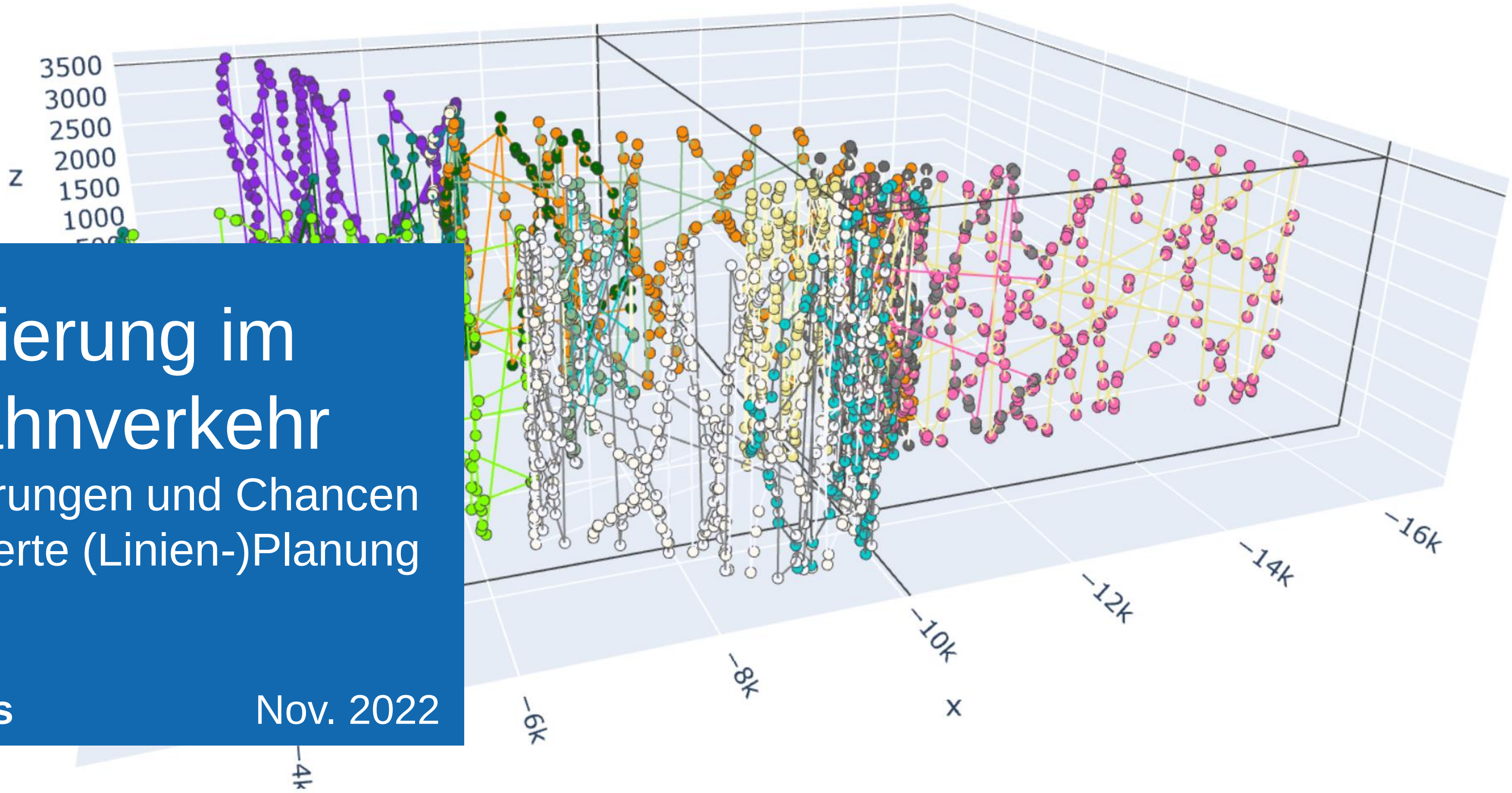
ETH zürich

Institute for Transport
Planning and Systems



Digitalisierung im Eisenbahnverkehr

Herausforderungen und Chancen durch integrierte (Linien-)Planung

Florian Fuchs

Nov. 2022

Agenda

1. Introduction

2. Integrated Planning, what and why?

3. Two recent projects on integrated planning

4. Outlook

5. Discussion

IVT – Transport Systems

Prof. Francesco Corman

Railway traffic control prediction & optimisation



Railway timetable optimisation



Passenger oriented railway traffic optimisation

Passenger route choice modelling


Energy efficient driving, dynamic coupling

Track maintenance scheduling

Introducing myself

What I did before:

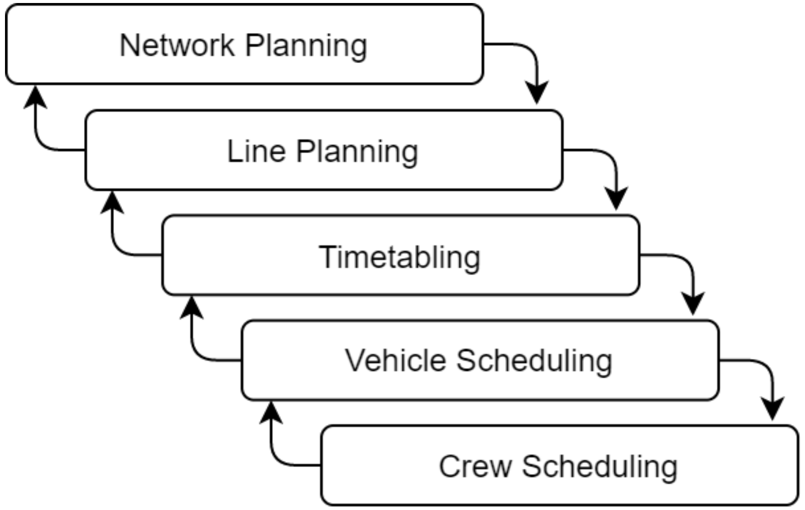
- MSc ETH in Spatial Development and Infrastructure Systems
- HIWI at Institute for Transport Planning and Systems, ETH Zurich
- Working Student at SMA Partner AG, “Software.Labs” department

Feel free to ask questions at any time

What is the link between Digitalization and Railway Planning?

Digitized Railway

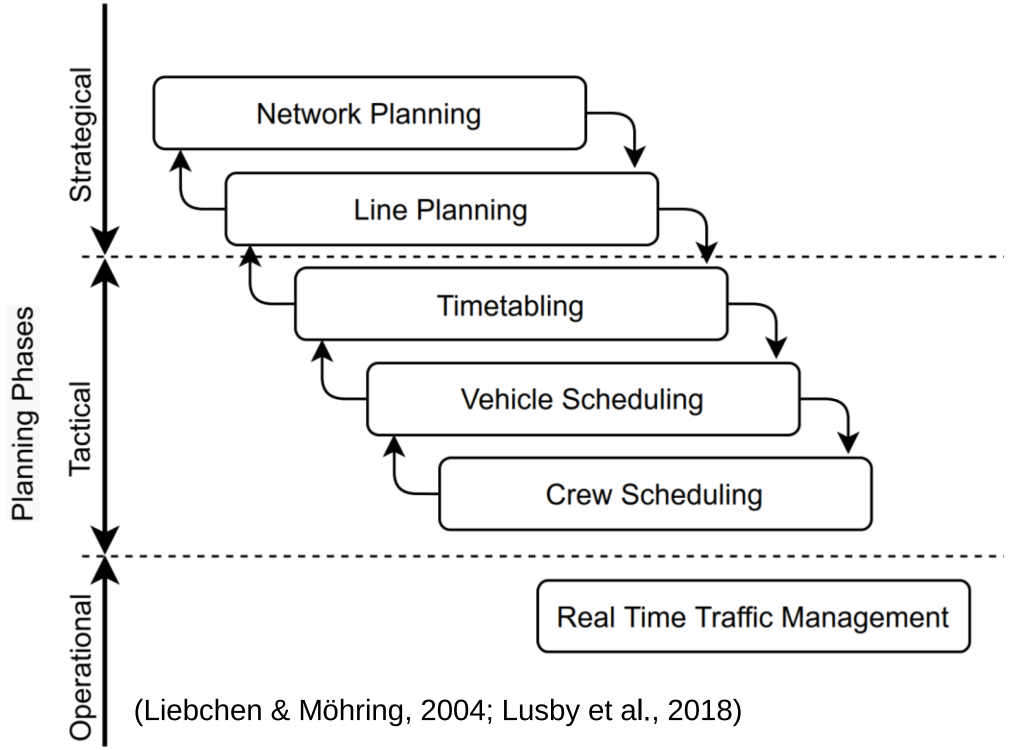
Planning Process



Even a fully digitalised railway needs to be planned

State of Research in Railway Planning: Combining stages is promising

Planning Stages:



(Liebchen & Möhring, 2004; Lusby et al., 2018)

