





The Ideal Train Timetabling Problem

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3rd Symposium of the European Association for Research
in Transportation

September 12, 2014

Purely commercial rail passenger services in Europe

	Market closed for commercial national rail passenger services.
	Open access, but no external RUs providing commercial national rail passenger services.
	Open access with external RUs providing commercial national rail passenger services.
	AT and CZ: commencing end of 2011, external RUs providing purely commercial national rail passenger services.



Liberalisation – Overview

Liberalisation time line

1 January 1993

Access for international groupings providing international services and for international combined transport goods service providers

15 March 2003

Access to the Trans-European Rail Freight Network for international freight services

1 January 2006

Access to the entire EU rail network for international freight services

1 January 2007

Access to the entire EU rail network for all types of rail freight (including domestic)

1 January 2010

Access to the infrastructure in all EU Member States for the purpose of operating international passenger services (cabotage permitted)

? December 2019

Access to the infrastructure in all EU Member States for all rail services, including domestic passenger services

Public Sector – Accessibility/Mobility

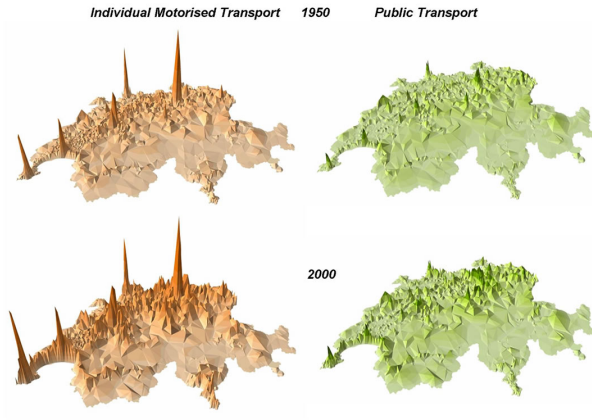


Figure : Mobility evolution in Switzerland¹

¹ – source: *Entwicklung der MIV und OV Erreichbarkeit in der Schweiz: 1950-2000*; Ph. Frohlich, M. Tschopp and K.W. Axhausen

Private Sector



Increase profits

Market Settings

Travel Time is the same



Serve Different Destinations



Better Quality

Departure / Class / Service	Duration	Stops	Train Number
06:27 - 09:53	3:25	4	9907
			Smart Prima Club
Base	83,50 €	111 €	123,50 €
Economy	55 €	71 €	111 €
Low Cost	36 €	57 €	
Prezzo Rate	47,50 €		
A/R Ingiornata	80 €	97,50 €	

Better Price



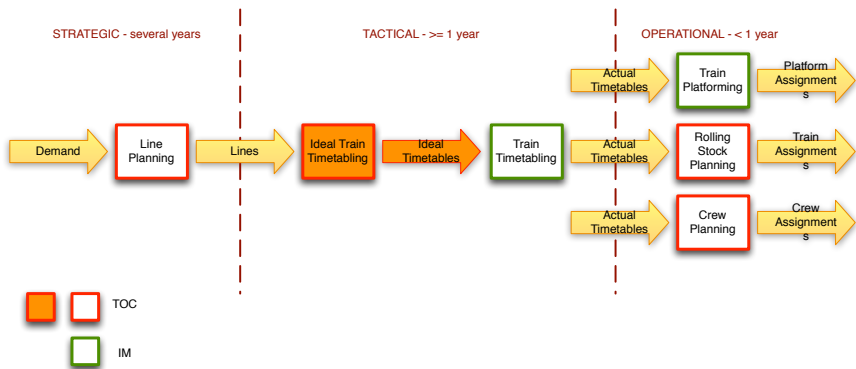
Better Departure Times

Origin of a Timetable?

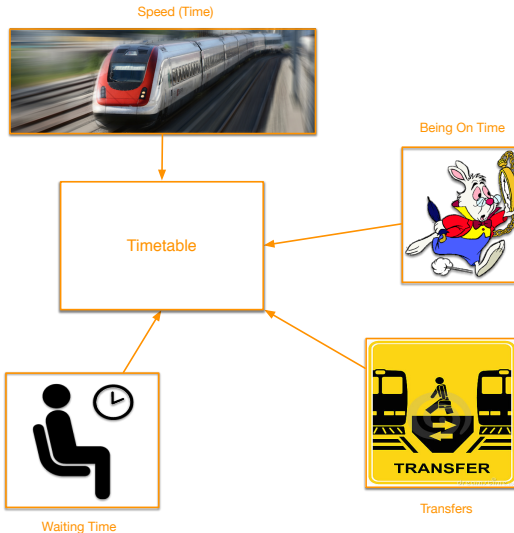
Johnson City Enterprise.	
Published Every Saturday,	
\$1. per year—Advance Payment.	
SATURDAY, APRIL 7, 1883.	
TIME TABLE	
E. T. V. & G. R. R.	
PASSENGER,	ARRIVES,
No. 1, West,	6:37, a. m.
No. 2, East,	9:45, p. m.
No. 3, West,	11:51, p. m.
No. 4, East,	3:56, a. m.
LOCAL FREIGHT,	ARRIVES,
No. 5,	7:20, a. m.
No. 8,	6:20, p. m.
Jno. W. EAKIN, Agent.	
E. T. & W. N. C. R. R.	
Passenger, leaves,	7, a. m.
“ arrives,	6, p. m.
J. C. HARDIN, Agent.	

