Railway Passenger Service Timetable Design

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Where Do the Babies Come From?

Figure : Calvin and Hobbes by Bill Watterson

Where Do the Timetables Come From?

Johnson City Enterprise.

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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

TRANSP-OR

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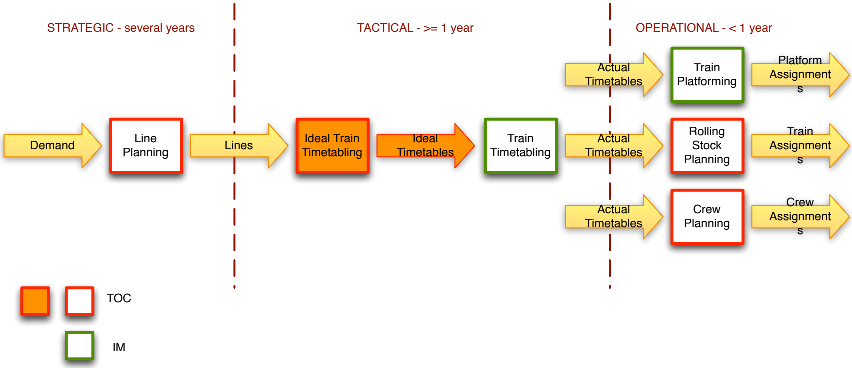
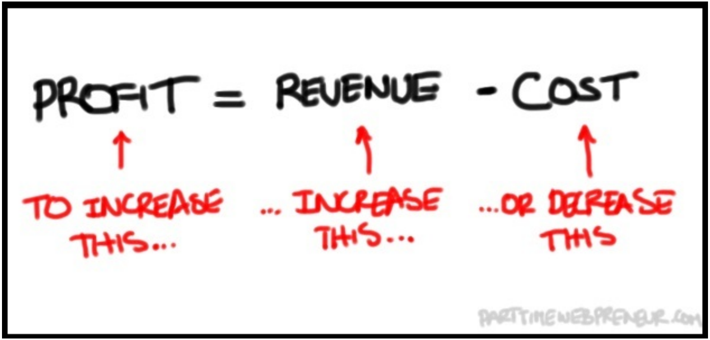
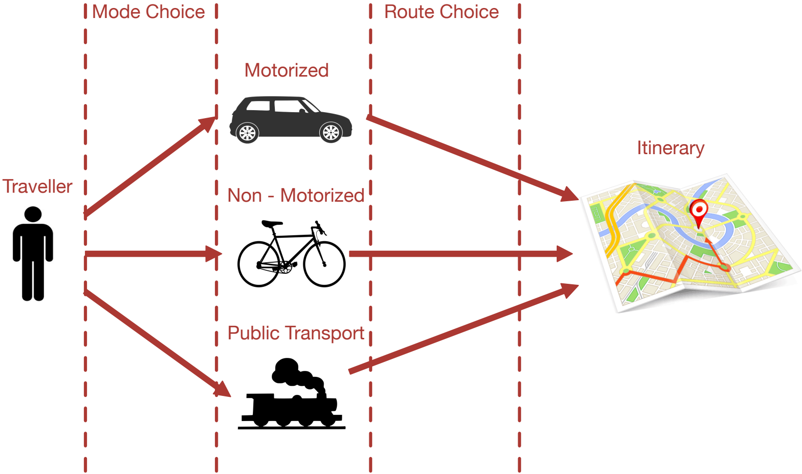
Update of Planning



