ETH zürich

Disruptions in railway/public transport networks

Francesco Corman

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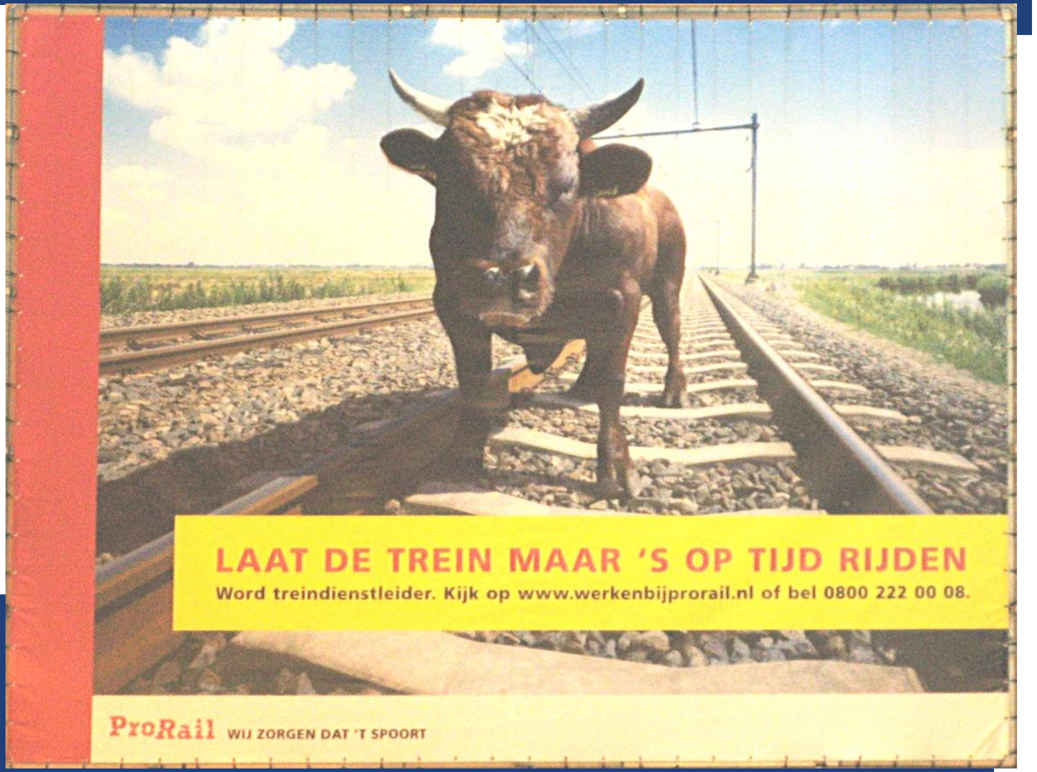
Chair for Transport Systems

Those slides

- Bad models
- Good reality
- Interactions
- Understanding more
- Understanding even more



Bad Models

F Corman, Assessment of advanced dispatching measures for recovering disrupted railway situations. Transportation Research Record

Prorail

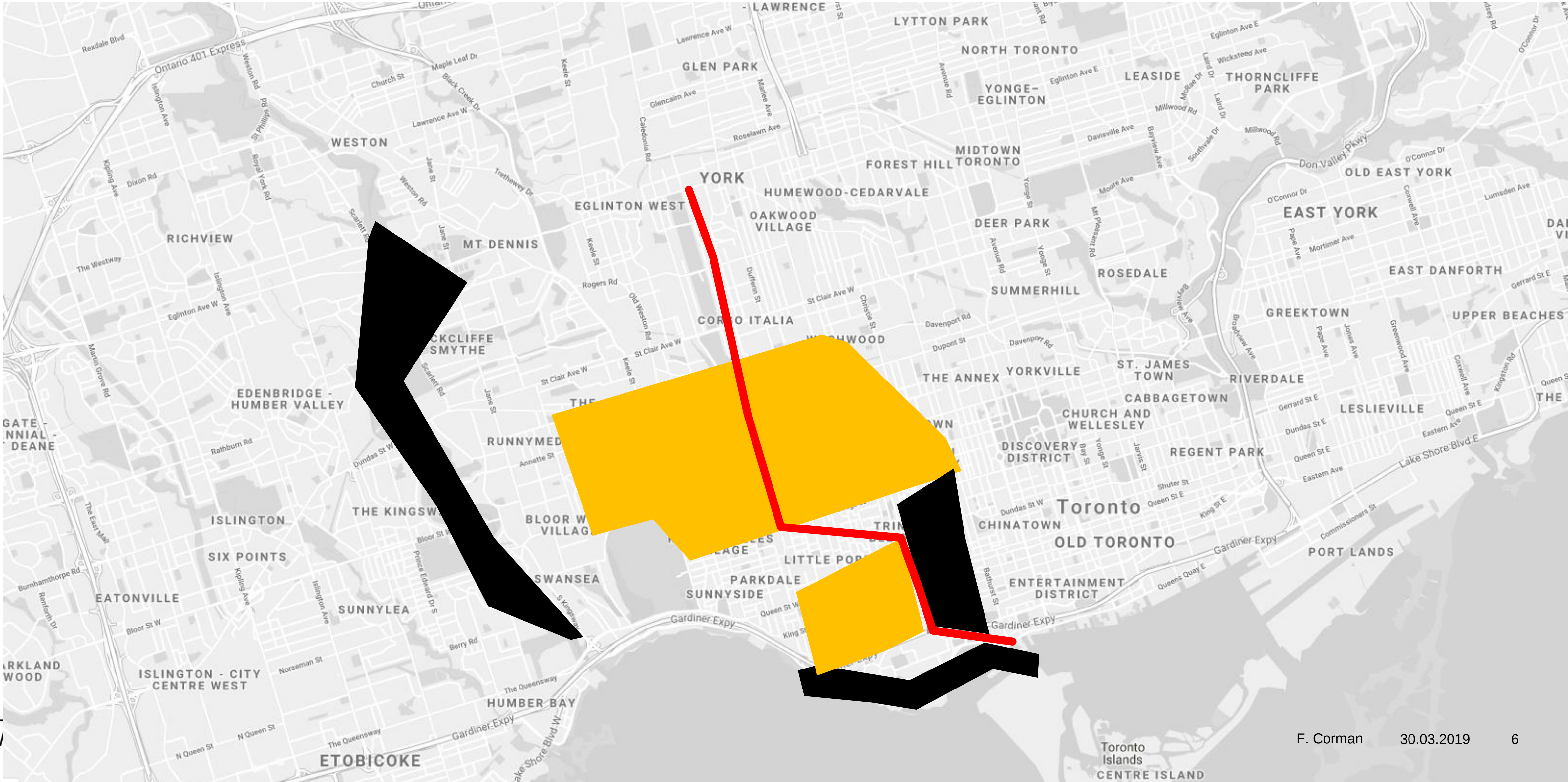
Routing /scheduling: Interesting instances

- When things are constant, and nobody influences anybody else: relatively easy
- In reality, there is some influence

- Routing in time and space models explicitly changes over time

- Interesting case: When capacity of links or intersections is limited
- Opportunity: When vehicles/people can be “controlled”
- Issues: when things “interact“

A space network in Toronto



An extended time space network

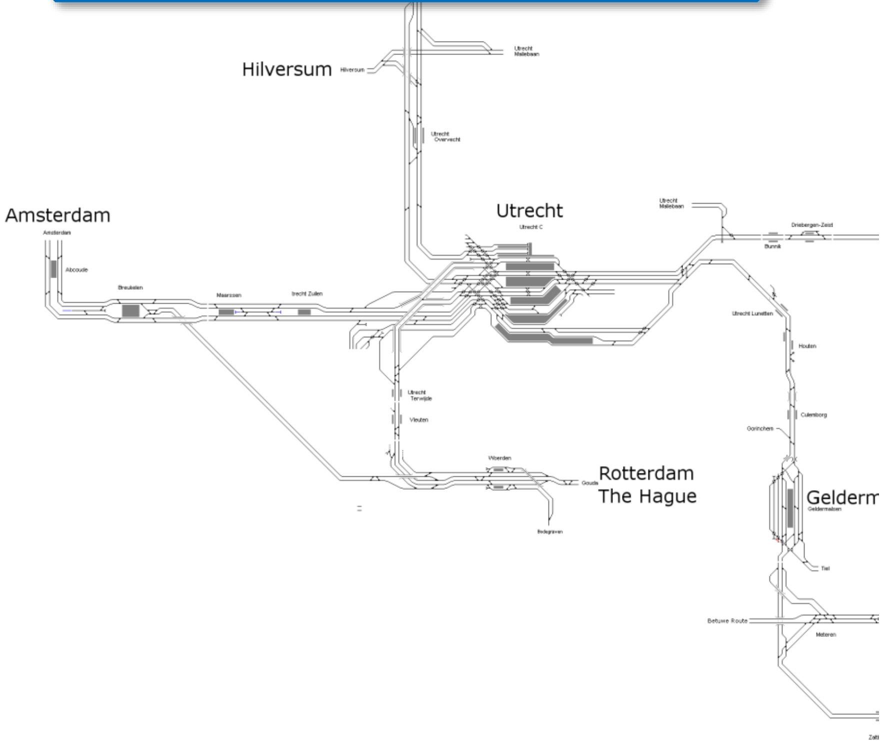
Some disruption management models

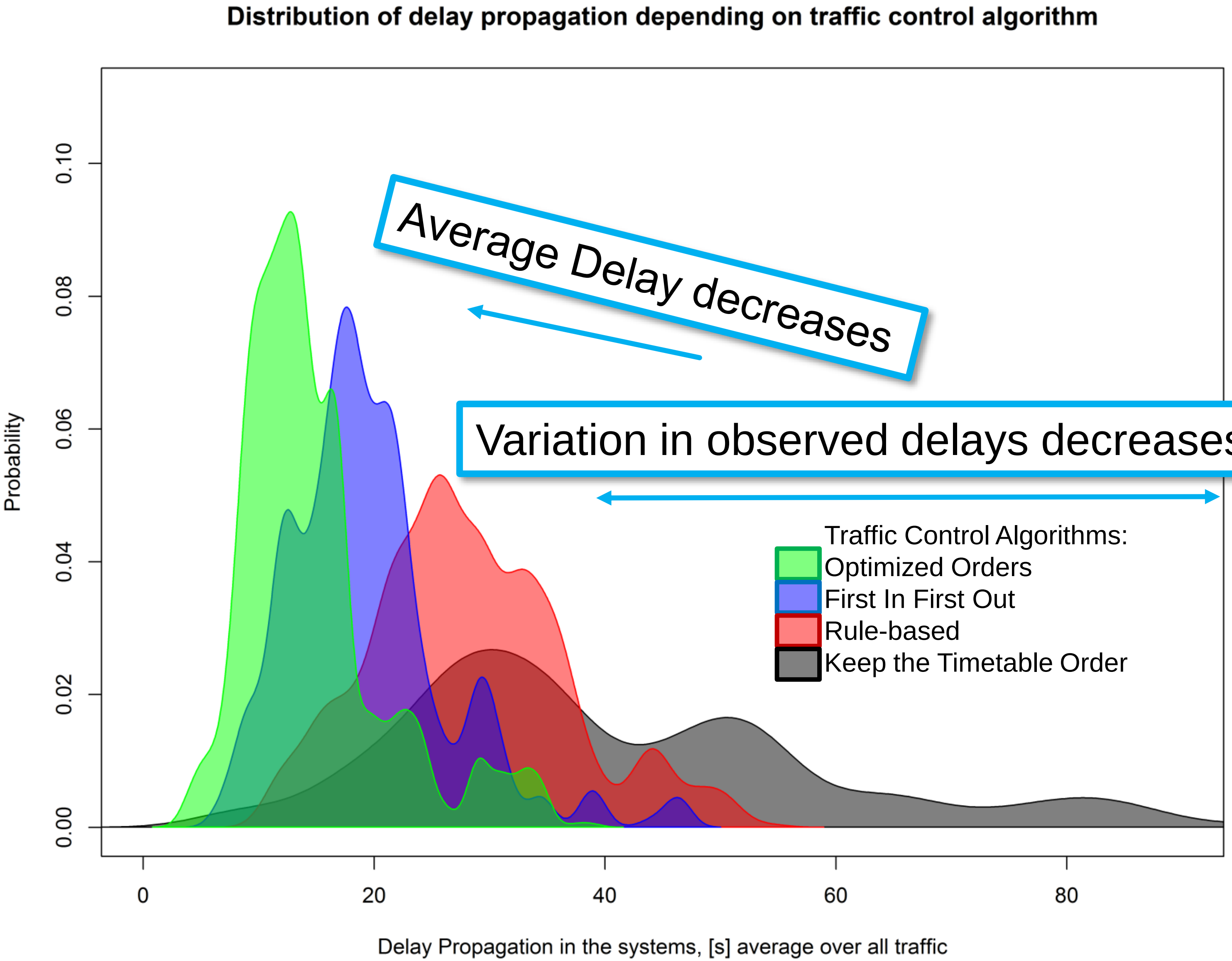
$$\begin{aligned} \min \quad & t_n - t_0 & \\ \text{s.t.} \quad & t_j - t_i \geqslant w_{ij} & (i,j) \in F \\ & (t_j - t_i \geqslant w_{ij}) \vee (t_k - t_h \geqslant w_{hk}) & ((i,j),(h,k)) \in A \end{aligned}$$

