Line Planning in Practice

RobustRailS

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Railway planning

From long to short time horizon:

Railway planning

From long to short time horizon:

- Network design

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- Line planning

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From long to short time horizon:

- Network design
- Line planning
- Timetabling

Railway planning

From long to short time horizon:

- Network design
- Line planning
- Timetabling
- Rolling stock routing
- Crew scheduling

Current Copenhagen S-train Network

- Seven lines
- 85 stations
- 350,000 passengers/day

A Line

- A route through the network
- A stopping pattern
- An hourly frequency
- [A rolling stock type]

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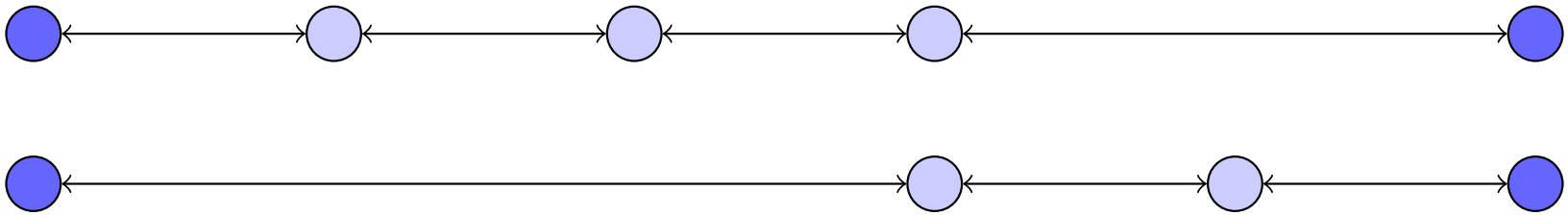


A Line Plan

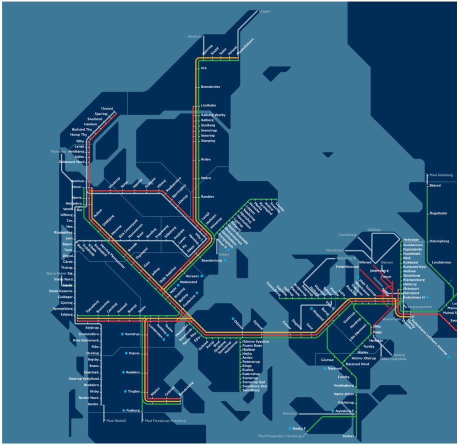
A set of lines that:

- has capacity for all passengers
- meets all operational and contractual requirements
  - min/max train per station per hour
  - max terminating train per station per hour
  - max trains per track per hour
  - minimum direct connections between certain stations per hour
- can be timetabled

Decompose the problem into two

- Generate a pool of potential lines
- Select a valid line plan from the pool

Rest of Denmark



Some considerations

- Operator
- Passenger

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- Operator
  - Operating cost
  - Robustness
  - Quality of service
- Passenger

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- Operator
  - Operating cost
  - Robustness
  - Quality of service
- Passenger
  - Travel time
  - Waiting time
  - Switching time
  - Line frequency

What is possible?

- We can select lines, check they "fit"
- We can estimate operating cost
- We know travel time and can estimate transfer time

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What is an optimal set of lines?

Passenger time

- Travel time is known
- We can count each transfer on each journey
- We can estimate a transfer time based on headways (from frequency)

Passenger Routes

- Don't know where passengers go
- Know 5,000 origin+destination pairs, with demands
- Passenger routes depend on the line plan selected

Modeling aims

First:

- Generate a pool of valid lines

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- Lines
- Frequencies

satisfying all operational, contractual requirements etc.

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Simultaneously:

- Find passenger routes
- Measure passenger ‘cost’

Dependent on:

- The lines present
- The lines’ frequencies

Model

For lines:

$$\sum_{l \in \mathcal{L}} \sum_{f \in \mathcal{F}_l} c_{lf} \cdot y_{lf} \leq c_{\max} \tag{1}$$

$$\sum_{f \in \mathcal{F}_l} y_{lf} \leq 1 \qquad \forall l \in \mathcal{L} \tag{2}$$

$$\sum_{l \in \mathcal{Z}} \sum_{f \in \mathcal{F}_l} f \cdot y_{lf} \geq \alpha(\mathcal{Z}) \qquad \forall \mathcal{Z} \in \mathcal{C} \tag{3}$$

$$\sum_{l \in \mathcal{Z}} \sum_{f \in \mathcal{F}_l} f \cdot y_{lf} \leq \beta(\mathcal{Z}) \qquad \forall \mathcal{Z} \in \mathcal{C} \tag{4}$$

$$\sum_{l \in \mathcal{Z}} \sum_{f \in \mathcal{F}_l} y_{lf} \leq |\mathcal{Z}| - 1 \qquad \forall \mathcal{Z} \in \mathcal{I} \tag{5}$$

$$y_{lf} \in \{0, 1\} \qquad \forall l \in \mathcal{L}, \quad \forall f \in \mathcal{F}_f \tag{6}$$