- In the industry – historical
- Timetable design in the literature
 - **non-cyclic**: using so called "ideal timetables"
 - **cyclic**: does not take into account anything
- Need to measure quality of a timetable!

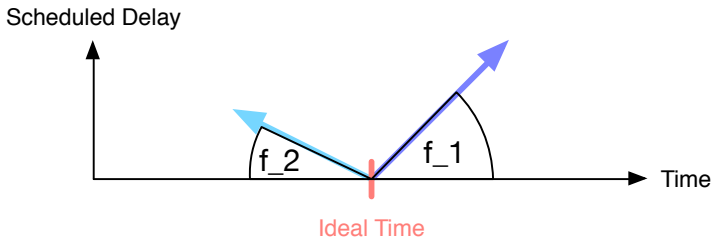
Update of Planning



How to Measure Quality of a Timetable?



Being on Time



- Scheduled delay times value of time (Arnott et al. (1990))
- Value of time in Switzerland for commuting using public transport: 27.81 CHF/h (Axhausen et al. (2008))
- **Example:** 10 min late = $10 * 27.81/60 = 4.6$ CHF
- **Example:** 10 min early = $10/2 * 27.81/60 = 2.3$ CHF

The Rest

Speed (Time)

- Running time multiplied by the value of time (Axhausen et al. (2008))
- Example: Lausanne to Bern = $66 * 27.81/60 = 30.6$ CHF; SBB price 32 CHF

Waiting Time

- Waiting time multiplied by the value of waiting time (Wardman (2004))
- Example: Lausanne to Chur: $9 * 2 * 27.81/60 = 8.3$ CHF

Transfers

- Minimum transfer time multiplied by the number of transfers and the value of waiting time (Wardman (2004))
- Example: Lausanne to Chur: $9 * 2 * 27.81/60 = 8.3$ CHF

Overall

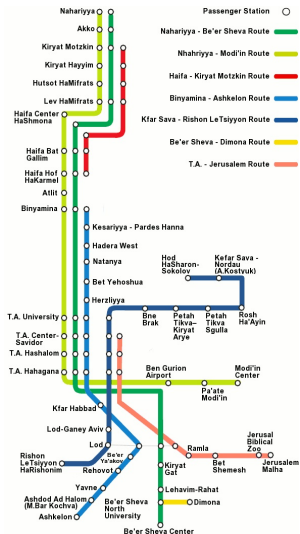
- Example: Lausanne to Chur: $94 + 8.3 = 102.3$ CHF; SBB price 95

References



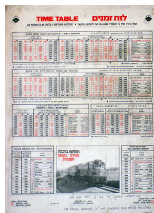
- Arnott, R., de Palma, A. and Lindsey, R. (1990). Economics of a bottleneck, *Journal of Urban Economics* **27**(1): 111 – 130.
- Axhausen, K. W., Hess, S., König, A., Abay, G., Bates, J. J. and Bierlaire, M. (2008). Income and distance elasticities of values of travel time savings: New swiss results, *Transport Policy* **15**(3): 173 – 185.
- Wardman, M. (2004). Public transport values of time, *Transport Policy* **11**(4): 363 – 377.

Case Study – Israel 2008

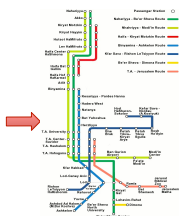


- OD Matrix for an average working day (Sunday to Thursday) in Israel during 2008
- 47 Stations
- 2162 ODs
- 36 (unidirectional) lines
- 389 trains
- Min. transfer – 4 mins
- VOT – 21.12 NIS per hour