Delay minimization via optimized traffic management

2700 block sections,
150 trains / h,
~300 km

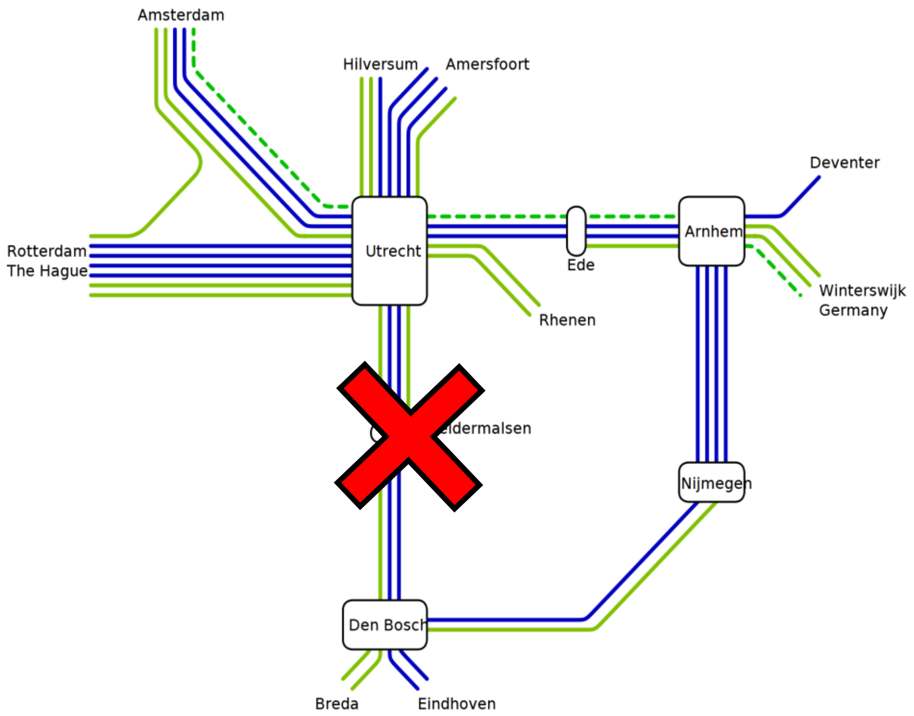
Delay reduction Optimization vs FIFO

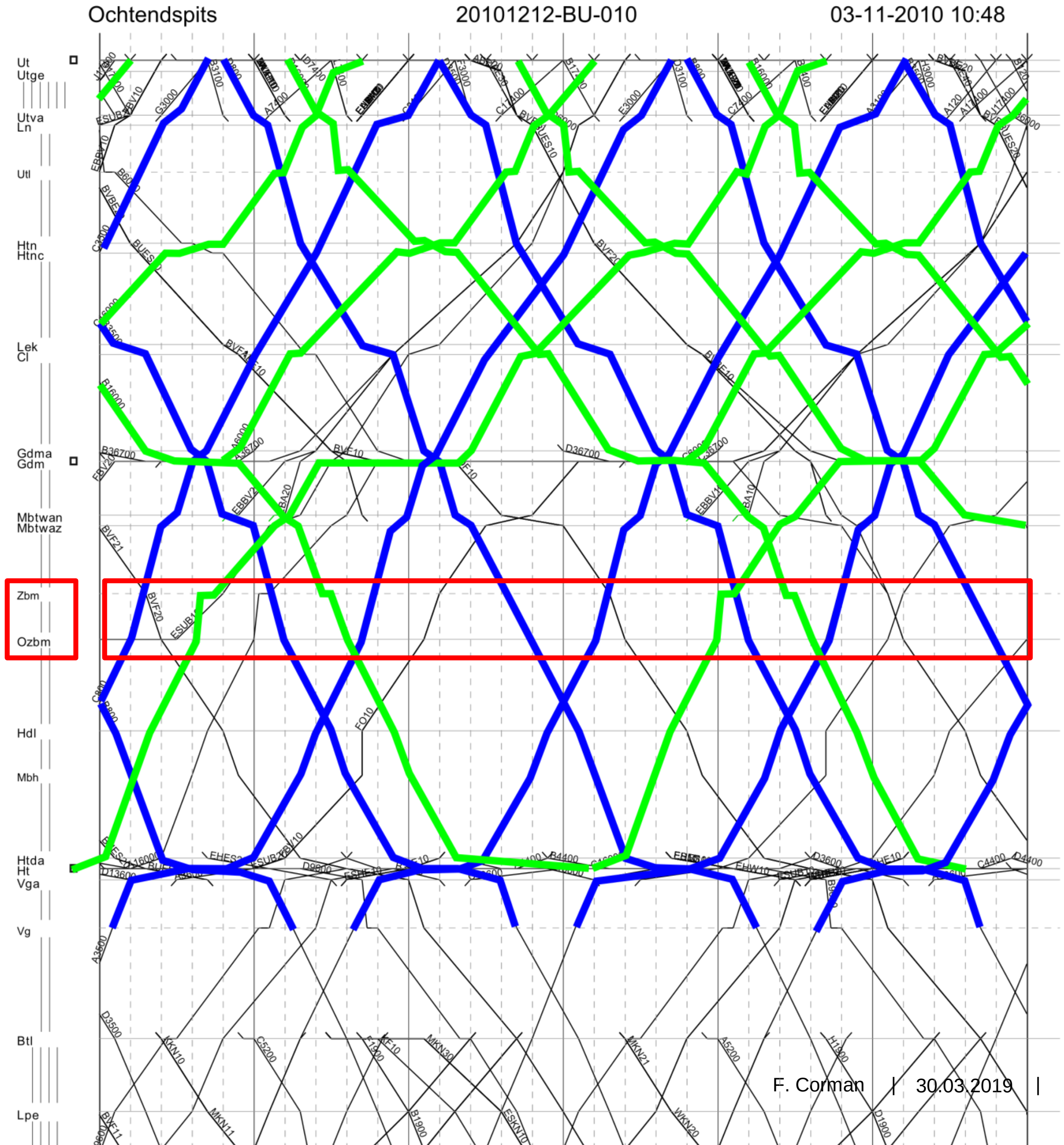




Corman D'Ariano Pacciarelli Pranzo , TR-B, TR-E

Disruption situation

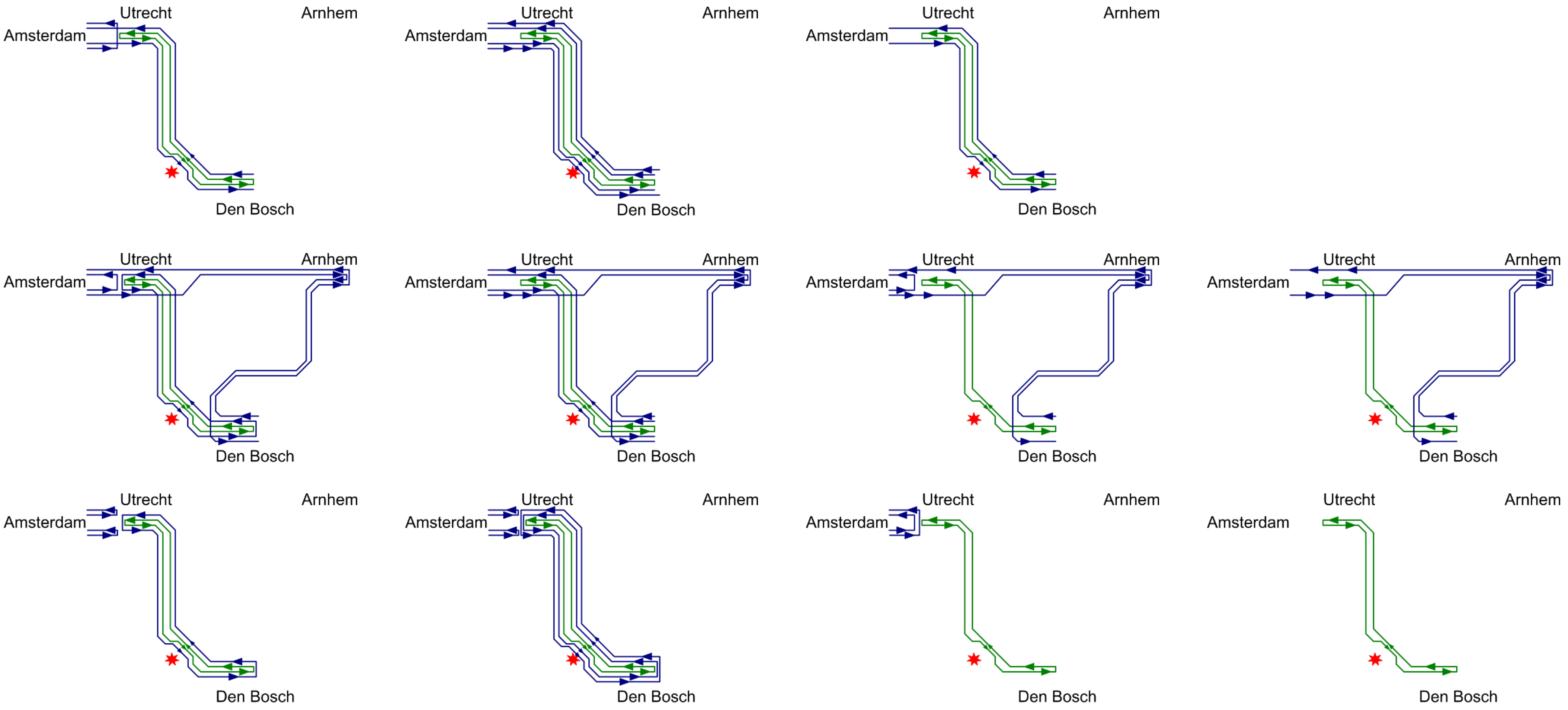




Institut für Verkehrsplanung
Institute for Transport Planni

Situation → Resolution → Disposition

A lot of resolution scenarios



Situation → **Resolution** → Disposition

A lot of performance indicators

Alternative	Gener Traveltime Ht→Aco	Freq Services Ht→Aco	Freq Services Ht→Ut	Gener TravelTime Ht→Ut	Gener Traveltime Ut→Aco	Freq Services Ut→Aco	Gener TravelTime Aco→Ut	Freq Services Aco→Ut	Gener Traveltime Aco→Ht	Freq Services Aco→Ht	Gener Traveltime Aco→Ht	Freq Services Aco→Ht
12_0_0	3765	6.5	4040	8	2144	15	2398	6.5	4455	4.5	3423	11.5
12+shuttle_0_0	3714	5	4057	8	3179	15	2518	6.5	7697	3.5	4010	12.5
8_4_0	3854	6.5	3844	6.5	3216	14.5	2104	6	5215	4	4704	11
8+shuttle_4_0	3839	3.5	3821	6.5	4333	15.5	2187	6	9358	2.5	5164	12.5
8 _0_4	3735	3.5	4326	5.5	3010	8.5	3153	3	5502	2	3660	7
8 _0_4+shuttle	3708	3.5	4326	5.5	2653	12	2440	6.5	6545	3.5	4028	9
8+shuttle_0_4+shuttle	3723	3.5	4592	5.5	2929	12	2518	6.5	7826	2.5	4248	8.5
4_4_4	3744	1.5	5055	3.5	5014	8.5	3390	2	7175	0.5	4370	4.5
4_4_4+shuttle	3719	1.5	5055	3.5	3828	12.5	2187	6	8194	1	4706	5.5
4_0_8	4000	0	4000	2	4000	0	4000	0	4000	0	5000	1.5
4_0_8+shuttle	3750	1	5471	2	2424	9	2518	6.5	8776	1.5	5592	4.5
TIMETABLE REF	3672	7	3589	8	2840	14	2540	6.5	4294	4.5	3228	11.5

