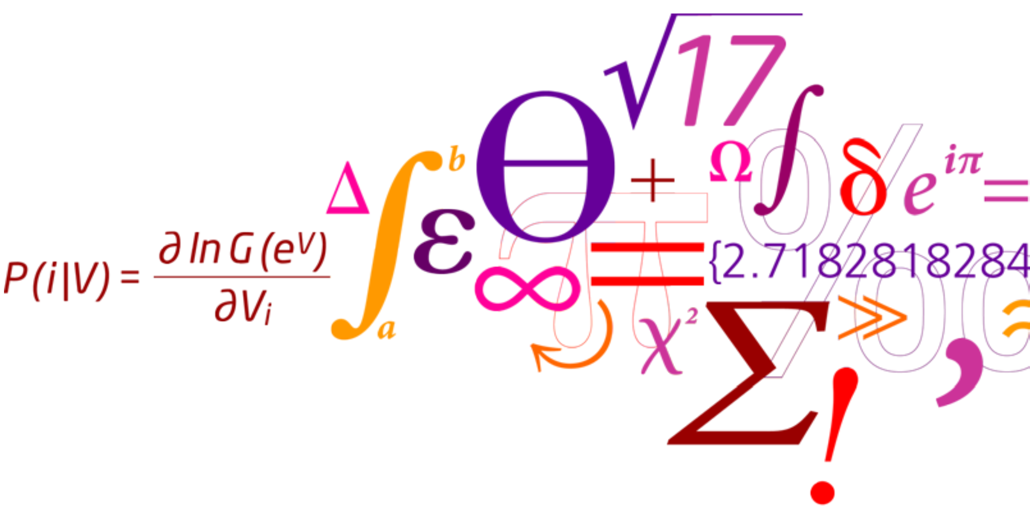
DTU

Assessment of robust capacity utilisation in railway networks

Lars Wittrup Jensen

RobustRailS Mini Conference 2015



RobustRailS

DTU Transport
Department of Transport

Agenda

1) Introduction to WP 3.1 and PhD project
2) Model for measuring capacity consumption in railway networks
   a) Motivation
   b) Deterministic method
   c) Stochastic method
   d) Case
   e) Excluding undesirable sequences

Work package (and PhD) scope

- RobustRailS
  - Work package 3.1 on robustness in the railway operational process

- The goal is to develop methods to improve robustness of railway timetables/operation

- PhD project: **Robustness indicators and capacity models for railway networks**
  - Robustness indicators

  - Model for measuring capacity consumption in railway networks
    - Extension: measure capacity (as trains over a given time period)

Work on robustness indicators

- Can robustness indicators be used in early planning phases and mathematical models instead of simulation which is time consuming?
- Identification and development of robustness indicators
- Comparison with simulation to determine ability to capture robustness
- Some robustness indicators linked well (complexities, UIC406 and train path risk profiles)
  - Some not (heterogeneity)
- Nothing can be concluded about the semantics of indicators

