Railway Disruption Management with Viriato and Algorithm Platform

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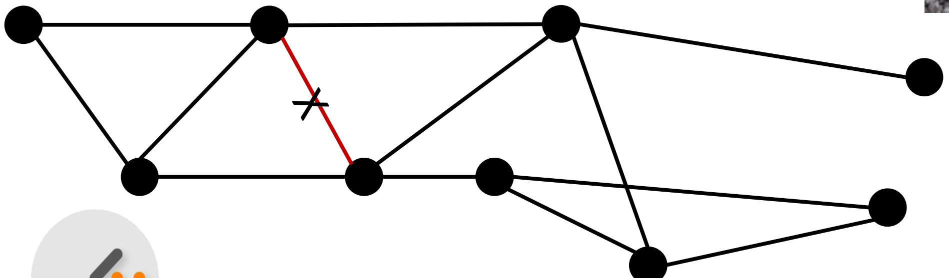
Outline

1. Introduction
2. State of the art
3. Data preparation
4. Algorithm implementation
5. Conclusions and future work

Introduction

- Disrupted train network
  - rearrange timetable
  - reroute trains
  - respect capacity
  - keep cost moderate
  - satisfy passenger comfort
  - flexible route choice



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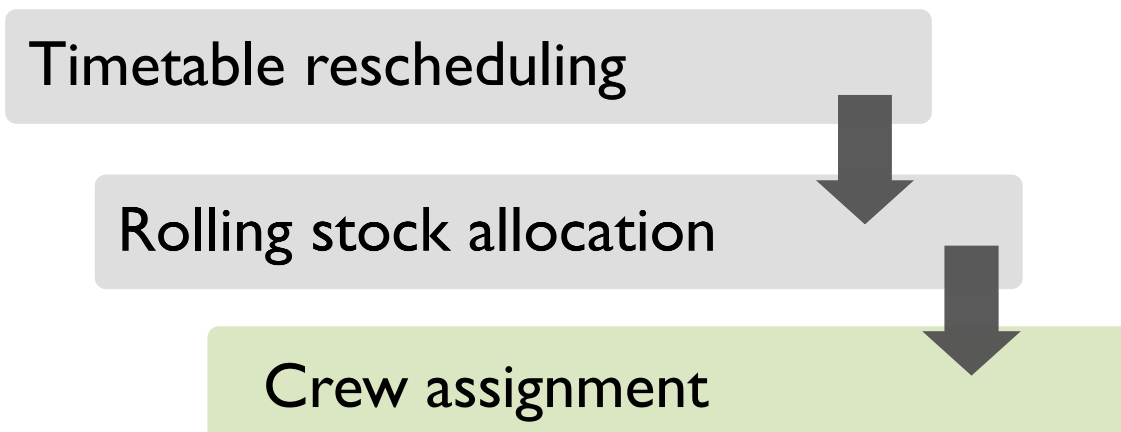
Recovery problem

- Recovery problem in 3 phases (Binder et al. (2017b), Veelenturf et al. (2015), Cacchiani et al. (2014)) :

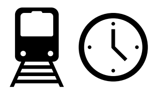


Timetable rescheduling problem

- Overview and Classification (Cacchiani et al., 2014)

