

Strategic timetabling

Gert-Jaap Polinder, Marie Schmidt, Dennis Huisman

Erasmus University Rotterdam
Netherlands Railways

October 22, 2019

Public transport planning - In Theory

Infrastructure + demand

Public transport planning - In Theory

Infrastructure + demand



Line plan

Public transport planning - In Theory

Infrastructure + demand

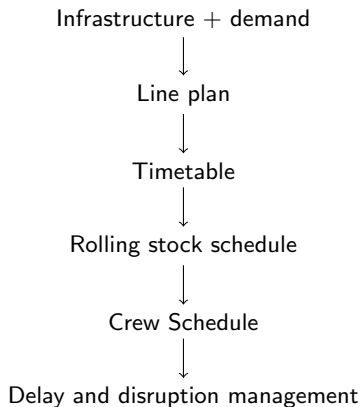


Line plan

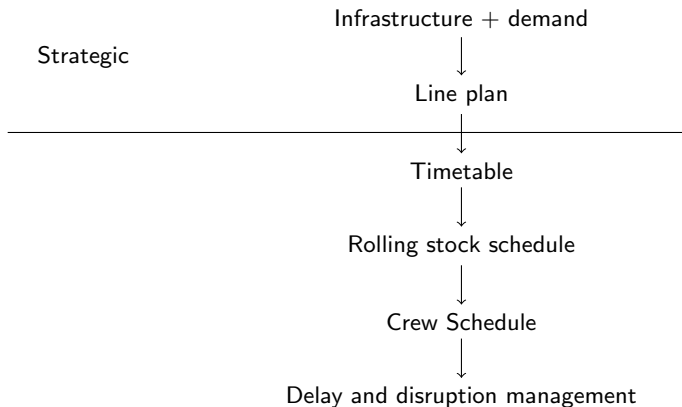


Timetable

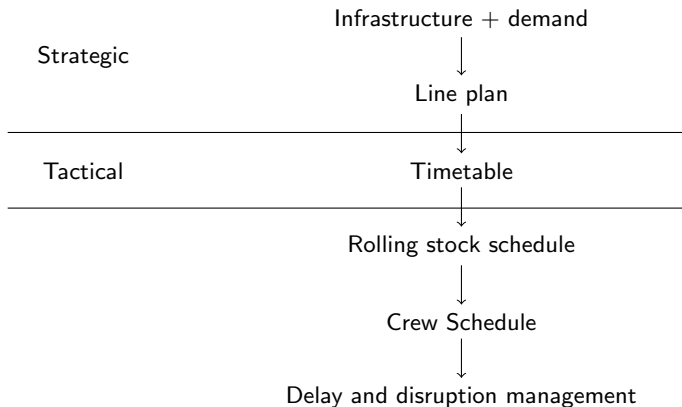
Public transport planning - In Theory



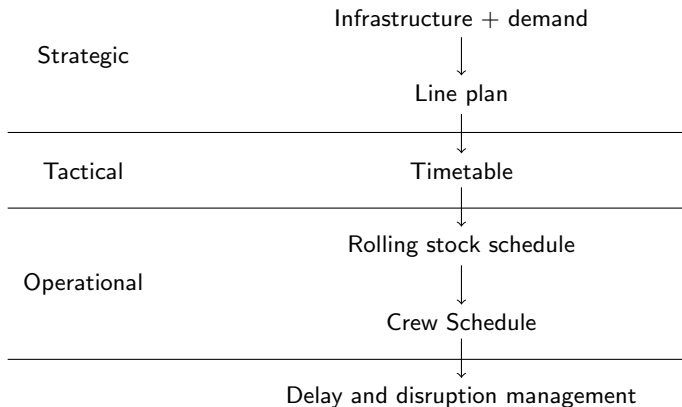
Public transport planning - In Theory



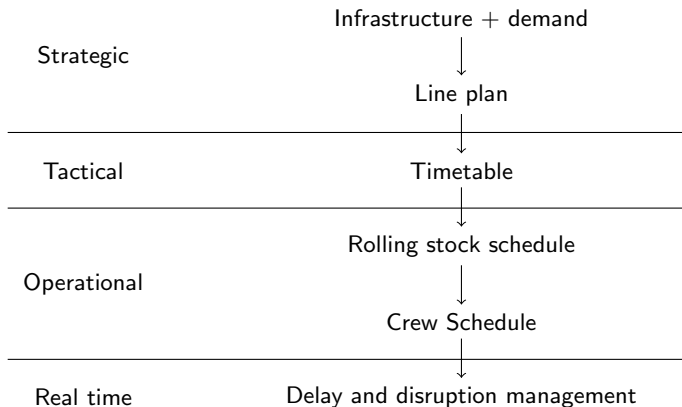
Public transport planning - In Theory



Public transport planning - In Theory

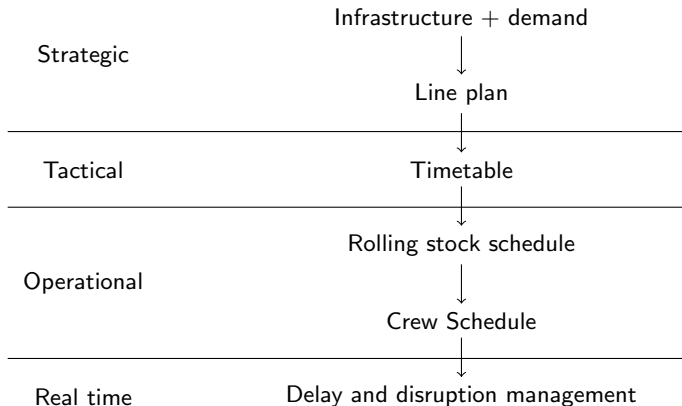


Public transport planning - In Theory



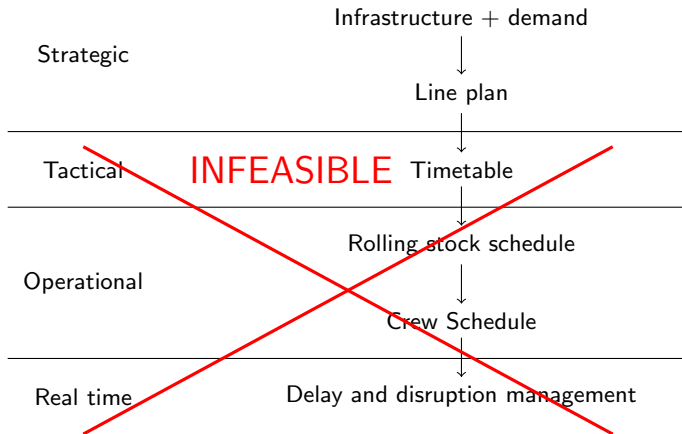
Public transport planning - In Practice

In theory there is no difference between theory and practice



Public transport planning - In Practice

In theory there is no difference between theory and practice, however..



Dealing with infeasibility

- In case of small/local conflicts: *Resolving infeasibilities* (Polinder et al, 2018)
Try to solve conflicts locally

Dealing with infeasibility

- In case of small/local conflicts: *Resolving infeasibilities* (Polinder et al, 2018)
Try to solve conflicts locally
- This study: Take step back and evaluate line plan:

Dealing with infeasibility

- In case of small/local conflicts: *Resolving infeasibilities* (Polinder et al, 2018)
Try to solve conflicts locally
