Evaluating the Quality of Railway Timetables

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Supply x Demand

Figure : Calvin and Hobbes by Bill Watterson

Liberalisation – 01.01.2010

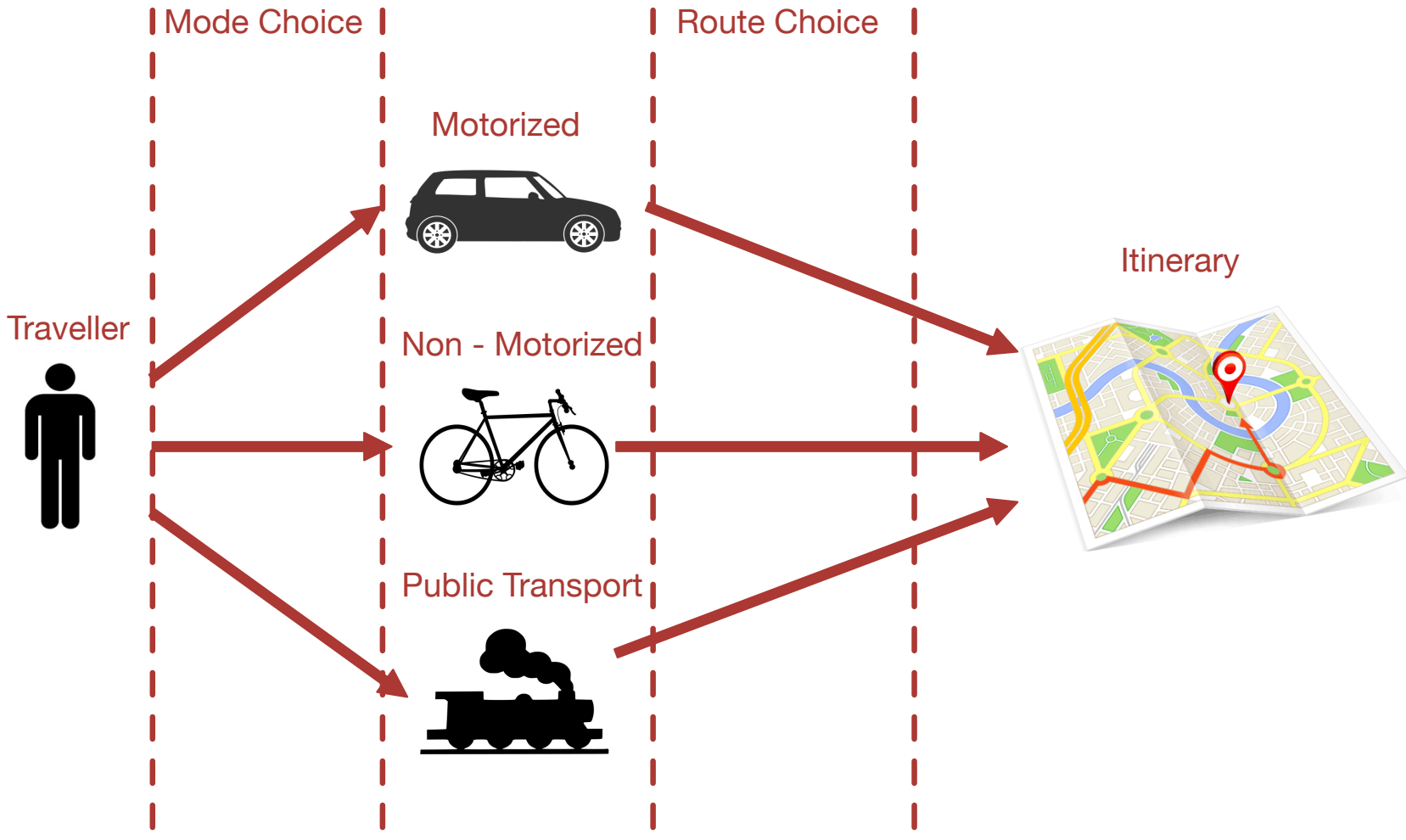
Purely commercial rail passenger services in Europe

	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.