  - **Perturbation**

    Disturbance

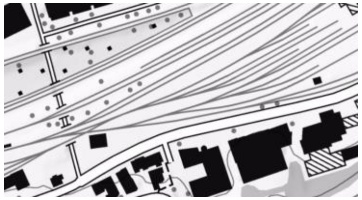
     + 3 min

    Disruption

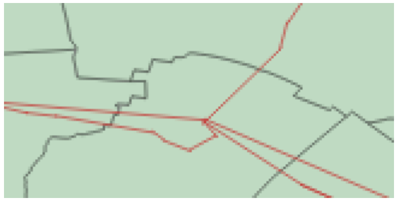
    

  - **Network**

    Microscopic

    Macroscopic

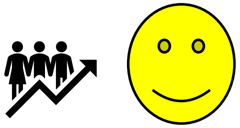
    

  - **Approach**

    Operation centric

    $ 

    Passenger centric

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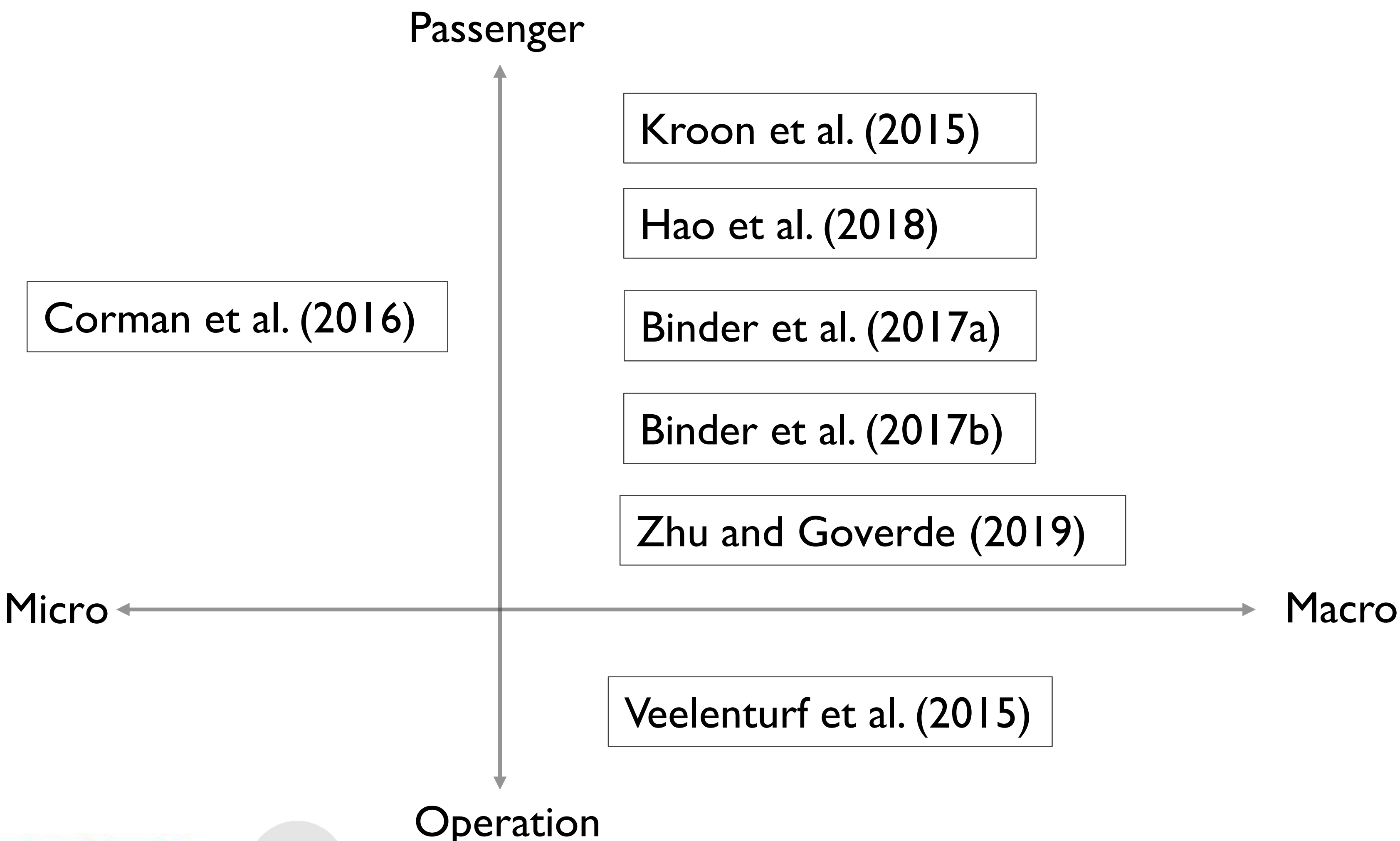
Timetable rescheduling problem



Modelling approaches

Network Graph

- Space - time: Kroon et al. (2015), Binder et al. (2017a,b), Hao et al. (2018)
- Event - activity: Zhu and Goverde (2019), Veelenturf et al. (2015)