Cyclic Version



1. Timetable of 2013/14



2. Select Random Line From Pool of Lines With a Taboo of One Third

6. If No Improvement for $|L|$ Times – Check One by One – if Improved Proceed as Before, if Not Finish



3. Find Best Start of the Cycle – Assuming 24 Trains a Day



4. Distribute Randomly n Trains to 24 Slots

5. Try 100 Times – Record Improvements

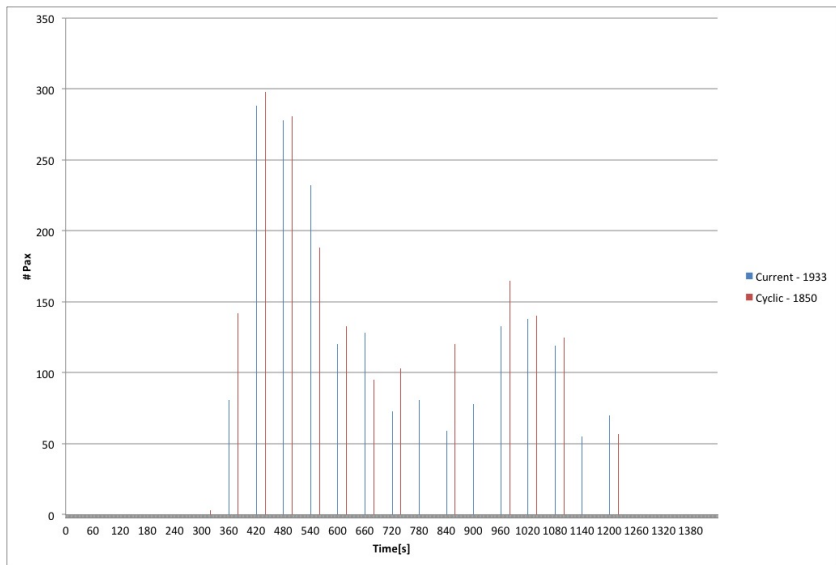
Cyclic Results

swiss cost = israeli cost \times conversion NIS/CHF \times SVOT/IVOT

Current [CHF]	Cyclic				
	# iter.	time	value [CHF]	decrease [CHF]	decrease [%]
3 263 548	867	6h 03m 26s	3 201 093	62 456	1.91
3 278 016	460	3h 07m 38s	3 217 560	60 456	1.84
3 290 186	721	5h 14m 16s	3 231 067	59 119	1.80
3 253 573	275	1h 59m 38s	3 194 455	59 118	1.82
3 278 722	468	3h 14m 51s	3 215 167	63 555	1.94
3 284 182	774	6h 38m 41s	3 221 440	62 742	1.91
3 256 893	576	3h 41m 29s	3 194 465	62 428	1.92
3 273 378	477	3h 24m 31s	3 213 290	60 087	1.84
3 271 945	722	5h 08m 23s	3 210 250	61 695	1.89
3 285 226	729	5h 00m 56s	3 230 887	54 340	1.65
3 251 899	417	2h 53m 34s	3 202 732	49 167	1.51
3 278 479	586	3h 57m 44s	3 215 982	62 497	1.90
3 256 135	695	5h 01m 43s	3 199 990	56 145	1.72
3 261 379	388	2h 45m 50s	3 200 562	60 817	1.87
3 265 327	459	3h 14m 32s	3 202 936	62 391	1.91
3 275 760	418	2h 50m 15s	3 211 820	63 941	1.95
3 264 604	333	2h 28m 10s	3 205 570	59 034	1.81
3 255 815	374	2h 30m 28s	3 196 851	58 964	1.81
3 263 143	499	3h 27m 27s	3 206 615	56 528	1.73
3 271 087	392	3h 01m 06s	3 221 016	50 070	1.53
3 268 965	532	3h 47m 14s	3 209 687	59 277	1.81

Monthly savings are 1 185 548 CHF.

Cyclic Version – Day 2, Line 11, Cycle – 00 to 19



Cyclic Timetable Comparison – Start of the Cycle

Line	Current	Day																			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	25	26	26	45	26	26	26	25	26	26	26	25	26	26	26	26	26	47	26	25	
2	53	51	53	16	53	53	30	53	30	53	28	30	30	30	16	53	16	50	16	30	50
3	00	47	36	35	42	23	06	05	00	04	08	30	47	05	26	40	03	45	01	07	50
4	28	23	31	52	20	48	07	31	29	35	34	07	25	24	30	31	46	20	00	07	54
5	02	02	02	01	02	02	02	02	02	02	02	01	02	01	02	02	02	02	02	01	01
6	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
7	55	55	55	49	49	53	49	54	49	53	55	49	49	55	49	49	53	55	52	49	53
8	56	56	56	56	54	56	56	56	54	56	56	56	54	56	55	58	56	55	54	56	56
9	15	14	14	15	15	15	09	15	15	13	14	12	15	15	15	15	15	14	15	11	15
10	54	54	54	53	54	54	54	54	54	54	56	54	54	54	54	54	54	54	54	54	53
11	00	24	24	19	00	24	19	19	19	19	22	19	19	24	24	24	24	19	19	19	20
12	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
13	42	42	42	37	42	42	42	42	42	42	42	42	42	42	42	42	42	42	37	42	41
14	40	40	40	40	40	40	40	40	40	40	24	40	40	40	40	40	40	40	40	40	40
15	18	20	20	15	20	20	20	20	20	20	20	20	20	20	20	20	20	20	15	20	19
16	26	29	29	29	29	29	29	29	29	29	13	29	29	29	29	29	29	52	29	29	29
17	02	14	14	02	10	14	10	14	10	14	14	10	10	14	10	10	14	14	13	10	14
18	20	40	35	54	30	35	32	32	55	32	55	32	55	54	55	35	35	32	32	54	54
19	27	27	15	09	31	58	27	02	02	27	27	32	32	27	35	32	27	27	27	01	31
20	54	55	03	54	59	03	54	03	54	03	03	54	54	54	02	55	03	03	55	54	54
21	42	58	58	35	02	27	02	26	32	02	42	01	54	58	58	02	58	02	02	24	53
22	34	34	34	36	34	34	34	34	34	34	34	34	34	34	34	34	34	34	36	34	33
23	54	02	32	50	54	09	54	50	50	58	02	54	02	01	05	55	02	58	50	50	01
24	14	15	17	24	17	17	11	17	11	17	20	22	22	23	24	17	24	14	24	21	14
25	42	43	43	42	43	43	43	43	43	43	43	42	43	42	43	43	43	43	43	42	42
26	00	03	03	03	02	03	03	03	03	03	00	03	03	03	03	03	03	02	03	03	02
27	03	09	09	03	03	03	03	09	03	09	09	03	07	09	03	18	09	09	10	03	09
28	18	18	18	18	18	18	11	18	18	18	18	18	18	18	18	18	18	18	18	18	18
29	25	25	17	24	17	17	17	17	17	17	17	17	17	17	17	17	17	17	25	17	16
30	58	20	56	07	20	20	07	07	07	20	04	55	20	20	20	20	20	56	20	07	55
31	30	30	32	30	32	32	32	32	32	32	30	32	32	32	32	55	32	32	32	32	30
32	14	56	56	13	18	18	56	56	56	58	18	18	18	18	56	18	18	56	56	34	17
33	55	56	56	51	46	56	46	56	56	56	56	56	56	56	56	33	56	56	53	56	55
34	40	18	18	56	56	56	18	18	18	40	56	56	56	18	56	56	18	13	56	56	56
35	46	18	23	17	22	21	23	19	22	22	22	24	24	19	24	24	22	22	21	24	20
36	58	35	34	34	35	34	35	39	35	32	44	34	32	39	34	32	35	32	34	07	36

