ROTTERDAM SCHOOL OF MANAGEMENT
ERASMUS UNIVERSITY

ERASMUS CENTER OF OPTIMIZATION IN PUBLIC TRANSPORT

PASSENGER ORIENTED DISRUPTION MANAGEMENT IN RAILWAYS

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OUTLINE

1. Introduction
2. Problem definition
3. Mathematical formulation
4. Solution approach
5. Computational results
6. Conclusion

RAILWAY SCHEDULES

In railway operations there are three major schedules

- Timetable
- Rolling stock schedule
- Crew schedule

Problem during operations:

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THE DISRUPTION MANAGEMENT PROCESS

Disruption management includes three major steps

1. Update timetable according to the disruption.
2. Reschedule rolling stock to cover the new timetable.
3. Reschedule crew to operate the rolling stock.

- Must be solved within seconds
- These steps are interdependent but solved separately
- Several iterations of steps 1–3 may be necessary

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PROBLEM DEFINITION

Passenger oriented disruption management

- Bring every passenger as fast (and comfortable) as possible to their destination by:
    - Adapting the rolling stock schedule
    - Adapting the timetable

Problem:

- The railway operator cannot assign passengers to a train
- Passengers reroute themselves

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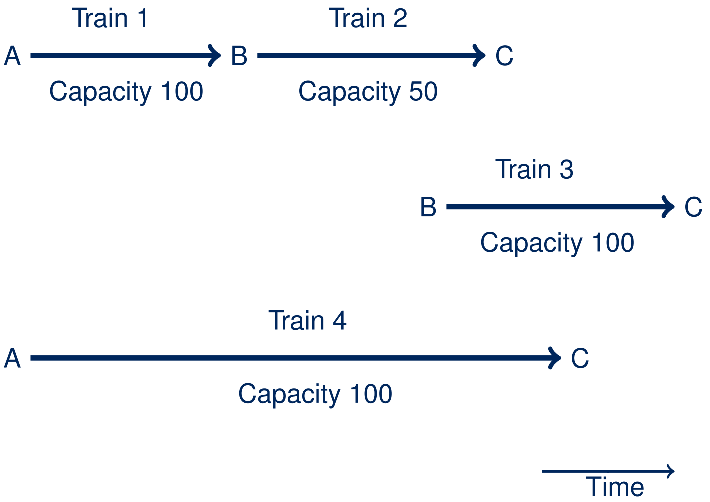
EXAMPLE OF PROBLEM WITH PASSENGER ASSIGNMENT



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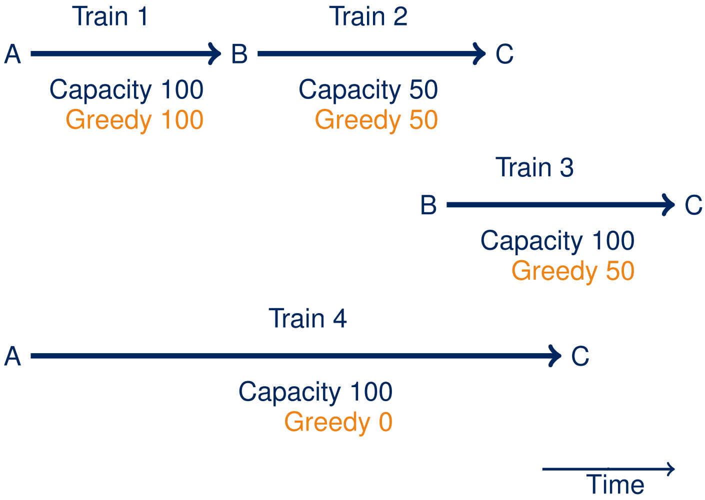


EXAMPLE OF PROBLEM WITH PASSENGER ASSIGNMENT

Train 1: A → B
Capacity 100
Greedy 100
Group opt. 50

Train 2: B → C
Capacity 50
Greedy 50
Group opt. 50

Train 3: B → C
Capacity 100
Greedy 50
Group opt. 0

Train 4: A → C
Capacity 100
Greedy 0
Group opt. 50

Time →

INTEGRATING TIMETABLE AND ROLLING STOCK DECISIONS

Effects of the disruption on passengers

- Passenger flows have changed by the disruption
- Excess demand on the alternative routes
- Capacity on the alternative routes must be increased

Rolling stock decisions may not be enough, by

- Limited time available
- Limited available rolling stock
- Limitations on shunting possibilities, platform lengths, etc.