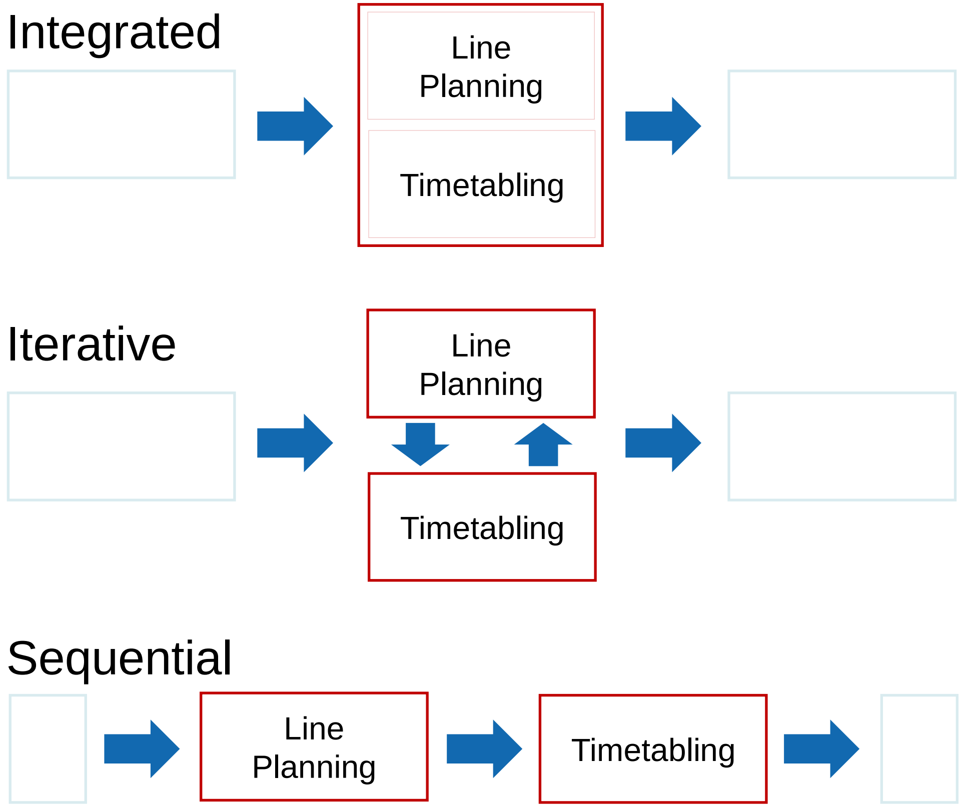
State of Research:

- Individual stages:
  - well understood
  - various models & heuristics
- Combining stages:
  - not fully explored
  - countless combinations

Strategies to combine multiple stages:

Strategy	**Potential Solution Quality**	**Computational Effort**
Integrated	Best (optimal)	High / Intractable
Iterative	Average	Medium
Sequential	Poor	Low

Summarised from Schiewe (2020)



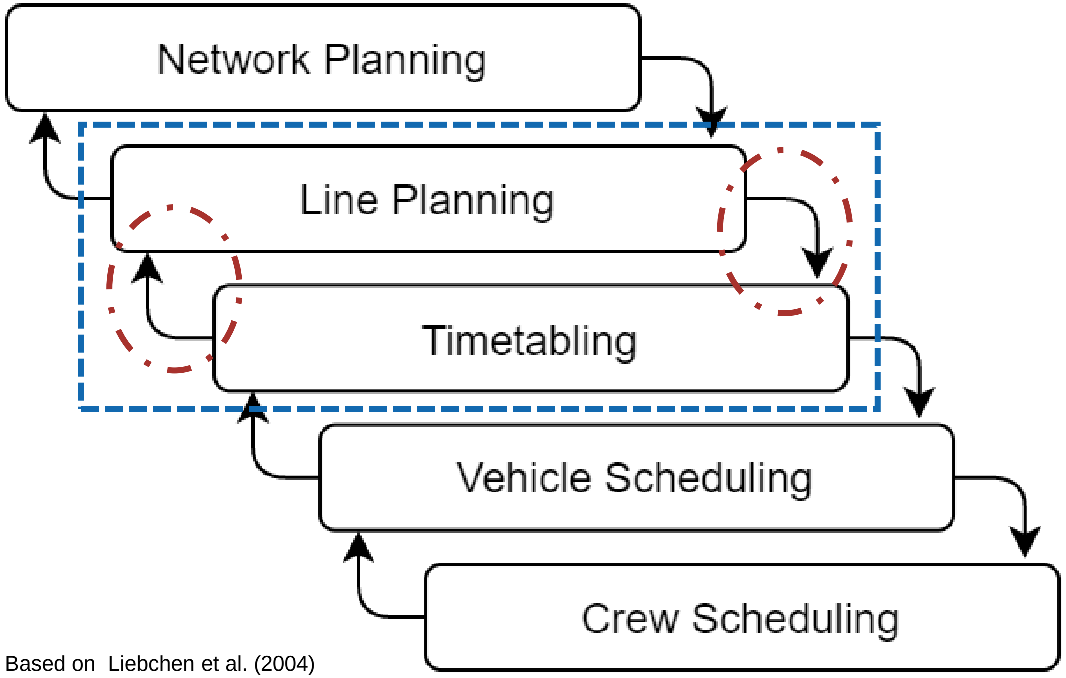
When aiming for an applicable approach, iterative approaches seem most promising

Recent Work PT 1:

Enhancing the Interaction of Line Planning and Timetabling with Infrastructure Awareness

Enhancing the Interaction of Line Planning and Timetabling with Infrastructure Awareness

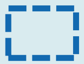
Planning Stages:



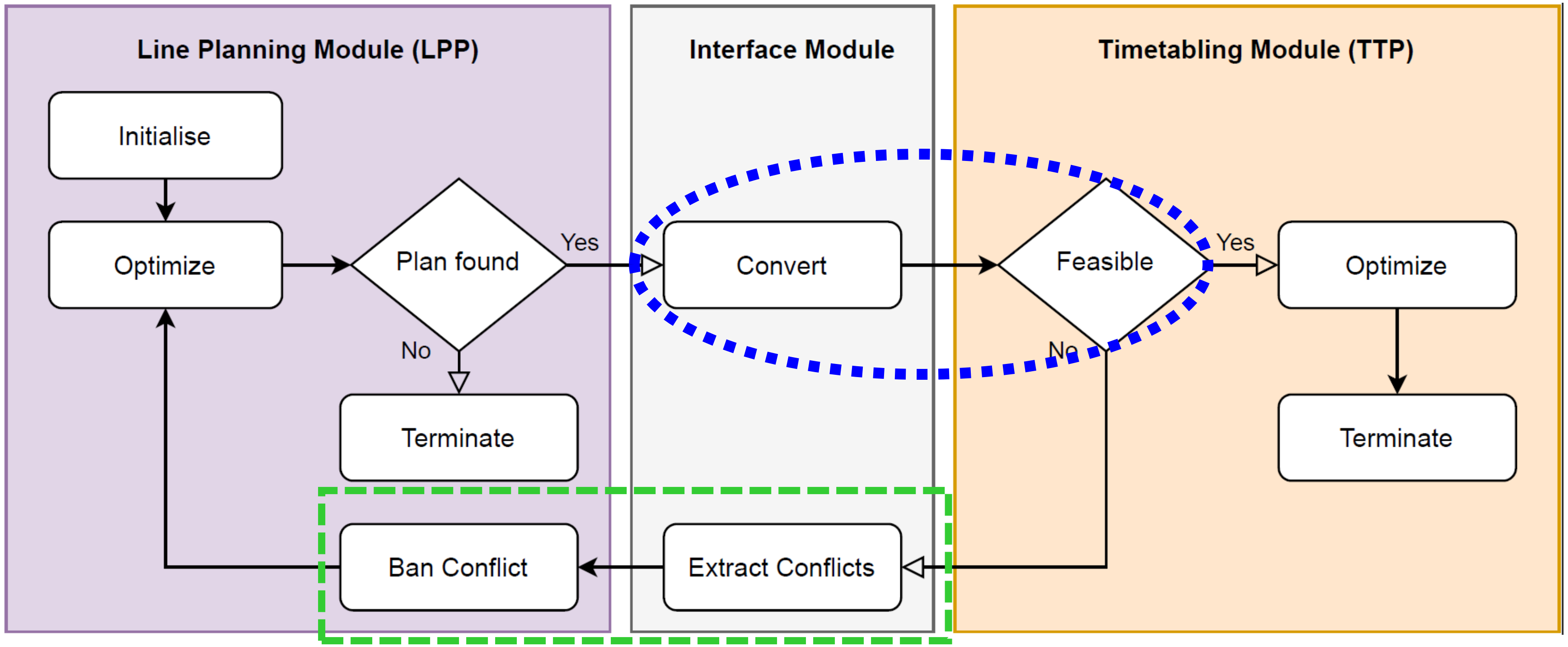
Based on Liebchen et al. (2004)

