Robust railway crew operations by simulation

Camiel Simons
Simulation research lead at NS Innovation

About me

- Background: civil engineering at University of Twente & TU Delft
- Simulation research lead at Netherlands Railways since 2020
- Research fields:
  - Stochastic simulation
  - Timetable adaptability
  - Disruption management
  - Crew operations

Netherlands Railways (NS) at a glance

1.2 million
train journeys every day

17 billion passenger kilometres every year

410,000 times round the earth

9 million people travel on NS trains every year

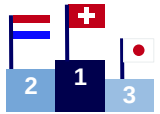
Amsterdam Centraal:
184,000 passengers
every day

6,830 kilometres of
railways
'from Utrecht to Tibet'
9,000 points

3,430 train drivers
and 2,950 conductors,
2,500 shifts every day

Revenue for 2018:
5.926 million euros

Profit:
106 million euros



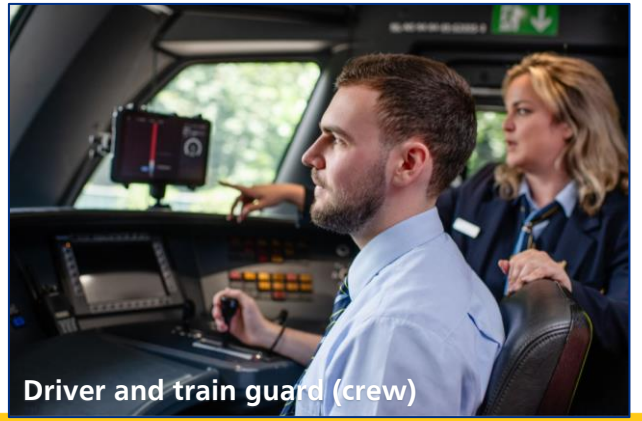
The world's busiest rail
networks
1. Switzerland
2. Netherlands
3. Japan

Train operations is not just trains


Train unit (rolling stock)