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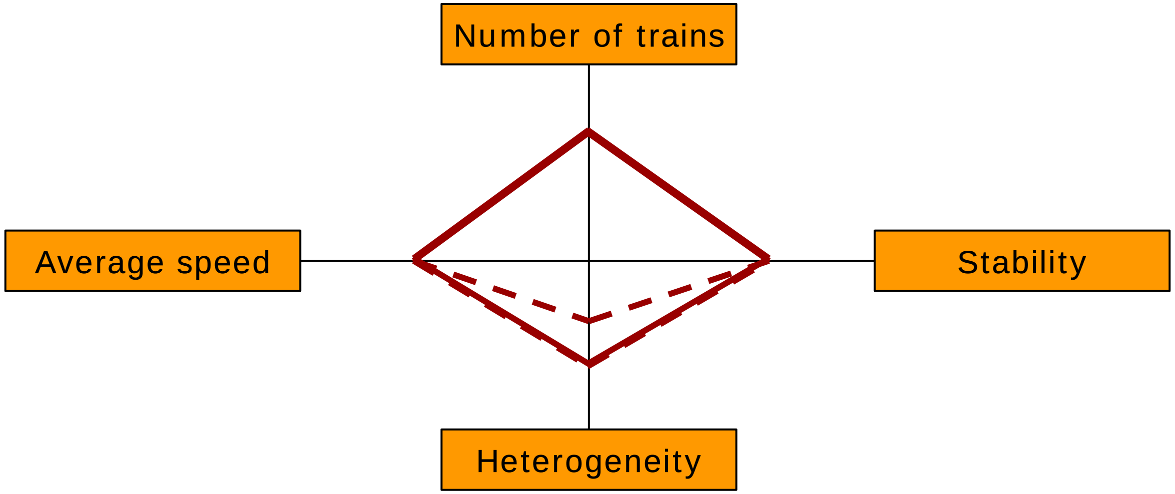
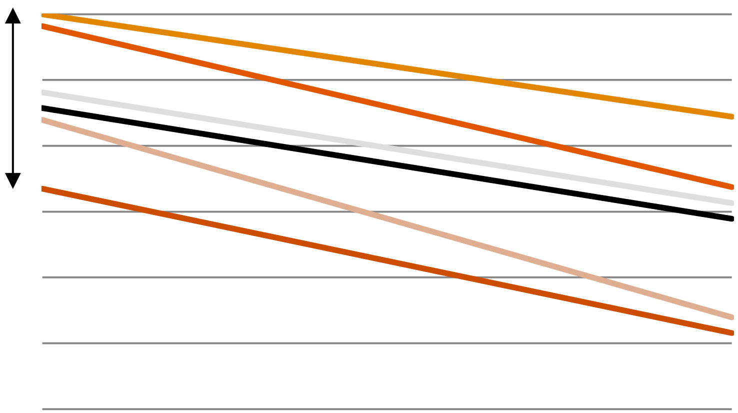
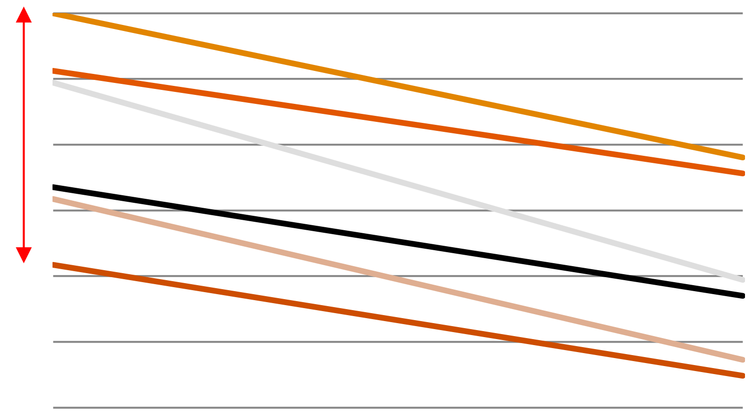
Motivation

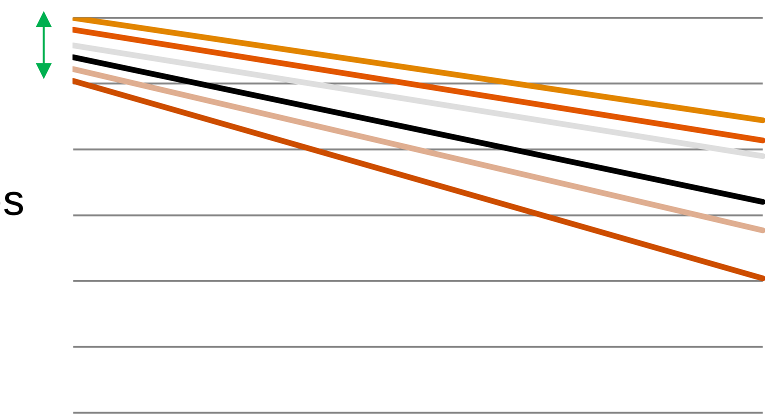
- *What is the capacity consumed by a given set of trains?*
- A timetable is usually needed
- Usually only line sections are assessed (UIC406)
- Aim is to measure capacity consumption of a set of trains in a network
  - Only number of trains, train running times and headways are given
- Calculate the distribution of capacity rather than one single number
  - Deterministic capacity consumption (without delays)
  - Stochastic capacity consumption (with delays)