- This study: Take step back and evaluate line plan:
 - Compute (sketch of) timetable for line plan.

Dealing with infeasibility

- In case of small/local conflicts: *Resolving infeasibilities* (Polinder et al, 2018)
Try to solve conflicts locally
- This study: Take step back and evaluate line plan:
 - Compute (sketch of) timetable for line plan.
 - Leave out as many details as possible

Dealing with infeasibility

- In case of small/local conflicts: *Resolving infeasibilities* (Polinder et al, 2018)
Try to solve conflicts locally
- This study: Take step back and evaluate line plan:
 - Compute (sketch of) timetable for line plan.
 - Leave out as many details as possible
 - Why assume infrastructure to be fixed?: discard this (big but important assumption)

Dealing with infeasibility

- In case of small/local conflicts: *Resolving infeasibilities* (Polinder et al, 2018)
Try to solve conflicts locally
- This study: Take step back and evaluate line plan:
 - Compute (sketch of) timetable for line plan.
 - Leave out as many details as possible
 - Why assume infrastructure to be fixed?: discard this (big but important assumption)
 - Optimize timetable for passengers

Dealing with infeasibility

- In case of small/local conflicts: *Resolving infeasibilities* (Polinder et al, 2018)
Try to solve conflicts locally
- This study: Take step back and evaluate line plan:
 - Compute (sketch of) timetable for line plan.
 - Leave out as many details as possible
 - Why assume infrastructure to be fixed?: discard this (big but important assumption)
 - Optimize timetable for passengers
- Result:

Dealing with infeasibility

- In case of small/local conflicts: *Resolving infeasibilities* (Polinder et al, 2018)
Try to solve conflicts locally
- This study: Take step back and evaluate line plan:
 - Compute (sketch of) timetable for line plan.
 - Leave out as many details as possible
 - Why assume infrastructure to be fixed?: discard this (big but important assumption)
 - Optimize timetable for passengers
- Result:
 - Passenger-oriented timetable
 - Indication of important transfers
 - Indication of good pattern
 - Point on horizon to aim for

Timetable patterns

Timetable patterns

- Passengers arrive according to uniform distribution

Timetable patterns

- Passengers arrive according to uniform distribution
- Schedule trains such that experienced travel time is minimized

Timetable patterns

- Passengers arrive according to uniform distribution
- Schedule trains such that experienced travel time is minimized
 - In train time
 - Transfer time
 - Transfer penalty
 - *Adaption time*

Timetable patterns

- Passengers arrive according to uniform distribution
- Schedule trains such that experienced travel time is minimized
 - In train time
 - Transfer time
 - Transfer penalty
 - *Adaption time*
- Depending on demand, good 'patterns' arise

Timetable patterns - example

Stations A, B, C

C _____

B _____

A _____

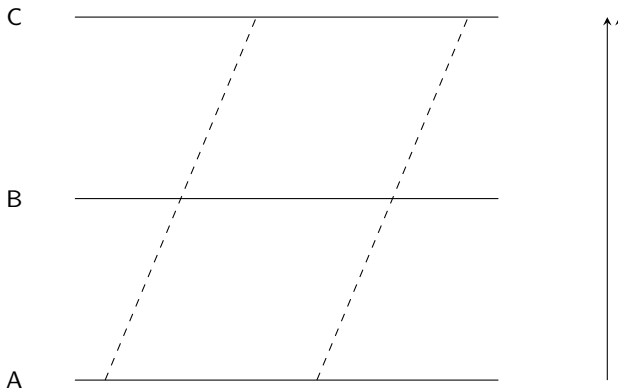
Timetable patterns - example

Stations A, B, C , 2 trains.



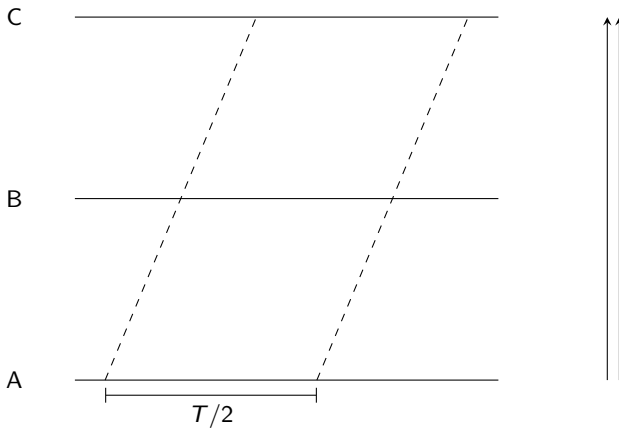
Timetable patterns - example

Stations A, B, C , 2 trains.



Timetable patterns - example

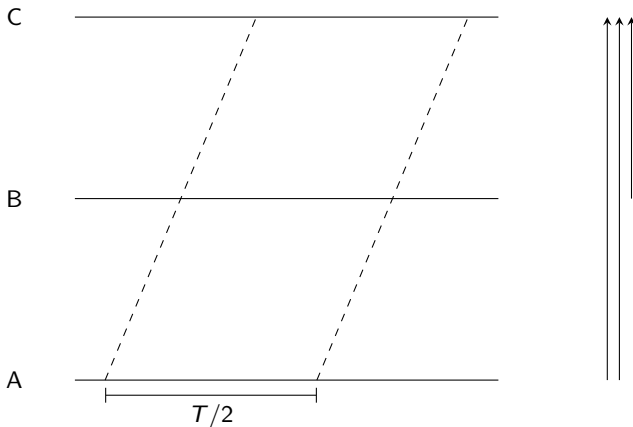
Stations A, B, C , 2 trains.



Timetable patterns - example

Stations A, B, C , 2 trains.