Motivation

- Quality & efficiency of public transport / railways determined by planning process
- Planning in public transport is usually done in stages (Liebchen et al. 2004)
- Looking at multiple stages jointly yields solutions of higher quality (Schiewe 2020)

The paper jointly considers *periodic* line planning and timetabling for *railways* 
with emphasis o the interaction 

Method:
An overview on the structure



Exploit infrastructure, by assigning tracks while solving

Reduce number of iterations, by locating and banning conflicts precisely

Find a line plan such that:

- Minimize total travel time
- Uses available vehicles
- Is free from identified conflicts

Given a line plan:

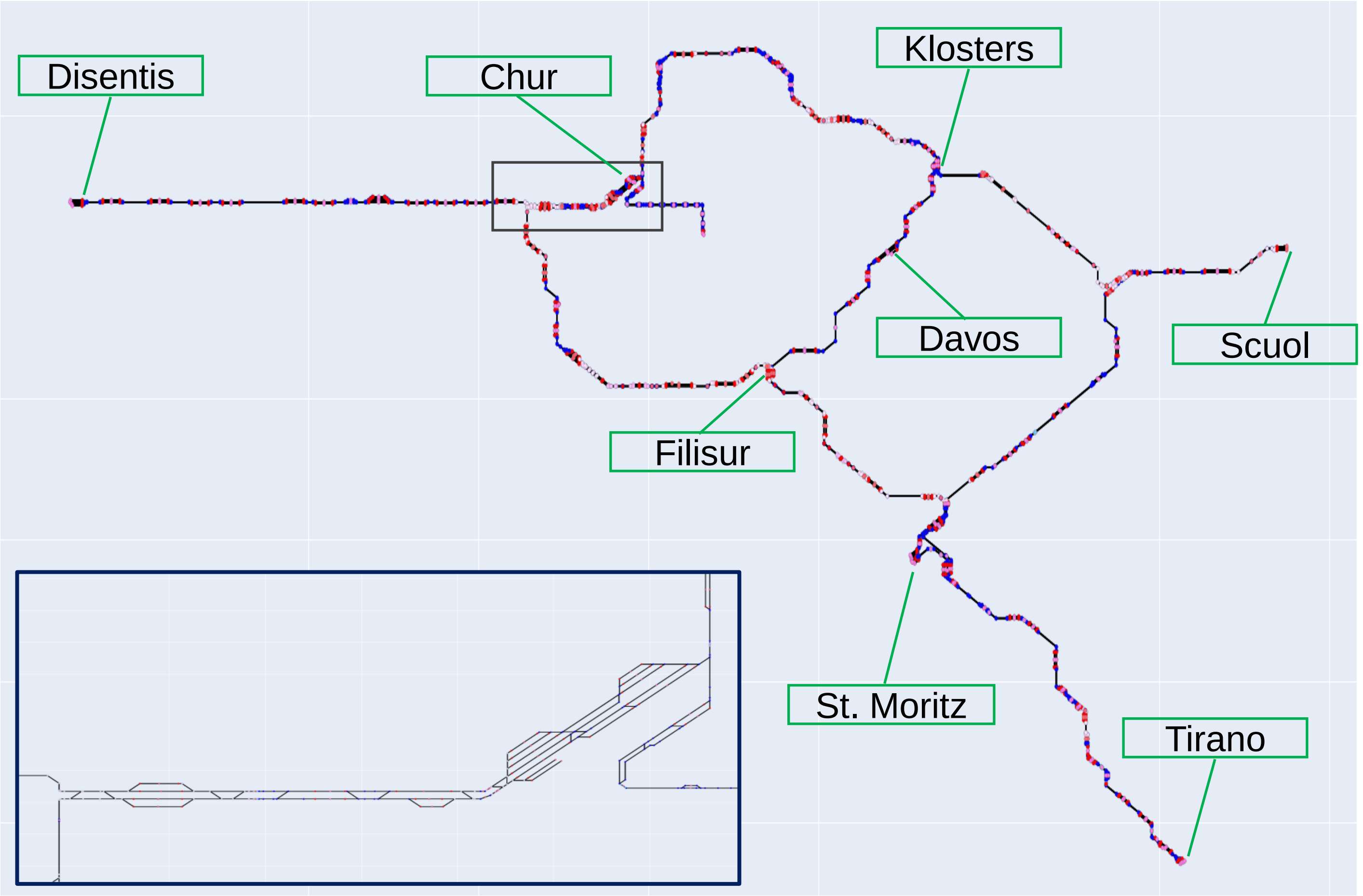
- Find a timetable
- Focus on feasibility
- Extract possible conflicts

Does it work:
Case Study

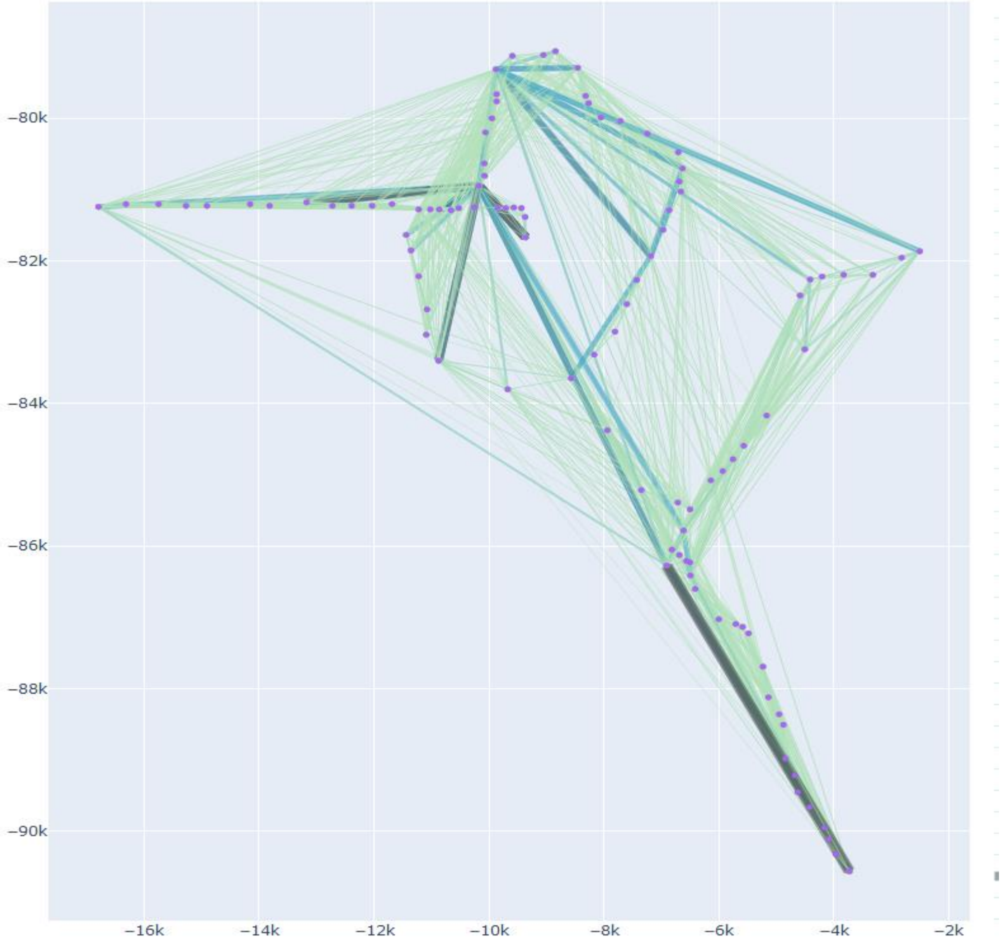
(c) Rhätische Bahn

(c) Rhätische Bahn

Case Study: Infrastructure & Demand



Mesoscopic level, many single-track sections



1763 OD pairs

Results: Integrated Problem

Parameters		$\mathcal{OD}_{\text{small}}$	$\mathcal{OD}_{\text{median}}$	$\mathcal{OD}_{\text{full}}$
none slack & restrict-6-14	iterations	5	17	21
	runtime [s]	111.3	1166.5	1506.8
	objective[h]	140.2	-	-
some slack & restrict-6-14	iterations	4	36	39
	runtime [s]	40.5	14'125.2	17'677.4
	objective[h]	140.2	4117.5	4217.3
max slack & restrict-8-16	iterations	4	7	7
	runtime [s]	40.8	1'170.6	3538.6
	objective[h]	140.2	3691.1	3779.3

Infeasible
(too restrictive)

