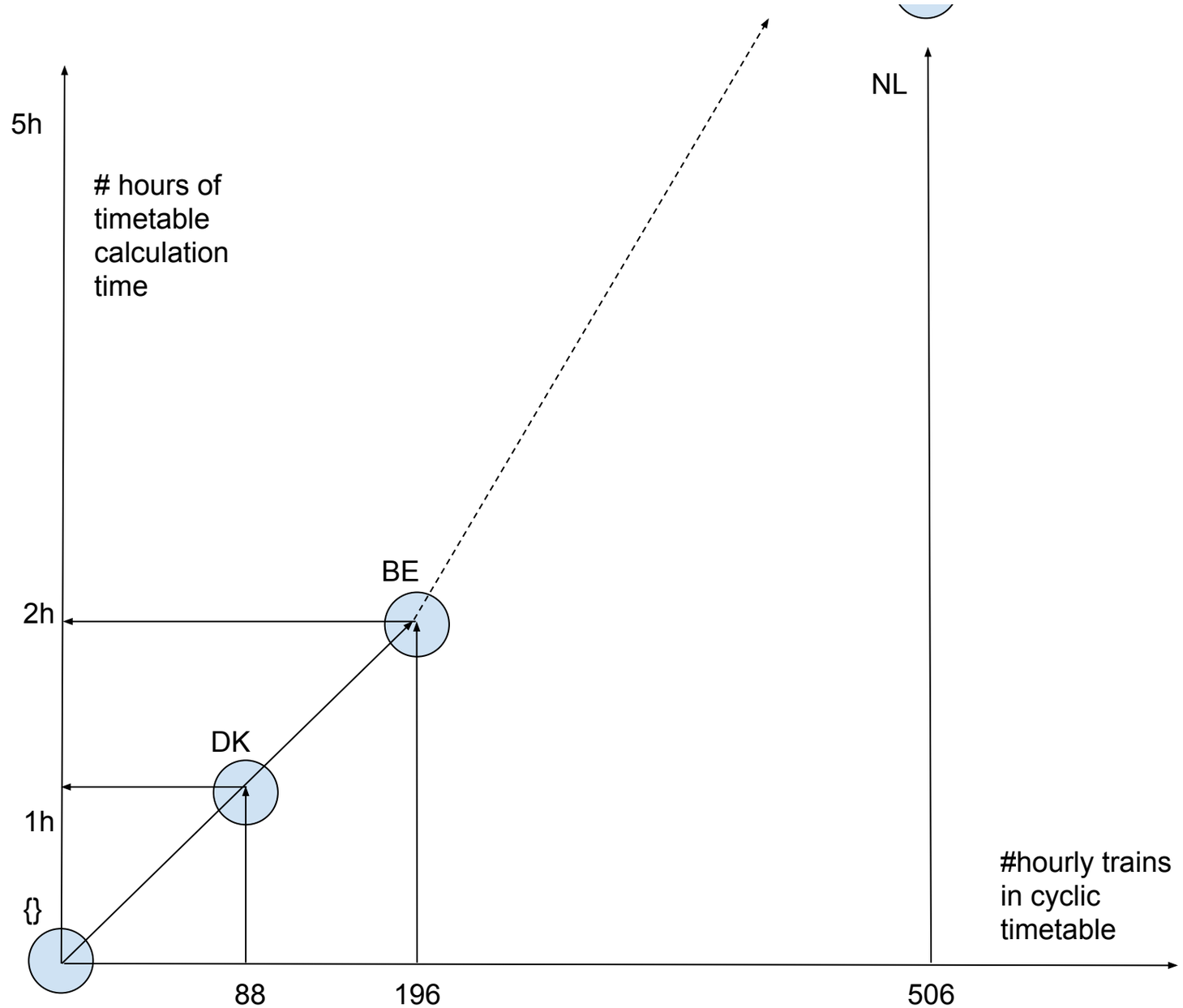
Timetabling

SCALABILITY?