A lot of performance indicators

Alternative	Average Total Delay (s)	Max Total Delay (s)	Average Consecutive Delay (s)	Max Consecutive Delay (s)	Punctuality 5 min (% of running trains)	Canceled trains (absolute number)	Capacity occupation, Ht←→Ut	Extra Units compared to plan
12_0_0	43.8998	510	21.2463	510	94.73684	0	1.231	0
12+shuttle_0_0	43.258	510	21.0339	510	95.83333	0	1.242	8
8_4_0	98.8813	1739	67.4402	1206	88.88889	0	1.143	4
8+shuttle_4_0	96.73	1739	65.6454	1206	89.16667	0	1.154	8
8_0_4	37.2391	510	14.6082	510	97.22222	4	0.959	-4
8 _0_4+shuttle	37.1944	510	14.4421	510	97.2973	4	0.948	0
8+shuttle_0_4+shuttle	36.7468	510	14.2366	510	96.49123	4	0.948	4
4_4_4	56.6107	1739	24.9972	1206	92.79279	4	0.948	0
4_4_4+shuttle	56.818	1739	25.2173	1206	92.98246	4	0.948	4
4_0_8	28.668	510	6.70236	510	100	8	0.959	-4
4_0_8+shuttle	29.3327	510	6.78802	510	100	8	0.959	0
TIMETABLE REF	26.8934	510	5.81801	510	100	0		0

Comparing them

?

Alternative	Average Total Delay (s)	Max Total Delay (s)	Average Consecutive Delay (s)	Max Consecutive Delay (s)	Punctuality 5 min (% of running trains)	Canceled trains (absolute number)	Capacity occupation, Ht←→Ut	Extra Units compared to plan	Gener Traveltime Ht→Aco	Freq Services Ht→Aco	Freq Services Ht→Ut	Gener TravelTime Ht→Ut	Gener Traveltime Ut→Aco	Freq Services Ut→Aco	Gener TravelTime Aco→Ut	Freq Services Aco→Ut	Gener Traveltime Aco→Ht	Freq Services Aco→Ht	Gener Traveltime Aco→Ht	Freq Services Aco→Ht
12_0_0	43.8998	510	21.2463	510	94.73684	0	1.231	0	3765	6.5	4040	8	2144	15	2398	6.5	4455	4.5	3423	11.5
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8+shuttle_4_0	96.73	1739	65.6454	1206	89.16667	0	1.154	8	3839	3.5	3821	6.5	4333	15.5	2187	6	9358	2.5	5164	12.5
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4_0_8+shuttle	29.3327	510	6.78802	510	100	8	0.959	0	3750	1	5471	2	2424	9	2518	6.5	8776	1.5	5592	4.5
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Disruption management is complex

- Models can help, …

- if you know which solutions would be acceptable (automatic scenario generation?)
- if you know which constraints exist (better model, more integration)
  If you know how dispatcher would take decisions (?)
- If you know how passengers would react

- Statistics cannot help
- More integration/optimization make smaller problems disappear, bigger problems arise

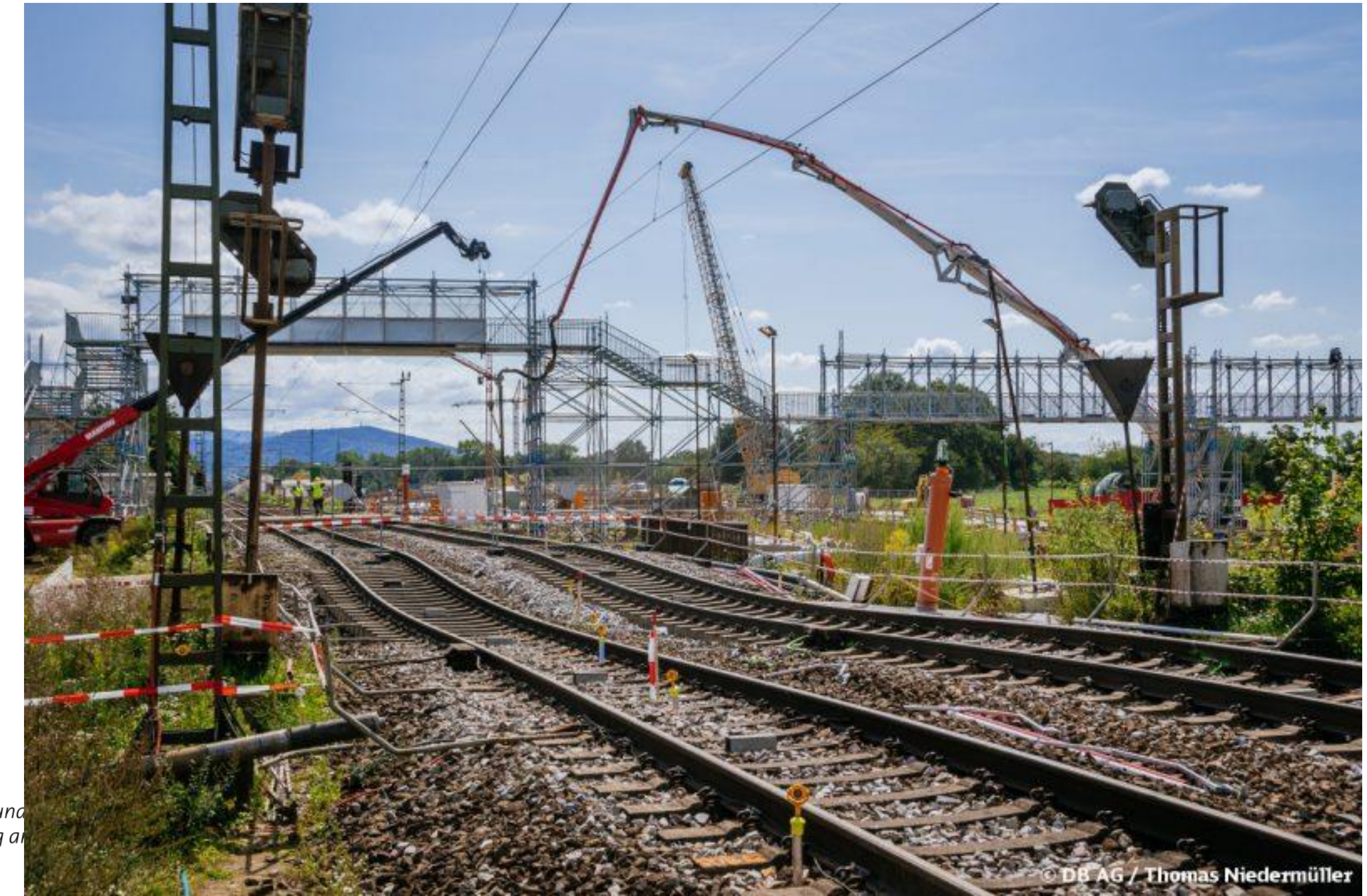
Some positive thoughts

T Partl, Master Thesis ETH

wikimedia

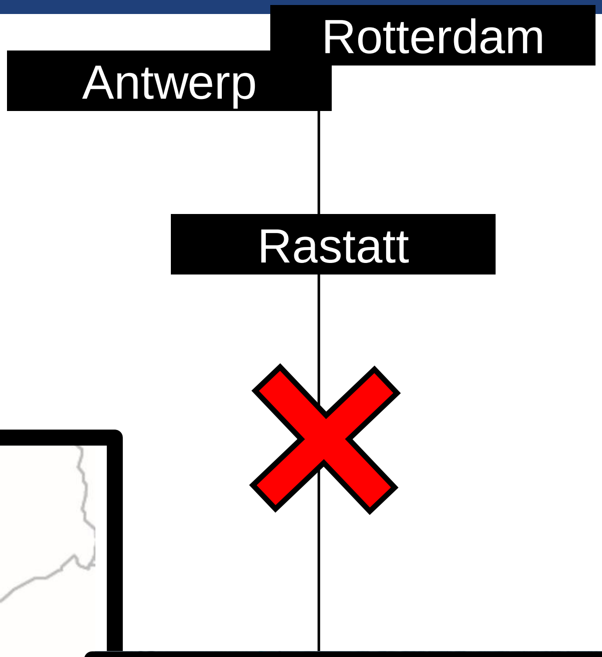
Rastatt

- Disruption for about two months, 15.08 to 02.10 2018. No traffic.

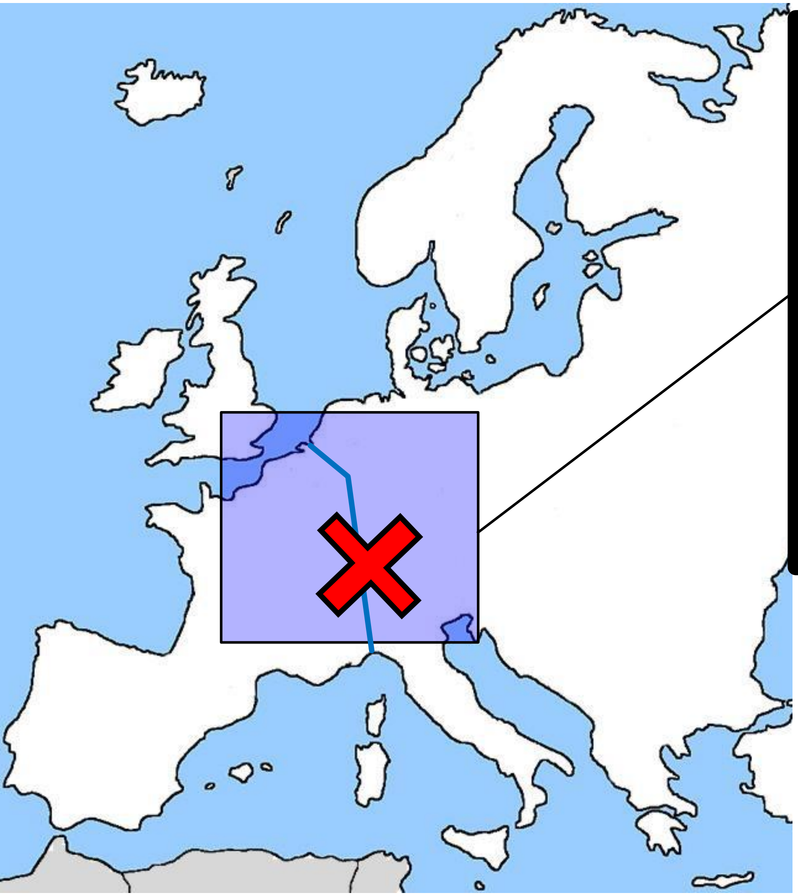


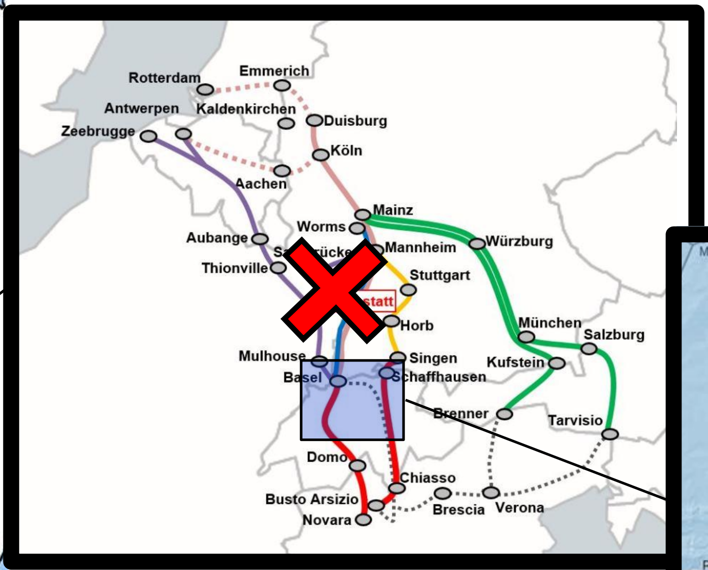
DB

Rastatt



- European corridor Rotterdam Genoa





Milan

Genoa

SBB

Cancellations; delays

- Cancel train
- Buses, passengers

- Freight? (not counted)