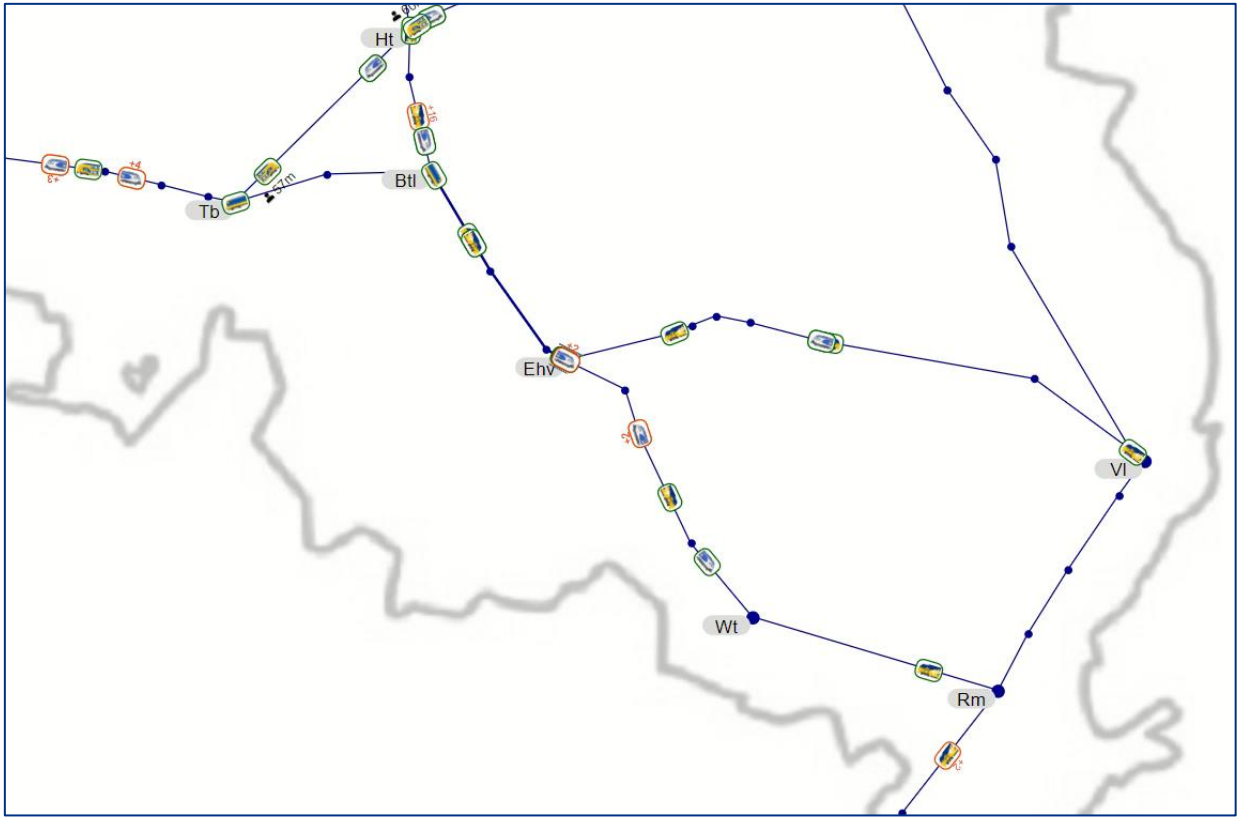

Track and energy supply (infrastructure)


Time and space on the track (timetable)


Driver and train guard (crew)

Our railway network: frequent passenger trains and freight corridors

- Every 10-15 minutes fast train
- Every 15 minutes local train
- Additional freight / international trains



Video: animation of railway network for crew simulation model

Business question: impact of crew on operational performance

Double-decker intercity train arriving on Utrecht Central Station - Credit: CreativeNature / DepositPhotos - License: DepositPhotos

BUSINESS NS TRAINS TRAIN TRAVEL STAFF SHORTAGES CROWDED TRAINS » MORE TAGS

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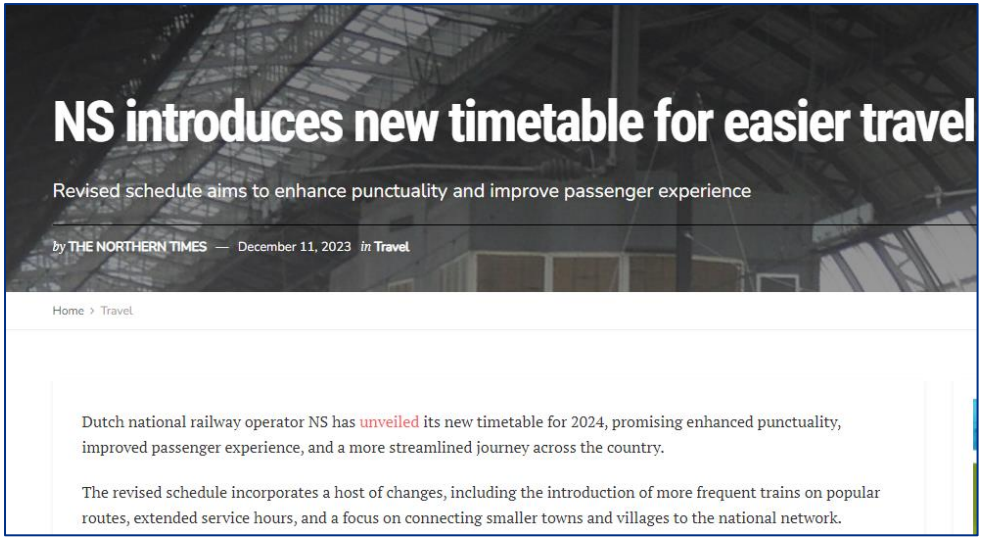
MONDAY, 19 DECEMBER 2022 - 09:30

NS says staff shortages were at their worst in September

The consequences of the staff shortage at national Dutch railway NS were most noticeable in September. During that month, in which major adjustments were also made to the timetable, it was too busy and crowded on an



NS introduces new timetable for easier travel

Revised schedule aims to enhance punctuality and improve passenger experience

by THE NORTHERN TIMES — December 11, 2023 *in* Travel

Home › Travel

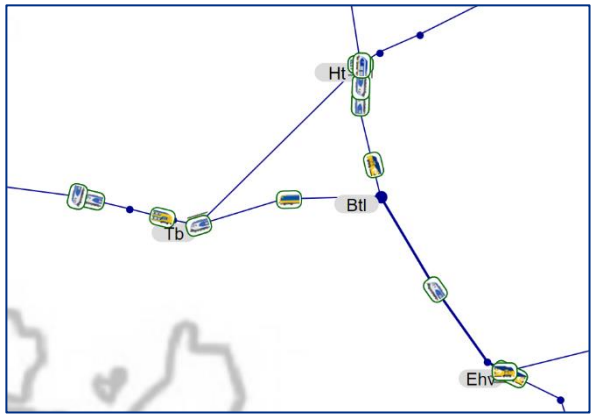
Dutch national railway operator NS has unveiled its new timetable for 2024, promising enhanced punctuality, improved passenger experience, and a more streamlined journey across the country.