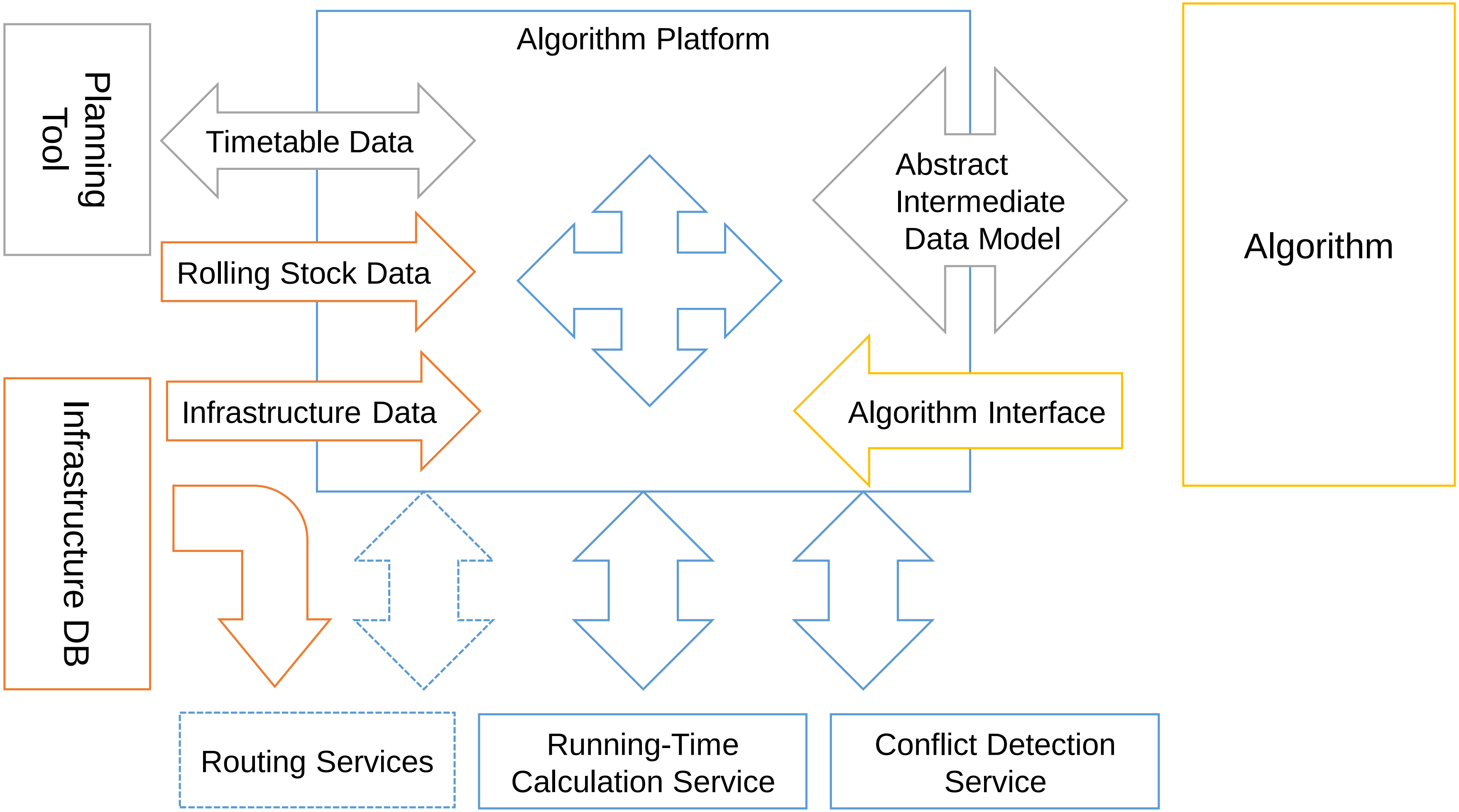
Passenger Groups

- Dividable: Kroon et al. (2015), Hao et al. (2018)
- Not dividable: Corman et al. (2016), Binder et al. (2017a, b), Zhu and Goverde (2019)

Recovery decisions

	Kroon et al. (2015)	Corman et al. (2016)	Veelenturf et al. (2015)	Hao et al. (2018)	Binder et al. (2017a, b)	Zhu and Goverde (2019)
Modify Rolling Stock	X					
Delay		X	X	X	X	X
Order		X	X	X	X	X
Reroute			X	X	X	X
Cancel			X		X	X
Emergency Trains					X	
Additional stops				X	X	X
Skip stops / short turns						X