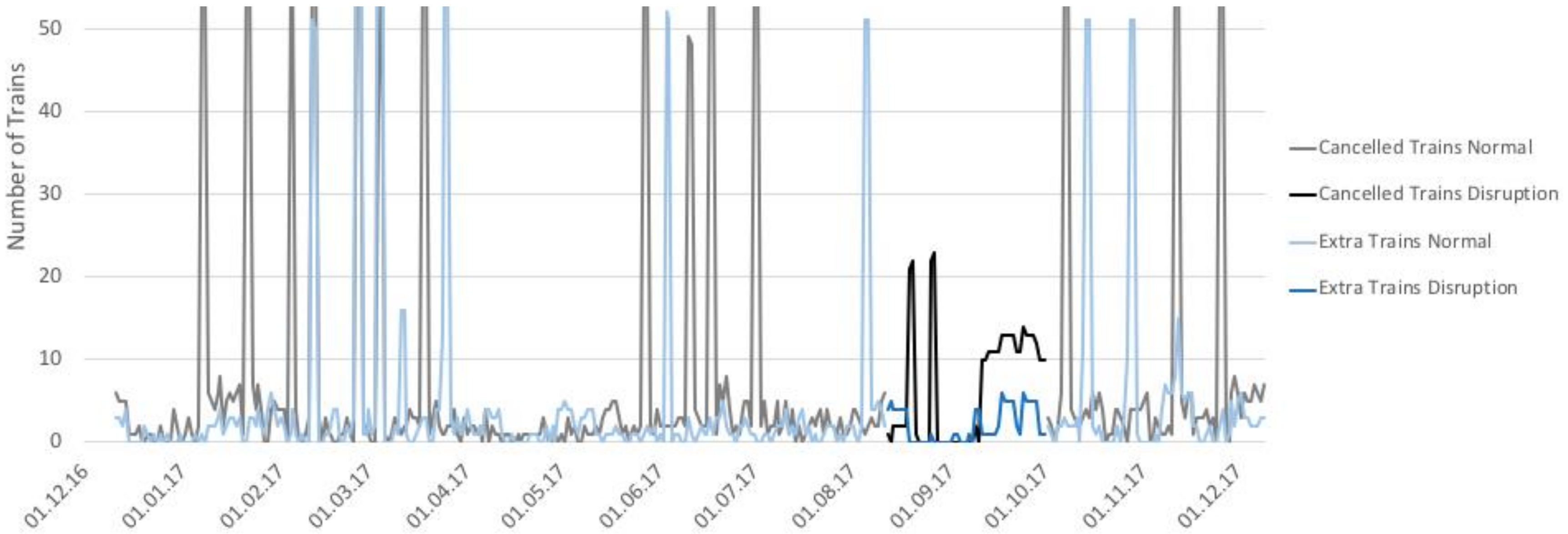


Figure 7: Numbers of extra and cancelled trains arriving at Zurich HB and Olten

Primary delays

- Trains coming from Germany

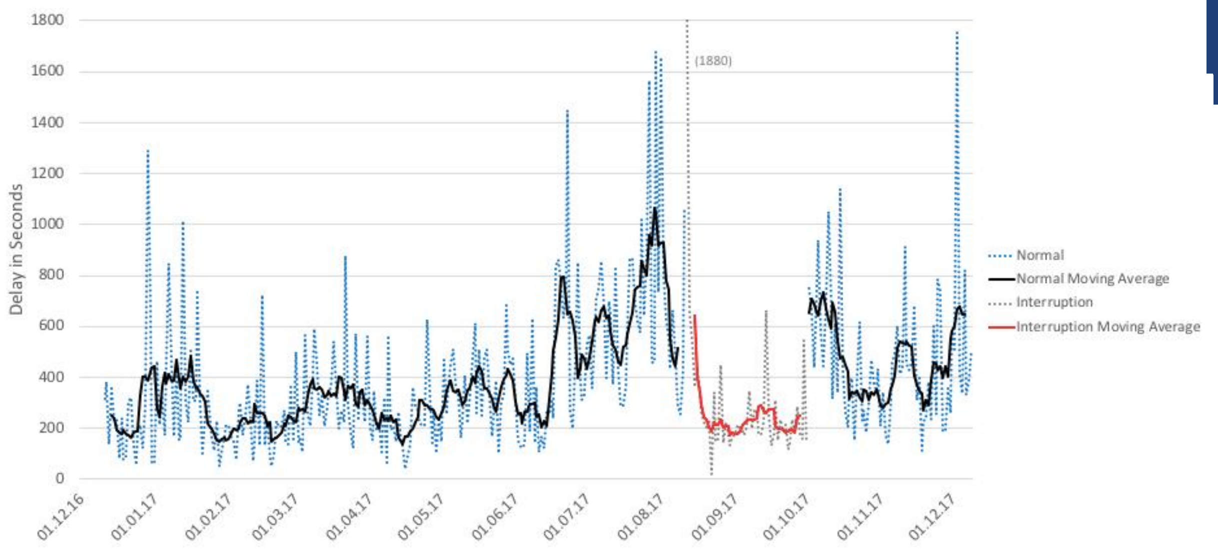


Figure 19: Yearly pattern of average delays of all trains from Germany arriving at Basel SBB

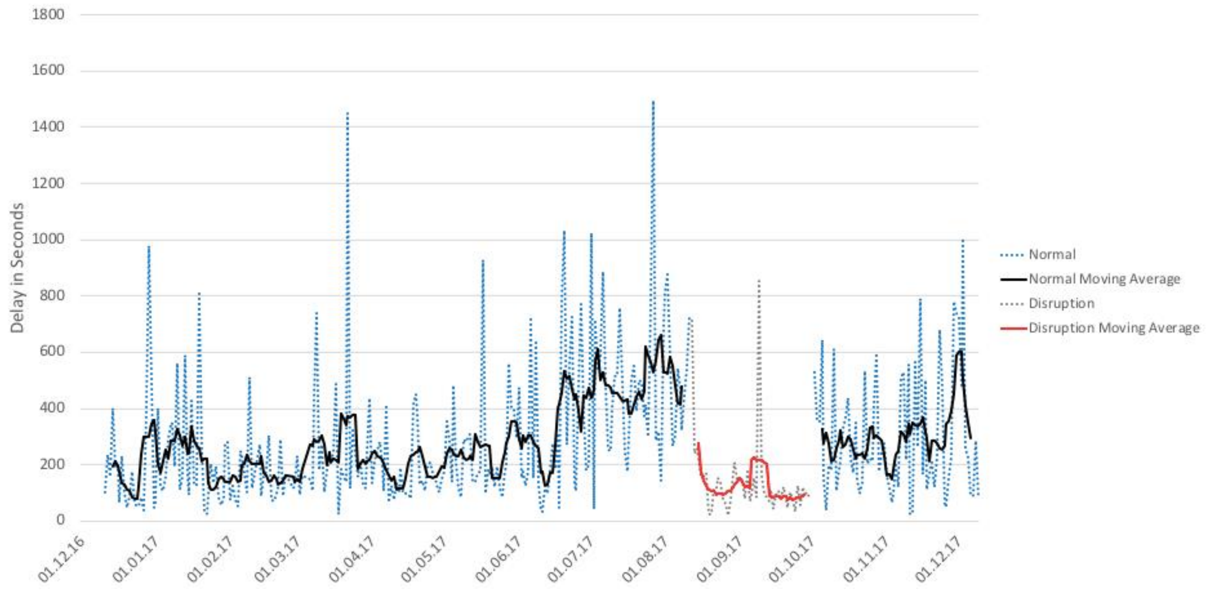


Figure 21: Delays of all trains from Germany arriving at Liestal and Zurich HB, which non-stop came from Basel SBB

Secondary delays

- (delays at other stations have been checked and are not relevantly changed)

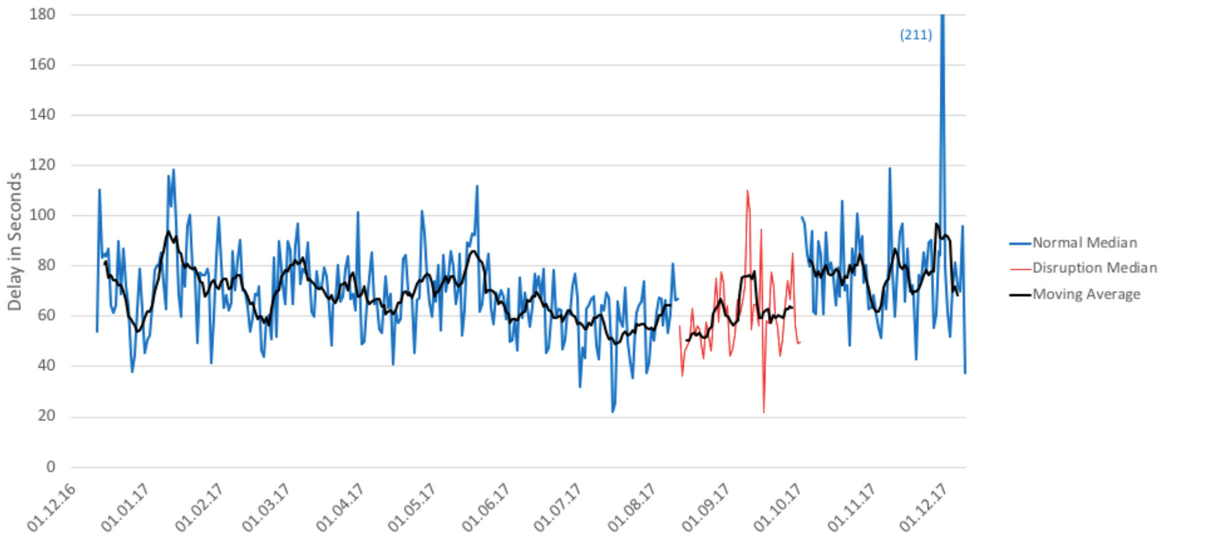


Figure 15: Yearly pattern of median delays in Liestal, Laufen and Rheinfelden including its moving average