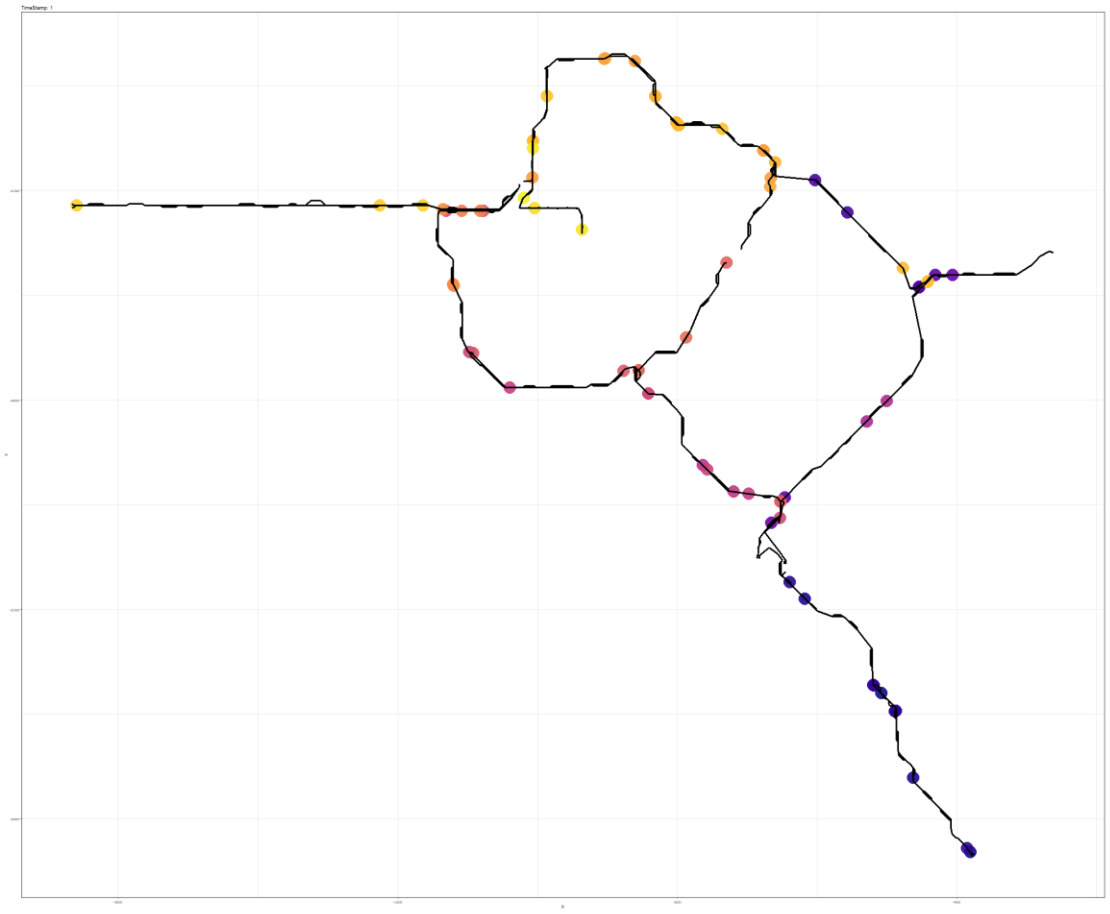
Feasible, solved in
at most 5 hours

Banning conflicts w.r.t. line plans

		$\mathcal{OD}_{\text{small}}$	$\mathcal{OD}_{\text{median}}$	$\mathcal{OD}_{\text{full}}$
Ban $\mathcal{X}_{\text{plan}}$	iterations	6	179	83
max slack & restrict-8-16	runtime [s]	56	36'000	36'000
Ban $\mathcal{X}_{\text{conflict}}$	iterations	4	7	7
max slack & restrict-8-16	runtime [s]	41	1'171	3'539

- Iterations down by **12-25 times**
- Solved in **1h** vs not solved in **10h**

The results animated:

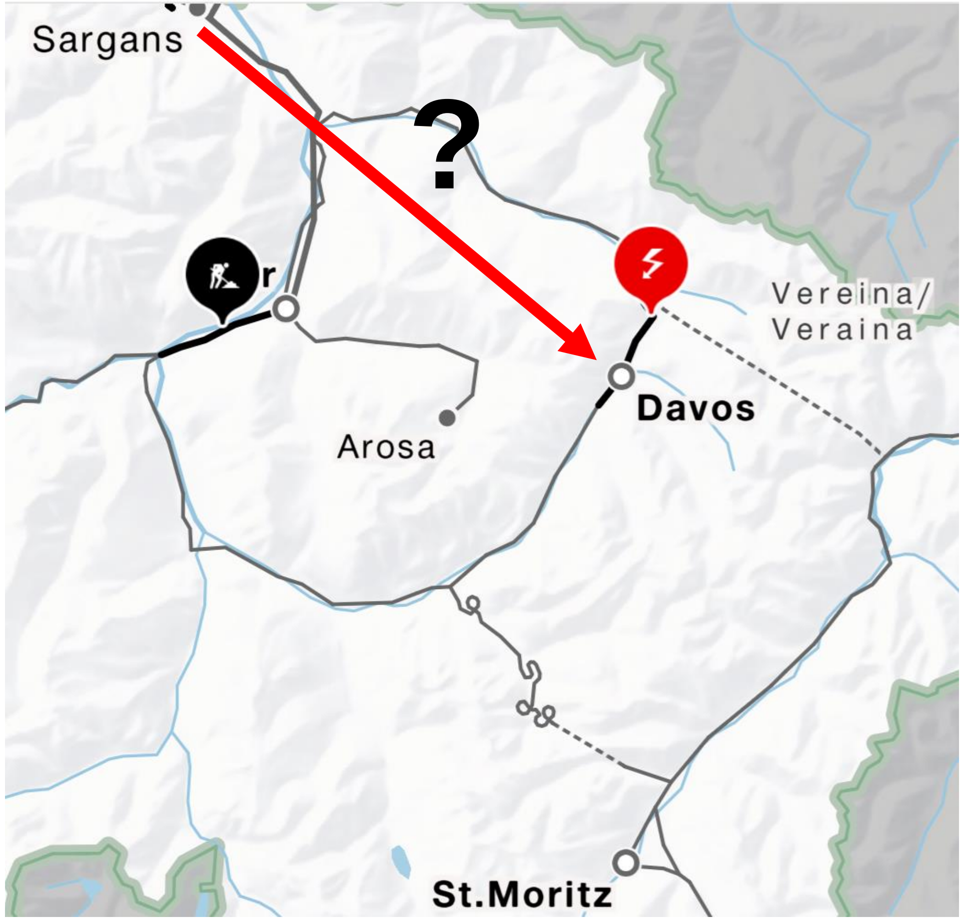


Recent Work PT 2:

Integration of Disruptions in Railway Planning

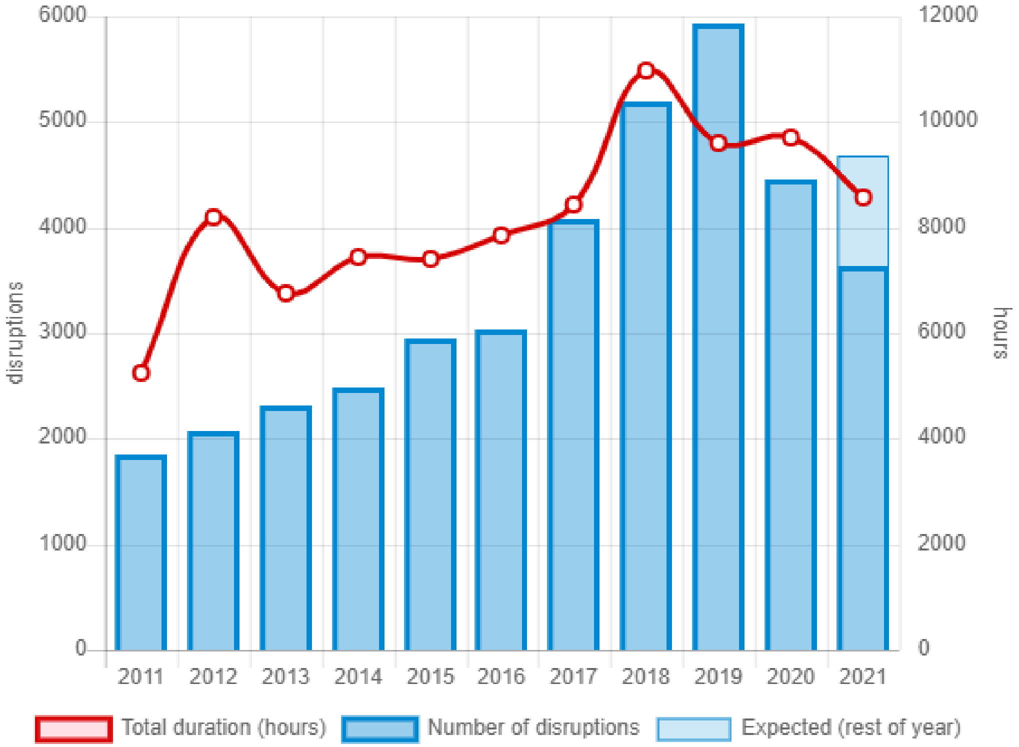
Introduction and Motivation

What is the Problem with Disruptions?