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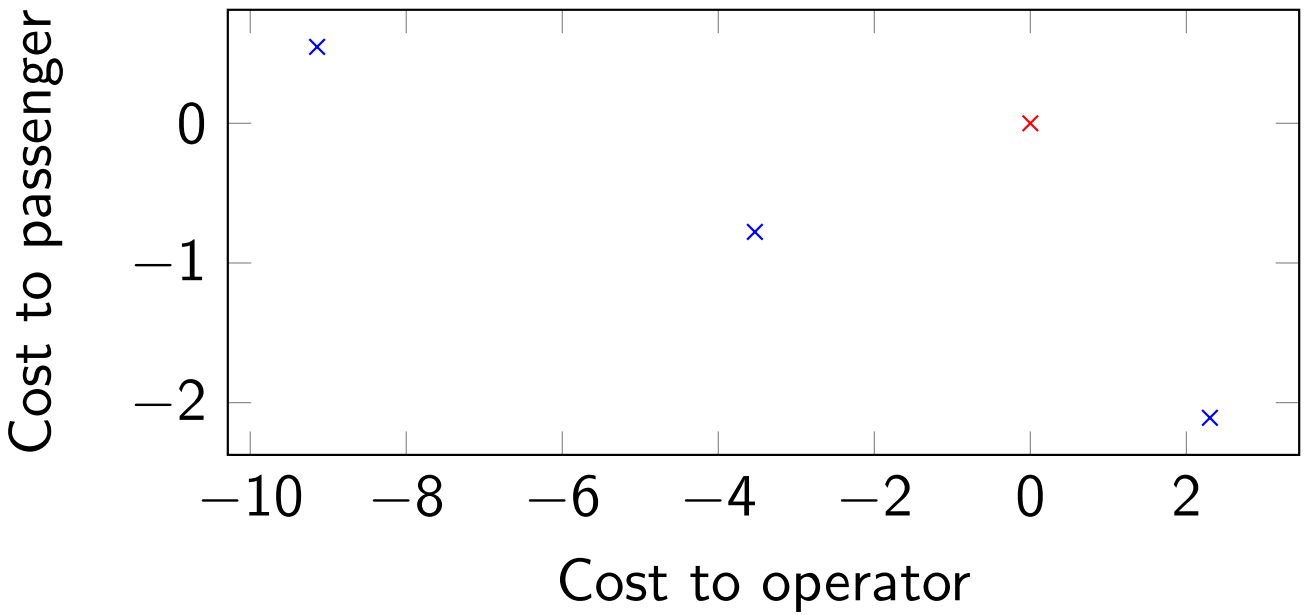
Additionally, passenger routing and linking to line decisions

Some results



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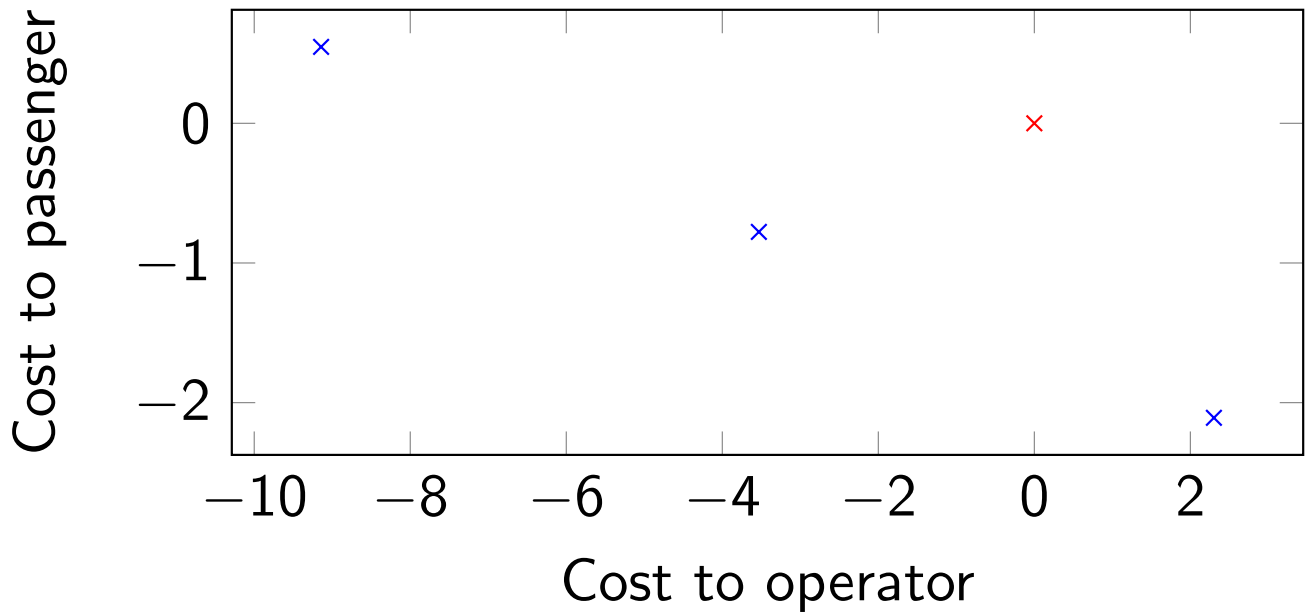

Transfers – more robust for passengers?gity

7% reduction in total passenger transfers, while improving passenger and operating costs

36% reduction in total passenger transfers (!), but increased passenger and operating costs

Questions we can answer

For our fixed line pool

- How can the passenger best be served?
- Could relaxing some lower service levels better serve passengers?
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Looking back to the network design:

- What other lines could improve solutions?
- What if certain stations had more turning capacity?
- What if new track existed?

Final remarks

Limitations:

- We model passenger route choice, but not shifting demand
- We don't include timetabling (only estimate costs and feasibility)

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Future work:

- Further investigate network design possibilities
- More thorough consideration of operator robustness
- Collaboration with Sofie Burggraeve and Pieter Vansteenwegen (KU Leuven)