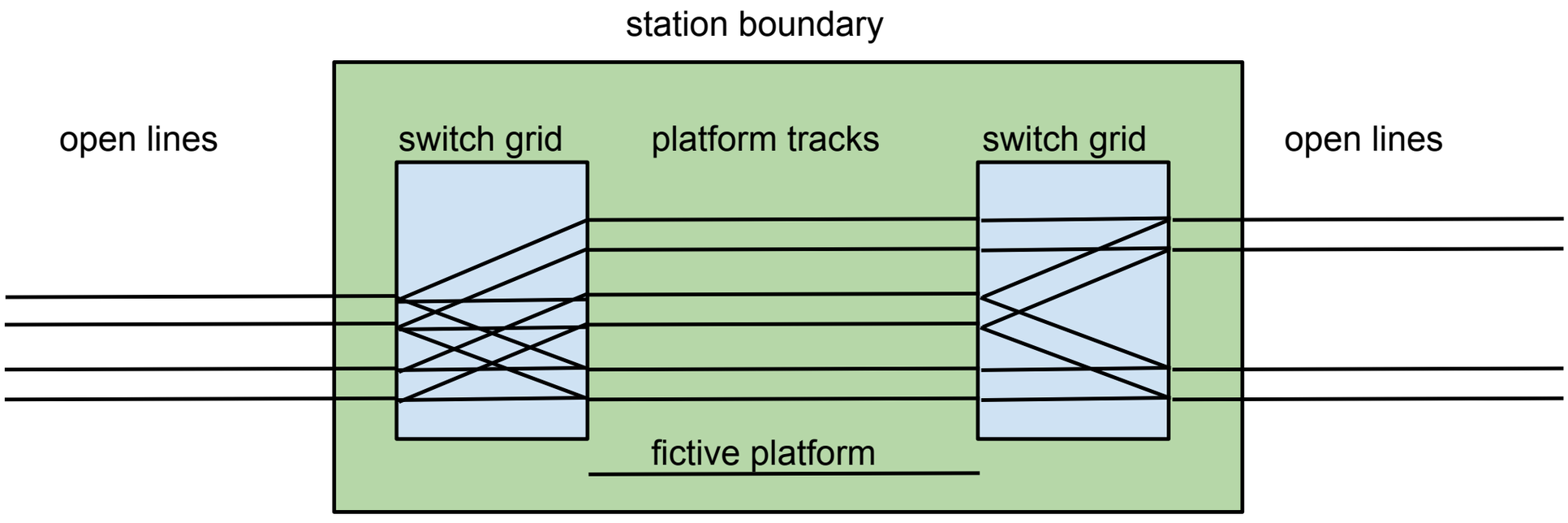
Timetabling

NL > 11H => SUPER-LINEAR