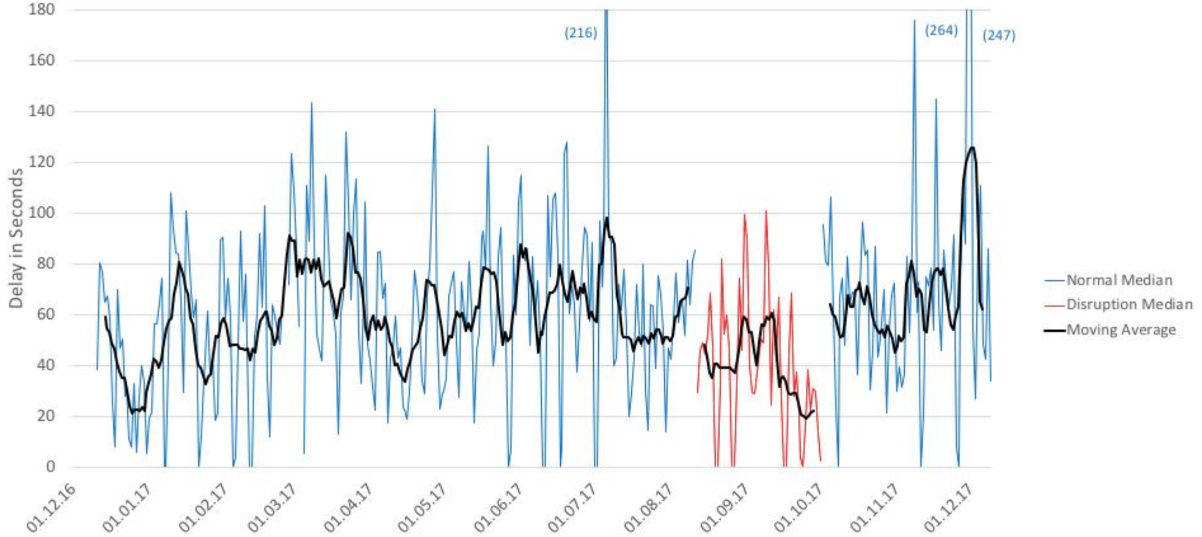
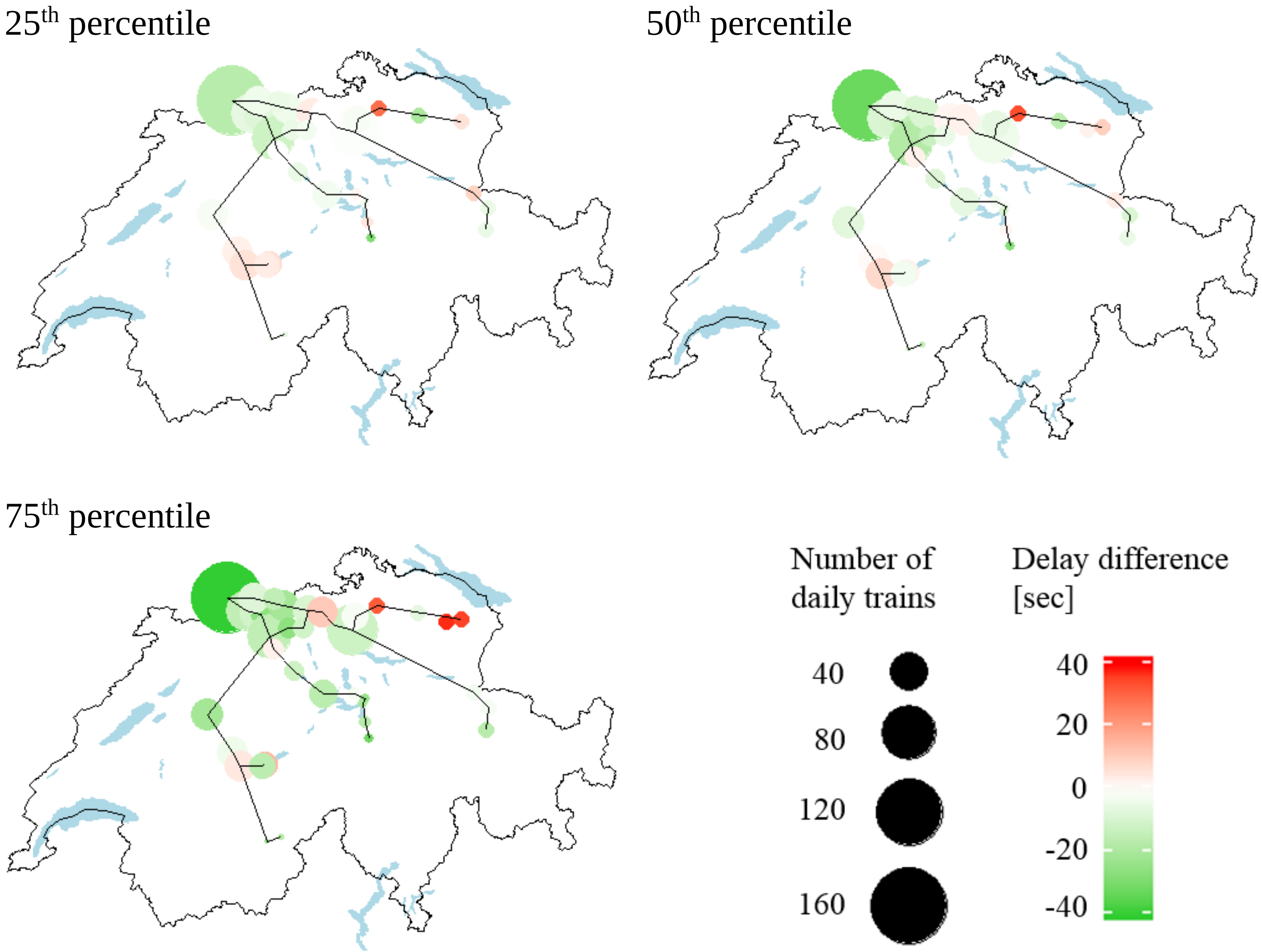
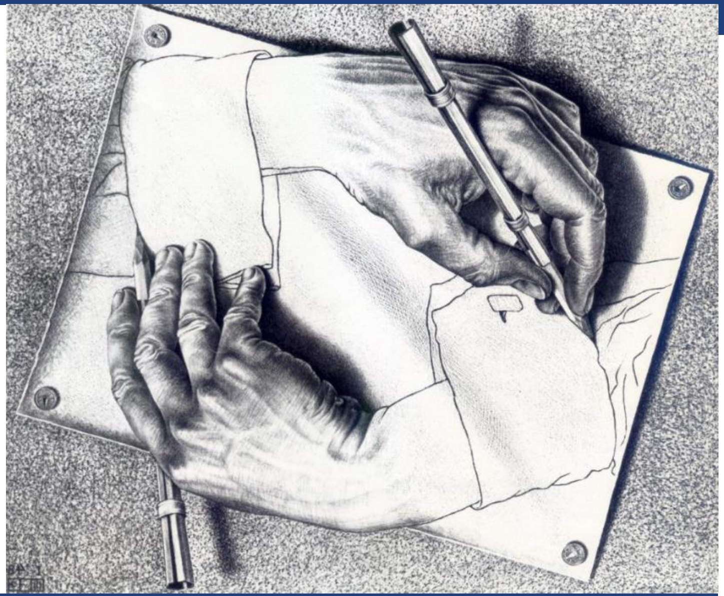


Figure 17: Yearly pattern of median delays in Zurich HB and Olten including its moving average

Disruptions are good (?)

- Clear effect of isolation of network, → less delays
- Possibility to understand the degree of interconnection of networks
- Lessons learnt for internal dynamics/ external dynamics
- Never again!



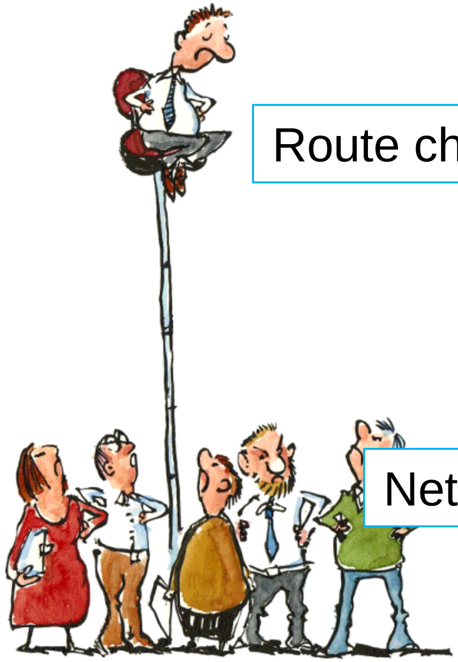


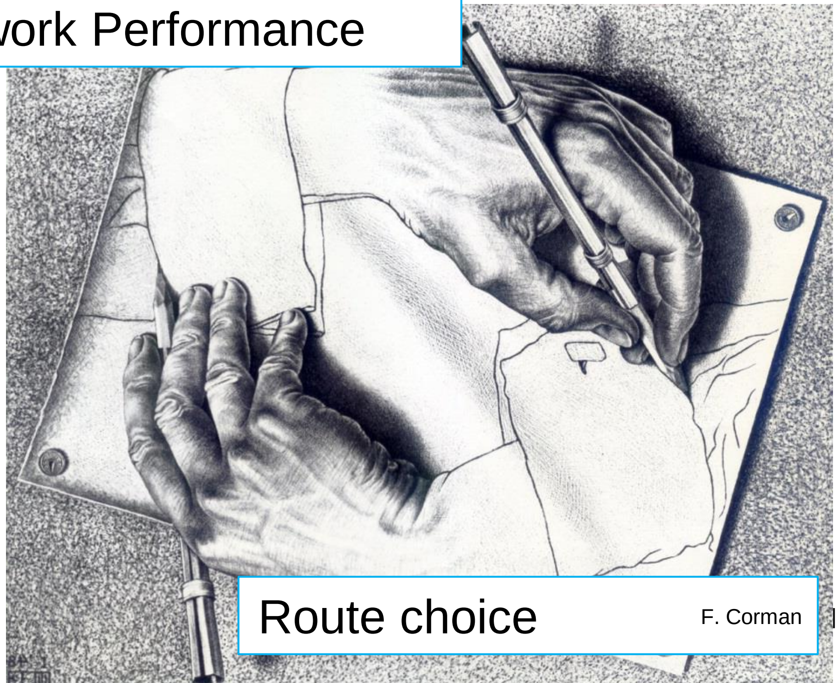
Interaction modelling

flickr

Passengers Routing in public transport networks

- Divide hierarchically into layers
  post process, simulate, adjust
- Equal importance given to problem: iterate coordinate, converge





escher

Schedule-based Transit assignment

Knowing passengers demand per time

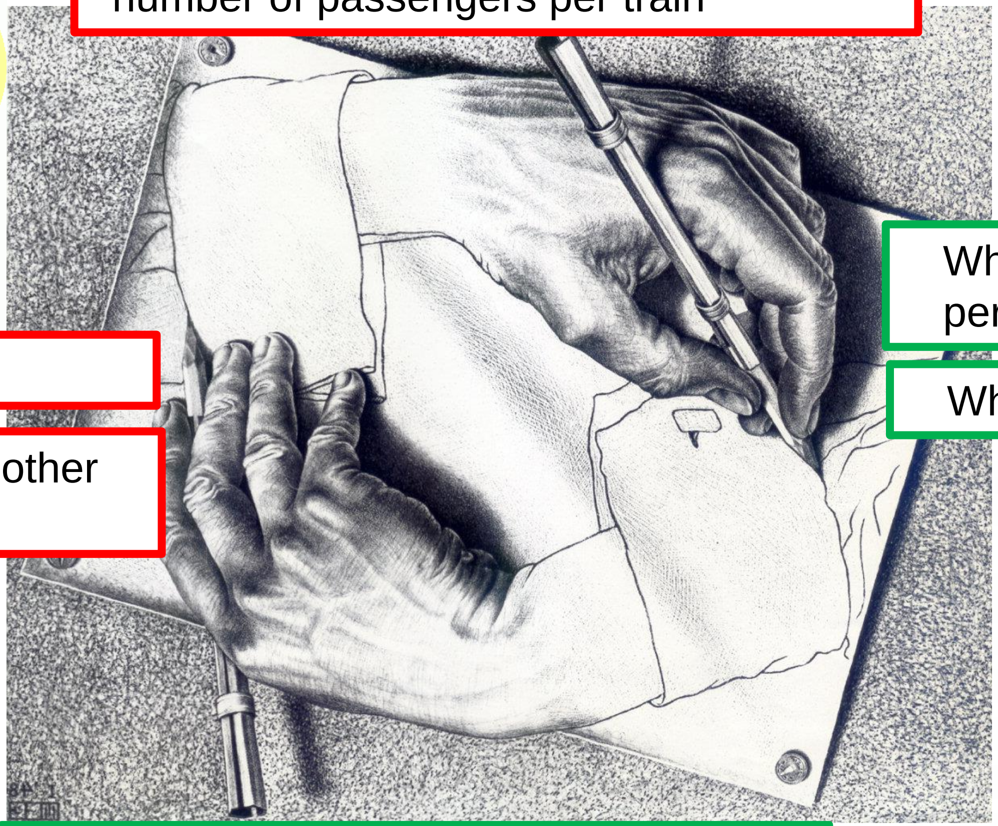
Routing of passengers is based on shortest travel time

Vehicles (trains) have infinite passengers capacity

(relatively strong assumptions!)