How to mix trains
- Heterogeneity







- n! for acyclic timetables
- (n-1)! permutations for cyclic timetables
- If more than 1 copy of a train type (k):
  - $n!/(k_1!k_2!...k_m!)$ (Multinomial coefficient)
- 16 trains (cyclic, 16 types)
  - 1.3 trillion permutations (1,307,674,368,000)

Deterministic capacity consumption

Input

- The network
    - Infrastructure
    - Headways
- Train type runs
    - Route
    - Running time
    - Number of each type

Calculate →

Output

- (Distribution of) capacity consumption

Calculate capacity consumption for each (random) permutation

Deterministic capacity consumption

Calculate capacity consumption for each (random) permutation

Loop

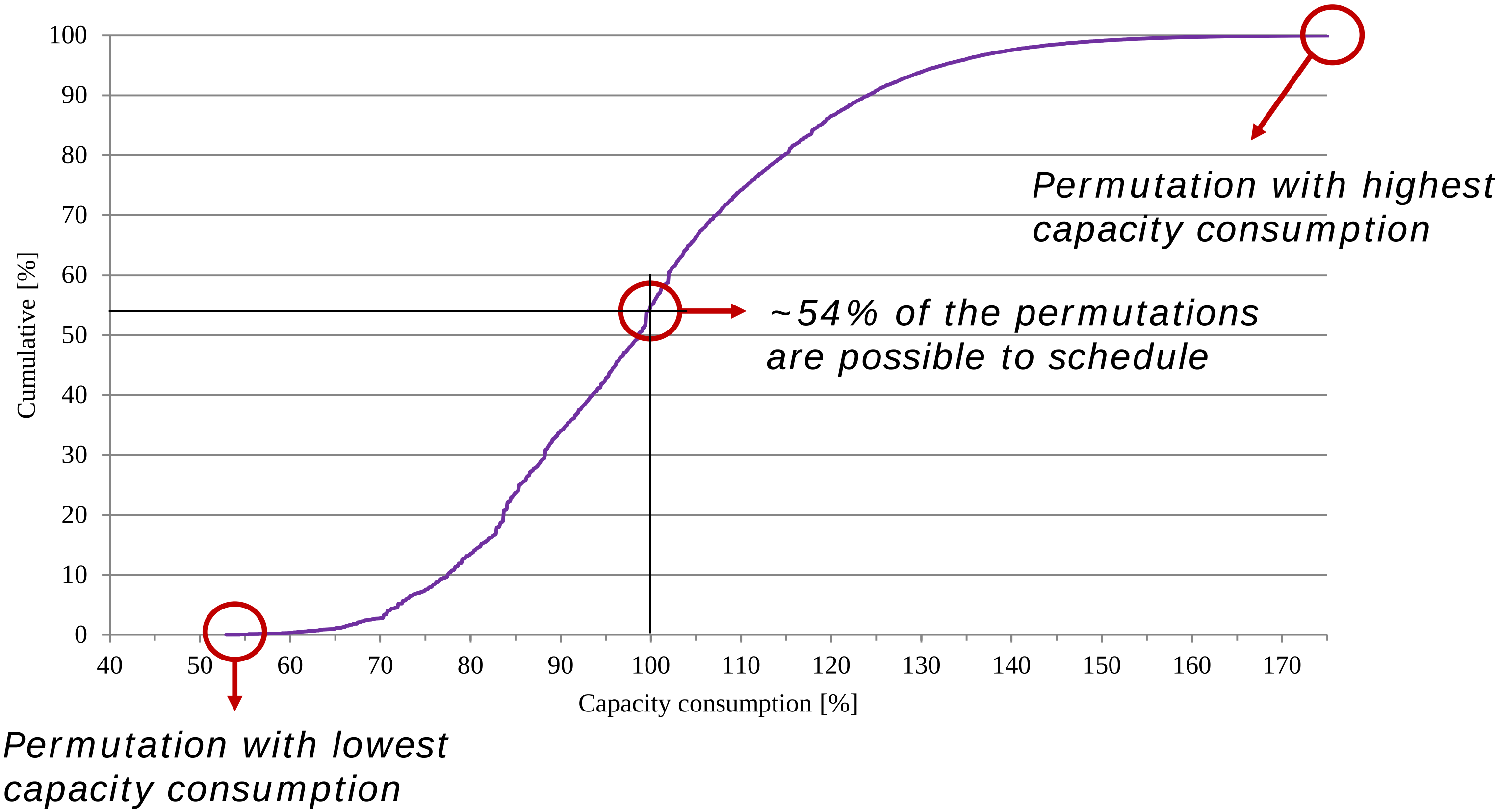
Generate next permutation
- If all, in lexicographic order
- If random, Fisher-Yates shuffle