Cyclic Timetable Comparison – Start of the Cycle

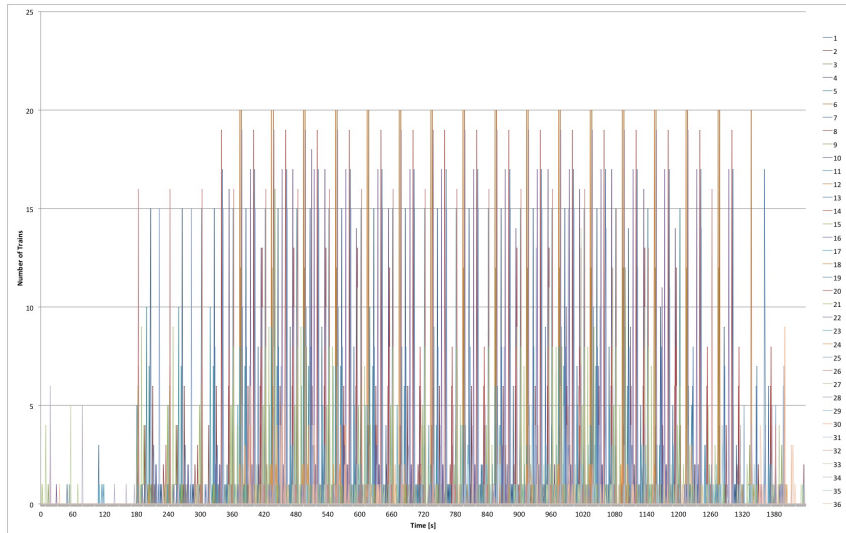
Line	Current	Recommendation
1	25	26
2	53	non-cyclic
3	00	NA
4	28	NA
5	02	keep
6	17	keep
7	55	49 – 55
8	56	keep
9	15	keep
10	54	keep
11	00	19 – 24
12	14	keep
13	42	keep
14	40	keep
15	18	20
16	26	29
17	02	10 – 14
18	20	non-cyclic

Line	Current	Recommendation
19	27	non-cyclic
20	54	54 – 03
21	42	non-cyclic
22	34	keep
23	54	50 – 02
24	14	11 – 24
25	42	43
26	00	03
27	03	03 – 09
28	18	keep
29	25	NA
30	58	NA
31	30	32
32	14	non-cyclic
33	55	56
34	40	18 or 56
35	46	22 – 24
36	58	32 – 39