Schedule-based assignment → min cost flow problem

Interaction



scheduling trains in an infrastructure with limited capacity, taking into account the number of passengers per train

What will I do?

What I believe the other person would do

What I believe the other person would do

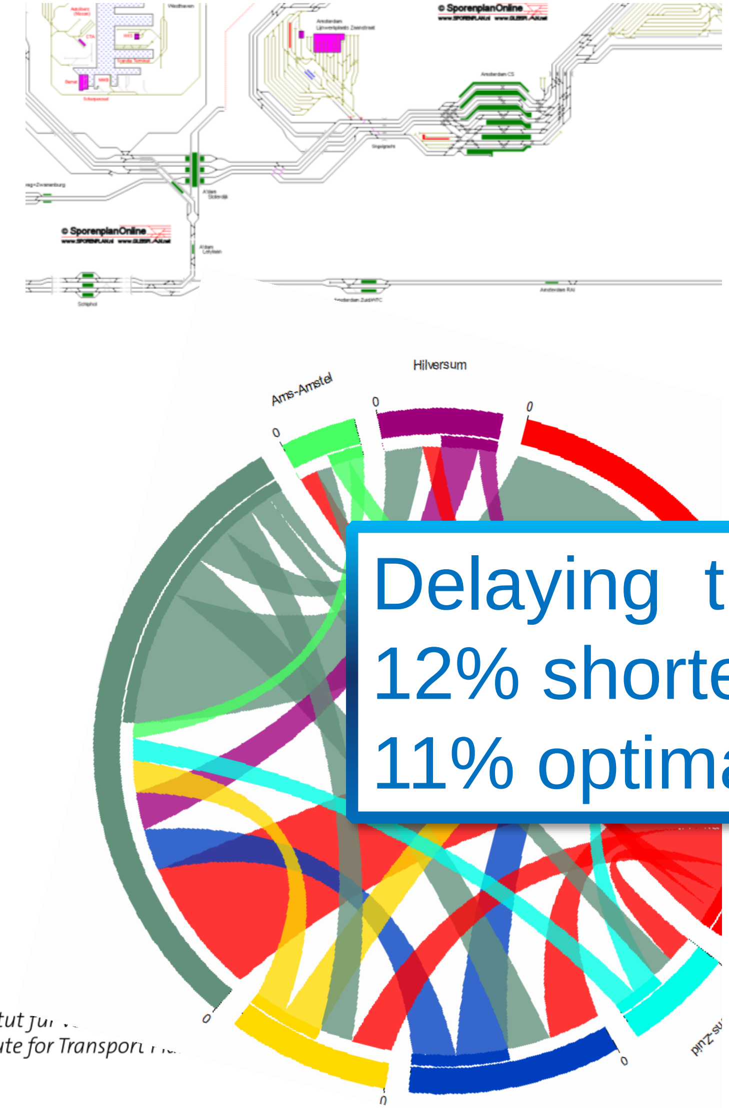
What will I do?

routing of passengers by taking into account the train schedule, their origin and destination, the minimization of their discomfort

Possible solutions –who does what, why?

- Optimize everything (integrated model) ~System optimum
- Minimize delay weighted by passengers;
  Passengers react to schedule,
  trains react to passengers choice ~Nash
- Keep the timetable order; or optimize schedule
  Passengers adjust route choices ~Inv. Stackelberg
- Passengers publish their choices / cost functions;
  optimize schedule to minimize travel time ~Stackelberg

Upper bound to optimum



Delaying trains instead of passengers:
12% shorter travel time vs timetable
11% optimality gap