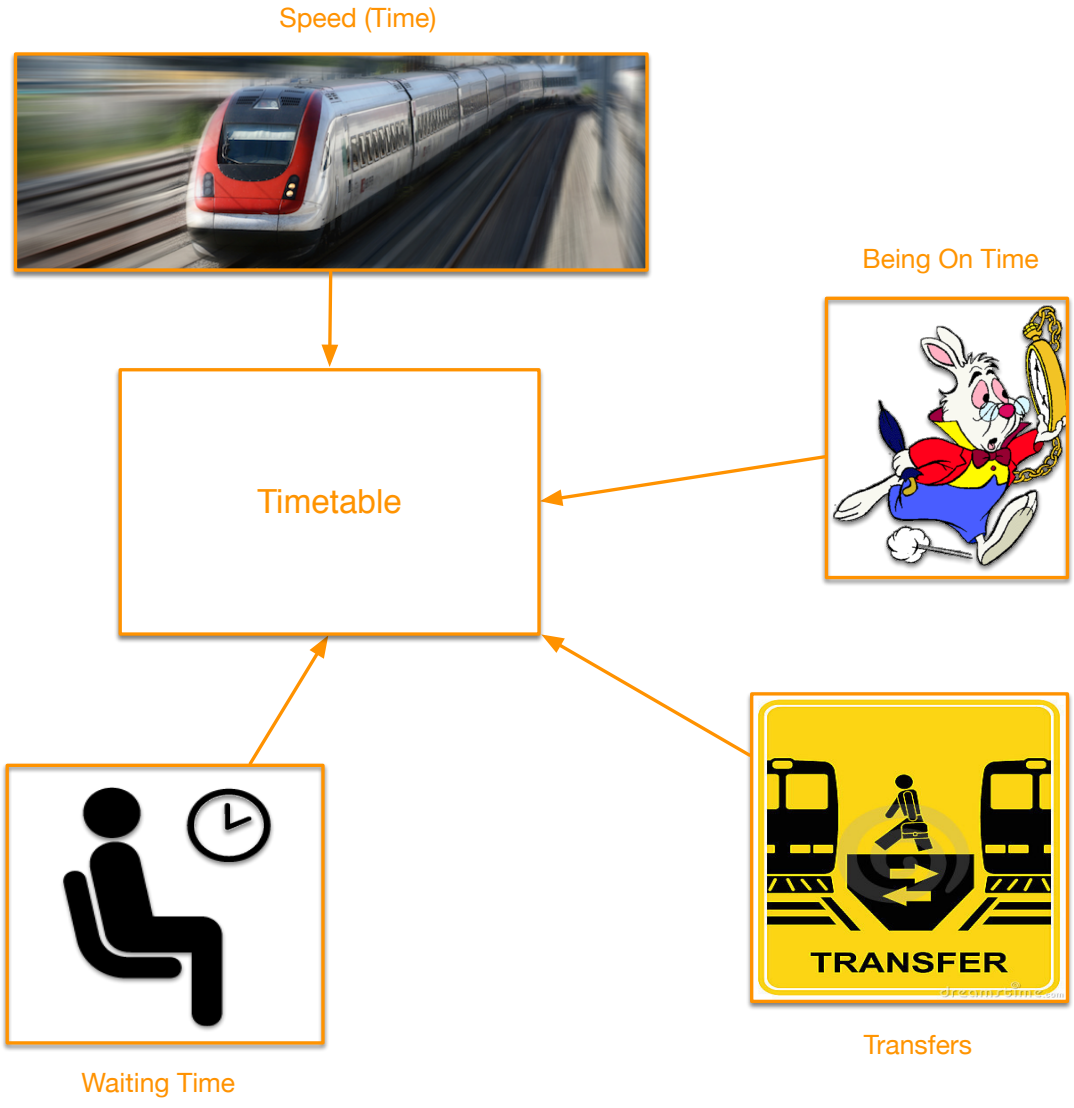
TRANSP-OR

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Transport Demand



Passenger Point of View



Passenger Satisfaction

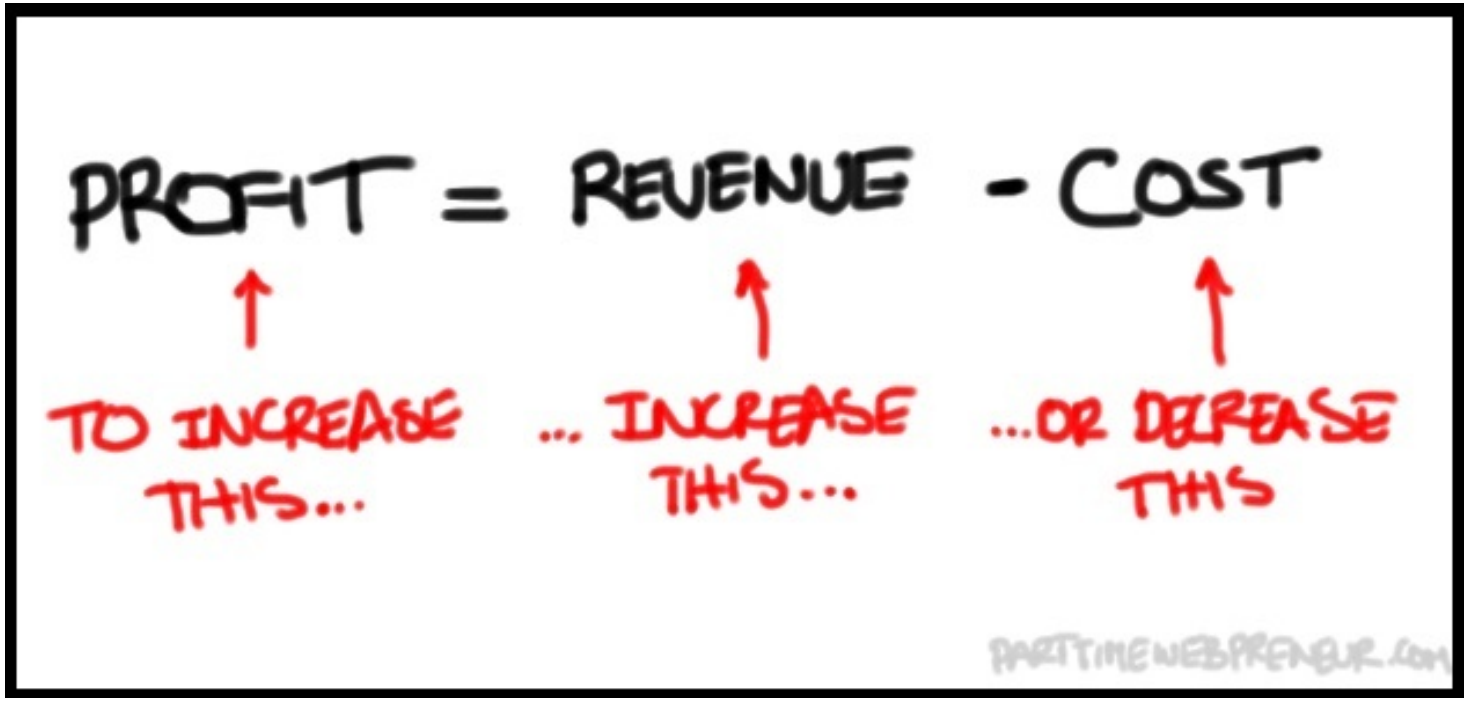
Perceived satisfaction of a given path using a given timetable (a path is defined as a sequence of train lines, in order to get from an origin to a destination):