Viriato and Algorithm Platform



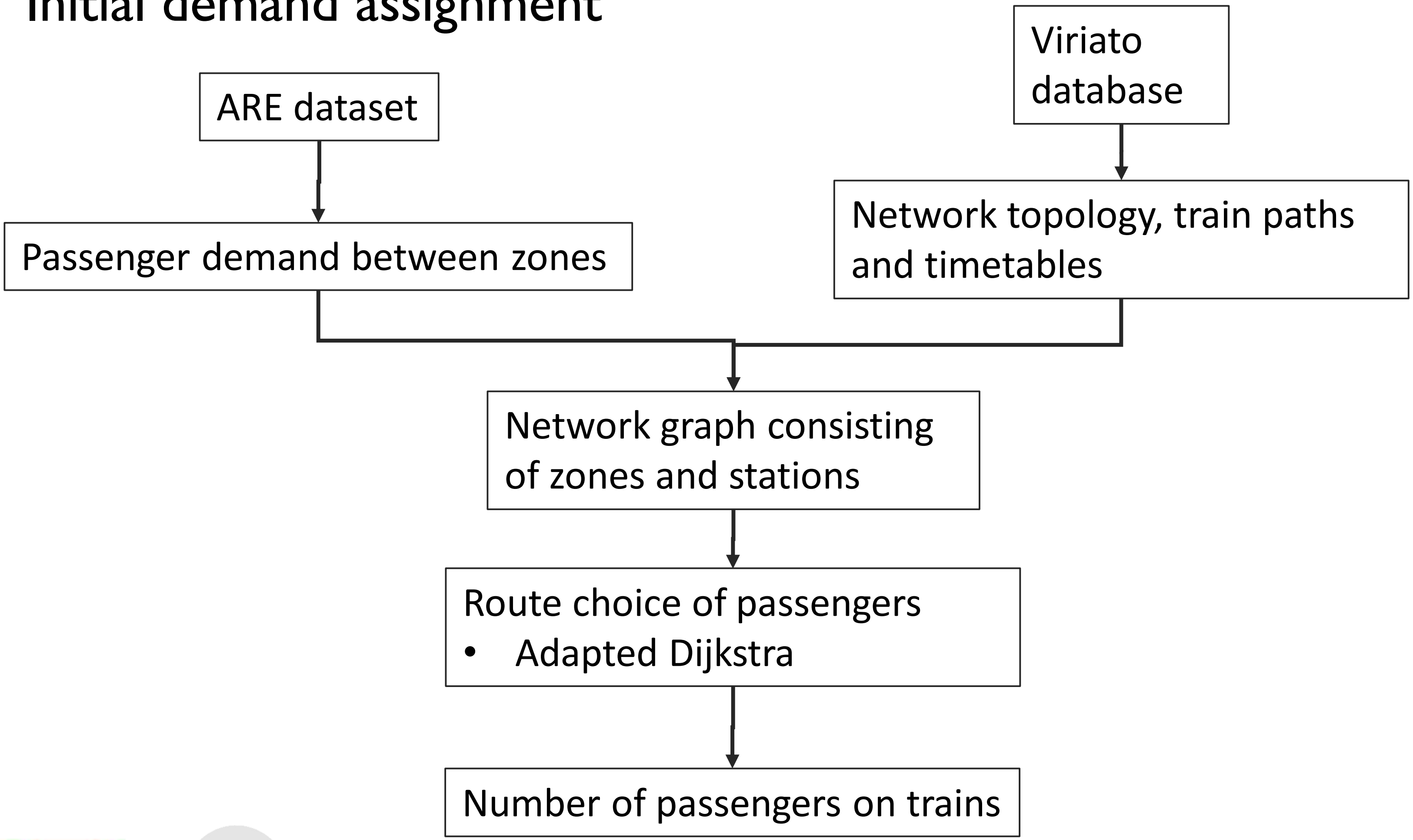
* Figure by SMA und Partner AG

Datasets

- Passenger trips - ARE (2010)
  - CH split into zones
  - Demand of trips between zones
  - Travel time and distance
- Viriato - SMA und Partner AG
  - Part of SBB railway network (stations, junctions, tracks, capacity)
  - Train schedule and paths

Data preparation

- Initial demand assignment



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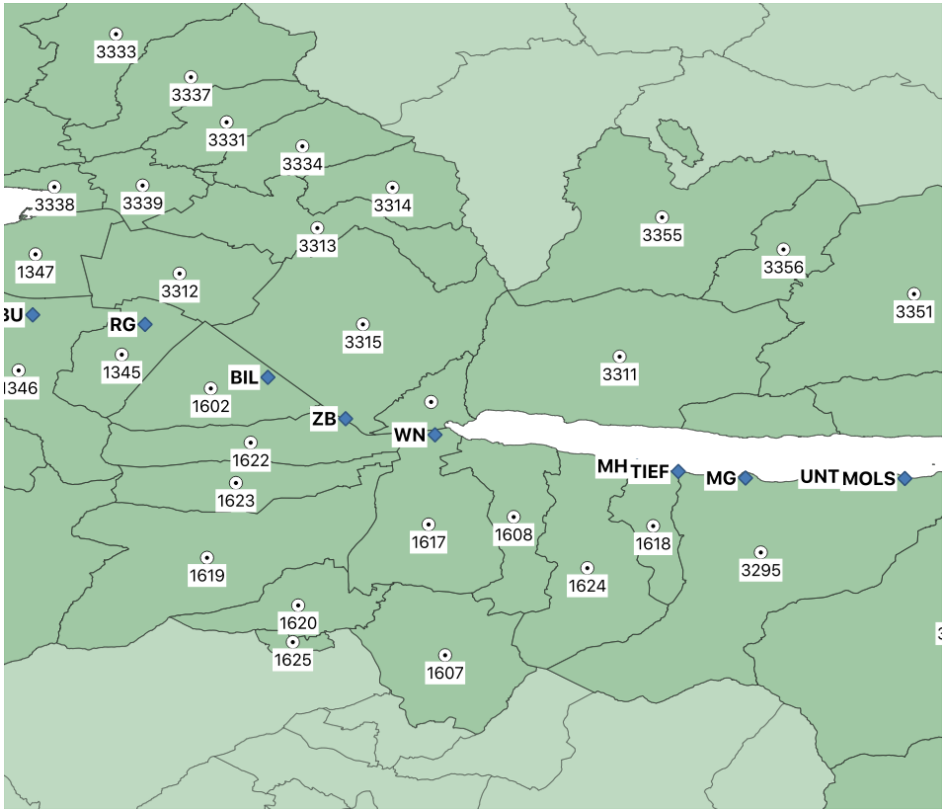
Assignment of stations to zones

- Demand of a zone is considered, if the distance to closest station is below a threshold
- Each zone is connected to several stations:
  - n closest stations by Euclidean distance
  - All stations in the k closest zones by travel time
  - Weighted connections with travel time by public transportation
  - n & k thresholds to be set



