Railway line planning for varying demand

with focus on stop planning, frequency setting, and asymmetric lines

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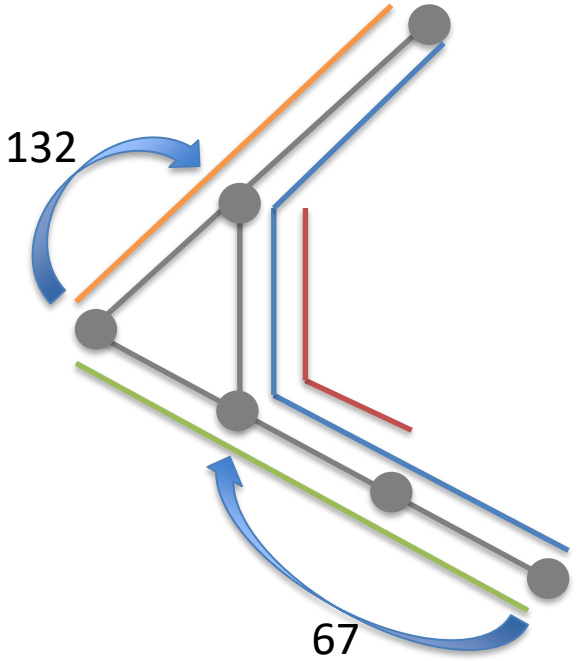
Outline

- Railway line planning: what & why for varying demand?
- Methodology: How to find flexible line plans?
- Preliminary case study results
- Key takeaways

Railway line planning

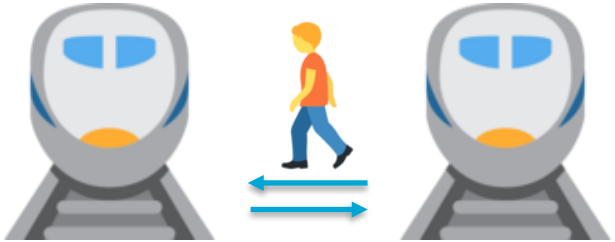
- Input:
  - Railway network
  - Demand
  - Line pool

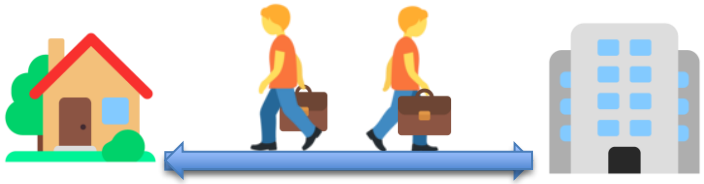
- Goal:
  - Determine set of lines
  - Each line has:
    - Route through network
    - Stopping pattern
    - Frequency



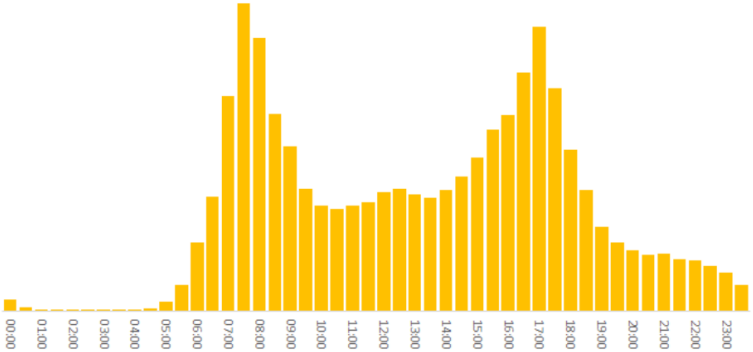
Line plan and demand

- Quality of service
- Dependent on demand
- Demand changes throughout the day
  - Volume
  - Structure





Number of trips per half hour on an average workday



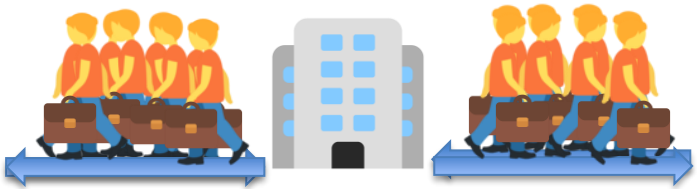
Source: Guis, Banninga, Verschuren - TRENO: gemiddeld is niet goed genoeg - rekenen met pieken en dalen in vervoersvraag (2018)

Line planning for varying demand

- Applied variations in the Netherlands
  - Extra trains during peak hours
  - Lower frequencies in the evening & weekend