The revised schedule incorporates a host of changes, including the introduction of more frequent trains on popular routes, extended service hours, and a focus on connecting smaller towns and villages to the national network.

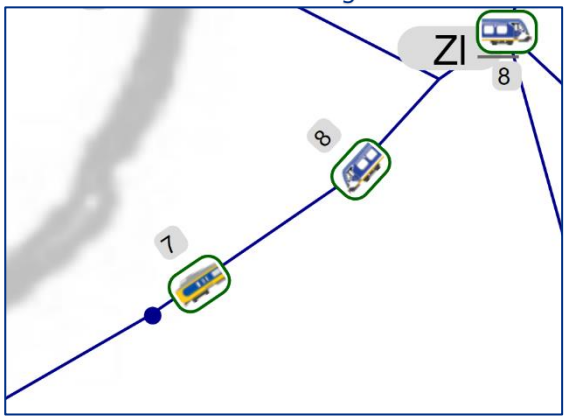
Purpose built AnyLogic model

- Macroscopic modelling
- Reused some code and logic from previous models

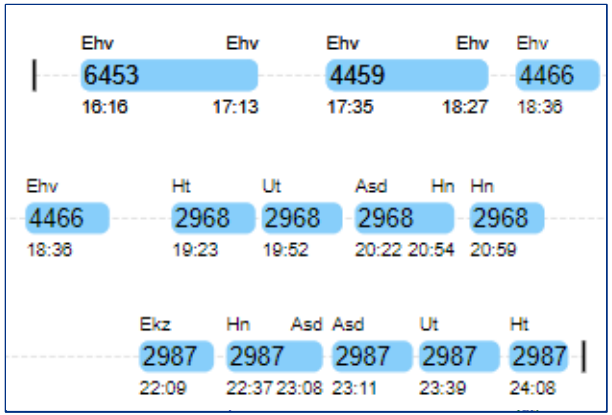
Timetable and macroscopic infrastructure



Rolling stock plan, including all units and train length

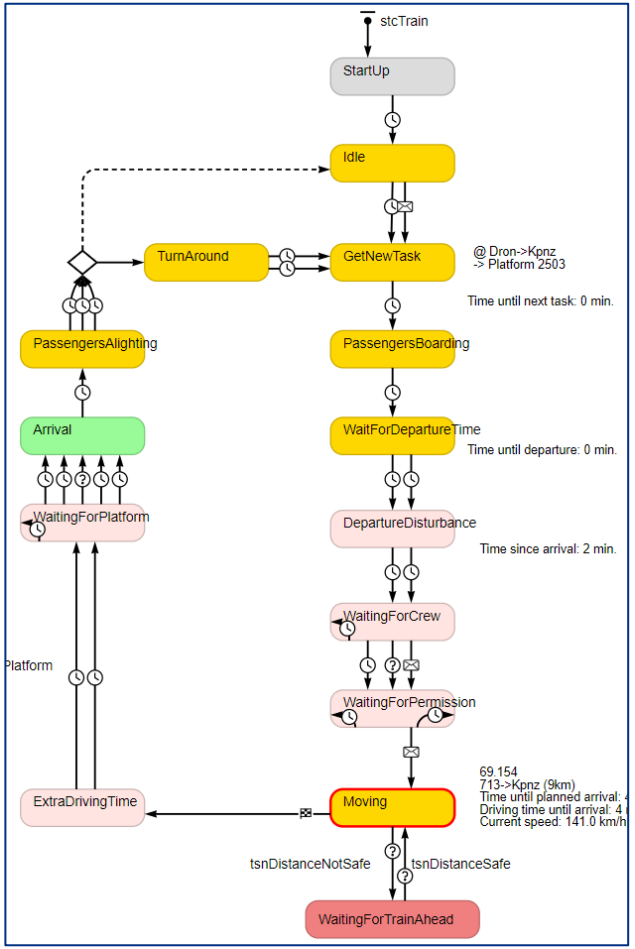


Crew plan, with all tasks and breaks



Why we chose AnyLogic

- Traditional microscopic simulation tools do not incorporate crew
- Separate modelling of agents was necessary
- Stochastic disturbances
- Read large amount of data from database