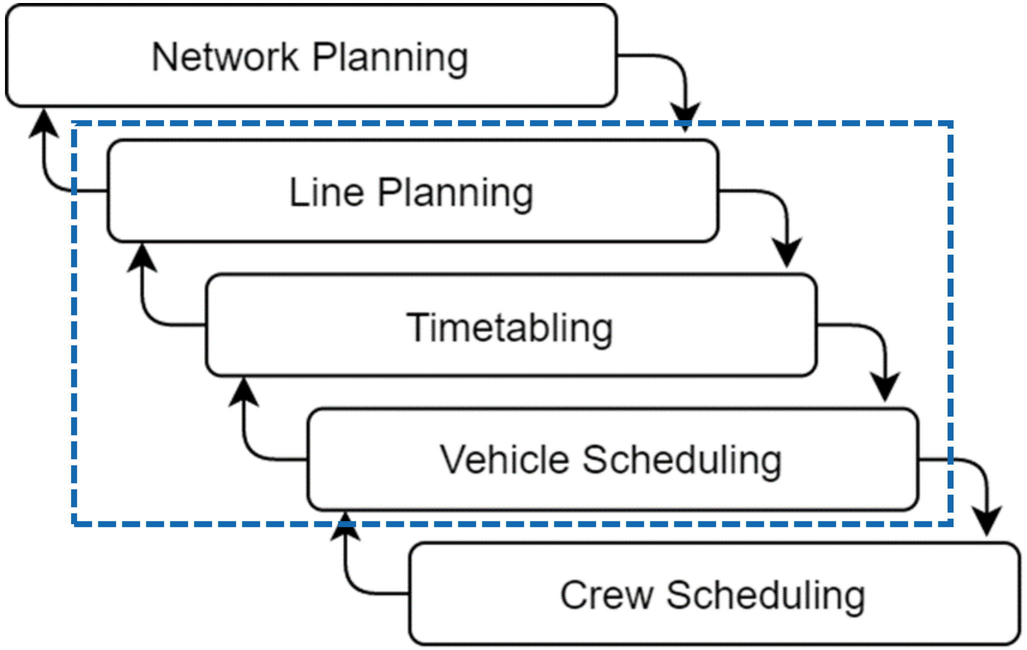
More than a Swiss Issue

Dutch statistics on disruptions
(Rijden de Treinen, 2022)



Creating resilient timetables with integrated planning

Railway Planning Process:



Core Idea:

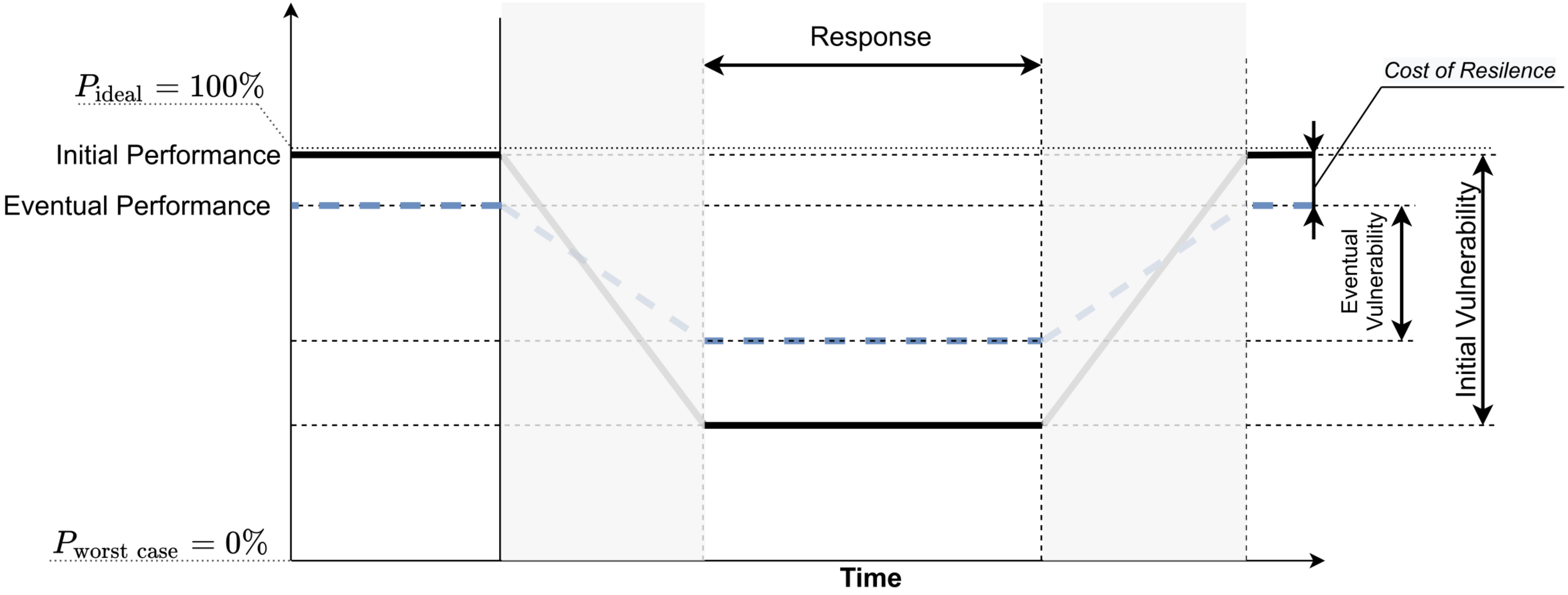
Consider disruptions already when creating a timetable – to be prepared when they occur.

Create a timetable that considers

- Passenger routes
- Vehicle pool
- Infrastructure

and which is **resilient**

How can we characterise resilience:



Train Slot Sequences as a means to reduce complexity:

The Key Issue:

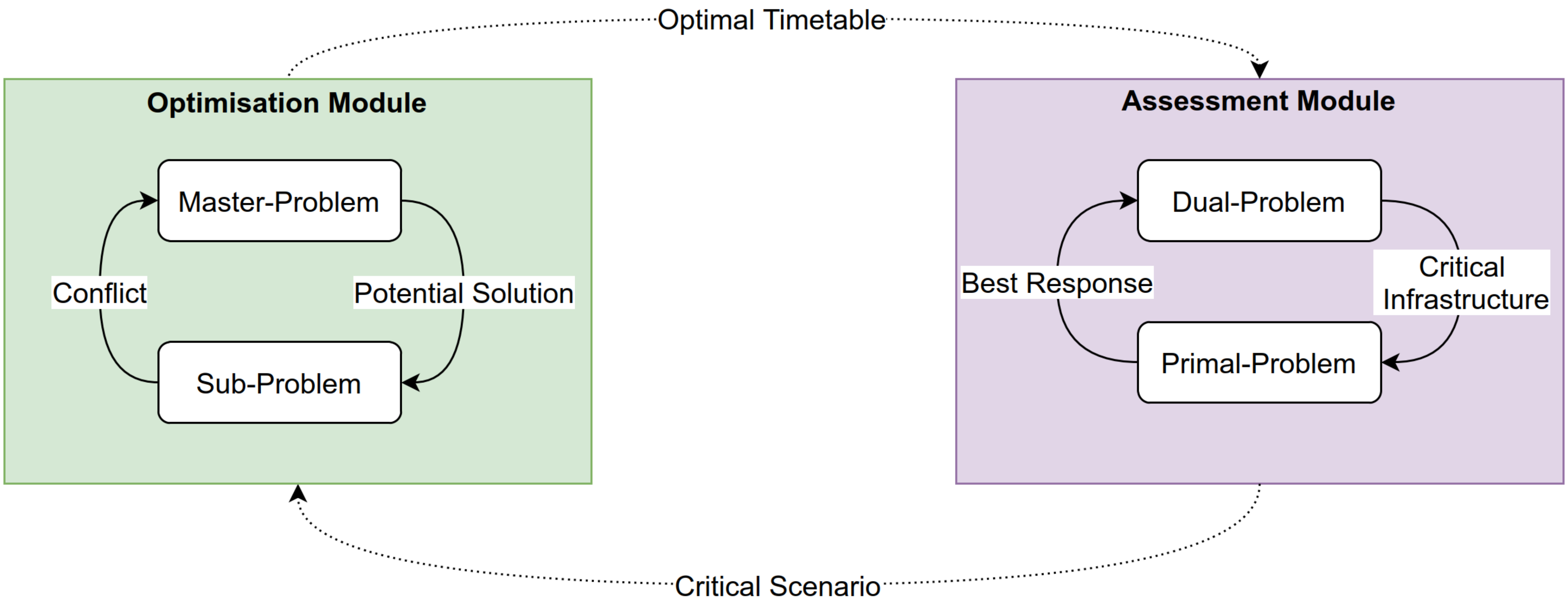
- Aim for a holistic assessment
- This requires:
  - passenger routing
  - vehicle circulation
  - track assignment