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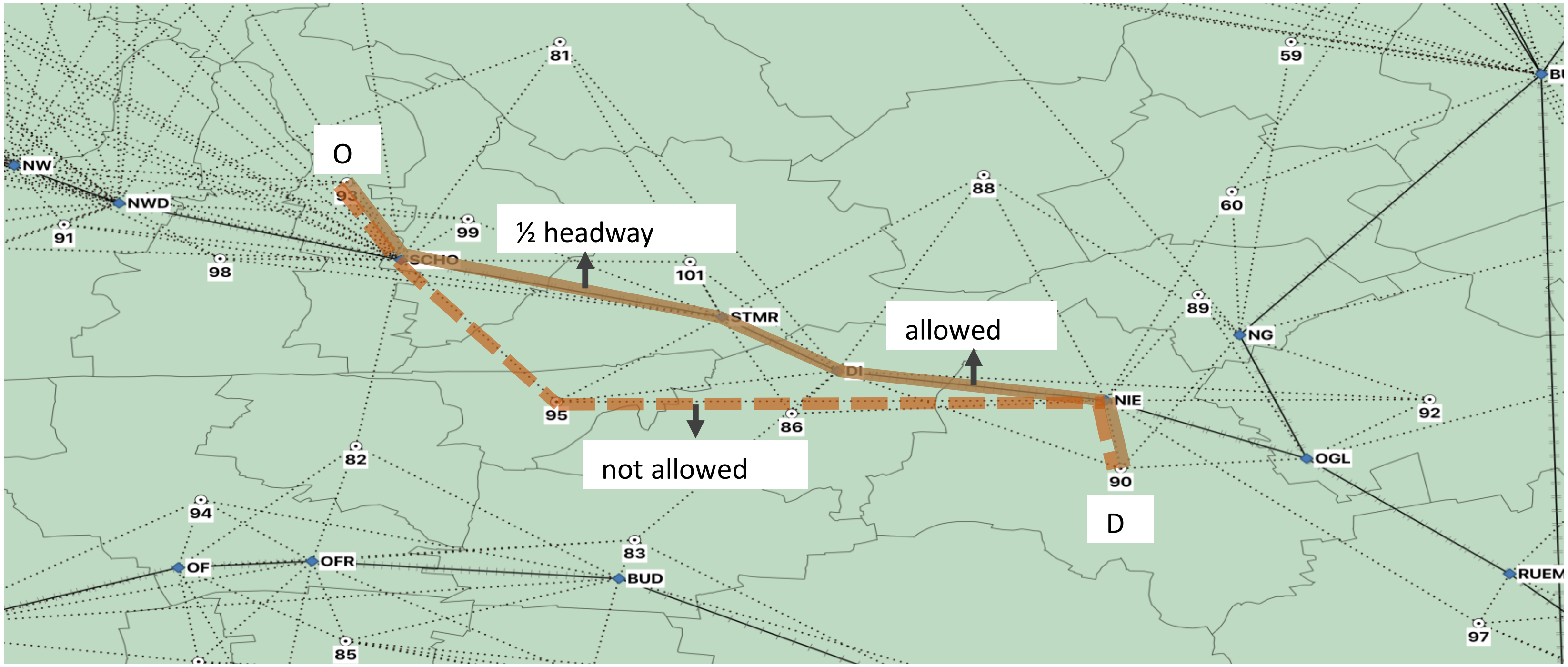
Adapted Dijkstra's shortest path algorithm

- Do not put the zones into the queue
- Add ½ of headway of 1st leg train to mimic waiting time at the first station



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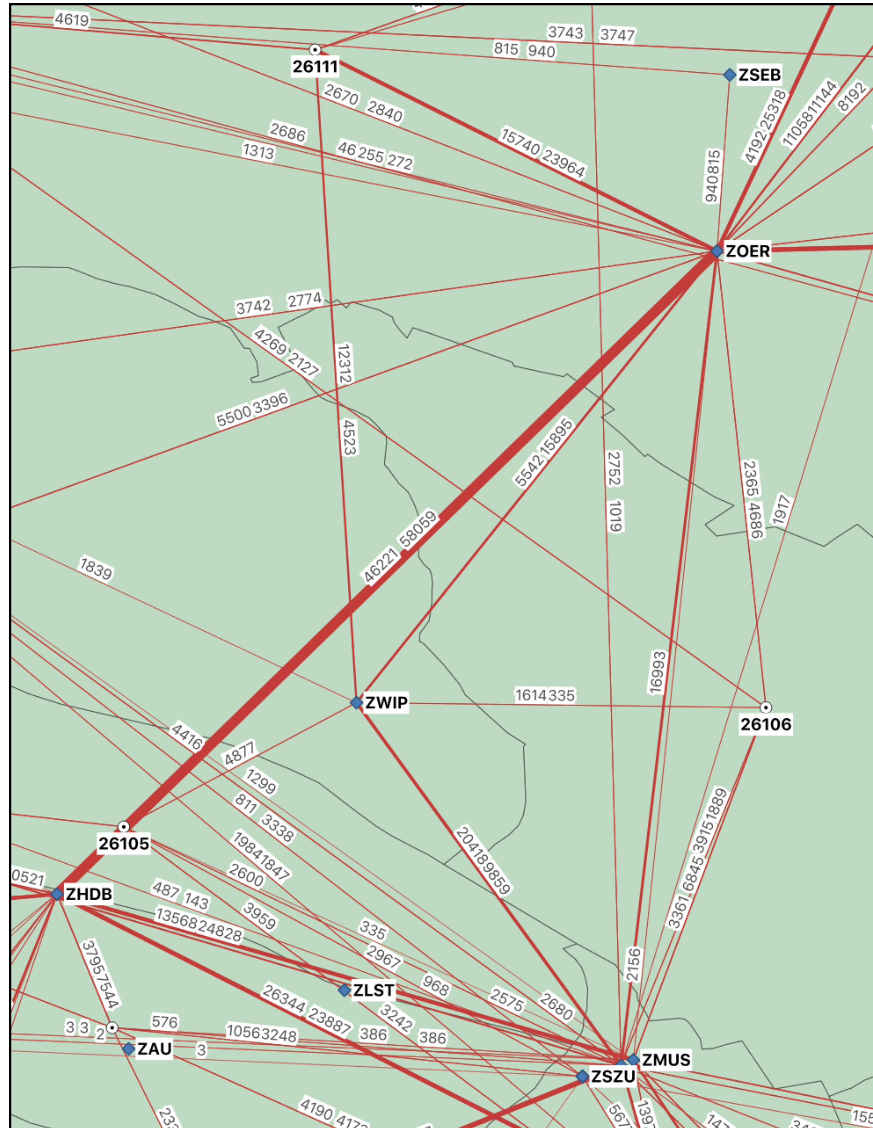
Resulting path loads