Picture: example statechart of Train agent

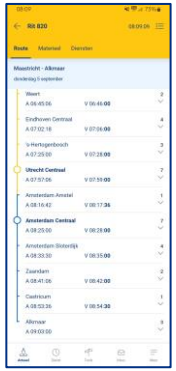
Added value of AnyLogic models

- Before AnyLogic: only microscopic simulations
- With AnyLogic: macroscopic / conceptual
  - Rapid development of concept (<1 week for new model)
  - Integration with other tools (input and output)
  - Less data hungry
  - Interactive
  - Easy to use
  - Explainable to end users

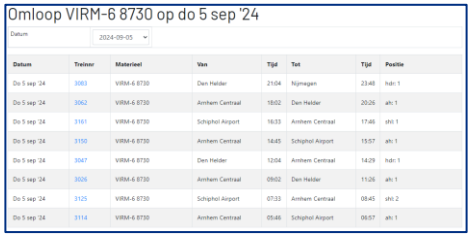
Picture: aerial view of complex railway junction at Utrecht, Netherlands

We use SQL and Python for data preparation

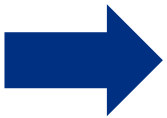
Timetable

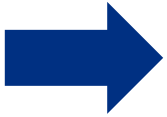


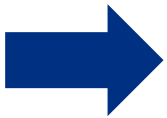
Crew plan



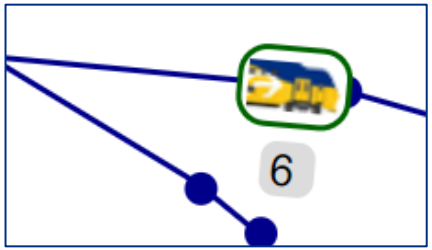
Rolling stock schedule





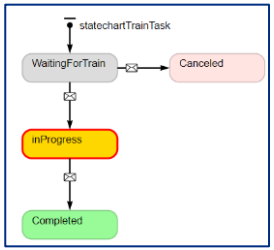


Assignments are modelled as agents



Train (~700)
Inseparable unit of rolling stock

1:N



TrainTask (~100.000)
Assignment of train to perform services

1-4

- serviceId: A1100-13
- timetablePatternId: A1100
- serviceSeries: 1100
- serviceName: 1112
- serviceTaskId: 1112_01
- serviceCharacteristic: IC
- carrierCode: NS
- originStationCode: Ehv
- destinationStationCode: Ehs
- departureTime: 194
- arrivalTime: 196.4
- departureActivity: V
- arrivalActivity: D
- departureIsPassengerStop: true
- arrivalIsPassengerStop: false
- departurePlatformName: 2
- arrivalPlatformName: 2
- firstActivityOfService: true

Service (~67.000)
Trip from A to B with one or more train units

- shiftId: 1
- crewType: Driver
- homebaseStationCode: Hn
- startTime: 650
- endTime: 1,058

CrewDuty (~1.000 for drivers)
Duty for one driver / guard on specific day

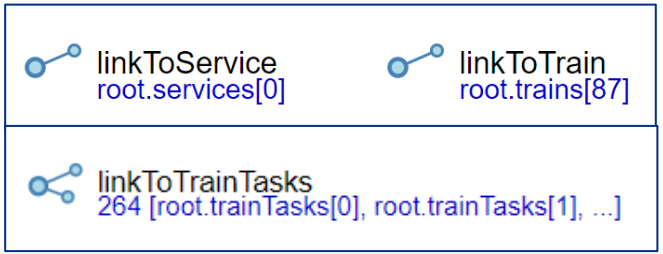
1:M

- taskId: 4,190
- shiftId: 1
- departureTrainNumber: 4136
- departureTrainTime: 665
- departureStation: Hn
- arrivalTrainNumber: 4151
- arrivalTrainTime: 687
- arrivalStation: Hn
- positioningTrip: false