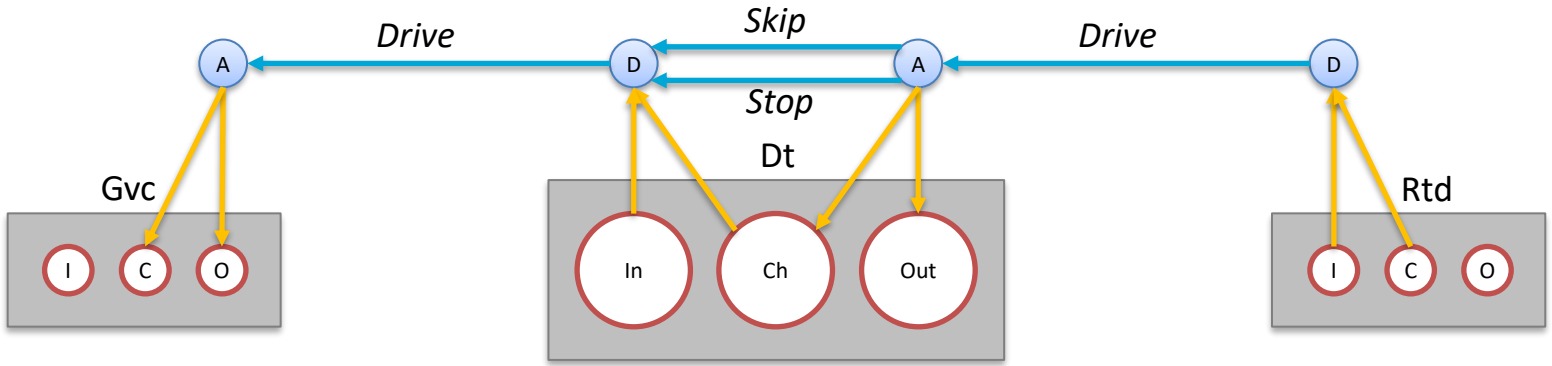
- Room for improvement:
  - Mainly symmetric lines (stopping pattern and frequency)
  - Stopping pattern is fixed (IC & Sprinter trains)

- Aim: create a line plan that better matches the demand that is varying throughout the day



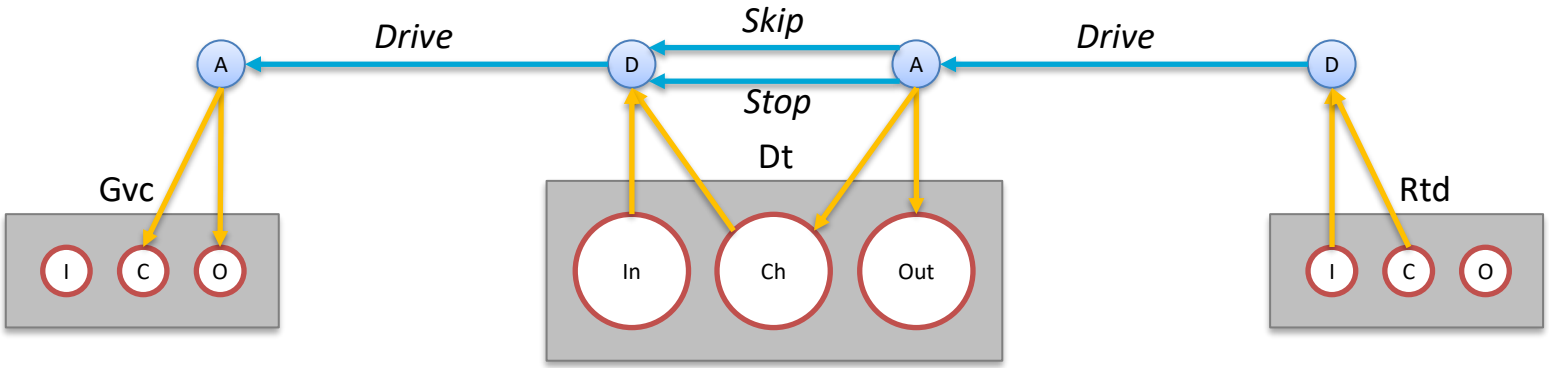
Methodology

- Mixed-Integer Linear Programming (MILP)
- Objective: Minimize total generalized journey time (GJT) of passengers
  - Waiting time for first train
  - In-vehicle time
  - Transfer waiting time
- Routing passengers in change-and-go network