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

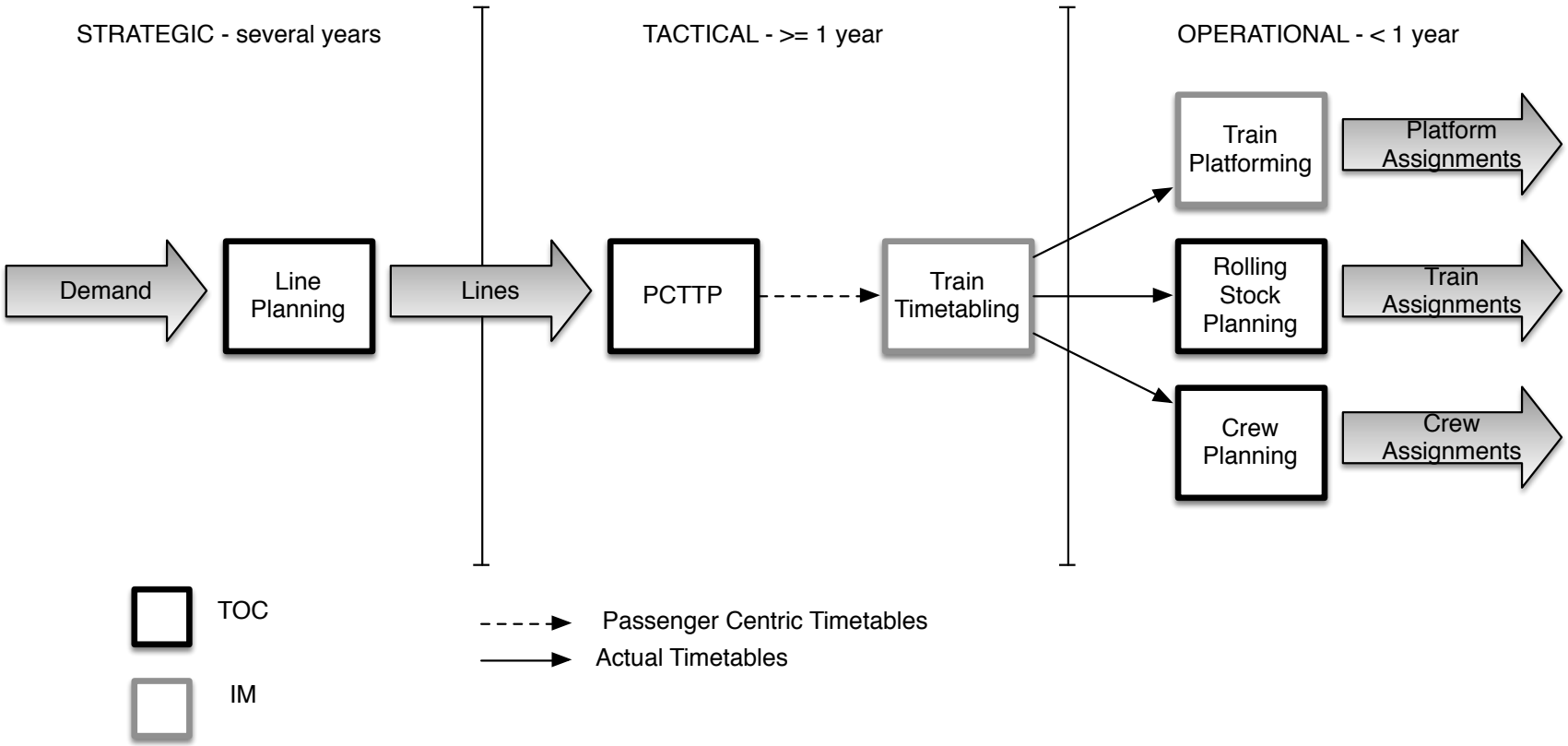
for all possible sets I, where:

- 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)

TOC Point of View



Update of Planning



Inputs

Passenger

- OD Matrix
- Desired arrival time to D
- All paths
- Behavior

Operator

- Network
- Fare structure
- Cost structure
- Rolling stock

Decision Variables I

$\mathcal{U}_i^t$ – passenger satisfaction (utility)