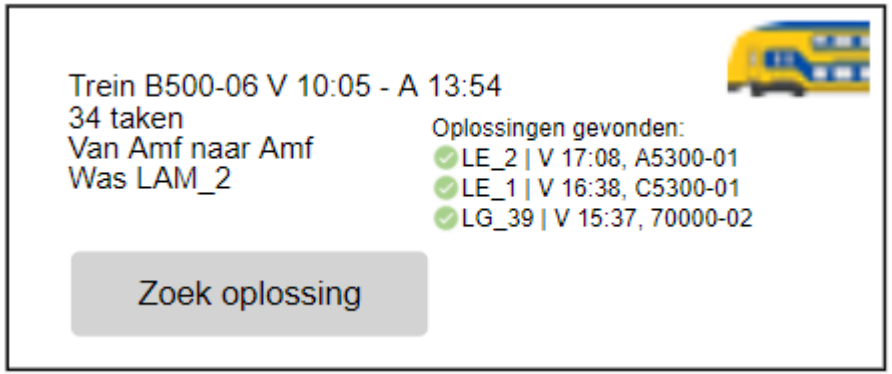
CrewTask (~12.000)
Assignment of crew shift to perform services

1:N

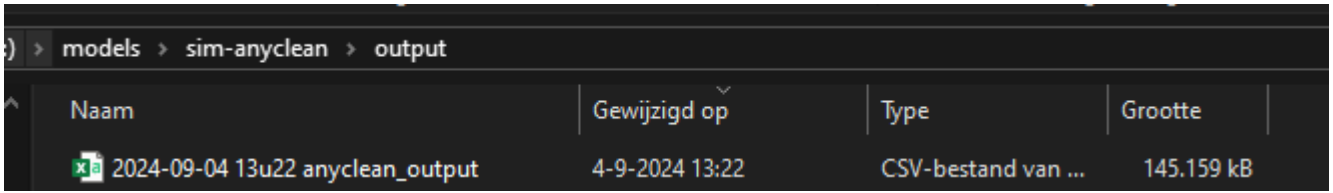
Best practices



Bi-directional agent links



Interactive interface, user can control the simulation and solve conflicts



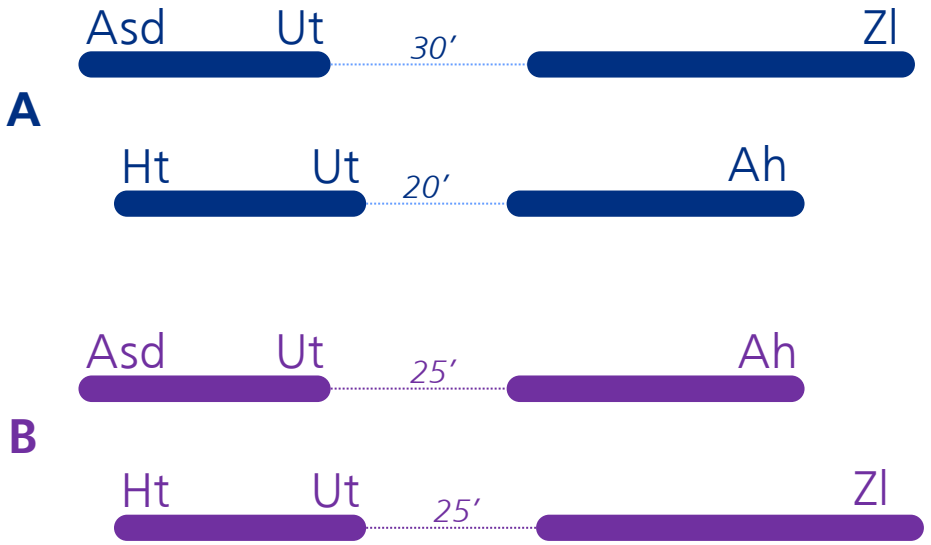
Automated export from AnyLogic Database to CSV, to be read in Power BI

Case study: buffer time allocation

Goal: make the crew plan more robust by allocating buffer time

Steps:

- Historical delay data
- Optimize buffer
- Simulate solution
- Evaluate robustness