Cyclic Timetable Comparison – Train Distribution

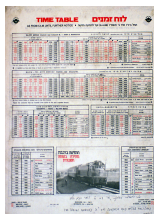
Line	Hour																							
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	0	0	0	17	20	20	20	20	20	20	20	20	20	20	20	20	20	20	19	15	9	14	6	0
2	0	0	0	14	14	20	20	20	20	20	20	20	20	20	20	20	20	20	20	18	8	18	8	0
3	0	0	0	0	0	8	9	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	11	1	0	0	0	0	0	0
5	0	0	0	5	5	20	20	20	20	20	20	20	20	20	17	19	20	18	19	16	19	1	1	0
6	0	0	0	0	0	0	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	0
7	2	3	0	0	0	4	16	20	20	19	6	5	3	8	13	18	17	17	14	10	4	9	12	0
8	0	0	0	0	0	2	20	20	19	17	14	4	6	5	17	19	20	18	17	14	3	0	5	0
9	1	0	0	8	8	0	15	18	19	17	2	3	4	16	16	16	19	20	16	15	16	18	6	7
10	0	0	0	0	0	18	16	20	20	16	16	8	2	5	16	19	19	20	18	17	8	1	1	0
11	0	0	0	19	19	19	20	20	20	20	20	17	15	10	11	12	18	20	18	7	14	1	0	0
12	0	0	0	0	0	0	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	0
13	0	0	0	3	3	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	17	17	0
14	0	0	0	1	1	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	19	19	0	0
15	0	0	0	0	0	0	2	19	9	1	6	0	0	0	0	4	9	11	13	2	3	0	1	0
16	1	0	0	0	0	2	1	2	20	4	5	0	0	0	3	1	12	7	11	11	0	0	0	0
17	0	0	0	0	0	0	14	16	17	15	11	8	6	8	10	5	12	8	2	3	0	4	1	0
18	0	0	0	0	0	4	18	16	12	9	9	6	1	1	8	15	15	8	9	3	5	1	0	0
19	0	0	0	13	13	20	20	20	20	20	20	20	20	20	20	20	20	20	20	19	17	8	8	2
20	0	0	0	12	12	20	20	20	20	20	20	20	20	20	20	20	20	20	19	20	14	8	9	6
21	1	0	0	19	19	19	20	20	20	20	18	15	11	13	9	14	17	19	13	11	13	5	3	1
22	0	0	0	3	3	3	20	20	20	20	20	20	20	20	19	18	20	20	19	19	18	17	1	0
23	0	3	0	3	0	3	2	13	14	13	7	4	6	10	6	13	18	17	15	9	8	6	7	3
24	0	0	0	2	0	1	14	20	20	18	5	5	4	3	5	14	8	12	10	4	4	1	3	7
25	0	0	0	15	15	20	20	20	20	20	20	20	20	20	20	20	20	19	17	16	19	5	9	5
26	0	0	0	19	19	20	20	20	20	20	20	20	20	20	20	20	20	20	19	16	1	20	1	5
27	5	1	0	12	12	0	14	20	20	18	9	11	10	13	12	18	17	19	15	16	3	5	4	6
28	0	0	0	1	1	1	20	20	20	20	0	19	20	19	20	20	19	20	19	19	20	1	0	1
29	0	0	0	0	0	0	5	1	0	0	2	0	0	0	1	0	0	0	0	1	2	1	1	6
30	0	0	0	0	0	0	0	0	0	0	1	4	0	1	0	0	0	3	1	0	0	0	0	9
31	0	0	0	0	0	0	7	11	8	2	2	6	4	4	9	17	20	15	6	4	2	2	0	1
32	4	0	0	0	1	1	14	20	17	7	6	3	5	6	4	10	12	6	4	3	6	2	3	6
33	6	0	0	0	1	7	15	6	9	14	7	5	1	4	11	17	20	17	12	9	8	3	4	4
34	6	6	3	1	2	2	16	20	20	17	13	4	8	11	12	10	14	8	7	8	7	6	9	10
35	0	0	0	0	0	0	0	1	2	1	3	1	1	4	12	13	10	6	6	2	1	9	7	1
36	1	0	0	0	0	0	16	18	9	9	5	0	0	2	0	2	6	2	3	3	2	0	11	11

Cyclic Version – Train Distribution

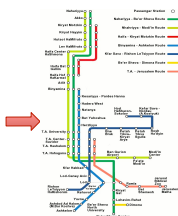


53.4 % of trains is distinctive.