Corman D'Ariano Pacciarelli Marra Samà TR-Part E 2016

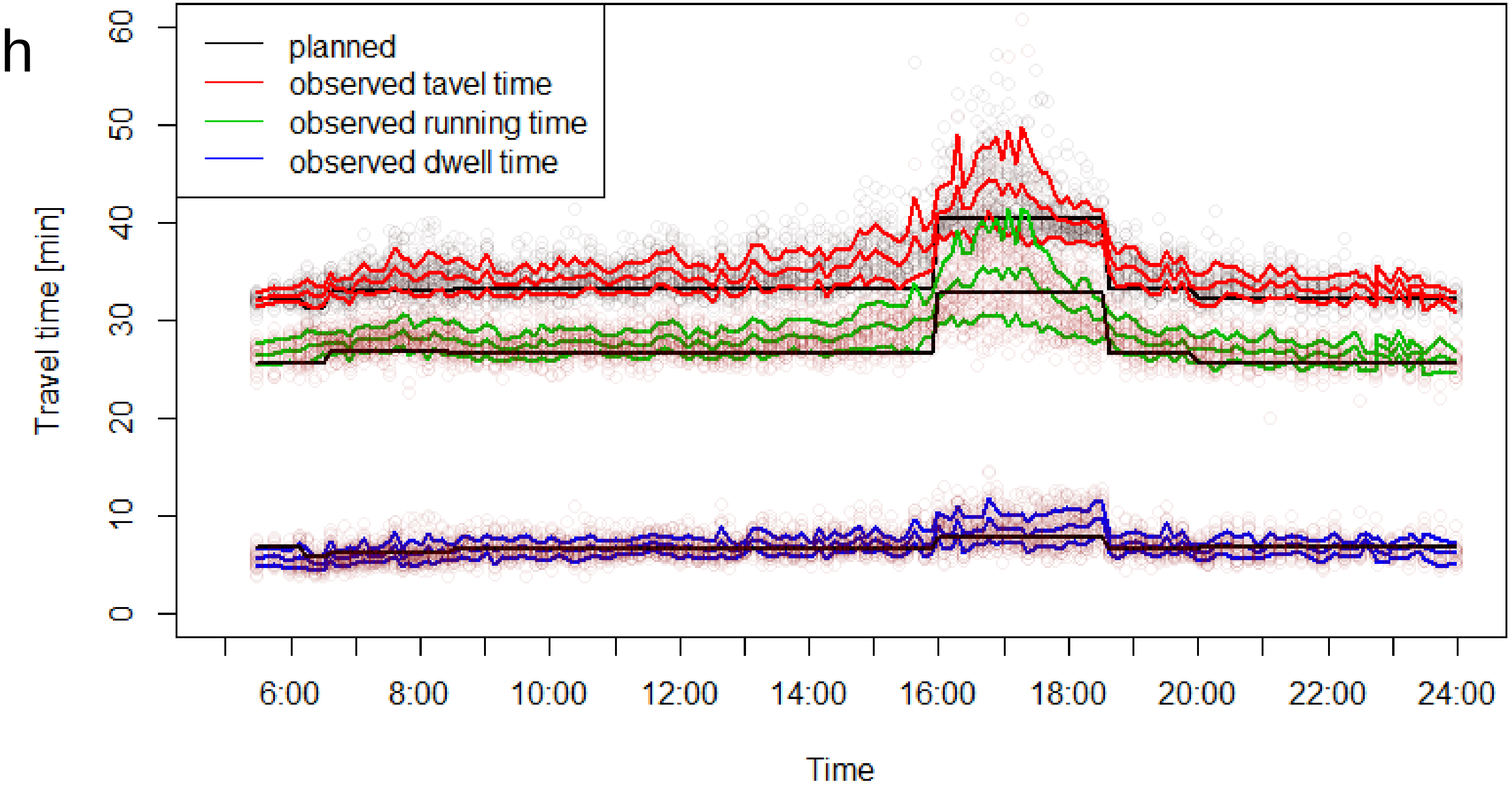
Larger/better models

N. Leng, Agent-based simulation approach for disruption management in rail schedule , CASPT

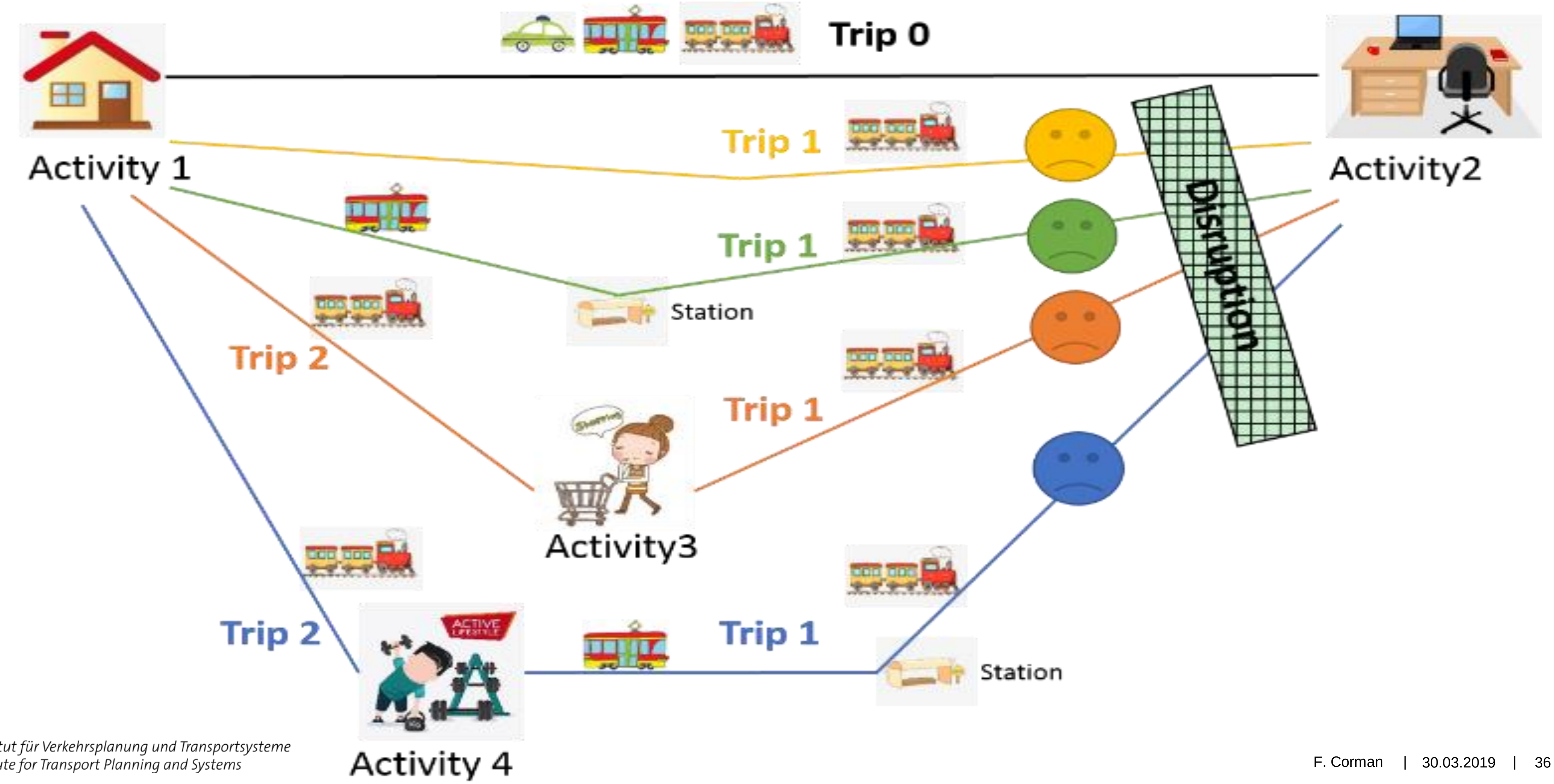
flickr

Operations are not terribly good

- Example delay in Zurich
- Very dense network

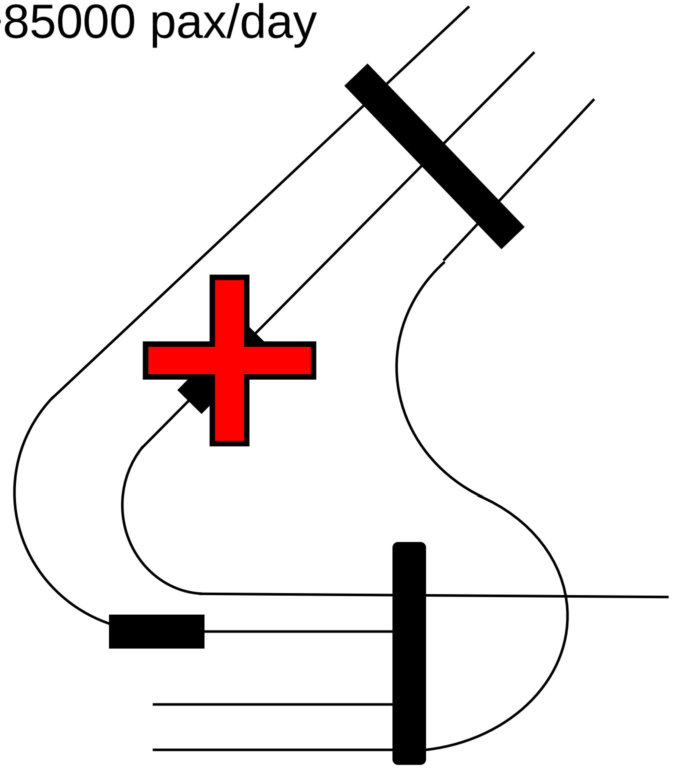


A larger perspective onto activities - MATSim

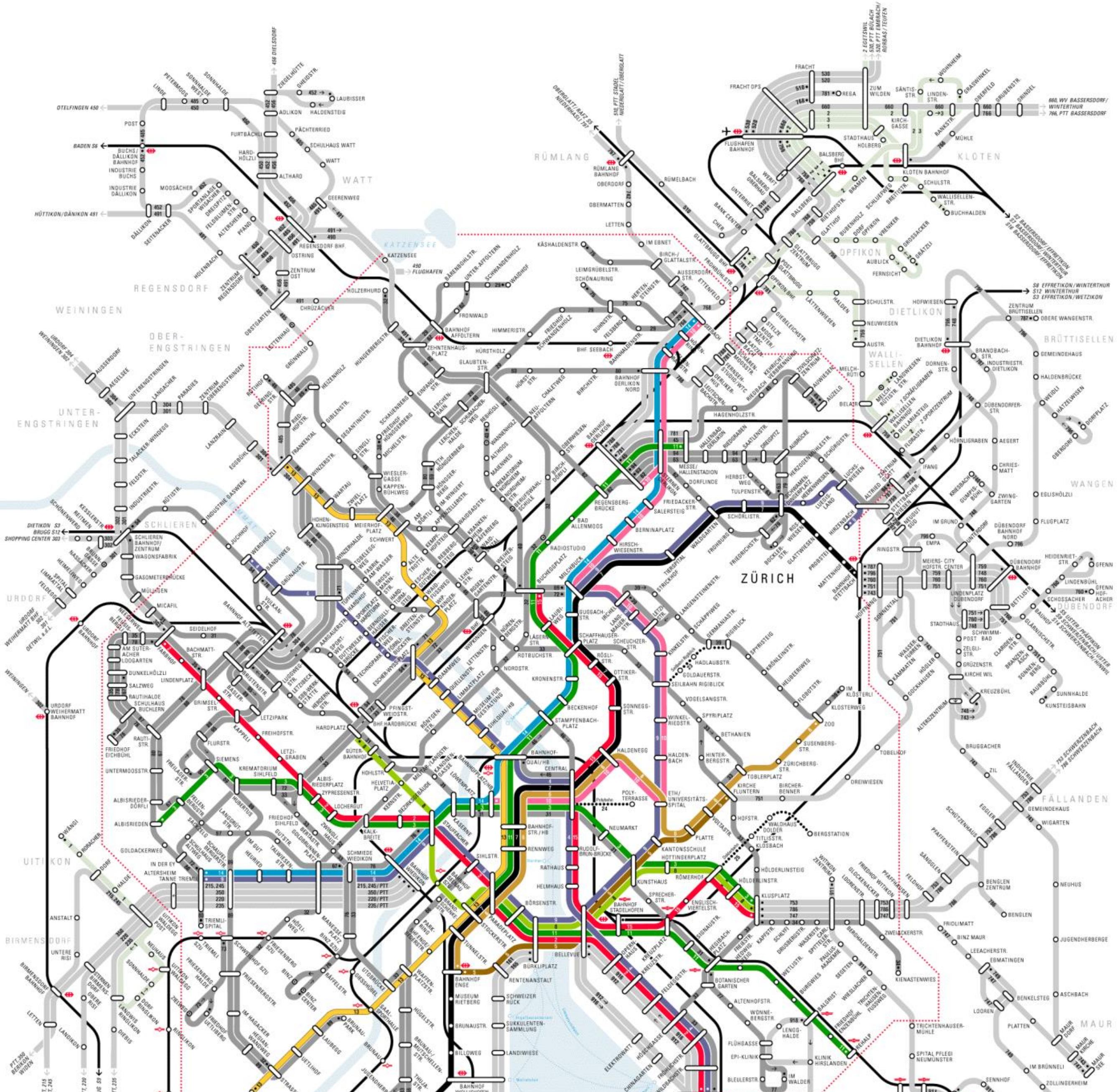


Example disruption, Zurich

Oerlikon
~300 trains/ day
~85000 pax/day



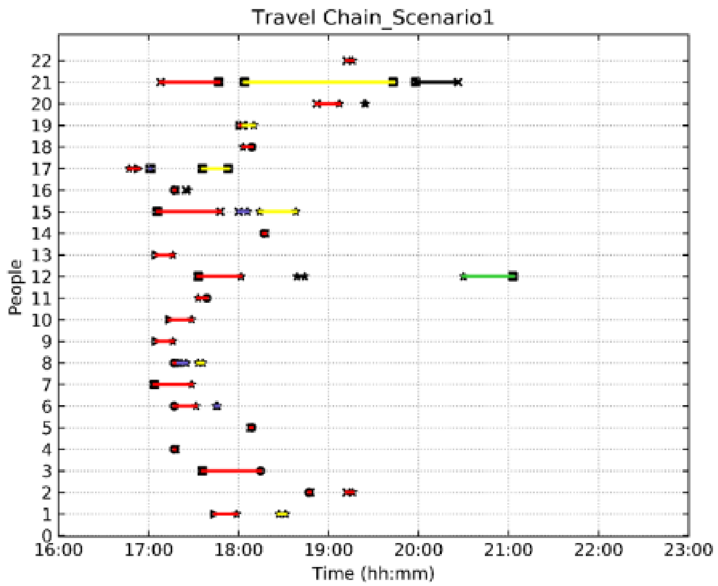
Main station
~2900 trains/ day,
450000 pax/ day

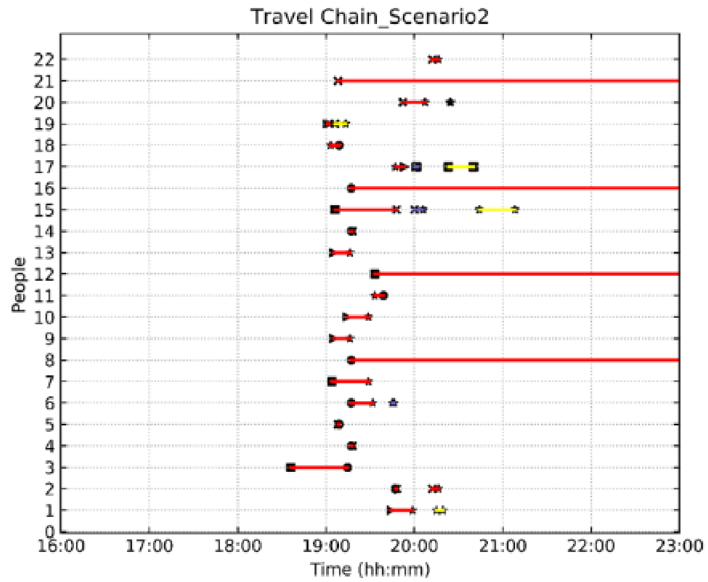


VBZ

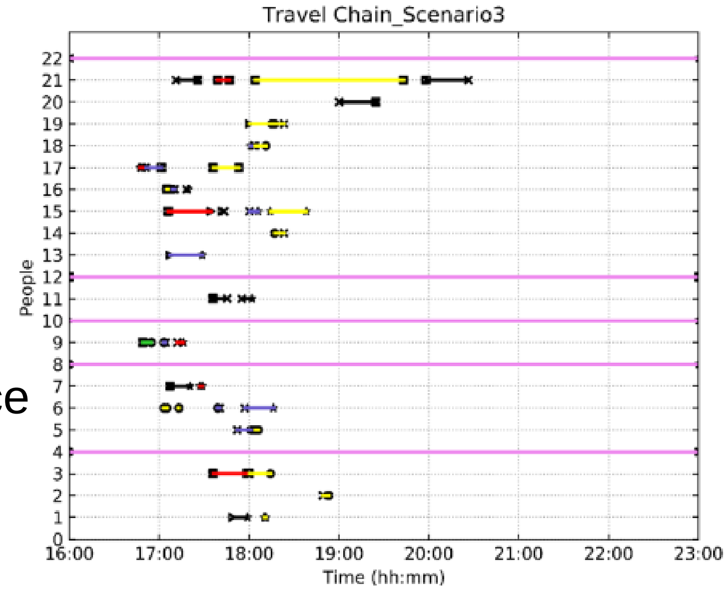
Adjusted activity chain

Original





I never update my plan;
Pessimistic



I know things in advance
“Vision of God”

Lessons learnt

- Large simulation models are complex
- The realistic behavior of people is complex to attain
- Interplay between operations, passengers decisions and (limited) information is crucial, but hard to model

- New developments possible soon

More understanding

A, Marra, Multimodal passive tracking of passengers to analyse public transport use, STRC