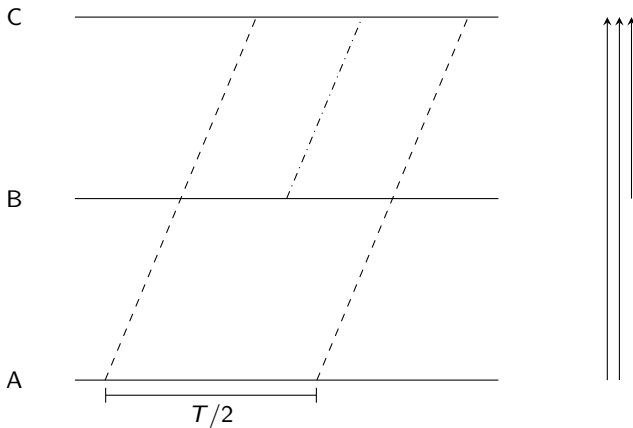
What if there is an additional train $B \rightarrow C$?



Timetable patterns - example

Stations A, B, C , 2 trains.

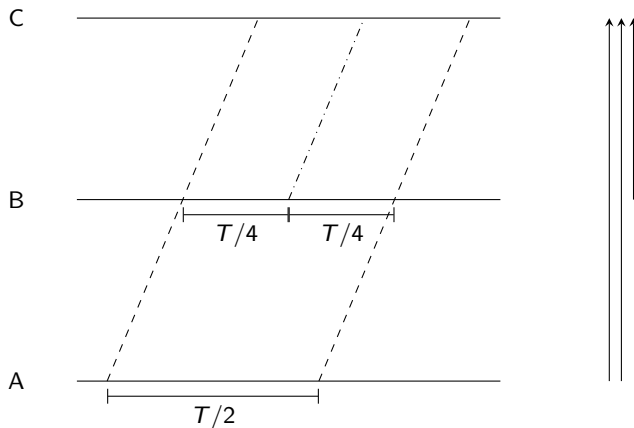
What if there is an additional train $B \rightarrow C$?



Timetable patterns - example

Stations A, B, C , 2 trains.

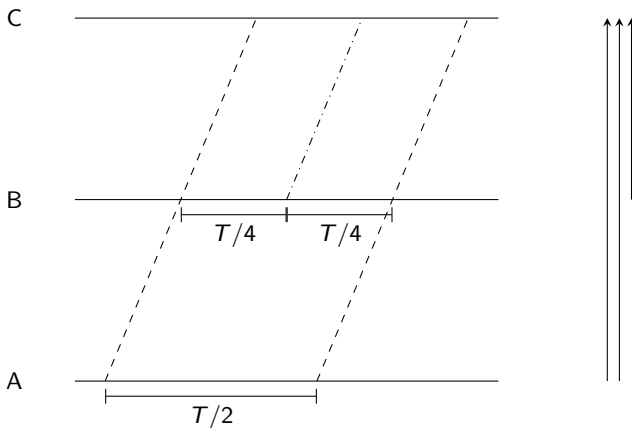
What if there is an additional train $B \rightarrow C$?



Timetable patterns - example

Stations A, B, C , 2 trains.

What if there is an additional train $B \rightarrow C$?

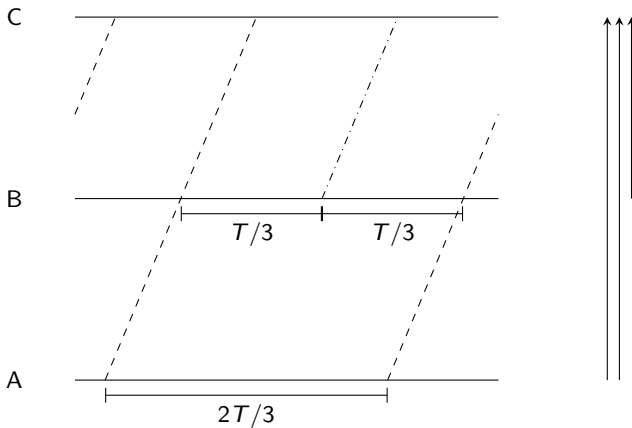


Not optimal for $B \rightarrow C$ passengers

Timetable patterns - example

Stations A, B, C , 2 trains.

What if there is an additional train $B \rightarrow C$?