Non-Cyclic Version



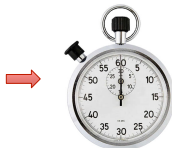
1. Our Solved Cyclic Timetable



2. Select Random Line From Pool of Lines With a Taboo of One Third



3. Select a Random Train of the Line



4. Assign Randomly a New Time

6. If No Improvement for $|L|$ Times – Check One by One – if Improved Proceed as Before, if Not Finish

5. Try 500 Times – Record Improvements

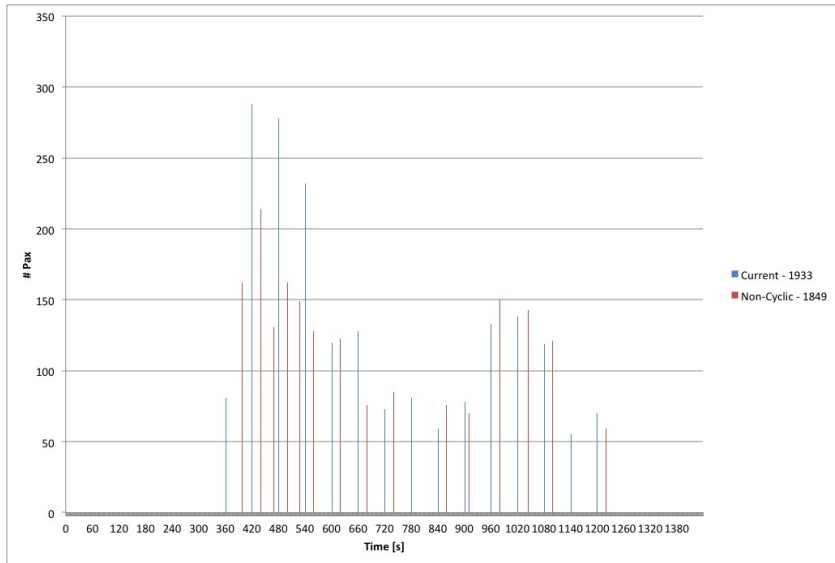
(Preliminary) Non-Cyclic Results

swiss cost = israeli cost \times conversion NIS/CHF \times SVOT/IVOT

Current [CHF]	Non-Cyclic				
	# iter.	time	value [CHF]	decrease [CHF]	decrease [%]
3 263 548	3287	3d 07h	3 152 281	111 267	3.41
3 278 016	2881	2d 22h	3 165 245	112 771	3.44
3 290 186	2462	2d 06h	3 176 861	113 325	3.44
3 253 573	2604	2d 07h	3 141 913	111 660	3.43
3 278 722	3705	3d 06h	3 166 204	112 518	3.43
3 284 182	3018	2d 18h	3 169 636	114 546	3.49
3 256 893	2735	2d 10h	3 143 743	113 150	3.47
3 273 378	3410	2d 22h	3 158 578	114 800	3.51
3 271 945	4561	4d 05h	3 159 107	112 838	3.45
3 285 226	3488	3d 04h	3 165 963	119 263	3.63
3 251 899	3484	3d 05h	3 139 429	112 470	3.46
3 278 479	4987	4d 07h	3 161 908	116 571	3.56
3 256 135	2297	2d 02h	3 144 254	111 881	3.44
3 261 379	2881	2d 15h	3 152 415	108 964	3.34
3 265 327	3345	3d 02h	3 154 688	110 639	3.39
3 275 760	2888	2d 13h	3 162 727	113 033	3.45
3 264 604	2361	2d 02h	3 153 554	111 050	3.40
3 255 815	3650	2d 23h	3 141 668	114 147	3.51
3 263 143	3811	3d 04h	3 14 5470	117 673	3.61
3 271 087	3209	2d 16h	3 160 563	110 524	3.38
3 268 965	3253	2d 22h	3 155 810	113 155	3.46

Monthly savings are 2 263 090 CHF.

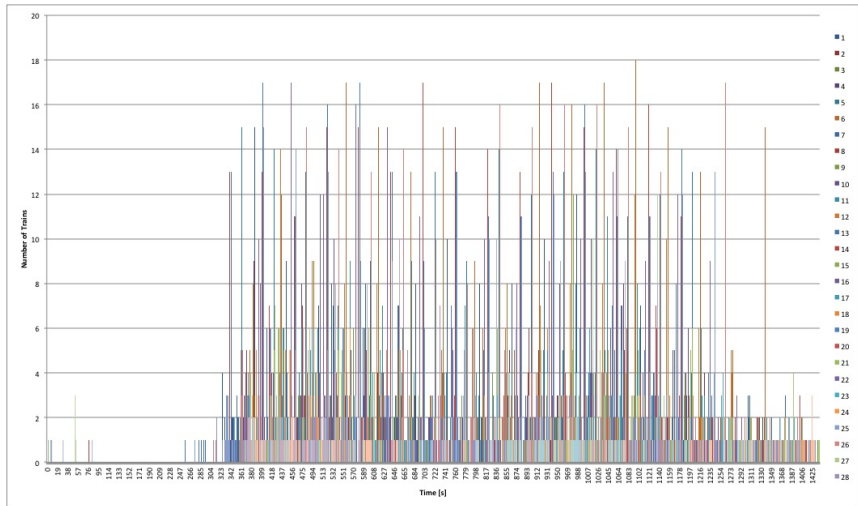
Non-Cyclic Version – Day 2, Line 11, Cycle – 00