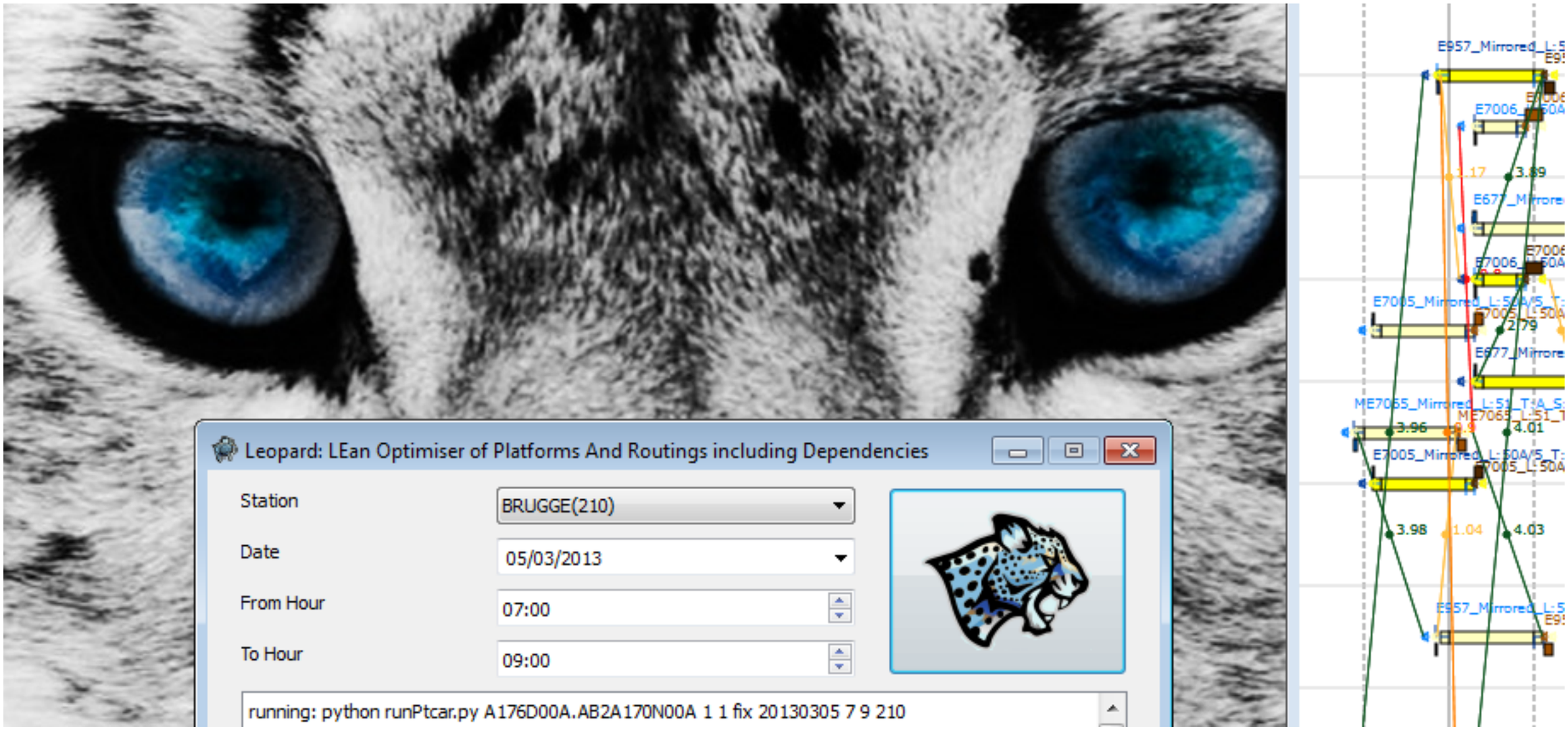
Platforming

STATION PLATFORM & ROUTES MODEL

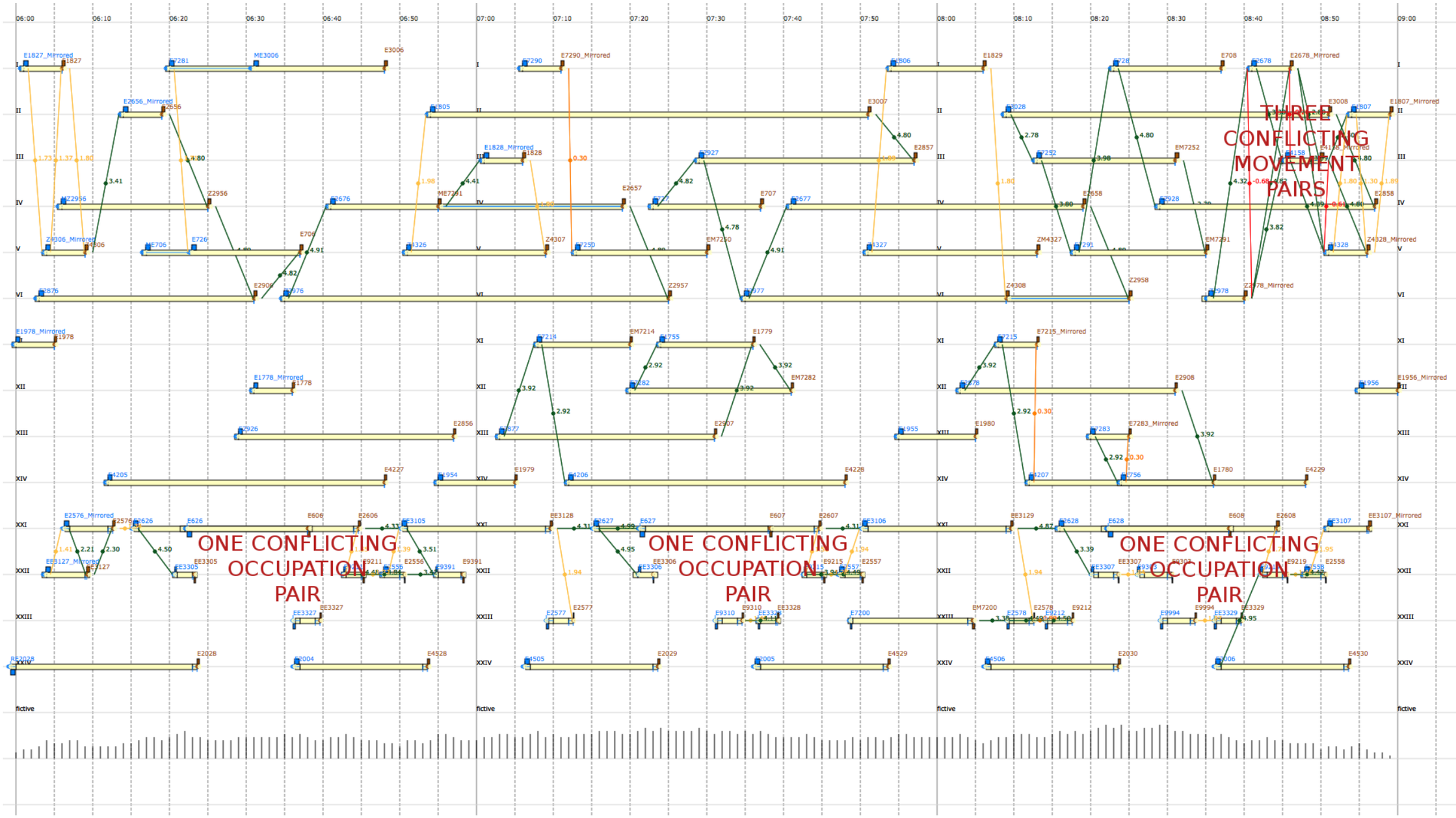


Platforming:

TOOL: LEOPARD

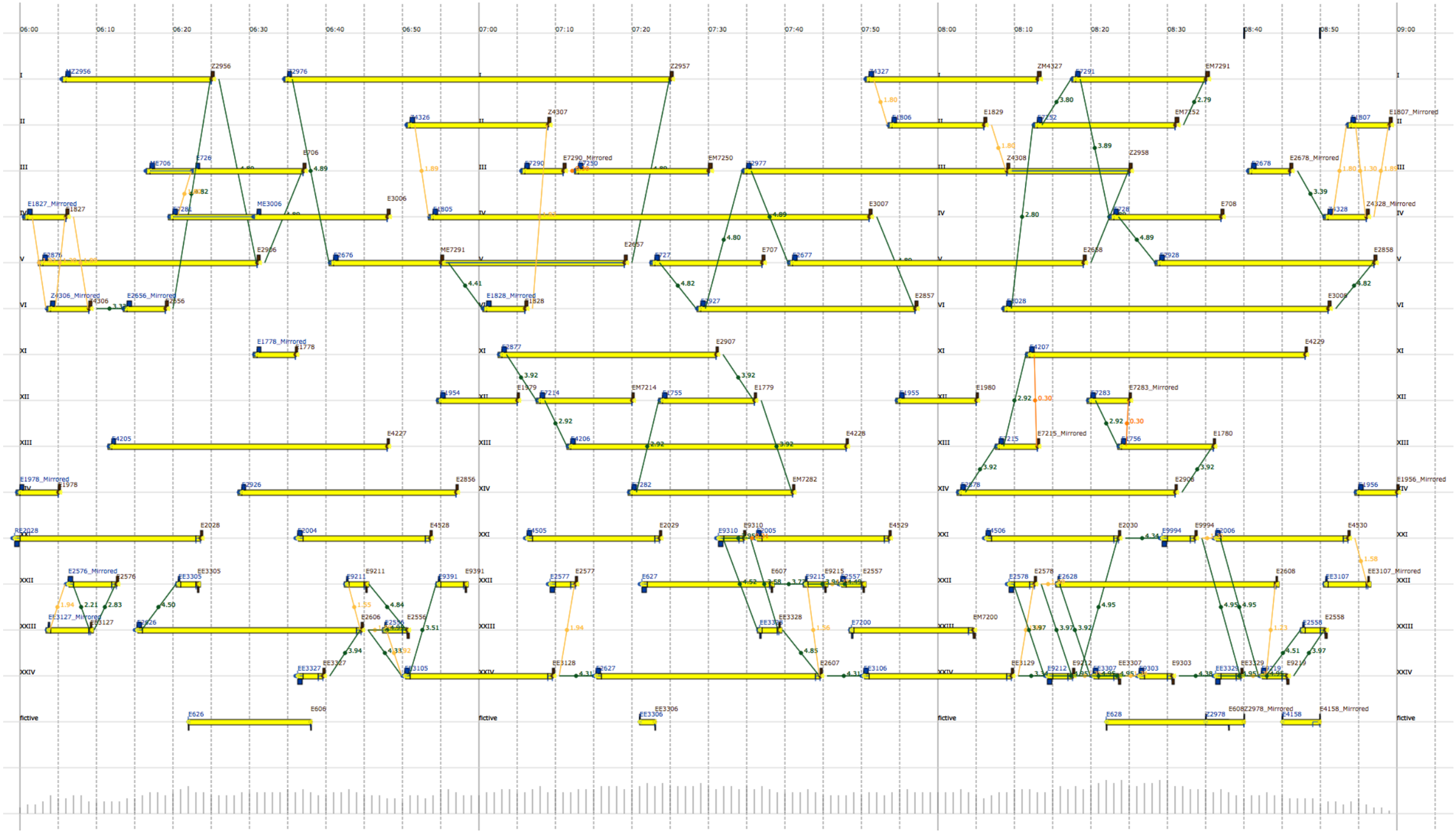


Platforming:Antwerp Central: Manual Assignment



DETECTED SOME PLATFORM CONFLICTS AND SOME ROUTING CONFLICTS

Platforming:Antwerp Central: Auto Assignment



RESOLVED PLATFORM CONFLICTS AND ROUTING CONFLICTS, BUT 3 UNPLATFORMED TRAINS

Platforming: Batch Processing

#platform	#UnplatformedOrig	Orig	#redLines	#darkOra	#lightOrar	#greenLine	RobustnessSc	#platformed(	#UnplatformedOrig	Opt	#redLi	#darkOra	#lightOrar	#greenLin	RobustnessSc	Both
33	0	Orig Plan 6	2	2	5	1	-31	31	2	Opt Plan 6	0	2	3	3	-11	Both Plan 6
36	0	Orig Plan 8	0	1	3	9	-7	36	0	Opt Plan 8	0	1	6	4	-10	Both Plan 8
39	0	Orig Plan 9	2	16	14	15	-96	32	7	Opt Plan 9	0	8	6	10	-38	Both Plan 9
9	0	Orig Plan 10	0	0	0	0	0	9	0	Opt Plan 10	0	0	0	0	0	Both Plan 10
12	0	Orig Plan 12	0	0	0	0	0	12	0	Opt Plan 12	0	0	0	0	0	Both Plan 12
7	0	Orig Plan 13	0	1	0	0	-4	7	0	Opt Plan 13	0	1	0	0	-4	Both Plan 13
27	0	Orig Plan 16	0	0	0	3	0	27	0	Opt Plan 16	0	0	0	3	0	Both Plan 16
9	0	Orig Plan 19	0	0	0	0	0	9	0	Opt Plan 19	0	0	0	0	0	Both Plan 19
24	0	Orig Plan 22	0	0	6	4	-6	24	0	Opt Plan 22	0	0	8	8	-8	Both Plan 22
24	0	Orig Plan 24	0	0	2	4	-2	24	0	Opt Plan 24	0	0	2	4	-2	Both Plan 24
25	0	Orig Plan 25	0	0	4	3	-4	25	0	Opt Plan 25	0	0	4	3	-4	Both Plan 25
36	0	Orig Plan 27	0	0	0	0	0	36	0	Opt Plan 27	0	0	0	0	0	Both Plan 27
34	0	Orig Plan 31	0	1	1	4	-5	34	0	Opt Plan 31	0	2	4	9	-12	Both Plan 31
9	0	Orig Plan 34	0	0	0	0	0	9	0	Opt Plan 34	0	0	0	0	0	Both Plan 34
15	0	Orig Plan 35	0	0	0	0	0	15	0	Opt Plan 35	0	0	0	0	0	Both Plan 35
84	2	Orig Plan 37	1	6	23	11	-56	80	6	Opt Plan 37	0	6	25	11	-49	Both Plan 37
22	0	Orig Plan 38	4	4	8	9	-60	20	2	Opt Plan 38	0	2	6	7	-14	Both Plan 38
41	0	Orig Plan 58	1	0	6	0	-15	40	1	Opt Plan 58	0	0	6	0	-6	Both Plan 58
12	0	Orig Plan 61	0	0	0	0	0	12	0	Opt Plan 61	0	0	0	0	0	Both Plan 61
37	0	Orig Plan 64	0	2	2	4	-10	37	0	Opt Plan 64	0	2	2	4	-10	Both Plan 64
19	0	Orig Plan 66	0	0	1	7	-1	19	0	Opt Plan 66	0	0	1	7	-1	Both Plan 66