O - D	NPVM	Simulated	Δ
ZHDB - ZOER	46’575	58’059	+11’484
ZOER - ZHDB	47’810	46’221	- 1’589
ZSEB - ZOER	6’124	815	- 5’309
ZOER - ZSEB	6’050	940	- 5’119
ZWIP - ZOER	52’867	15’895	- 36’972
ZOER - ZWIP	51’689	5’542	- 46’147



Problem definition by Binder et al.

- Multi-objective railway timetable rescheduling problem as an Integer Linear Program:
  - f_p: minimization of passenger inconvenience,
  - f_o: minimization of operational costs, and
  - f_d: minimization of the deviation from the undisrupted timetable.

Network model

- Discretized planning horizon (1 minute period)
- Macroscopic model of railway network
  - Stations - with or without a shunting yard
  - Tracks – considered to be bidirectional
- Original and emergency trains
  - The latter deployed only from the shunting yards

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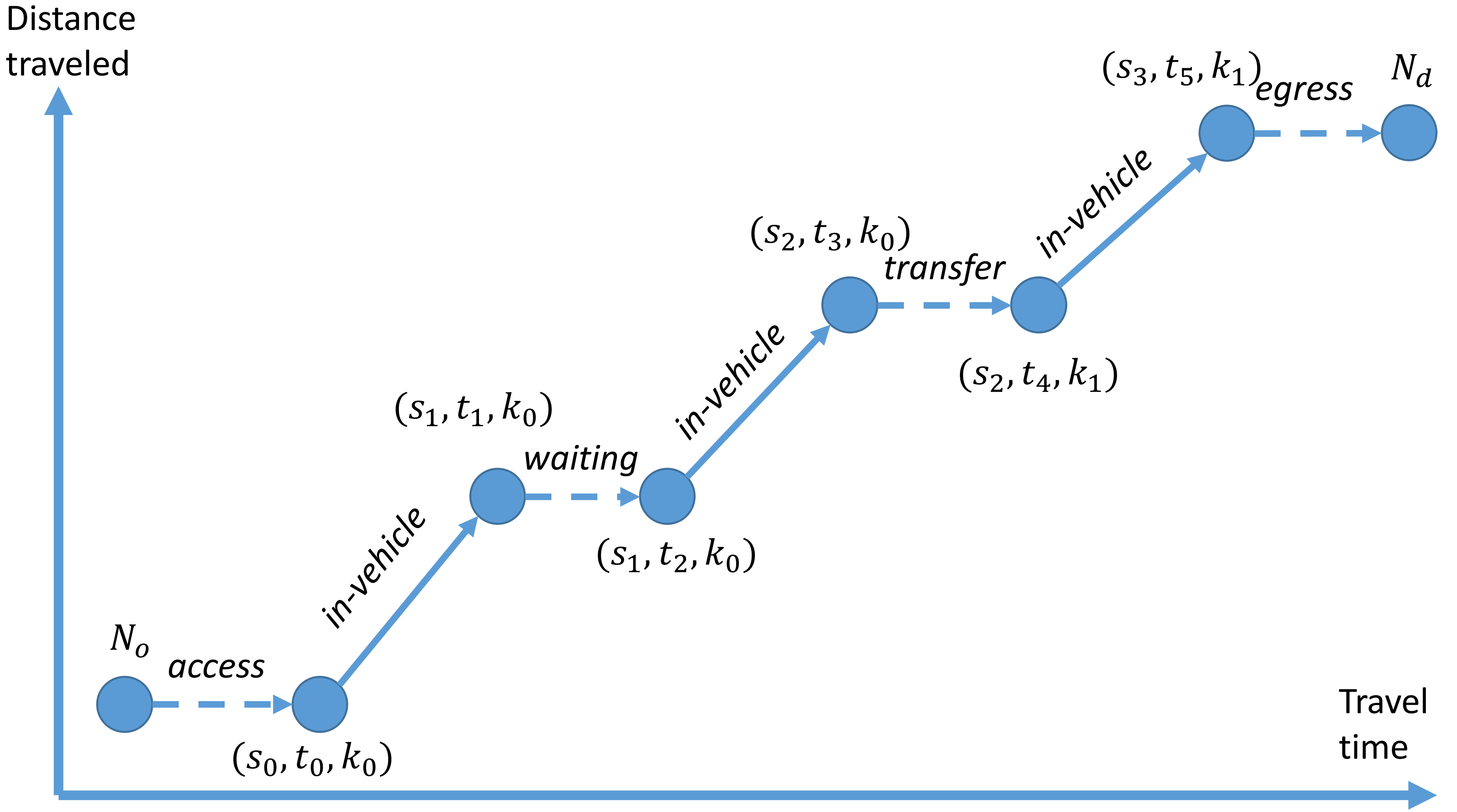
Time-expanded network