Non-Cyclic Timetable Comparison – Train Distribution

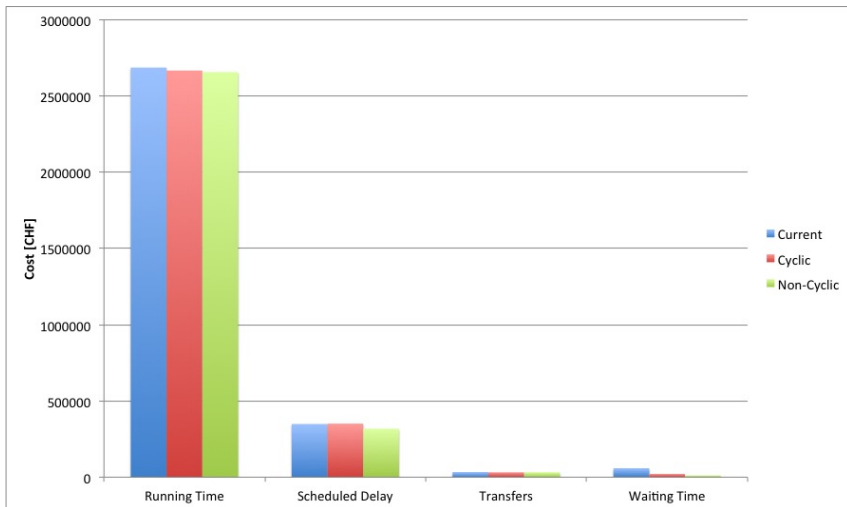
Line	Hour																							
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	0	0	0	0	0	20	32	38	28	20	20	19	17	20	20	22	21	20	19	13	11	9	11	0
2	0	0	0	0	0	1	23	23	27	18	18	19	20	19	20	33	36	30	22	17	14	10	10	0
3	0	0	0	0	0	14	2	2	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
4	0	0	0	0	0	0	0	0	0	4	0	2	0	0	7	5	0	1	1	0	0	0	0	0
5	0	0	0	0	0	0	25	34	28	18	22	15	20	17	18	17	20	23	22	12	20	3	6	0
6	0	0	0	0	0	0	20	20	20	20	20	20	20	20	26	22	20	20	20	19	15	18	0	0
7	0	0	0	0	0	8	24	12	20	20	6	3	3	5	12	21	20	17	15	5	1	11	14	3
8	0	1	0	0	0	0	24	26	23	17	5	5	5	6	17	15	21	18	13	6	1	5	4	8
9	0	0	0	0	0	4	3	24	22	20	15	14	12	15	5	14	21	23	22	18	4	10	5	9
10	0	0	0	0	0	1	29	17	17	14	12	14	11	5	14	20	20	20	17	15	3	2	1	8
11	0	0	0	0	0	0	25	43	32	20	20	18	13	15	12	19	20	20	20	7	13	2	1	0
12	0	0	0	0	0	0	16	20	21	19	19	9	16	12	19	24	36	32	19	19	19	12	7	1
13	0	0	0	0	5	19	21	27	21	20	20	20	23	24	29	25	20	20	20	19	4	3	0	0
14	0	0	0	0	0	17	29	34	26	20	20	20	20	20	20	20	20	20	20	19	8	6	1	0
15	0	0	0	0	0	1	6	16	13	1	3	0	0	0	0	0	16	6	15	2	1	0	0	0
16	0	0	0	0	0	0	7	22	2	6	1	0	0	0	2	11	8	15	6	0	0	0	0	0
17	0	0	0	0	0	0	19	15	19	19	16	7	2	5	0	0	1	11	14	2	0	6	3	1
18	0	0	0	0	0	0	20	18	9	8	9	0	0	0	6	19	20	15	9	1	0	5	1	0
19	0	0	0	0	0	0	18	22	28	25	18	20	23	17	22	25	33	29	26	25	13	10	1	5
20	0	0	0	0	0	0	28	37	41	27	30	10	14	8	13	24	26	24	36	11	11	5	3	12
21	0	0	0	0	0	0	9	21	24	20	19	14	8	17	8	28	29	37	21	15	16	6	2	6
22	0	0	0	0	0	0	24	33	24	28	23	20	18	16	16	15	18	24	15	20	11	14	1	0
23	0	0	0	0	0	0	1	10	12	13	7	6	2	10	7	10	23	22	22	7	11	9	1	7
24	0	0	0	0	0	0	12	25	33	18	3	0	5	5	5	10	11	11	8	2	5	0	1	6
25	2	0	0	0	1	20	20	21	21	20	21	22	20	19	21	20	20	20	20	21	19	10	12	10
26	1	0	0	0	0	2	28	17	21	24	19	20	23	18	20	20	21	20	21	20	14	26	15	10
27	1	0	0	0	0	0	17	30	25	22	13	7	1	3	14	17	20	23	21	15	6	11	6	8
28	0	0	0	0	0	7	23	20	21	18	6	18	18	16	18	20	20	19	19	17	13	1	6	0
29	0	0	0	0	0	0	3	5	3	0	1	2	0	0	0	0	0	0	0	1	2	0	0	3
30	0	0	0	0	0	0	13	0	0	0	0	0	0	0	0	1	4	1	0	0	0	1	0	0
31	3	1	0	0	0	0	12	9	9	6	4	2	7	1	10	14	14	11	4	5	0	1	4	3
32	0	0	0	0	0	0	15	23	23	9	6	1	7	5	5	11	17	9	2	0	1	0	1	5
33	4	0	0	0	0	0	12	16	8	13	7	2	4	4	9	23	33	21	13	6	0	0	2	3
34	0	0	0	0	0	0	20	38	30	21	15	1	5	18	7	16	10	13	10	3	6	0	4	3
35	0	0	0	0	0	0	1	1	2	3	5	3	5	13	10	13	2	3	1	0	12	6	0	0
36	0	0	0	0	0	11	16	9	14	7	0	3	0	0	0	2	4	1	4	7	6	7	9	0