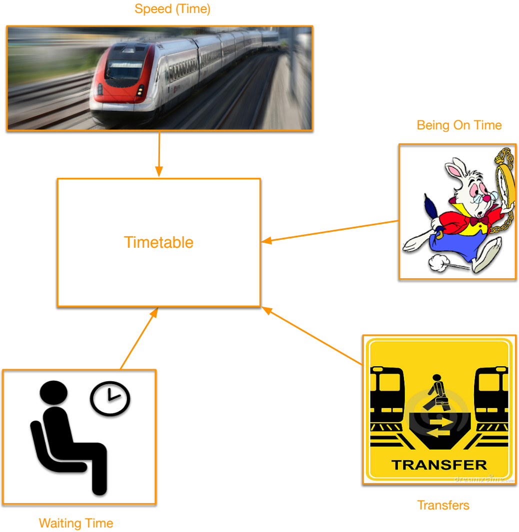
TOC Point of View



Transport Demand



Passenger Point of View



Passenger Cost

Perceived cost of a given path using a given timetable (a path is defined as a sequence of train lines, in order to get from an origin to a destination):

$$C = \text{argmin}\left(\alpha \cdot \sum_{i \in I} VT + \beta \cdot \sum_{j \in J^I} WT + \gamma \cdot NT + \min\left(\epsilon \cdot SD_e, \eta \cdot SD_l\right)\right)$$

for all possible sets I, where:

I	–	set of possible trains in a given path
J^I	–	set of transfers in a given path using given trains
α	–	value of time (monetary units per minute)
β	–	value of waiting time (monetary units per minute)
γ	–	penalty for having a transfer (monetary units)
ϵ	–	value of being early (monetary units per minute)
η	–	value of being late (monetary units per minute)

Decision Variables I

- $\mathcal{C}_i^t$ – the total cost of a passenger with ideal time t between OD pair i
- w_i^t – the total waiting time of a passenger with ideal time t between OD pair i
- x_i^{tp} – 1 – if passenger with ideal time t between OD pair i chooses path p; 0 – otherwise
- s_i^t – the value of the scheduled delay of a passenger with ideal time t between OD pair i
- d_v^l – the departure time of a train v on the line l (from its first station)

Decision Variables II

- y_i^{tplv} – 1 – if a passenger with ideal time t between OD pair i on the path p takes the train v on the line l; 0 – otherwise
- z_v^l – dummy variable to help modeling the cyclicity corresponding to a train v on the line l
- o_{vg}^l – train occupation of a train v of the line l on a segment g
- u_v^l – number of train units of a train v on the line l
- α_v^l – 1 – if a train v on the line l is being operated; 0 – otherwise

Model

$$\max\,(\textit{revenue} - \textit{cost}) \quad (1)$$

$$\textit{passenger cost} \leq \epsilon \quad (2)$$

$$\textit{cost function} \quad (3)$$

$$\textit{at most one path per passenger} \quad (4)$$

$$\textit{link trains with paths} \quad (5)$$

$$\textit{cyclicity} \quad (6)$$

$$\textit{train scheduling} \quad (7)$$

$$\textit{train capacity} \quad (8)$$

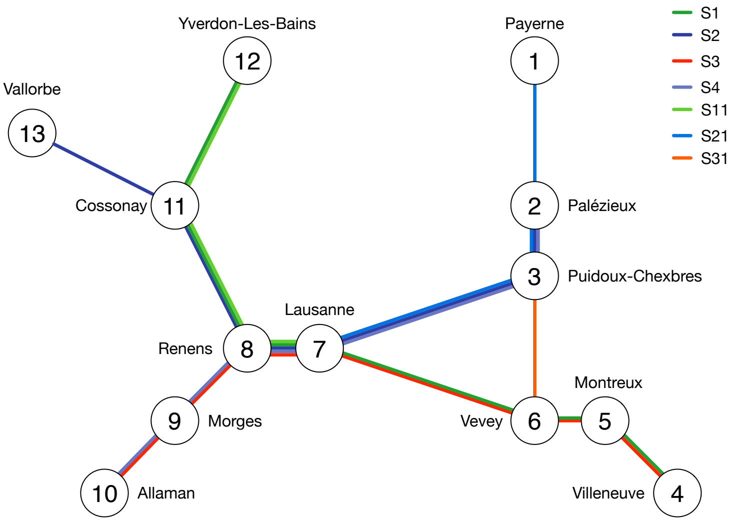
$$\textit{scheduled delay} \quad (9)$$

$$\textit{waiting time} \quad (10)$$

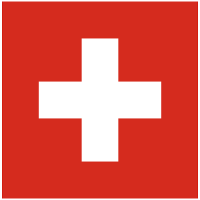
Case Study – Switzerland

[0] source: www.myswitzerland.com

S-Train Network Canton Vaud, Switzerland



SBB 2014 (5 a.m. to 9 a.m.)