  while timetabling

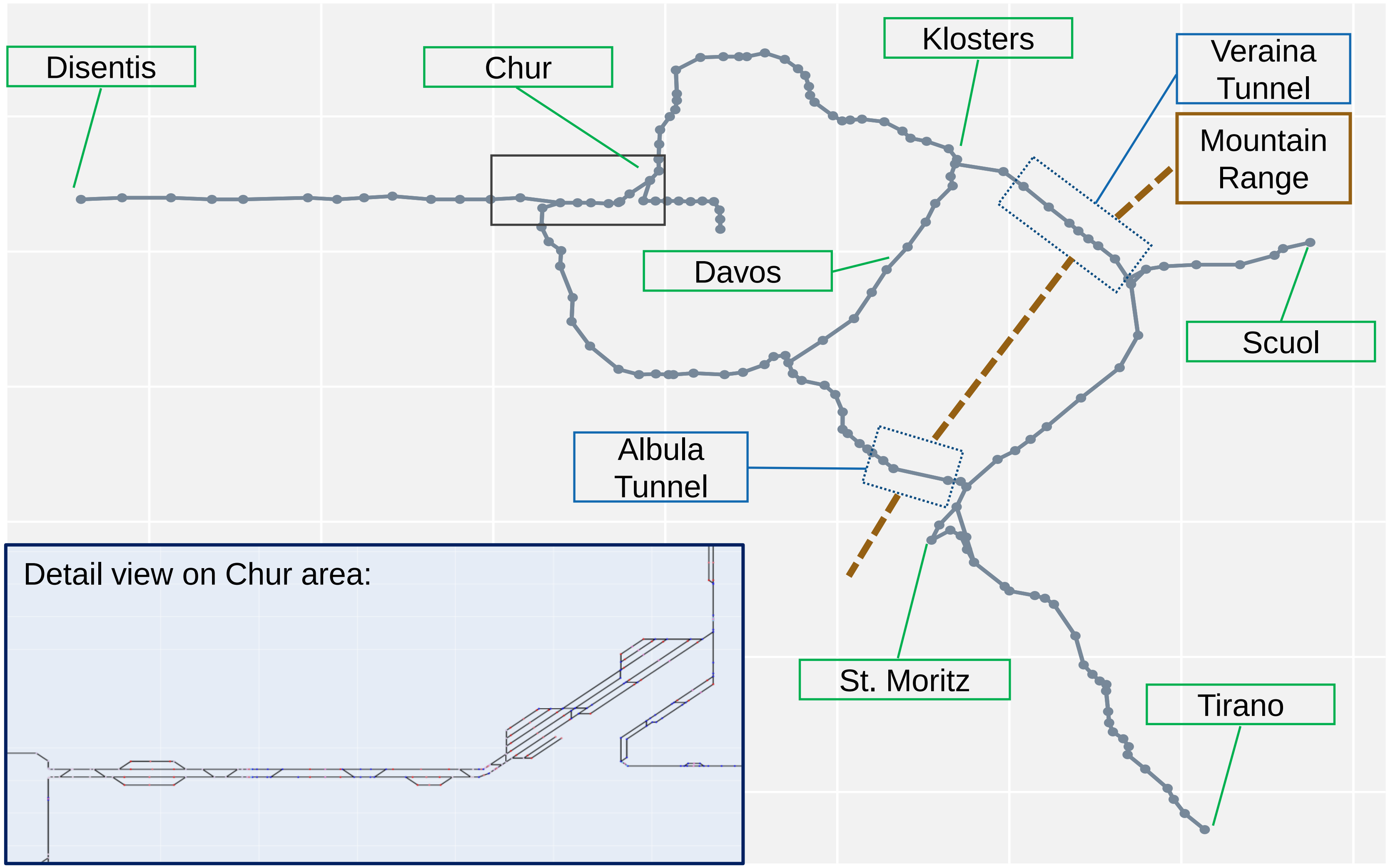
Already challenging when only a subset of tasks is considered (Schiewe, 2020)

How to Break down Complexity:

Optimising and assessing timetables in one loop:



Case Study Network:



Characteristics:

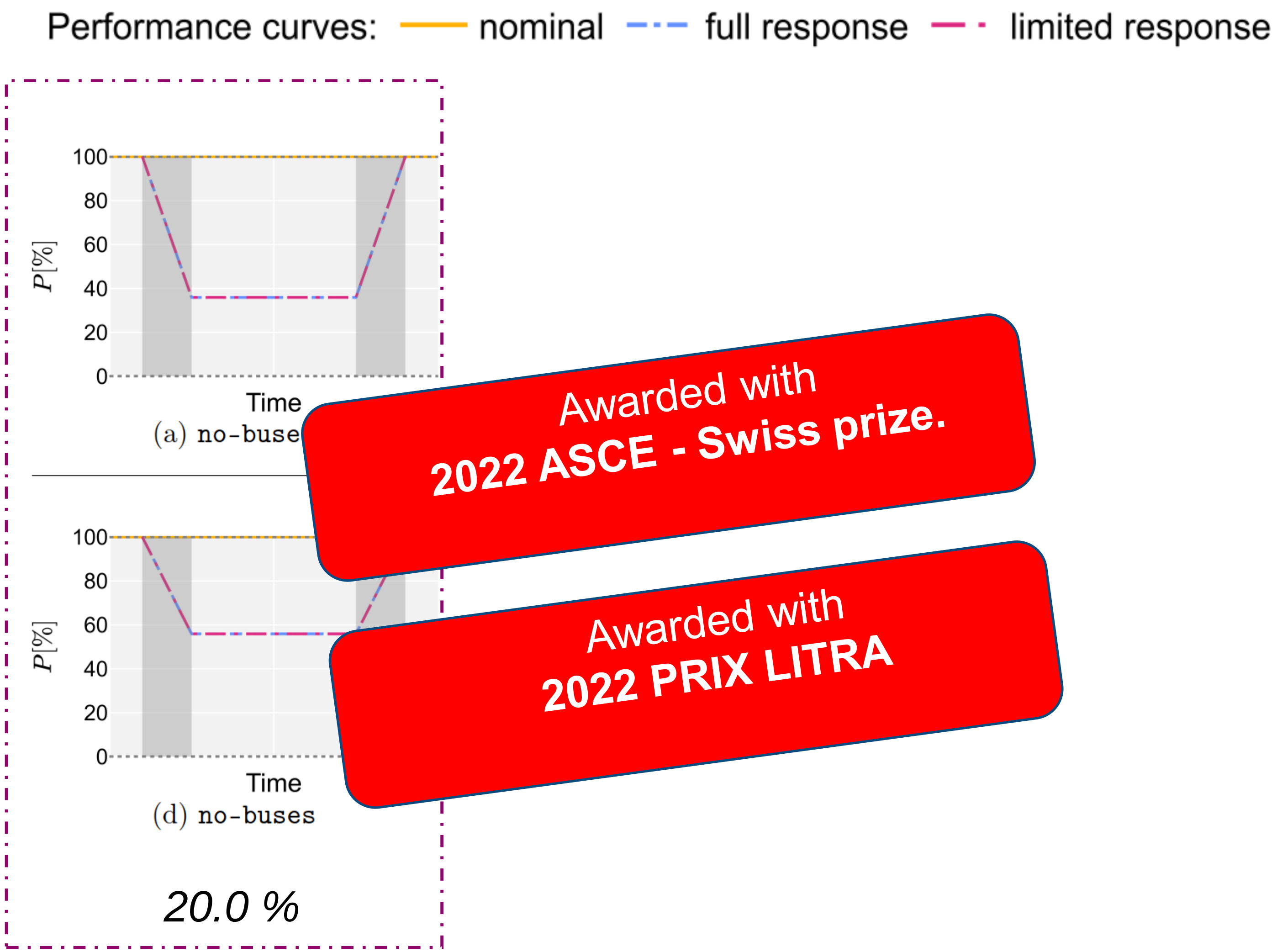
- 384 km tracks
- 102 stations
- Mostly single track
- Passengers & cargo
- Car shuttle service

Challenging for timetabling
(Fuchs et al., 2022)

Some Results for one iteration:
Can we improve Resilience?