INTEGRATING TIMETABLE AND ROLLING STOCK DECISIONS

Solution

- Increase capacity by adapting the timetable
  - Inserting extra train services
  - Rerouting existing trains
  - Additional stops of existing trains

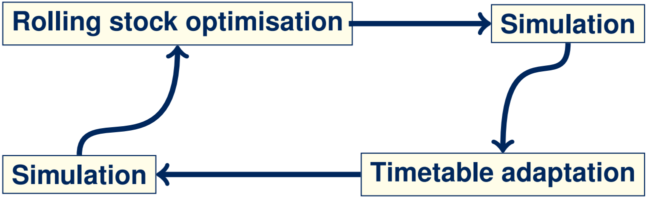
MATHEMATICAL FORMULATION

$$
\begin{aligned}
\min \quad & c(x) + d(y) + e(z) \\
\text{s.t.} \quad & z \in \mathcal{Z} \\
& x \in \mathcal{X}_z \\
& y = f(x, z) \in \mathcal{Y}
\end{aligned}
$$

Where:

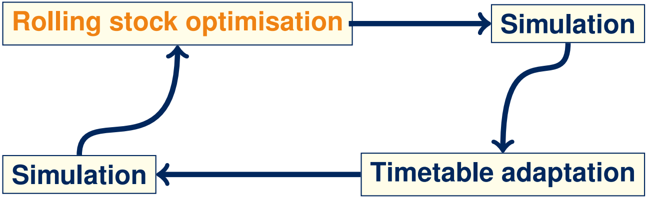
- $\mathcal{Z}$: the set of all possible timetables
- $\mathcal{X}_z$: the set of all possible rolling stock assignments to the timetable z.
- $\mathcal{Y}$: the set of all feasible passenger flows

ITERATIVE PROCEDURE



- Solving the problem in an exact manner is not possible in real-time disruption management
- Iterative procedure to solve the problem
- No guarantee that it converges to the optimal solution

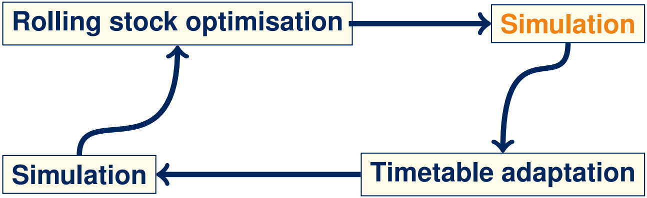
ITERATIVE PROCEDURE



Rolling stock optimisation:

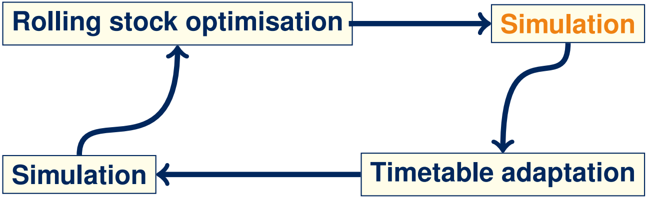
- computes a *rolling stock assignment*
- existing, flexible, well-tested MIP model
- solved in seconds for normal instances
- solved in minutes for *most complex* instances

ITERATIVE PROCEDURE



- Passengers are aggregated into groups
- Passenger groups have a size, departure time, origin, destination and traveling strategy
- Passengers know the complete timetable
- If more passengers will enter the train than there is capacity in it, from every group the same percentage of passengers enters the train.

ITERATIVE PROCEDURE



1. Compute for each passenger group the most preferred (shortest) path in a graph.
2. For each trip (in order of departure time)
   a) Check who have this trip on their path
   b) Check who fit in the train
   c) Recompute the most preferred path for the rejected passengers.