Find longest path in headway graph

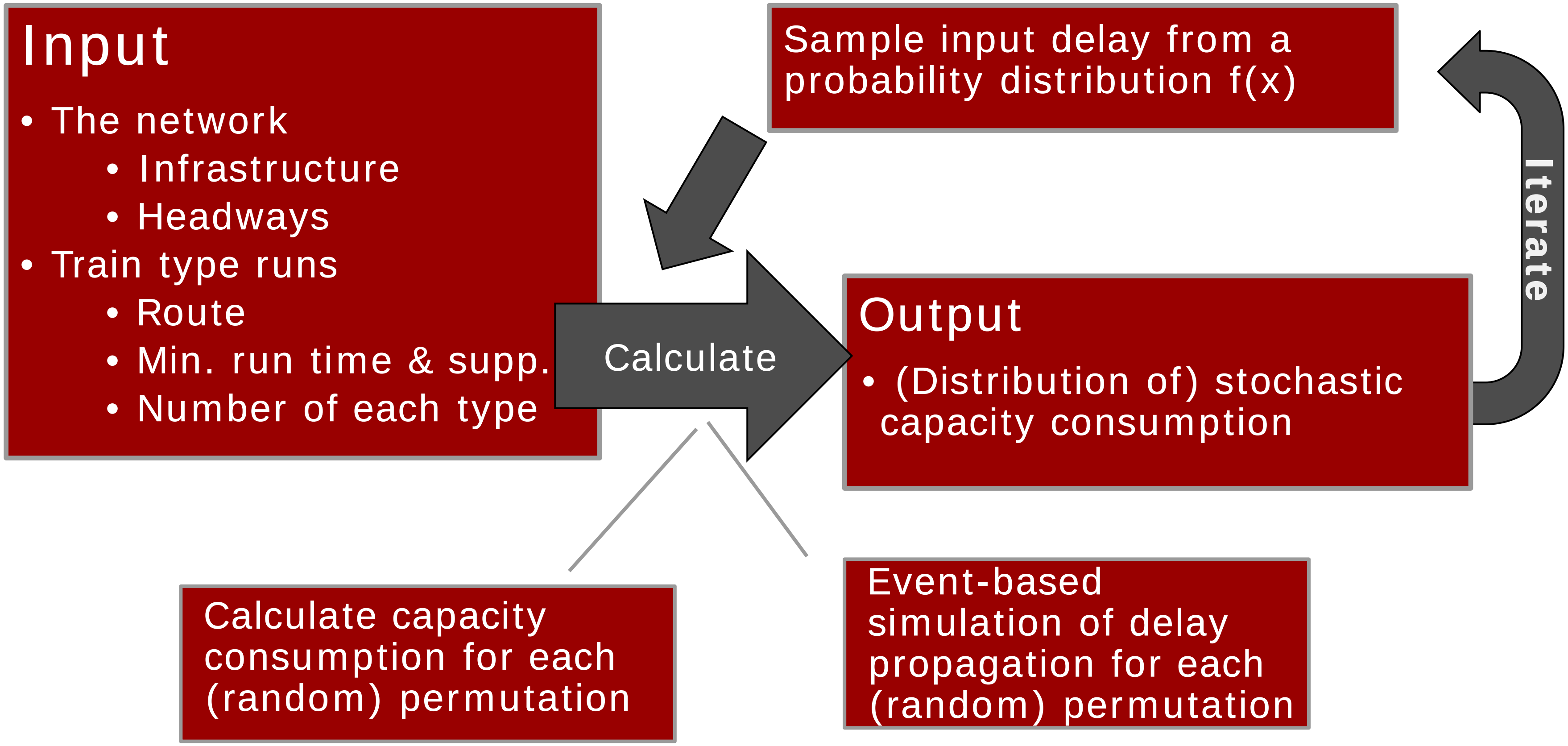
Output, capacity consumption
- If cyclic, (minimum cycle time)/(time period)
- If acyclic,
  (time from start of first to start of last)/(time period)