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

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

$$\textit{passenger satisfaction} \leq \epsilon \tag{2}$$

$$\textit{satisfaction function} \tag{3}$$

$$\textit{at most one path per passenger} \tag{4}$$

$$\textit{link trains with paths} \tag{5}$$

$$\textit{cyclicity} \tag{6}$$

$$\textit{train scheduling} \tag{7}$$

$$\textit{train capacity} \tag{8}$$

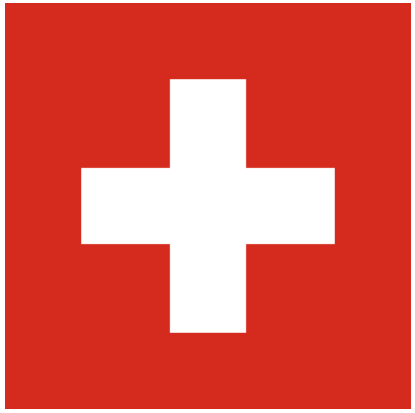
$$\textit{scheduled delay} \tag{9}$$

$$\textit{waiting time} \tag{10}$$

Case Study – Switzerland

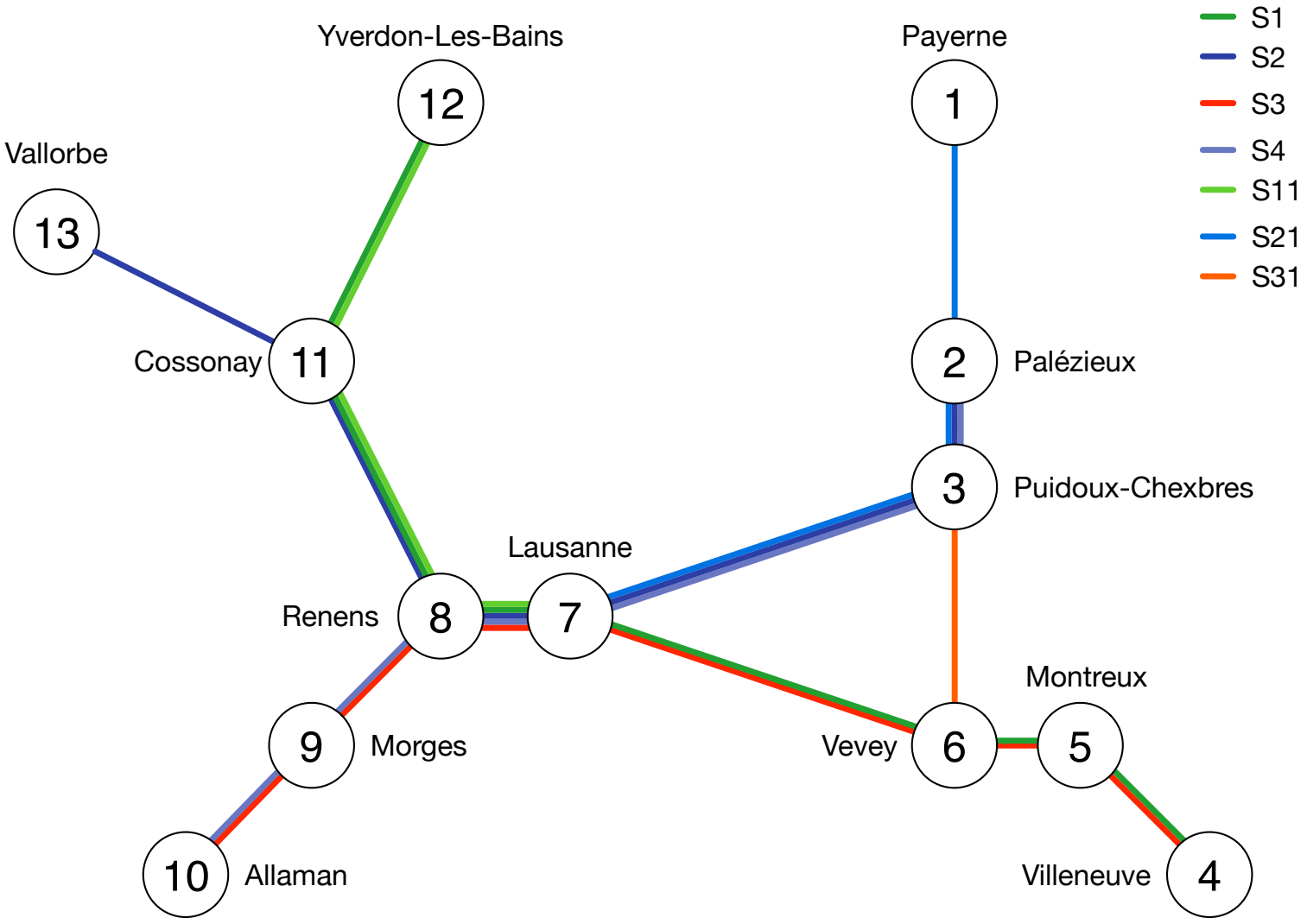
[0] source: www.myswitzerland.com

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 scenarios – SBB 2014, cyclic PCTTP, non-cyclic PCTTP