Model formulation

Model formulation

- Determine timetable and routes in integrated way

Model formulation

- Determine timetable and routes in integrated way
- We take the time between the departures into account, to minimize travel time

Model formulation

- Determine timetable and routes in integrated way
- We take the time between the departures into account, to minimize travel time
- Optimize time to previous train, without knowing which train this is

Model formulation

- Determine timetable and routes in integrated way
- We take the time between the departures into account, to minimize travel time
- Optimize time to previous train, without knowing which train this is
- Extension of RailNorrköping presentation:
 - Passengers do not have to board the first departing train
 - Heuristic
 - Larger instances
 - Transfers included

IP Model formulation (TTwPR)

$$\text{Minimize } \sum_{k \in \mathcal{OD}} d_k \sum_{v \in V^k} \frac{A_v^k}{T} \cdot (\gamma_w \cdot W_v^k + \hat{Y}_v^k)$$

$$\text{Such that } y_{ij} = \pi_j - \pi_i + T p_{ij}$$

$$\ell_{ij} \leq y_{ij} \leq u_{ij}$$

$$Y_r = \sum_{a \in r} y_a + \gamma_t \cdot 1_t(a)$$

$$\hat{Y}_v^k = \min_{v' \in V^k} \min_{r \in \mathcal{R}_{v'}^k} \{Y_r + \gamma_w \cdot (\pi_{v'} - \pi_v + T \alpha_{v,v'})\} \quad \forall k \in \mathcal{OD}, v \in V^k$$

$$A_v^k = \min_{v' \in V^k \setminus \{v\}} \{\pi_v - \pi_{v'} + T \alpha_{v',v}\} \quad \forall k \in \mathcal{OD}, v \in V^k$$

$$\alpha_{v,v'} + \alpha_{v',v} = 1 \quad \forall k \in \mathcal{OD}, v \in V^k, v' \in V^k \setminus \{v\}$$

$$W_v^k = \frac{1}{2} A_v^k \quad \forall k \in \mathcal{OD}, v \in V^k$$

$$A_v^k \in [0, T], W_v^k \in [0, T/2] \quad \forall k \in \mathcal{OD}, v \in V^k$$

$$p_{ij} \in \mathbb{Z}_{\geq 0} \quad \forall (i, j) \in A$$

$$Y_r, \hat{Y}_v^k \in [0, \infty) \quad \forall r \in \mathcal{R}, k \in \mathcal{OD}, v \in V^k$$

$$\pi_v \in \{0, \dots, T-1\} \quad \forall v \in V$$

$$\alpha_{v,v'} \in \{0, 1\} \quad \forall k \in \mathcal{OD}, v \in V^k, v' \in V^k \setminus \{v\}.$$