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Recovery decisions

- **Cancellation:** A train may be fully or partially canceled
- **Delay:** The arrival or departure may be delayed up to a maximal amount of time
- **Rerouting:** A train may be rerouted through another path than the originally planned one
- **Emergency train:** At every station with a shunting yard, a limited number of emergency trains is available
- **Emergency bus:** If the track between two neighboring stations is disrupted, an emergency bus may be scheduled to connect the two stations directly

Passenger travel choice

- Passenger: (o_p, d_p, t_p)
- Travel options: $\Omega(o_p, d_p)$
- Generalized path cost for passenger p and path $\omega \in \Omega(op, d_p)$:

$$C_\omega^p \ = VT_\omega^p + \beta_1 \cdot WT_\omega^p + \beta_2 \cdot NT_\omega^p + \beta_3 \cdot ED_\omega^p + \beta_4 \cdot LD_\omega^p$$

Solution methodology (Binder et al.)

- In real cases, the problem is too big to be solved exactly
- Heuristic approach: generate a set of "good" disposition timetables, and quantify the trade-off between the objectives

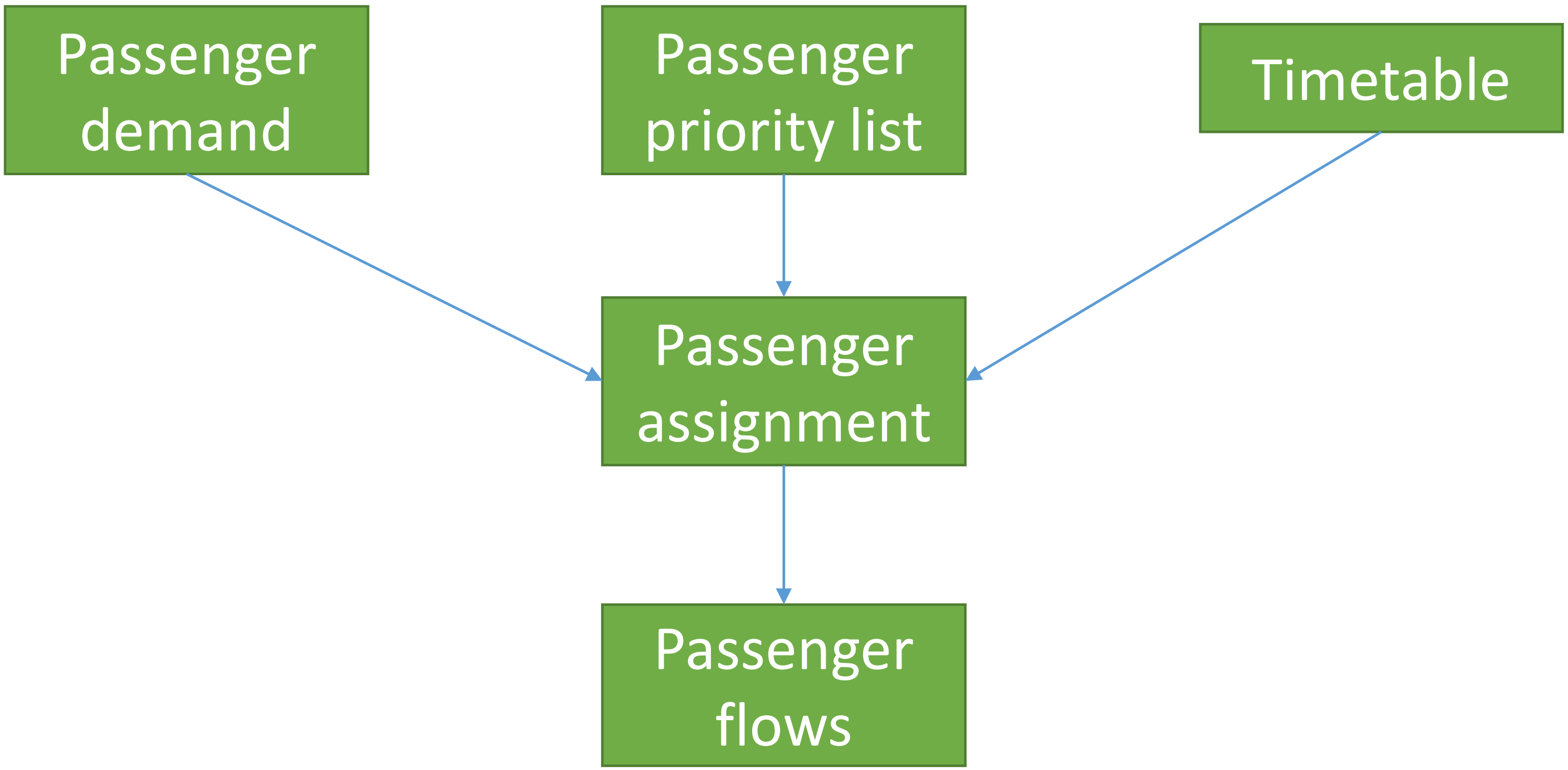
Solution methodology

- Adaptive Large Neighborhood Search (ALNS) meta-heuristic is implemented to construct the disposition timetable
- Neighborhood operators are inspired from real-life recovery strategies
- Each operator is chosen with a certain probability
  - Probabilities are updated during the execution
- The algorithm keeps track of non-dominated solutions using an archive of solutions