S-Train Network Canton Vaud, Switzerland



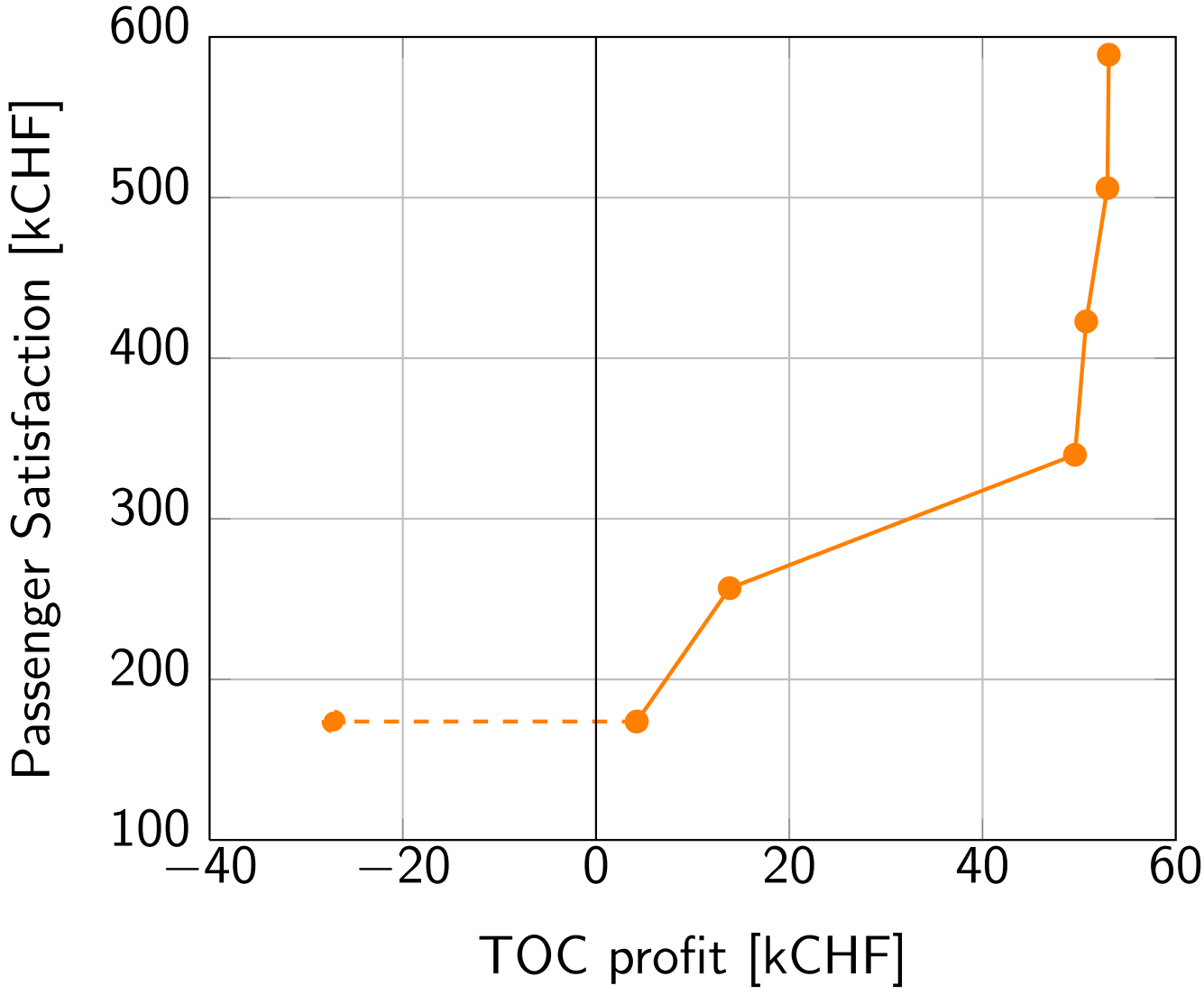
Current Timetable (Morning Peak)