20	0	Orig Plan 67	0	0	0	1	0	20	0	Opt Plan 67	0	0	0	1	0	Both Plan 67
14	0	Orig Plan 68	0	0	0	0	0	14	0	Opt Plan 68	0	0	0	0	0	Both Plan 68
30	0	Orig Plan 70	25	15	7	11	-292	22	8	Opt Plan 70	0	11	2	9	-46	Both Plan 70
20	0	Orig Plan 74	0	0	0	0	0	20	0	Opt Plan 74	0	0	0	0	0	Both Plan 74
15	0	Orig Plan 75	1	1	1	1	-14	15	0	Opt Plan 75	0	0	1	2	-1	Both Plan 75
32	0	Orig Plan 77	1	1	2	5	-15	32	0	Opt Plan 77	0	1	4	4	-8	Both Plan 77
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6	0	Orig Plan 84	0	0	0	0	0	6	0	Opt Plan 84	0	0	0	0	0	Both Plan 84
15	0	Orig Plan 100	0	0	0	0	0	15	0	Opt Plan 100	0	0	0	0	0	Both Plan 100
21	0	Orig Plan 102	0	1	2	2	-6	21	0	Opt Plan 102	0	1	2	2	-6	Both Plan 102
6	0	Orig Plan 104	0	0	0	0	0	6	0	Opt Plan 104	0	0	0	0	0	Both Plan 104
0	12	Orig Plan 105	0	0	0	0	0	12	0	Opt Plan 105	0	0	0	0	0	Both Plan 105
0	12	Orig Plan 106	0	0	0	0	0	12	0	Opt Plan 106	0	0	0	0	0	Both Plan 106
6	0	Orig Plan 107	0	0	0	0	0	6	0	Opt Plan 107	0	0	0	0	0	Both Plan 107

CONFLICT & ROBUSTNESS OVERVIEW FOR ALL STATIONS

Research Results: Timetabling

- formulated expected passenger time in practice as (objective) function of decision supplements
- removes need for artificial upper bounds on supplements
- avoids infeasibility due to these upper bounds
- formulated cycle set that reduces computation time

Research Results: Platforming

- formulated fixed arrival & departure time TPP as Infrabel sees it
- added filter to avoid unnecessary constraint generation
- visual feedback of checks and optimisations

Practical Results: TimeTabling & Platforming

- expected passenger time in practice as objective function works up to large-scale
- automatically generated Belgian & Danish timetable, reducing passenger time by 3.8%, 2.9%, in 2h, 1h
- reduced missed chance of transfer from >10% to <3%
- automatically checked & corrected platform plans
- takes 10 min calculation time for all Belgian station
- integrated tools for both at Infrabel

Destiny?