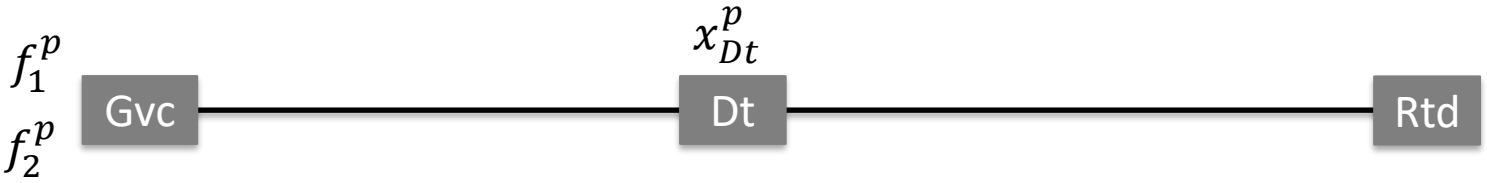


Decision variables

- Passenger flow variables

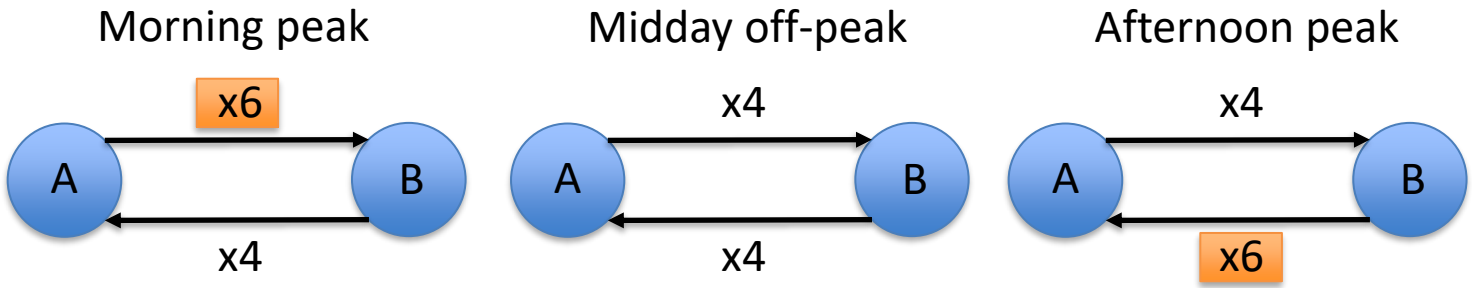


- For each line in the line pool and each period:
  - Stop choice (binary)
  - Frequency choice (binary)



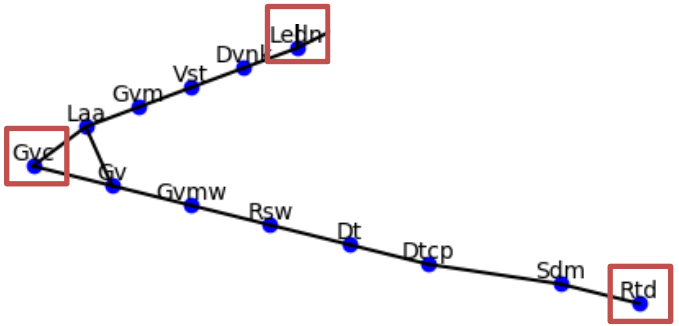
Constraints

- Passenger flow conservation
- Usage of arcs in change-and-go network
- Budget on cost of line plan
- Frequencies over the day should be symmetric



Case study

- Part of Dutch railway network
  - Rtd = Rotterdam Centraal
  - Gvc = Den Haag Centraal
  - Ledn = Leiden



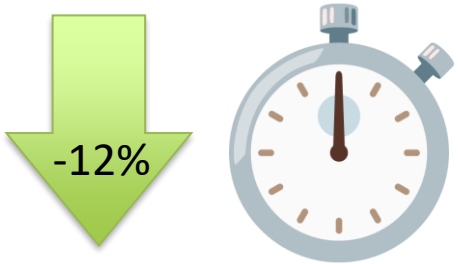
- Demand: 2019 smart-card data of NS

- 3 periods on average Tuesday:
  - Morning peak
  - Midday off-peak
  - Afternoon peak

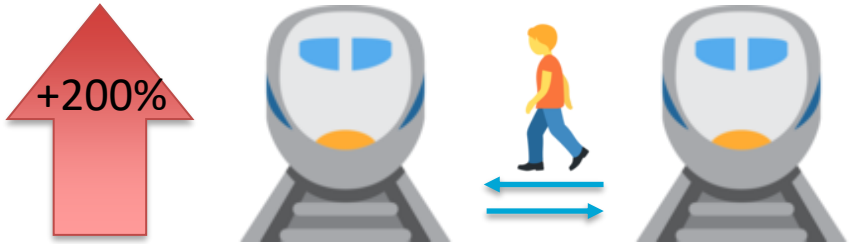
Preliminary results of case study

- Different plans in different periods

- Compared to 2023 line plan:



GJT



Transfers

- Average GJT per passenger reduced by 4 minutes

Key takeaways

- Passenger railway demand changes throughout the day,
- But changes to the line plan are limited

- Find line plans that are more flexible to the demand with MILP model

- Different line plans are optimal for different periods

- Passengers can benefit from more flexibility (in terms of GJT),
- But will have to accept more transfers.

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Smart Public Transport Lab

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