Deterministic capacity consumption

- Output
  - Cumulative distribution of capacity consumption

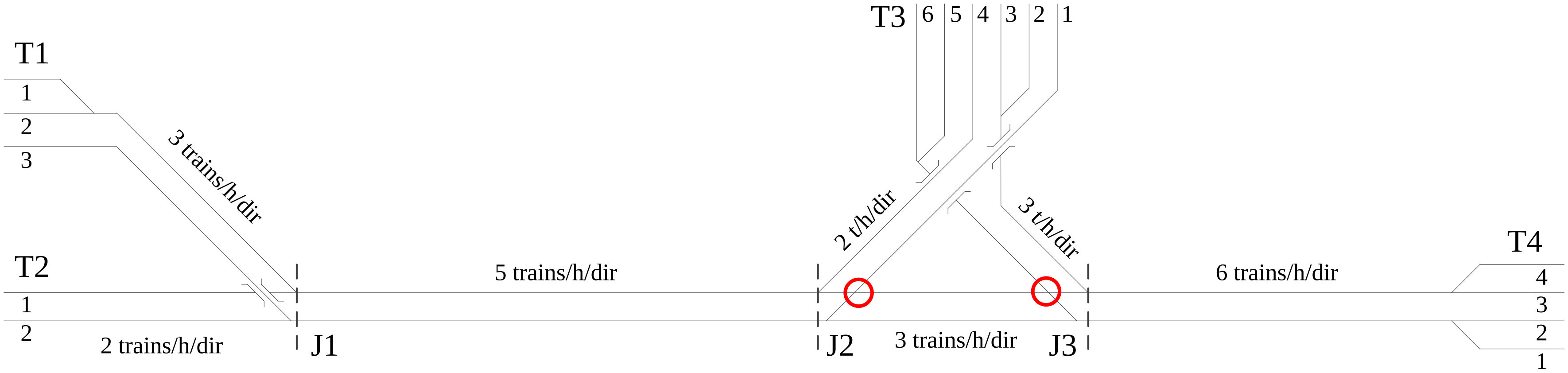


Stochastic capacity consumption



Case

- 16 trains (1 ICE, 2 IC, 2+1 regional & 2 freight per direction)
- Mesoscopic network (feasibility can be ensured by microscopic input data)
- Scenarios:
  - Base: J2 & J3 at-grade junctions
  - J2 upgraded (to out-of-grade)
  - J3 upgraded
  - J2 & J3 upgraded
- Entrance delays at T1-T4 and delays at stops
  - Weibull distributed truncated at 10 minutes (no rescheduling)