Non-Cyclic Version – Train Distribution

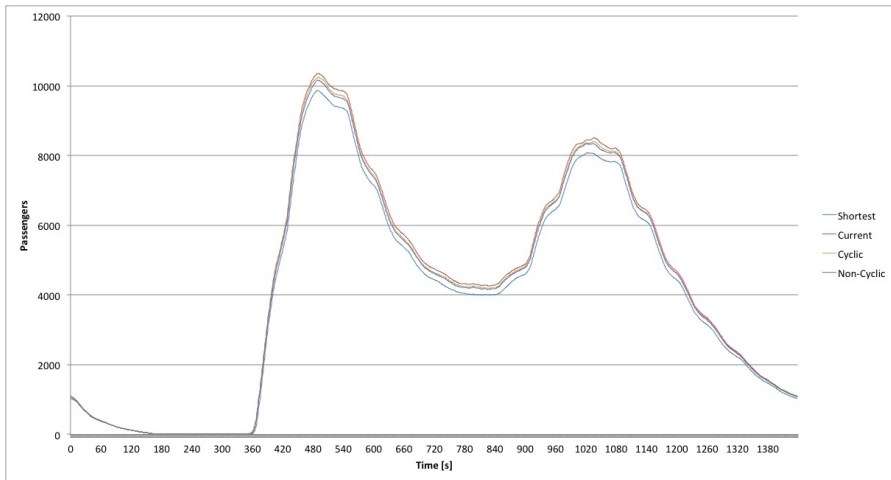


22.5 % of trains is distinctive.

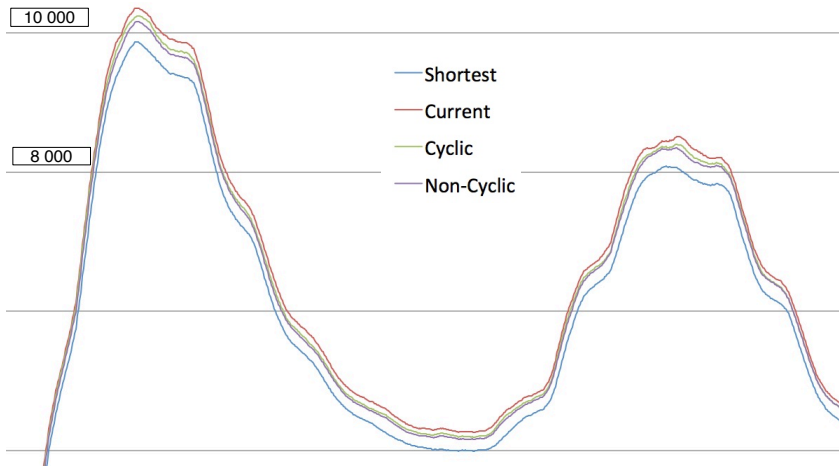
Average Cost Breakdown



Average Network Load



Average Network Load



Average Train Occupation 1/2

Line	Current	Cyclic	Difference	Non-Cyclic	Difference
1	162	161	-1	178	16
2	158	160	2	167	9
3	8	31	23	30	22
4	2	28	26	23	21
5	879	913	34	891	12
6	946	854	-92	821	-125
7	527	523	-4	495	-32
8	518	504	-14	531	13
9	271	259	-12	295	24
10	357	323	-34	321	-36
11	131	124	-7	127	-4
12	112	113	1	123	11
13	926	868	-58	882	-44
14	835	845	10	867	32
15	5	5	0	5	0
16	5	5	0	5	0
17	210	185	-25	194	-16
18	224	211	-13	224	0

Average Train Occupation 2/2

Line	Current	Cyclic	Difference	Non-Cyclic	Difference
19	135	149	14	144	9
20	142	144	2	154	12
21	121	132	11	147	26
22	164	175	11	158	-6
23	195	159	-36	147	-48
24	203	172	-31	170	-33
25	521	546	25	516	-5
26	652	586	-66	559	-93
27	370	295	-75	305	-65
28	250	251	1	267	17
29	190	143	-47	143	-47
30	204	135	-69	134	-70
31	99	79	-20	70	-29
32	76	76	0	73	-3
33	54	70	16	79	25
34	54	64	10	68	14
35	104	685	581	664	560
36	101	457	356	449	348

Conclusions

- New planning phase based on the demand
- In line with the new market structure
- Can handle both non- and cyclic timetables
- Takes care of the connections, in the current practice:
 - non-cyclic – does not exist
 - cyclic – always imposed
- Returns ideal timetables, its cost and the routings of the passengers
- Timetables in Israel have good quality
- The leading savings are waiting times – *i.e.* better connections
- Cyclic timetable is more distinct, but non-cyclic timetable has larger savings.
- Cyclic timetable can be operated with less trains
- Higher number of passengers per line does not necessarily mean better service

Future Work

- Improve non-cyclic version
- Deviations
- Robustness
- Exploitation of the cyclicity
- Effect of different stopping patterns



Thank you for your attention.