Neighborhood operators

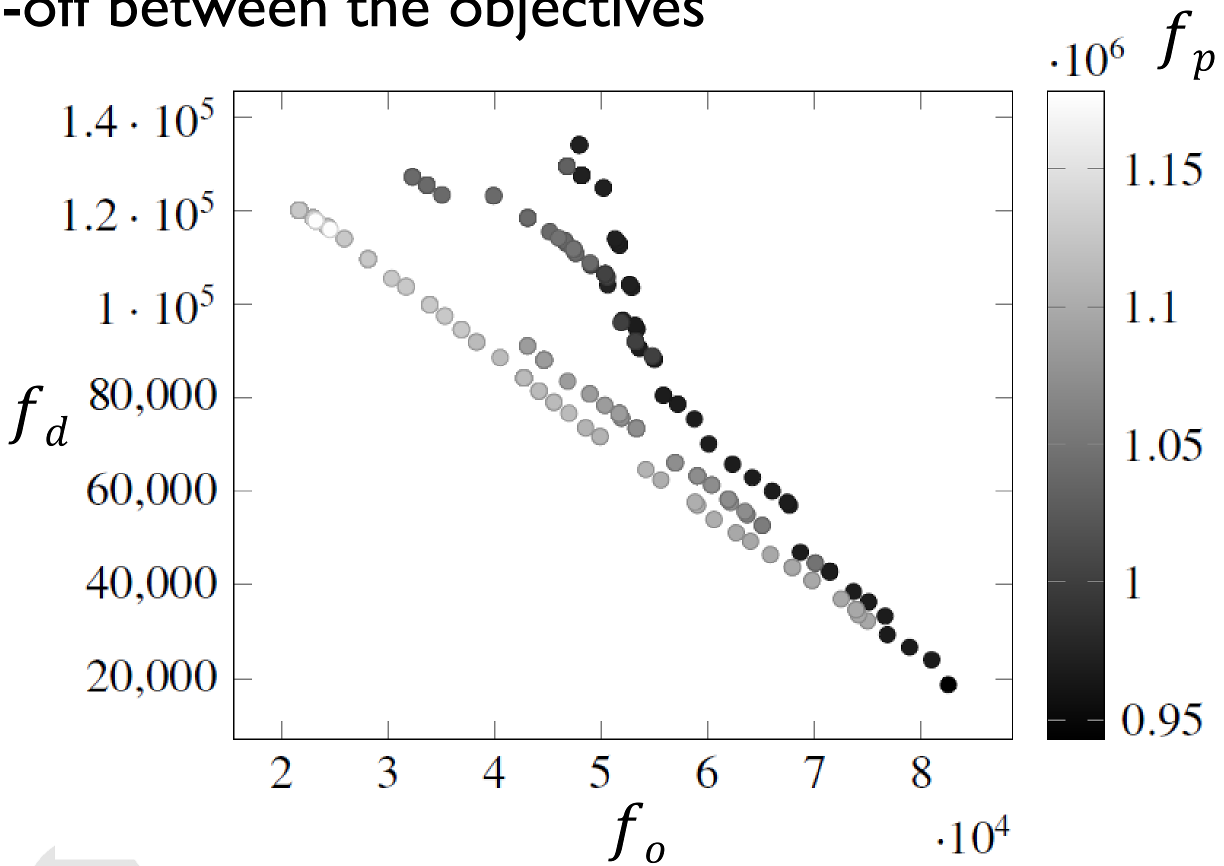
- Cancel trains completely
- Cancel trains after a given station
- Delay trains completely
- Delay trains after a given station
- Reroute trains between neighboring stations
- Add an emergency train
- Add an emergency bus

Passenger assignment procedure



Results

- The three-dimensional Pareto frontier allows to analyze the trade-off between the objectives



Implementation with Viriato and Algorithm Platform

- Data:
  - Network data
  - Timetables
- Used REST API methods:
  - Data access methods
  - neighbor-nodes – nodes connected with a direct track
  - section-tracks-between – finding a sequence of tracks which link two nodes
  - section-tracks-parallel-to – finding a parallel section for a given input
  - set-section-track – defining the section tracts for a train path
  - reroute-train – set the new path and the used section tracks
  - Scenario definition methods

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Conclusions

- From the previous research:
  - Proposed methodology gives satisfactory results and allows analysis of the trade-offs between the different objectives
  - Significant improvements can be achieved in passenger satisfaction with only a minor increase in the operational cost of the timetable
  - The higher the deviation from the undisrupted timetable is allowed, the better the timetable will perform in terms of passenger satisfaction and operational cost

Conclusions

- Viriato provides access to **valuable data**
- By using the Viriato environment and off-the-shelf methods of Algorithm Platform, **algorithm development is faster**
  - Expert can focus on the scientific work
- Faster industrial application of theoretical developments
- Viriato could be improved by including demand models

Future work

- H2020 project (or similar program) application:
  - *Intelligent algorithms for real-time railway management*

Thank you!

Questions?

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