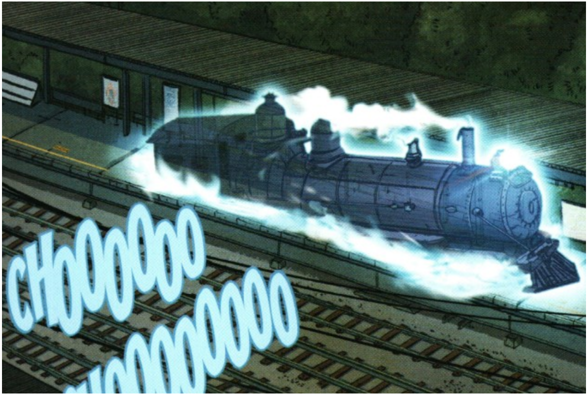
- OD Matrix based on observation and SBB annual report
- 13 Stations
- 156 ODs
- 14 (unidirectional) lines
- 49 trains
- Min. transfer – 4 mins
- VOT – 27.81 CHF per hour
- 3 models – current (SBB), cyclic (60 min cycle optimal), non-cyclic

Current Timetable (Morning Peak)

Line	ID	From	To	Departures			
S1	1	Yverdon-les-Bains	Villeneuve	–	6:19	7:19	8:19
	2	Villeneuve	Yverdon-les-Bains	5:24	6:24	7:24	8:24
S2	3	Vallorbe	Palézieux	5:43	6:43	7:43	8:43
	4	Palézieux	Vallorbe	–	6:08	7:08	8:08
S3	5	Allaman	Villeneuve	–	6:08	7:08	8:08
	6	Villeneuve	Allaman	–	6:53	7:53	8:53
S4	7	Allaman	Palézieux	5:41	6:41	7:41	8:41
	8	Palézieux	Allaman	–	6:35	7:35	8:35
S11	9	Yverdon-les-Bains	Lausanne	5:26*	6:34	7:34	8:34
	10	Lausanne	Yverdon-les-Bains	5:55	6:55	7:55	8:55
S21	11	Payerne	Lausanne	5:39	6:39	7:38*	8:39
	12	Lausanne	Payerne	5:24	6:24	7:24	8:24
S31	13	Vevey	Puidoux-Chexbres	–	6:09	7:09	8:09
	14	Puidoux-Chexbres	Vevey	–	6:31*	7:36	8:36

There was a Bug

There is a Ghost Train in the Network

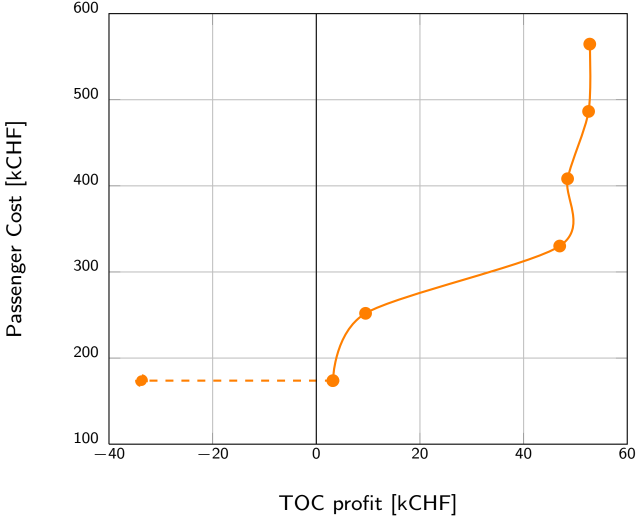


- Unlimited capacity
- Single departure time
- Pax on the board don't need to pay for the service