ITERATIVE PROCEDURE

Timetable adaptation:

- Limited to additional stops of intercity trains at regional stations
- Intercity trains normally only stop at large stations

ITERATIVE PROCEDURE

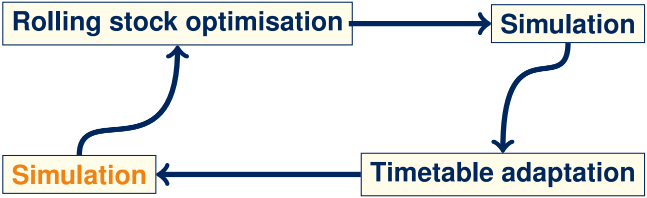
- Positive effects of an additional stop:
  - Passengers to and from the regional station will have shorter travel times.
  - It lowers the demand for the next regional train
- Negative effects of an additional stop:
  - The intercity will get a small delay
  - The available capacity for intercity passengers decreases

ITERATIVE PROCEDURE

Idea for timetable adaptation:

- Add one additional stop per iteration
- Test two approaches
  - compute the exact effect of each additional stop
  - approximate the effect of each additional stop
- Add the additional stop which reduces total passenger delay the most

ITERATIVE PROCEDURE



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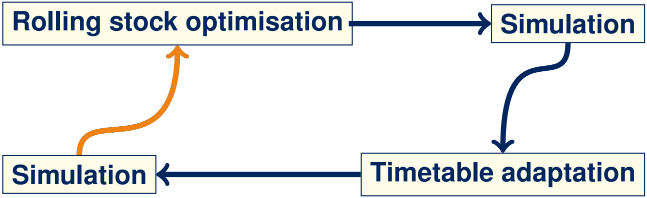


Feedback:

- Update the objective function of the rolling stock optimization
- Compute for each trip the average delay caused by a rejection
- Use this to penalize too low capacities

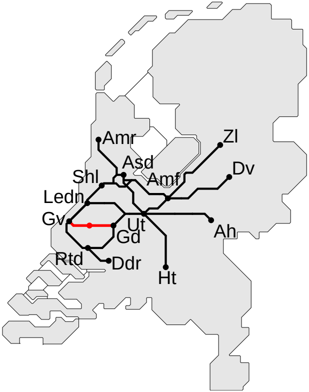
COMPUTATIONAL RESULTS

Realistic test instances

- Part of the Dutch railway network
- 1 day, 3,200 trips
- 4 rolling stock unit types
- 10 allowed composition per trip
- 14,000 passenger groups

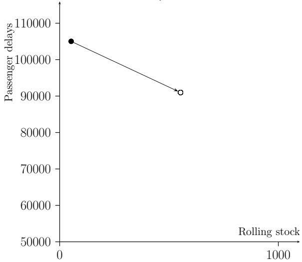
- Reduced #trains on 1 line segment for 3 hours

- MIP model solved by CPLEX 11.0



COMPUTATIONAL RESULTS

ZTM1 without additional stops



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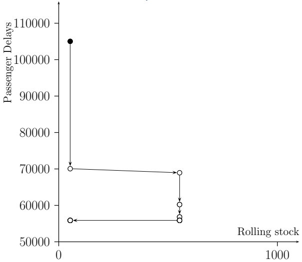
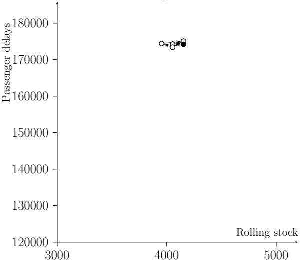
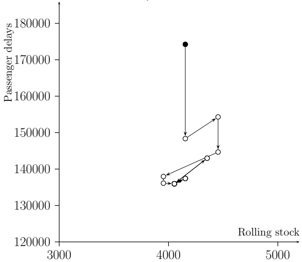


ZTM2 without additional stops



ZTM2 with additional stops



CONCLUSION AND FURTHER RESEARCH

- Preliminary computational results seem promising
- We want to extend the approach with more timetable changes and on a more detailed level
- We are interested in the integration of our approach with delay management
- We have to look at the robustness of the system

THANKS FOR YOUR ATTENTION

Questions/Remarks?