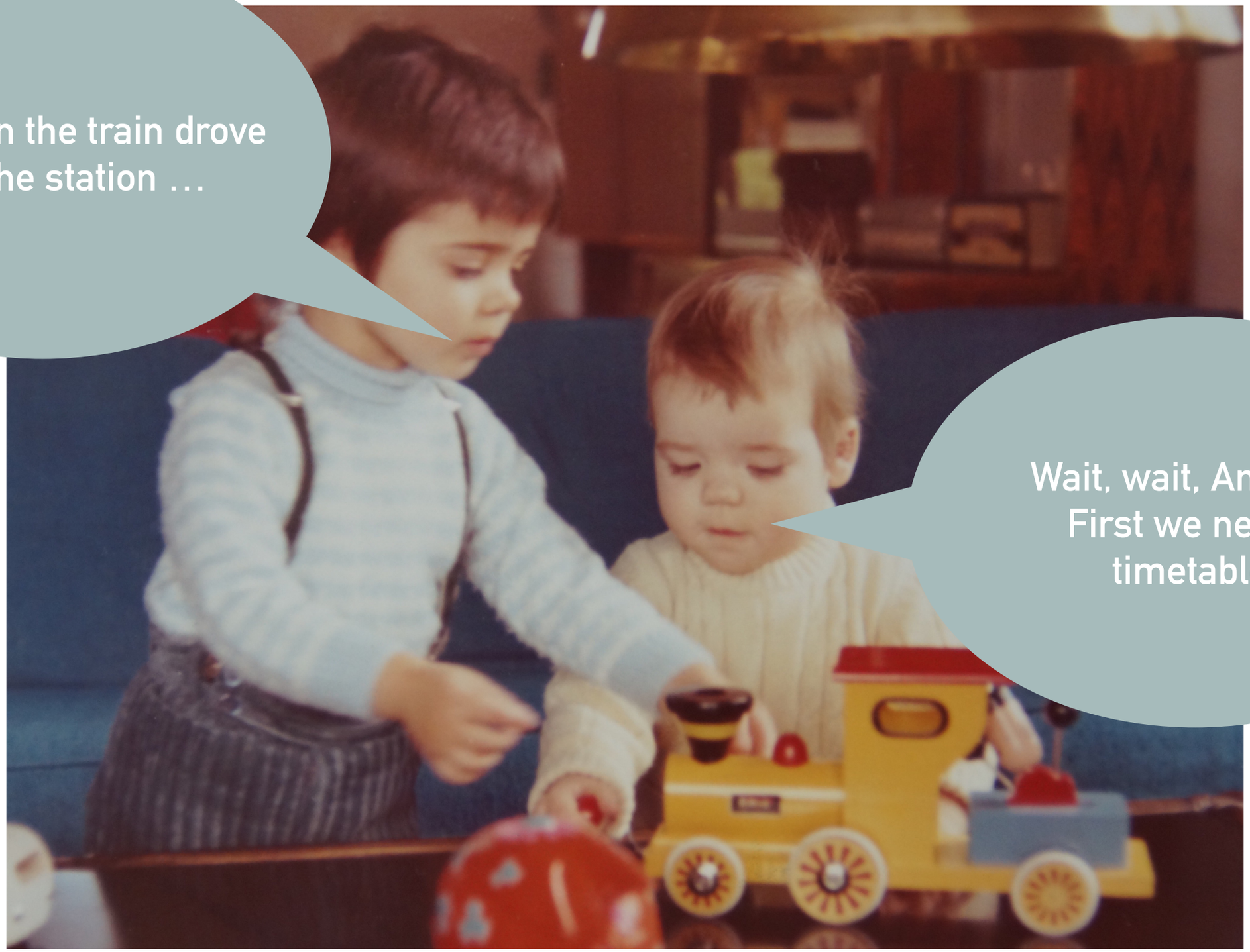
Destiny?


embrace
optimisation
downloaded from pickywallpapers.com

Destiny?

Destiny?

… and then the train drove out of the station …



Wait, wait, Annabel! First we need a timetable!

Destiny?