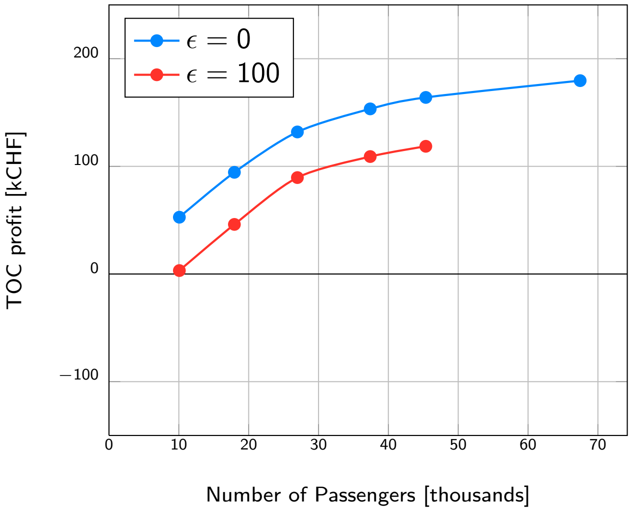
Results of the Current Model for the Base Case

ϵ [%]	0	20	40	60	80	100	100*
profit [CHF]	52 764	52 538	48 487	46 965	9 507	3 205	-33,726
cost [CHF]	564 597	486 438	408 278	330 119	251 959	173 800	173 797
lb [CHF]	53 771	54 153	54 259	54 627	54 615	50 527	168 153
gap [%]	1.91	3.07	11.90	16.31	474.47	1 476.51	3.25
gap [CHF]	1 007	1 615	5 772	7 662	45 108	47 322	5 644
time [s]	7 200	7 200	7 200	7 200	7 200	7 200	7200
drivers [-]	16	16	22	21	44	44	48
rolling stock [-]	31	30	32	30	49	51	96
served [%]	98.48	98.68	100.00	99.98	100.00	100.00	100.00

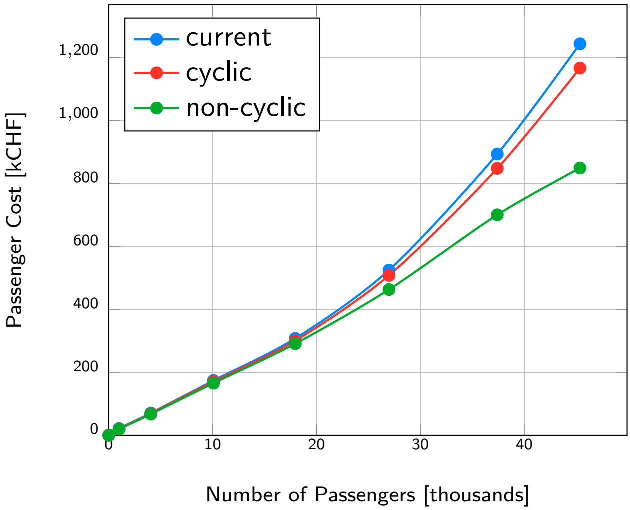
Pareto Frontier of the Current Model for the Base Case