Picture: example of two possible solutions for a crew connection

Feedback loop with crew optimization software

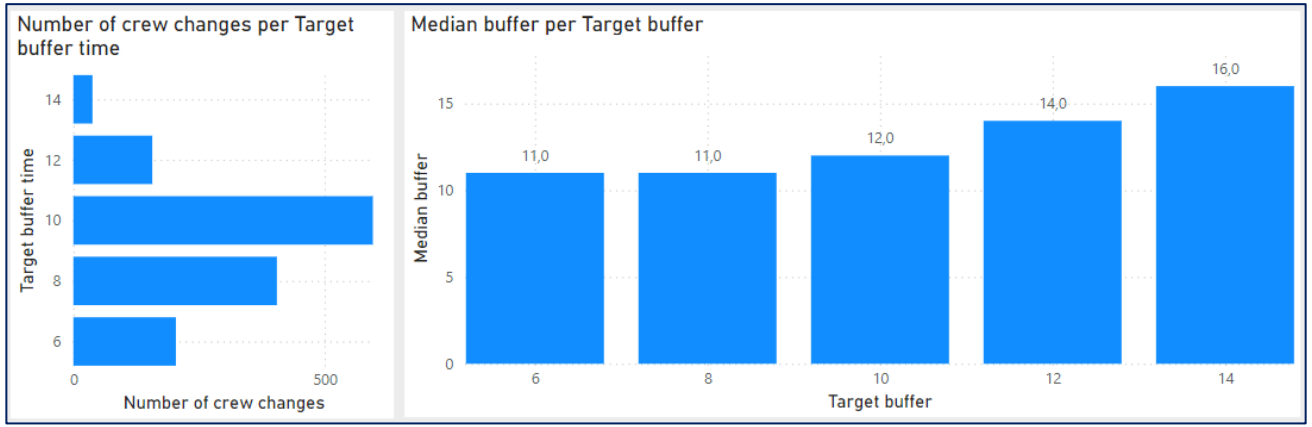
- Scenario's with less duties have more changes and less buffer
- This impacts operational performance

Scenario	Duties count	Number of crew changes	Median buffer	Average buffer
10 minutes transfer time	844	8625	3,00	7,66
18-22 minutes transfer time based on data	846	8642	3,00	7,74
Second iteration run based om simulation output	856	8581	4,00	9,17
Optimised on cancellation prevention	857	8595	4,00	8,99
First iteration run based om simulation output	859	8587	4,00	9,24
20 minutes transfer time	859	8590	4,00	9,22
Totaal	**5121**	**51620**	**4,00**	**8,67**

Table: output of crew optimization with different transfer times

Model validation

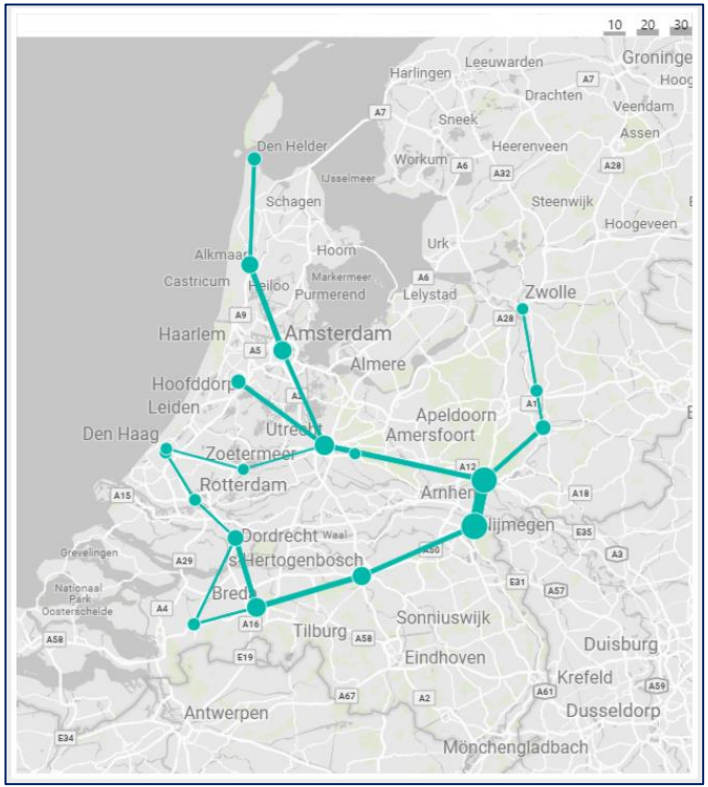
- First train operator in EU to model crew operation
- Visualisation of crew plan



Picture: validating whether the target buffer times are achieved. Unit: minutes

Business value starts during development

- First train operator in EU to model crew operation
- Visualisation of crew plan
- Improved data interfaces



Picture: map of tasks per home base

More developments coming in the future

- Clear output metrics
- Comparing 2024 and 2025 timetable
- Identify critical spots in crew plan
- See effects of train cancellations

Picture: our future, the newest type of Intercity train

Recent results with AnyLogic

- Placement of maintenance facilities
- Interior cleaning of trains
- Operational performance new safety system

Picture: regional train ‘Sprinter’, newest type

We wish you a pleasant journey

Camiel Simons
Simulation research lead
NS Innovation
camiel.simons@ns.nl