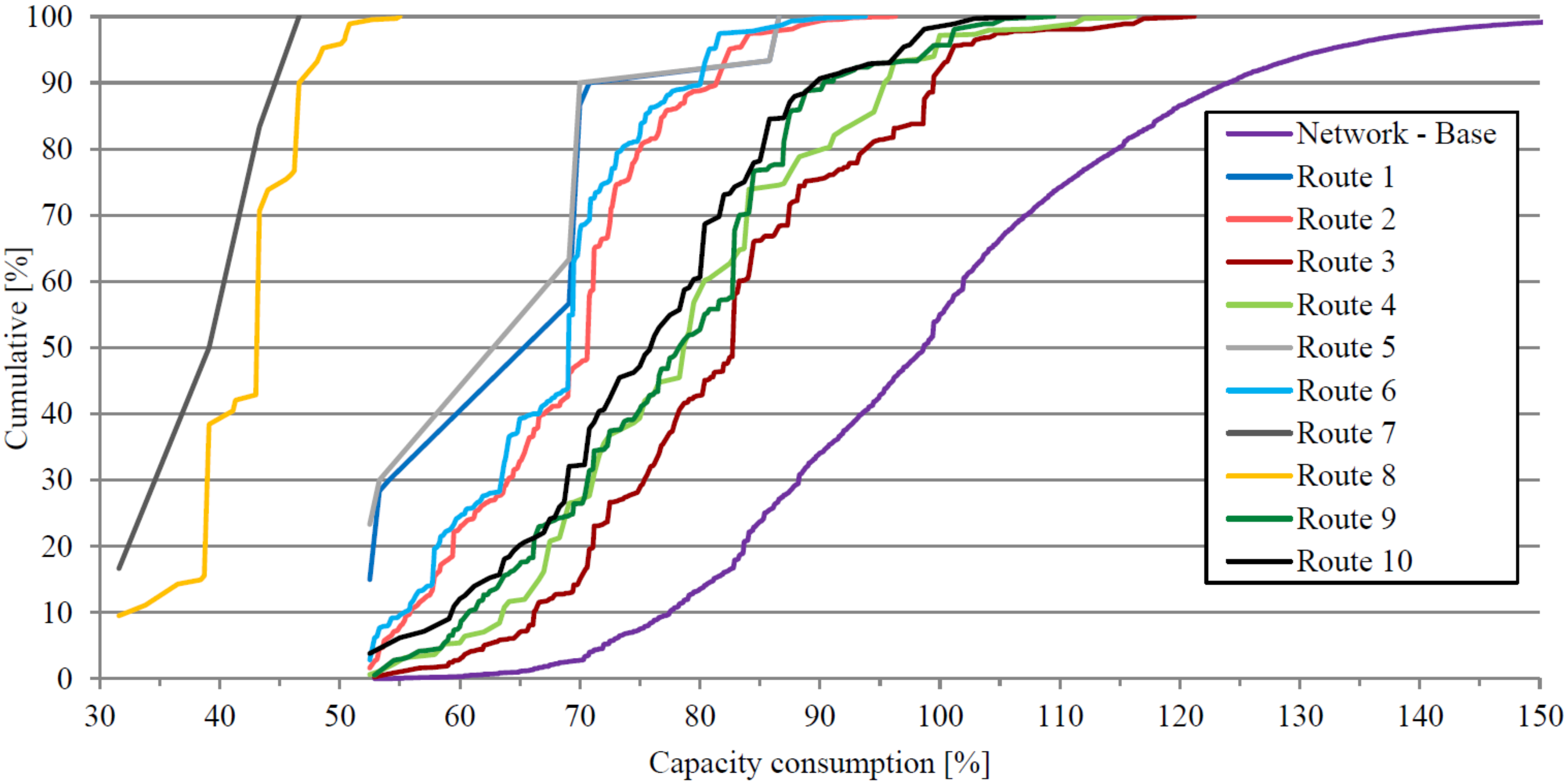


Computational characteristics and results

- Sample of ~13 mil. permutations
- 60 iterations for stochastic simulation
- 12 seconds computation time for deterministic calculation (whole network)
- ~30 minutes computation time for stochastic calculation