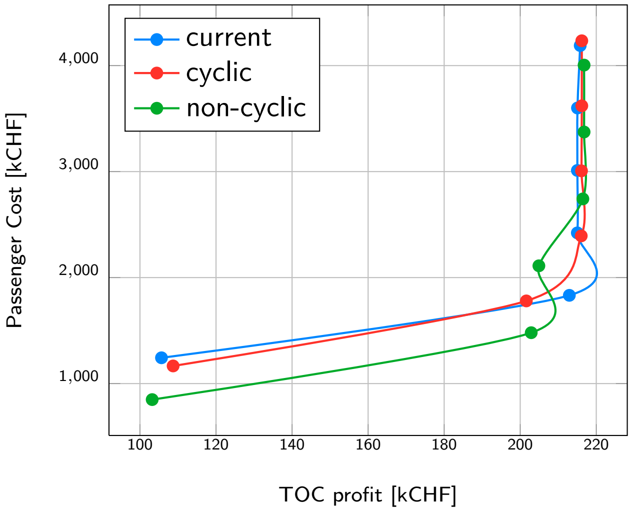
TOC Profit as a Function of the Demand



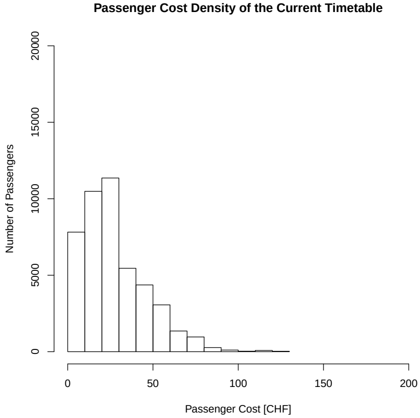
Passenger Cost as a Function of the Demand



Pareto Frontiers of the Congested Case

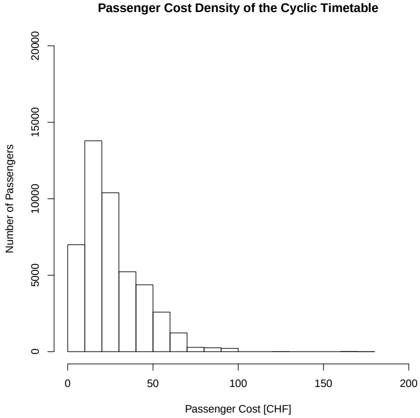


Passenger Cost Density I



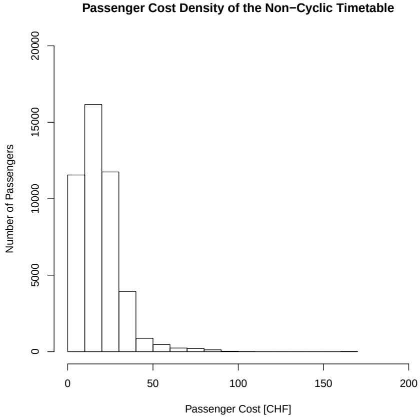
- Min – 2.78 CHF
- Mean – 27.40 CHF
- Max – 125.14 CHF

Passenger Cost Density II



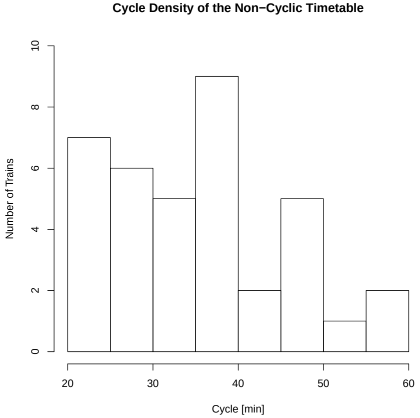
- Min – 2.78 CHF
- Mean – 25.71 CHF
- Max – 170.10 CHF

Passenger Cost Density III



- Min – 2.78 CHF
- Mean – 25.71 CHF
- Max – 166.86 CHF

Better Cycle?



- Mean – 35.72 min

Conclusions

- We formulate the ITTP problem
  - max profit or min pax cost
  - cyclic or non-cyclic timetables
  - pax flows (connections)
- Biased – Ghost Train
- TOC can choose the best trade-off between cost and profit
- Non-cyclic timetable is better
- Shorter cycle can reach the costs of the non-cyclic timetable (need to verify on a full day)

Future Work

- Heuristics
- Full day

Thank you for your attention.