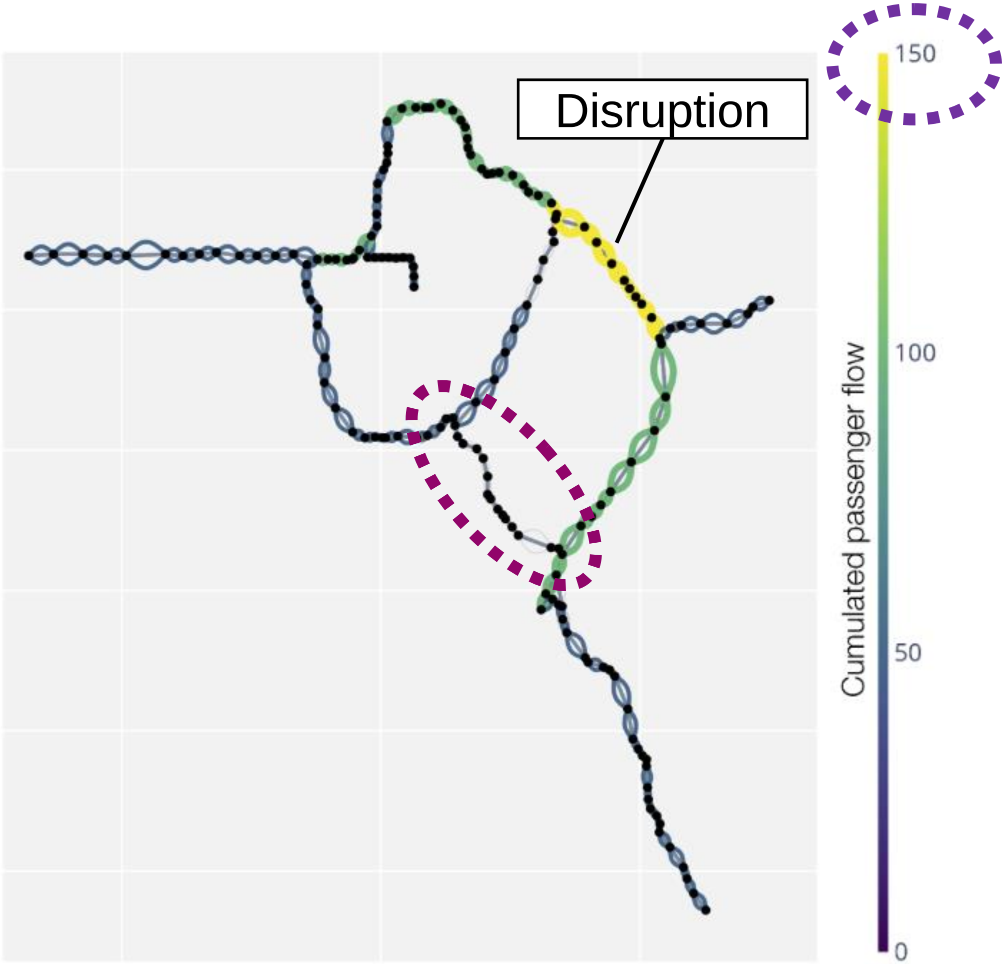
Setup:

- 1 artificial demand scenario
- All passenger trains
- 0 / 5 / 10 buses as response
- Compare *before* & *after*

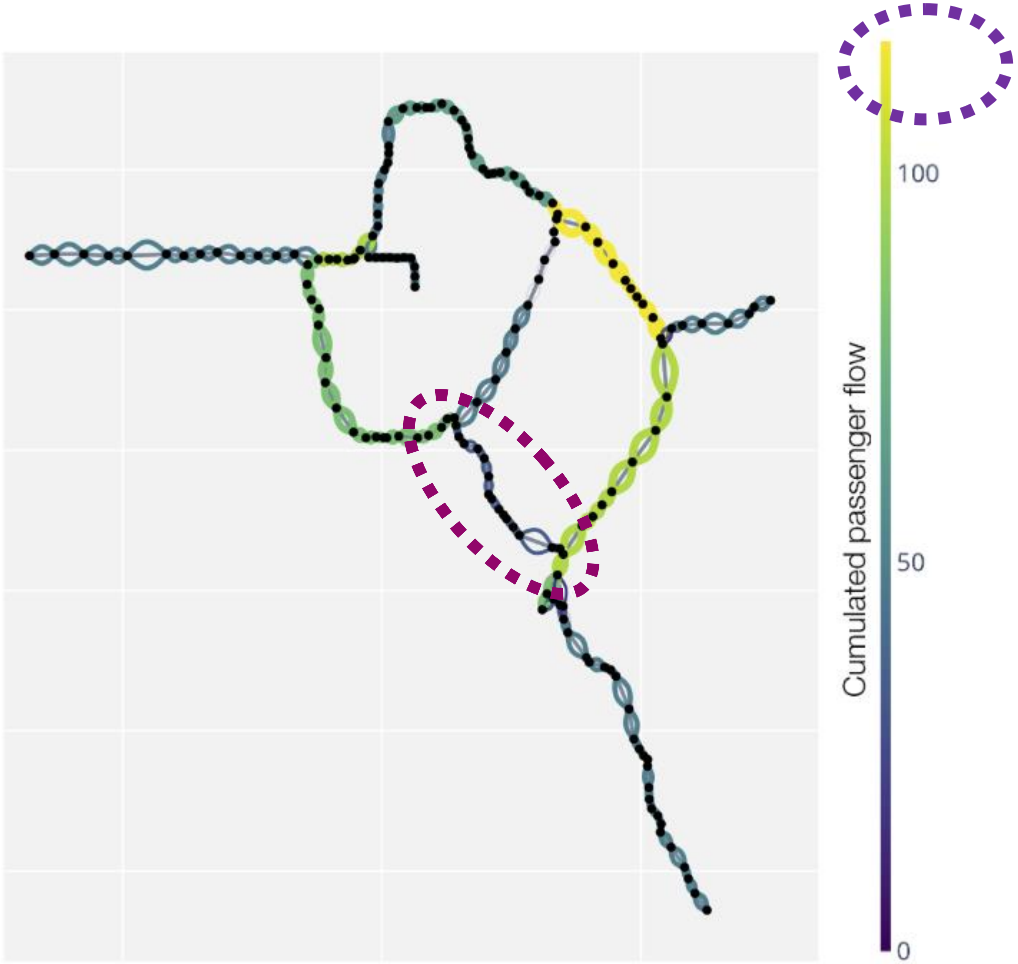


D: *20.0 %*

Some insights:



(a) *before adaptation*

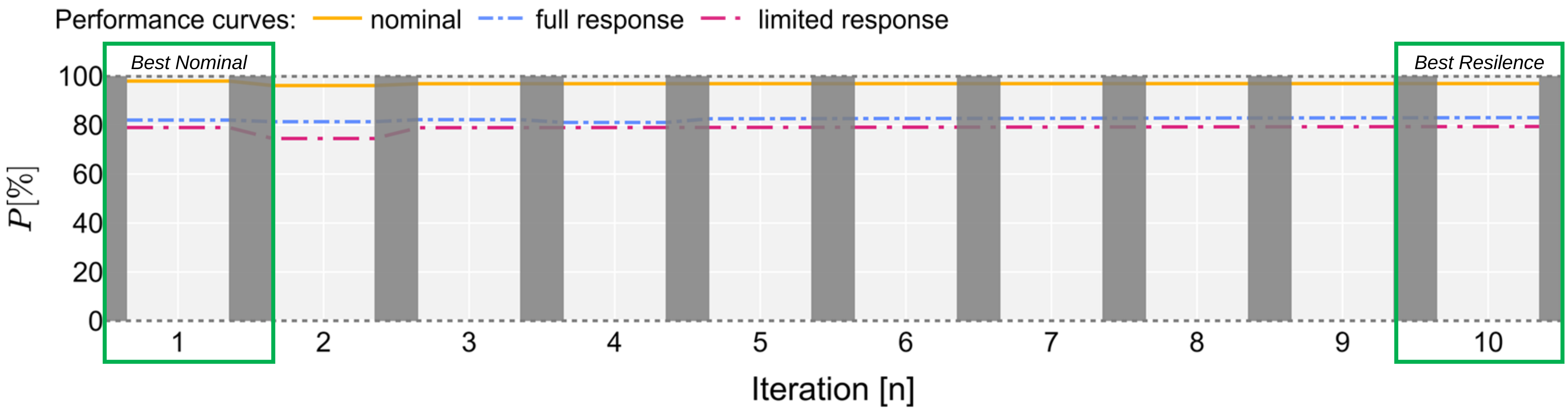


(b) *after adaptation*

10 iterations, what happens during the iterations?