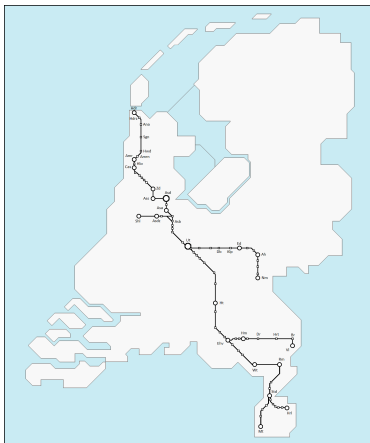
Instances

Instances

A2-corridor

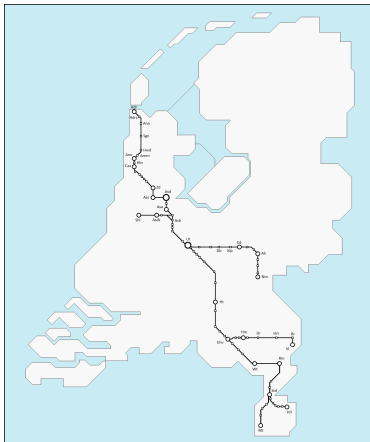
Instances

A2-corridor



Instances

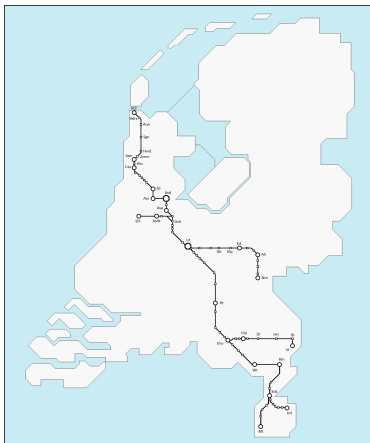
A2-corridor



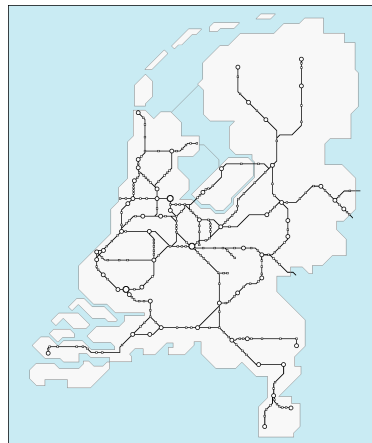
Dutch intercity network

Instances

A2-corridor

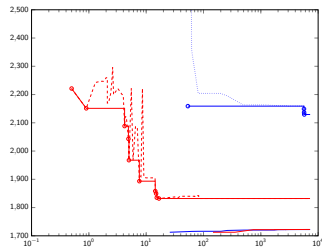


Dutch intercity network



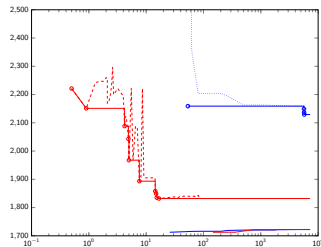
Heuristic/Scalability

Heuristic/Scalability

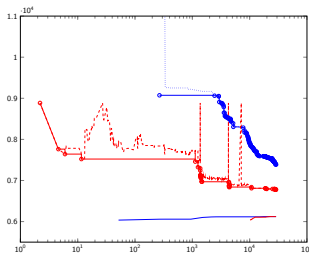


(a) A2-corridor

Heuristic/Scalability

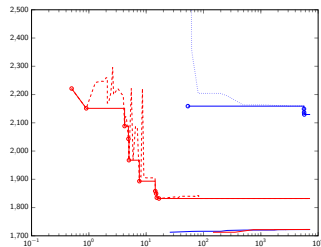


(a) A2-corridor

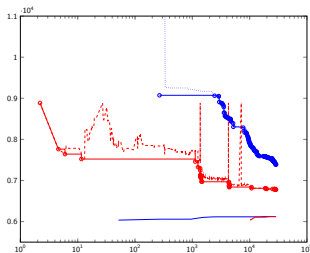


(b) IC network, only direct passengers

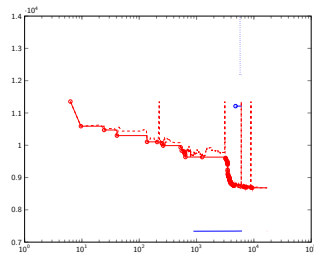
Heuristic/Scalability



(a) A2-corridor



(b) IC network, only direct passengers



(c) IC network with all passengers

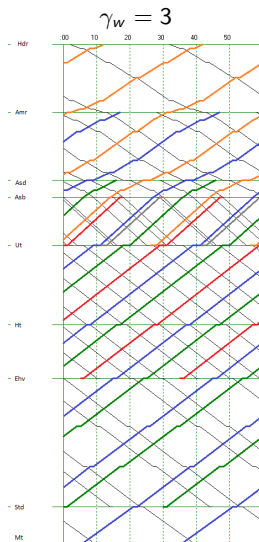
Balancing regularity and efficiency

Balancing regularity and efficiency

$$\gamma_w = 3$$

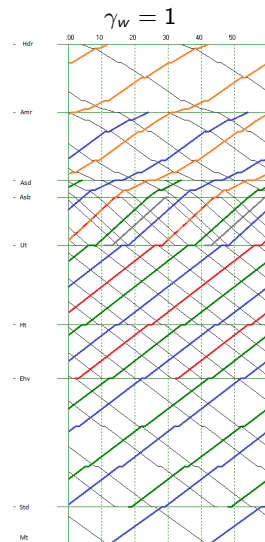
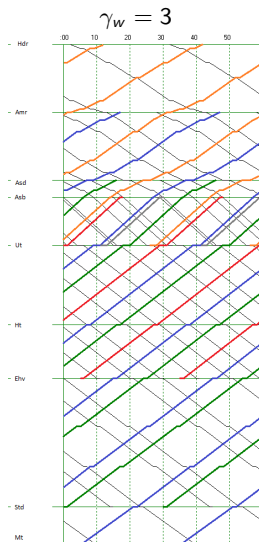
$$\gamma_w = 1$$

Balancing regularity and efficiency



$\gamma_w = 1$

Balancing regularity and efficiency



Summary

- Method to generate strategic timetables
- Provides point on horizon to aim for
- Provides decision support on regularity of trains
- Work in progress: Find a feasible timetable (wrt infrastructure) that is close to computed timetable (with Valentina Cacchiani)