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

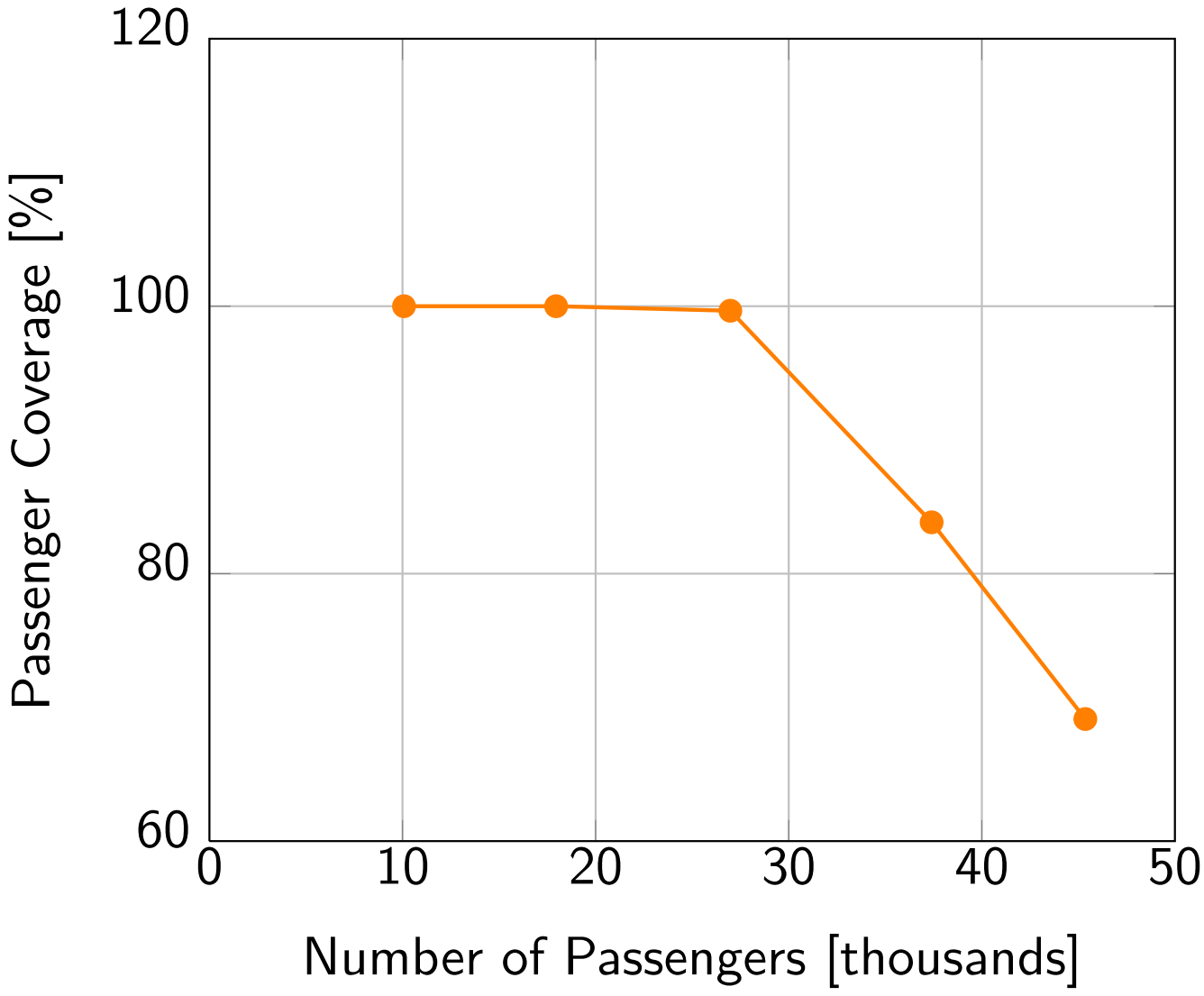
Results – Current Demand SBB 2014

ϵ [%]	0	20	40	60	80	100	100*
profit [CHF]	53 067	52 926	50 730	49 564	13 826	4 211	-27 168
satisfaction [CHF]	588 934	505 899	422 864	339 828	256 793	173 759	173 758
ub/lb [CHF]	54 046	54 598	54 776	54 394	54 600	51 195	168 016
gap [%]	1.84	3.16	7.98	9.74	294.91	1115.74	3.30
gap [CHF]	979	1 672	4 046	4 830	40 774	46 984	5 742
drivers [-]	17	17	22	22	46	48	49
rolling stock [-]	32	32	32	32	46	55	98
covered [%]	99.35	99.34	100.00	100.00	100.00	100.00	100.00