Setup:

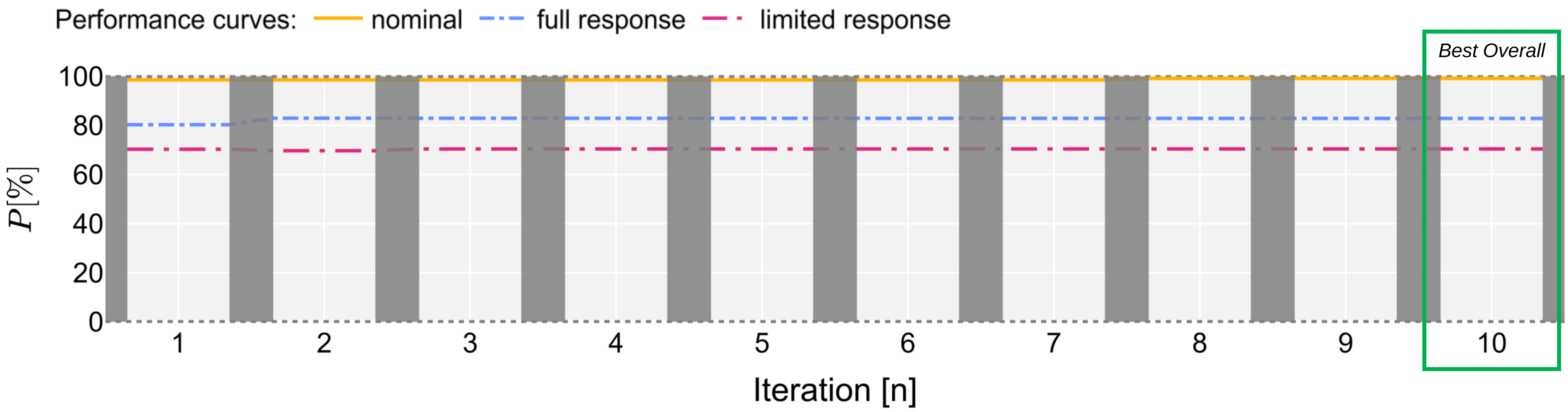
- Subset of a real demand data-set (173 OD-pairs)
- 24 Passenger trains / 10 Iterations
- 5 Buses



10 iterations, what happens during the iterations?

Setup:

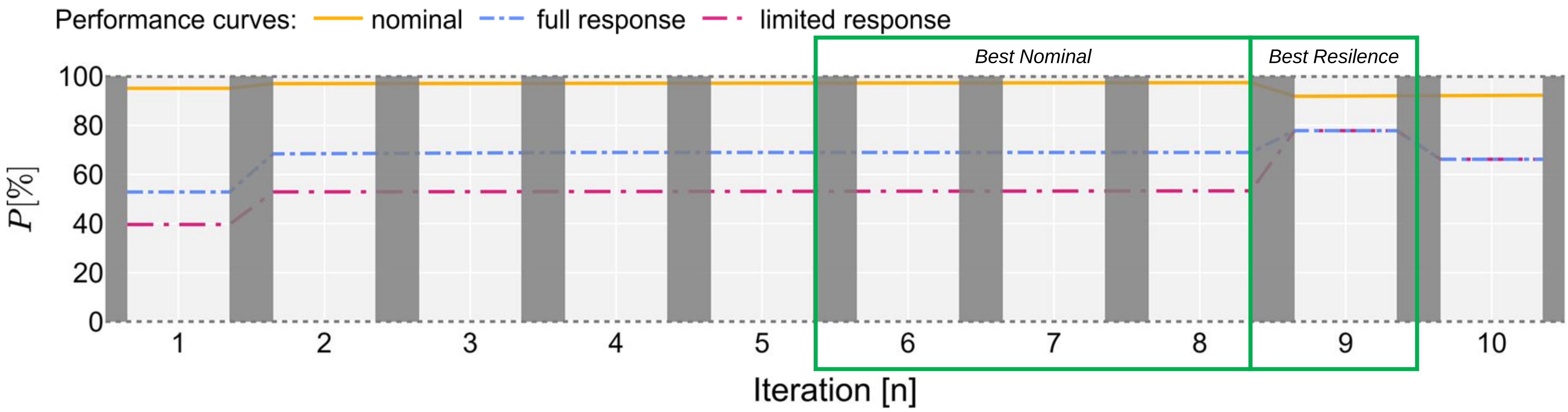
- Real demand data-set (1747 od-Pairs)
- 24 Passenger trains / 10 Iterations
- 5 Buses



10 iterations, what happens during the iterations?

Setup:

- Artificial demand data-set (8 od-pairs)
- 24 Passenger trains / 10 Iterations
- 5 Buses



Summary and Outlook:

Future Chances,

1. Integrated planning
   – Large potential
   – Need for collaboration/toolboxes

2. Enhanced accuracy:
   – ATO etc., reduce variance
   – Allows increasing the efficiency

Future Challenges

1. Passenger focus:
   – Understanding passenger choices is vital
   – “We can optimise the system,
     but not the passengers

2. Increasing complexity:
   – Complete integration leads to sophisticated systems

Florian Fuchs
florian.fuchs@ivt.baug.ethz.ch
ETH - Transport Systems
Institut für Verkehrsplanung und Transportsysteme IVT HIL F 13.3
Stefano-Franscini-Platz 5
8093 Zurich, Switzerland

References

Borndörfer, Ralf, Niels Lindner, and Sarah Roth. 2020. “A Concurrent Approach to the Periodic Event Scheduling Problem.” *Journal of Rail Transport Planning and Management* 15:140–59.

Burggraeve, Sofie, Simon Henry Bull, Pieter Vansteenwegen, and Richard Martin Lusby. 2017. “Integrating Robust Timetabling in Line Plan Optimization for Railway Systems.” *Transportation Research Part C: Emerging Technologies* 77:134–60.

Fuchs, Florian and Francesco Corman 2019 An open toolbox for integrated optimization of public transport, paper presented at the *2019 6th International Conference on Models and Technologies for Intelligent Transportation Systems (MT-ITS)*, 1–7

Liebchen, Christian and Rolf H. Möhring 2004 The Modeling Power of the Periodic Event Scheduling Problem: Railway Timetables - and Beyond, *Computer-aided Systems in Public Transport*, 117–150, Springer Berlin Heidelberg, Berlin, Heidelberg

Pätzold, Julius, Alexander Schiewe, Philine Schiewe, and Anita Schöbel. 2017. “Look-Ahead Approaches for Integrated Planning in Public Transportation.” *OpenAccess Series in Informatics* 59(17):1–16.

Rhätische Bahn RhB. 2020. Streckennetz, https://www.rhb.ch/de/service-souvenirs/streckennetz. retrieved on 11.10.2020

Schiewe, Philine. 2020. *Integrated Optimization in Public Transport Planning*. Vol. 160.

Yan, Fei and Rob M. P. Goverde. 2019. “Combined Line Planning and Train Timetabling for Strongly Heterogeneous Railway Lines with Direct Connections.” *Transportation Research Part B: Methodological* 127:20–46.

References

Borndörfer, Ralf, Niels Lindner, and Sarah Roth. 2020. “A Concurrent Approach to the Periodic Event Scheduling Problem.” *Journal of Rail Transport Planning and Management* 15:140–59.

Burggraeve, Sofie, Simon Henry Bull, Pieter Vansteenwegen, and Richard Martin Lusby. 2017. “Integrating Robust Timetabling in Line Plan Optimization for Railway Systems.” *Transportation Research Part C: Emerging Technologies* 77:134–60.

Herrigel, Sabrina, Marco Laumanns, Jacint Szabo, and Ulrich Weidmann. 2018. “Periodic Railway Timetabling with Sequential Decomposition in the PESP Model.” *Journal of Rail Transport Planning and Management* 8(3–4):167–83.

Großmann, Peter. 2016. “Satisfiability and Optimization in Periodic Traffic Flow Problems.”

Kümmling, Michael, Peter Großmann, Karl Nachtigall, Jens Opitz, and Reyk Weiß. 2015. “A State-of-the-Art Realization of Cyclic Railway Timetable Computation.” Public Transport 7(3):281–93.

Liebchen, Christian, H. M. Rolf, David Hutchison, and John C. Mitchell. 2007. *Algorithmic Methods for Railway Optimization*. Vol. 4359. edited by F. Geraets, L. Kroon, A. Schoebel, D. Wagner, and C. D. Zaroliagis. Berlin, Heidelberg: Springer Berlin Heidelberg.

Rhätische Bahn RhB. 2020. Streckennetz, https://www.rhb.ch/de/service-souvenirs/streckennetz. retrieved on 11.10.2020

Schiewe, Philine. 2020. *Integrated Optimization in Public Transport Planning*. Vol. 160.

Wüst, Raimond, Stephan Bütikofer, Severin Ess, Claudio Gomez, Albert Steiner, Marco Laumanns, and Jacint Szabo. 2019. “Periodic Timetabling with ‘Track Choice’-PESP Based on Given Line Concepts and Mesoscopic Infrastructure.” 571–78.

Yan, Fei and Rob M. P. Goverde. 2019. “Combined Line Planning and Train Timetabling for Strongly Heterogeneous Railway Lines with Direct Connections.” *Transportation Research Part B: Methodological* 127:20–46.