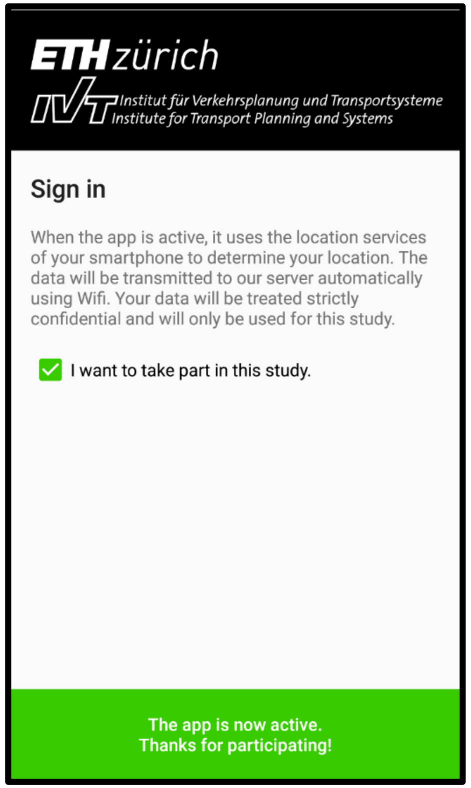
Walt disney

Study mobility in-vivo

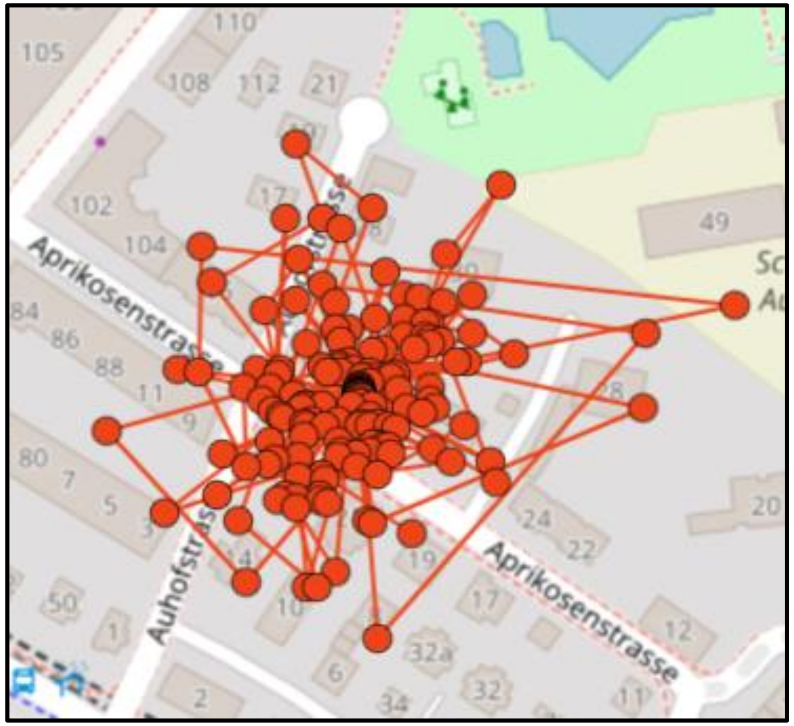
- Typically user interaction-intensive
- Typically battery intensive

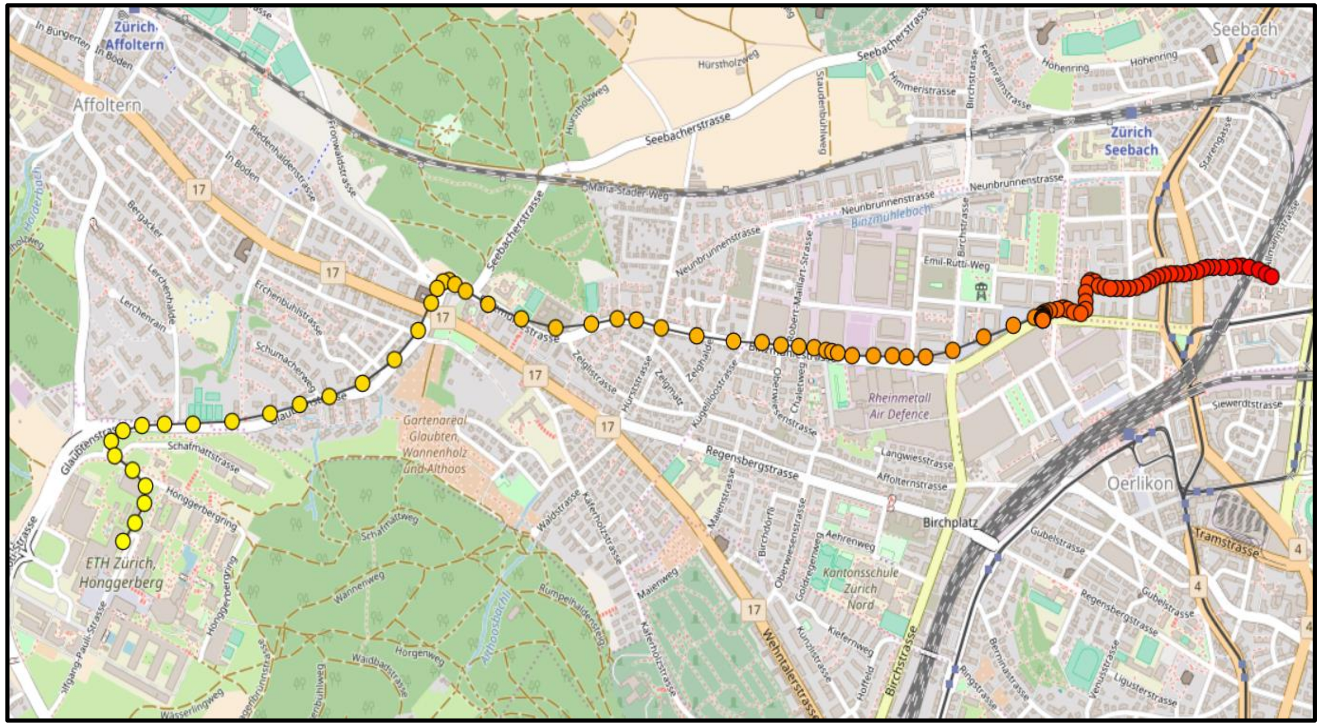
- Own developed

- Tested on ~50 students



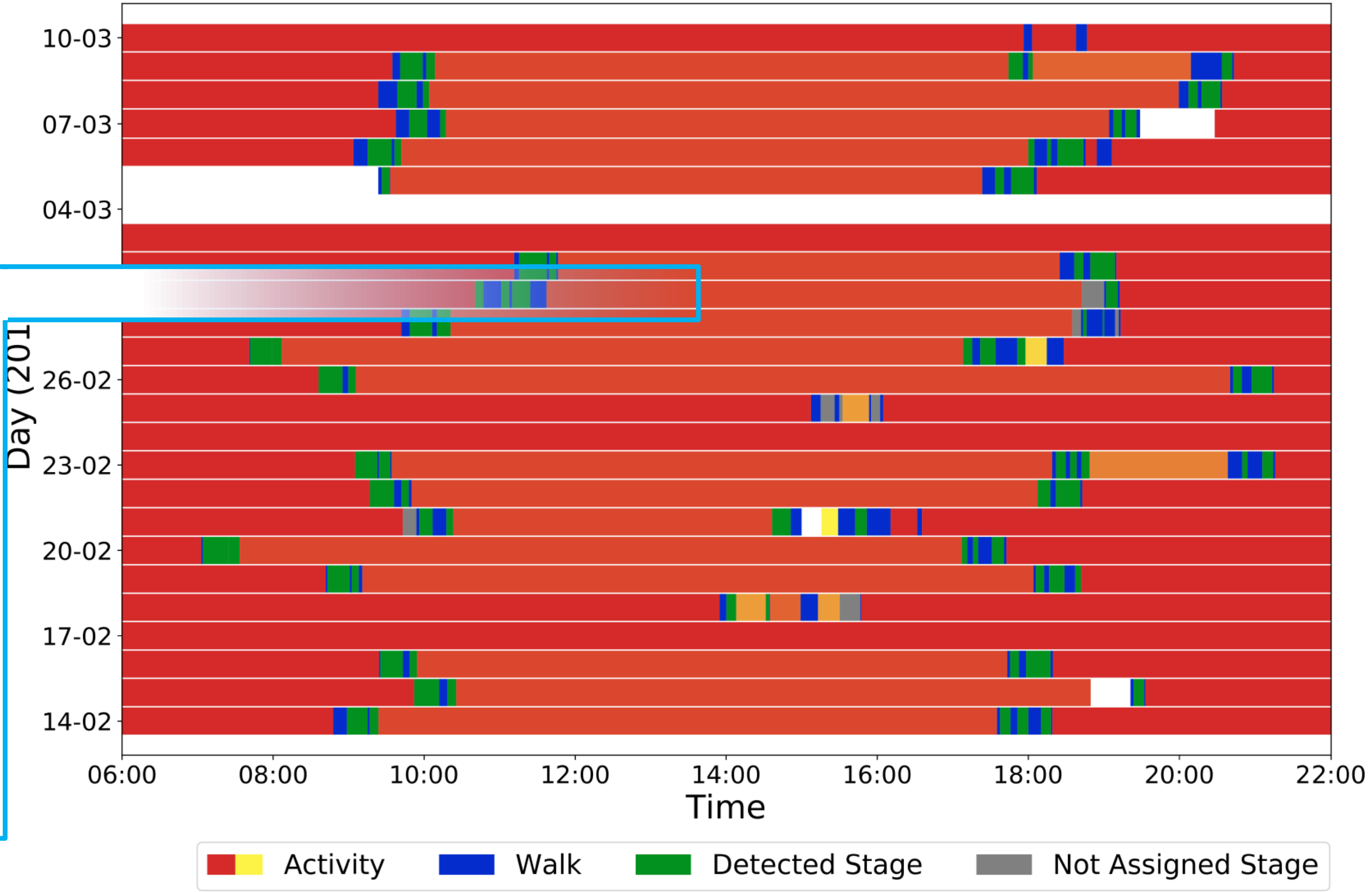
Cleaning of data



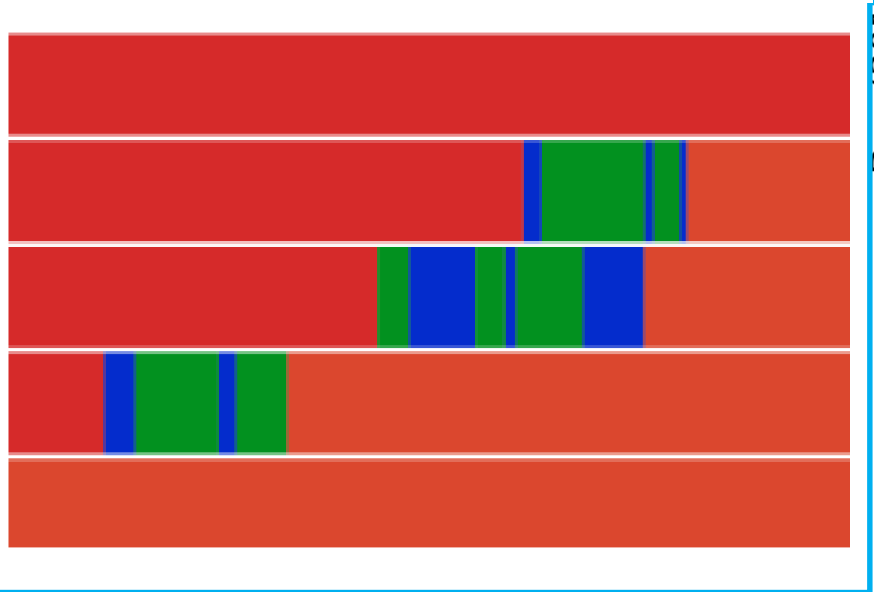


Diary

Fig. 7 Continuous tracking of a single user for one month. Activities in the same place have the same color, that goes from red to yellow according to the time spent in the activity. A white space indicates absence of signal.



This is different!



Lessons learnt

- Disruptions are gray
- Large samples might help; data must be complemented with annotations
- Choice models can be estimated
- Mobility providers might know about us than we know

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