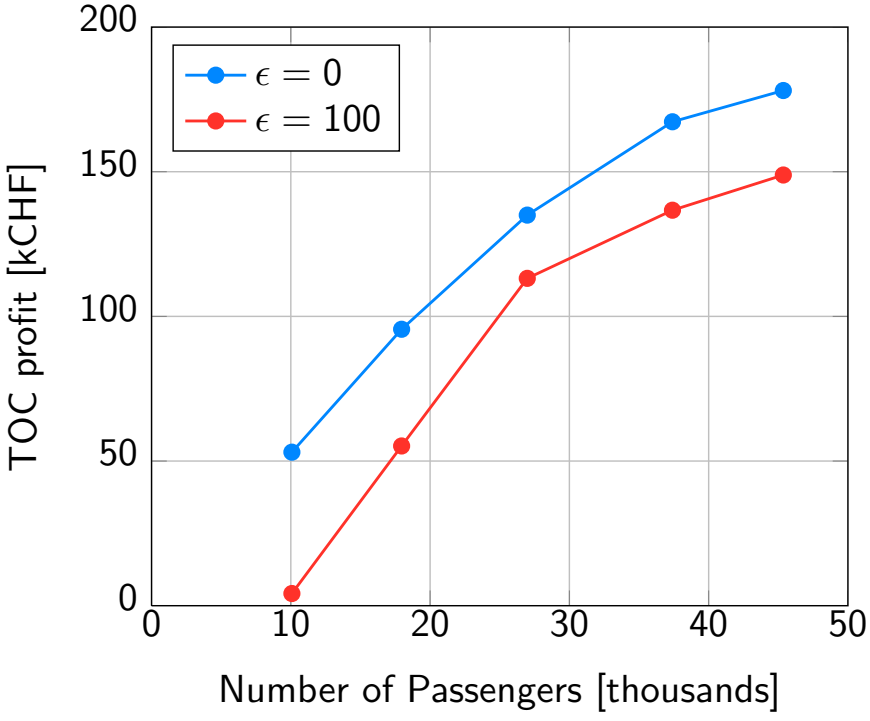
Pareto Frontier

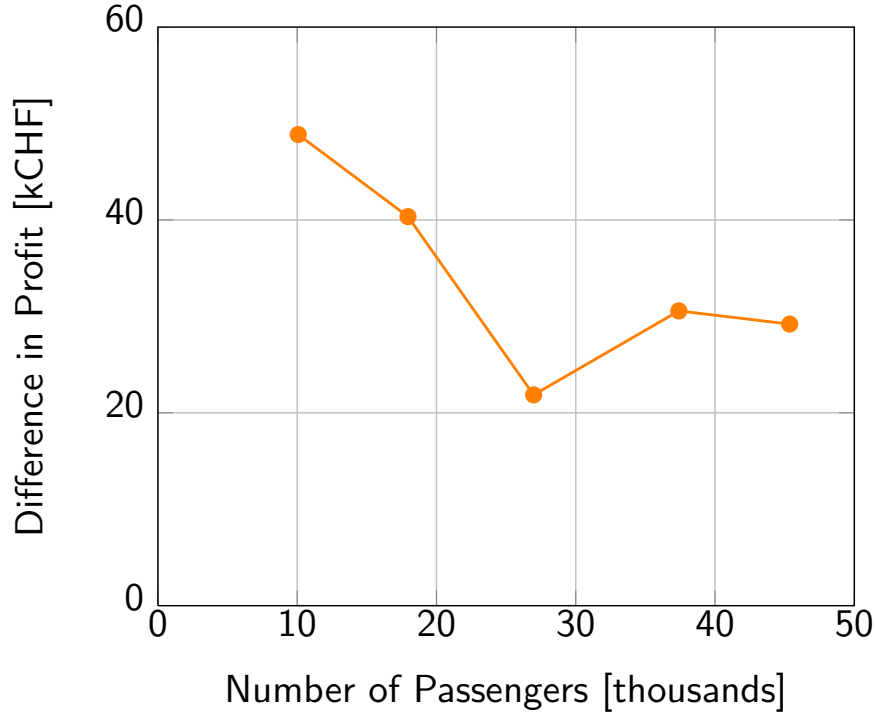


Sensitivity Analysis on Passenger Congestion

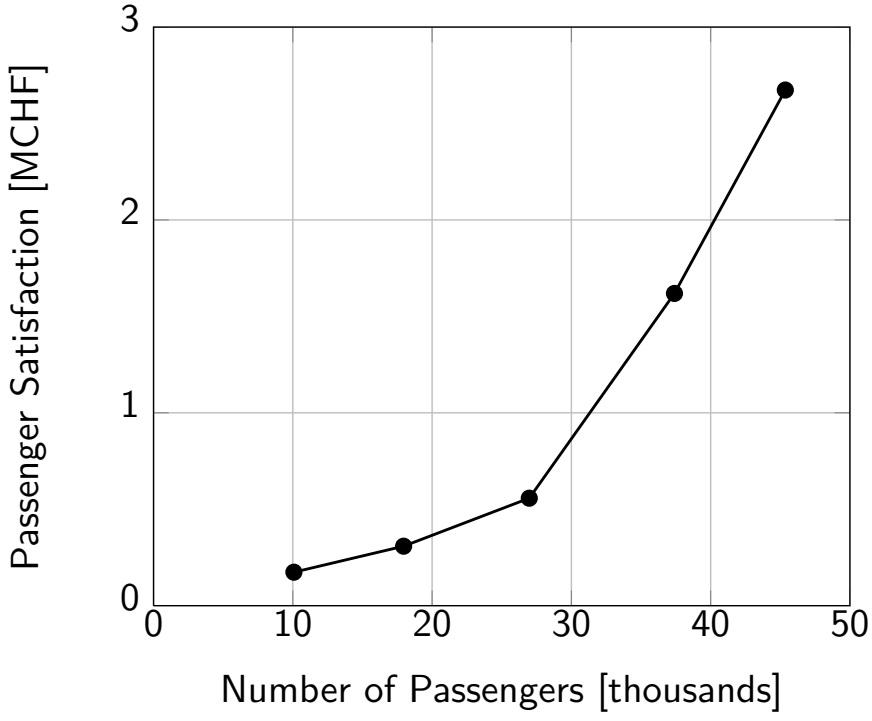


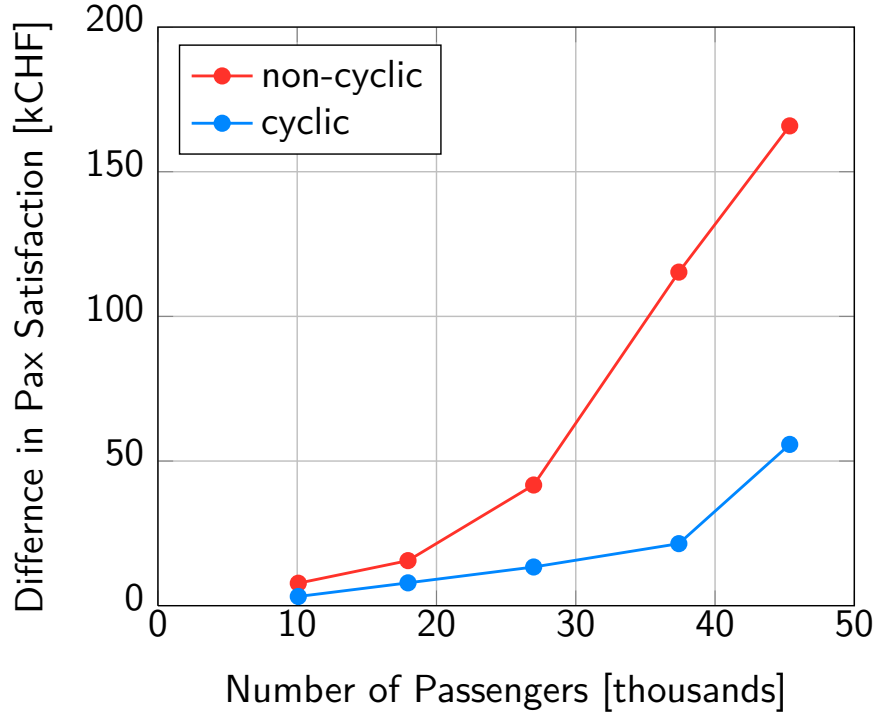
Sensitivity Analysis – Operator



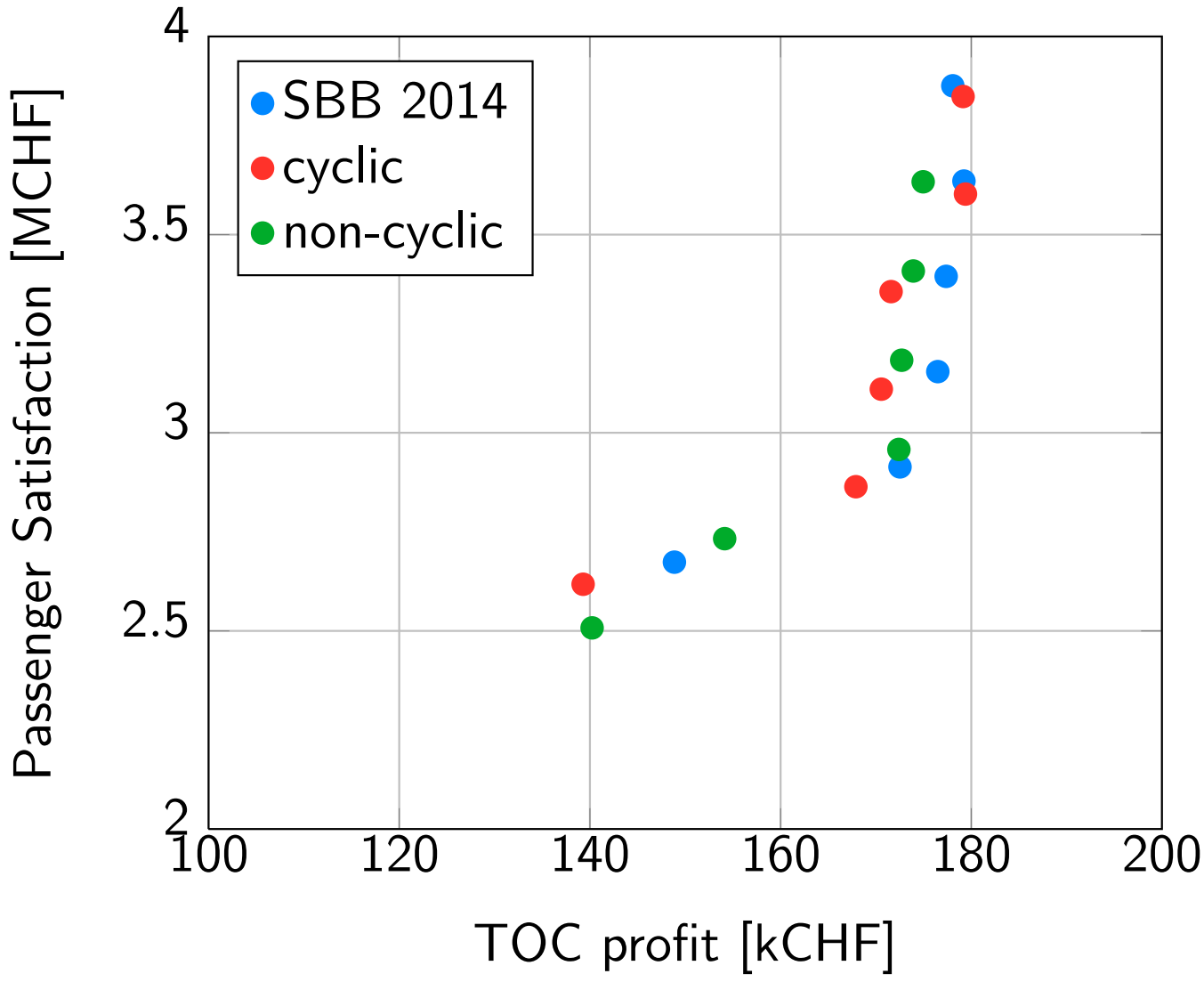


Sensitivity Analysis – Passenger





Sensitivity Analysis – Pareto Frontiers



Conclusions

- Current demand
  - cyclic timetable is by 3 000 CHF better than the SBB 2014 timetable
  - the non-cyclic timetable is by 4 000 CHF better than the cyclic timetable
- Most congested
  - cyclic timetable is by 55 000 CHF better than the SBB 2014 timetable
  - the non-cyclic timetable is by 110 000 CHF better than the cyclic timetable

Future Work

- Heuristics to solve for a full day
- Estimate the cost of cyclicity

Thank you for your attention.