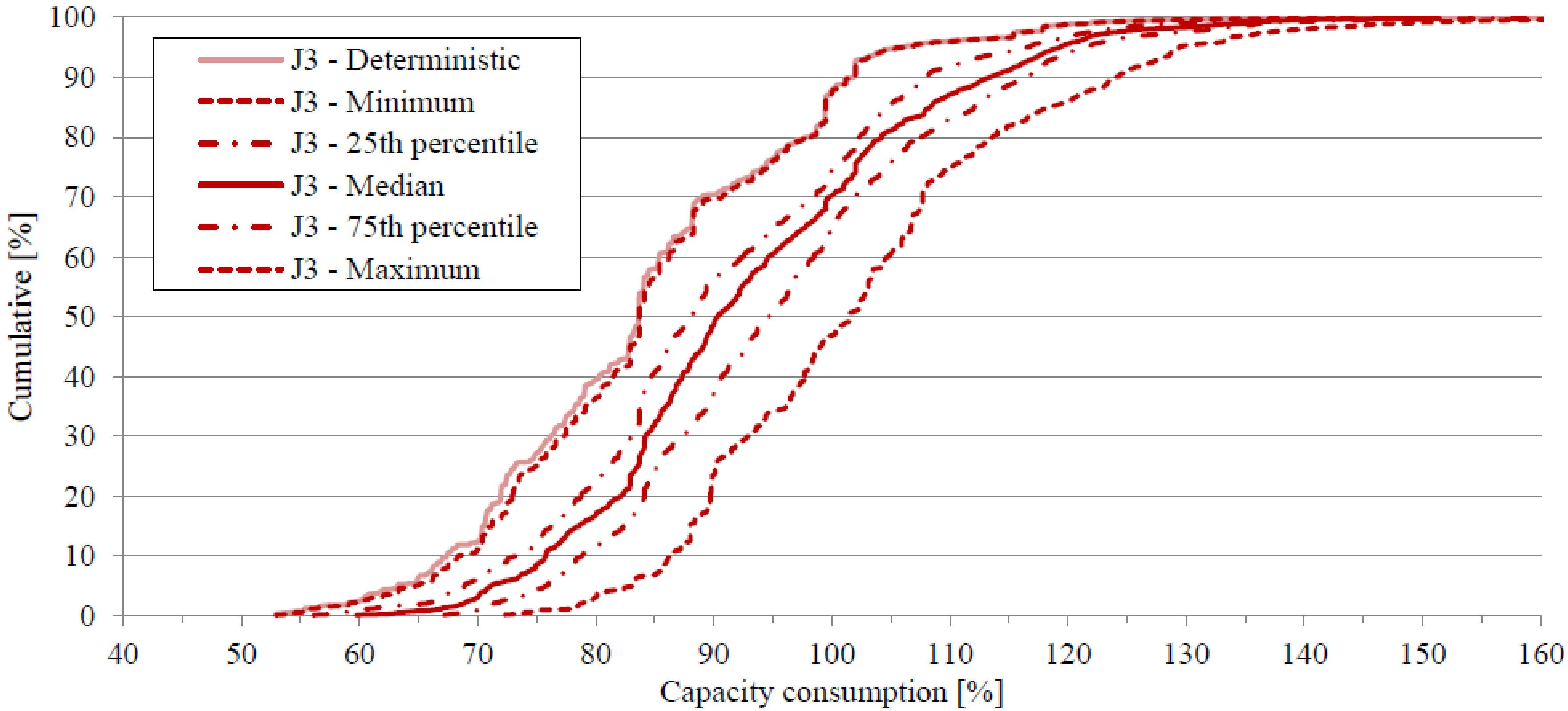
Deterministic results – impact of assessment area

- Route and network capacity consumption



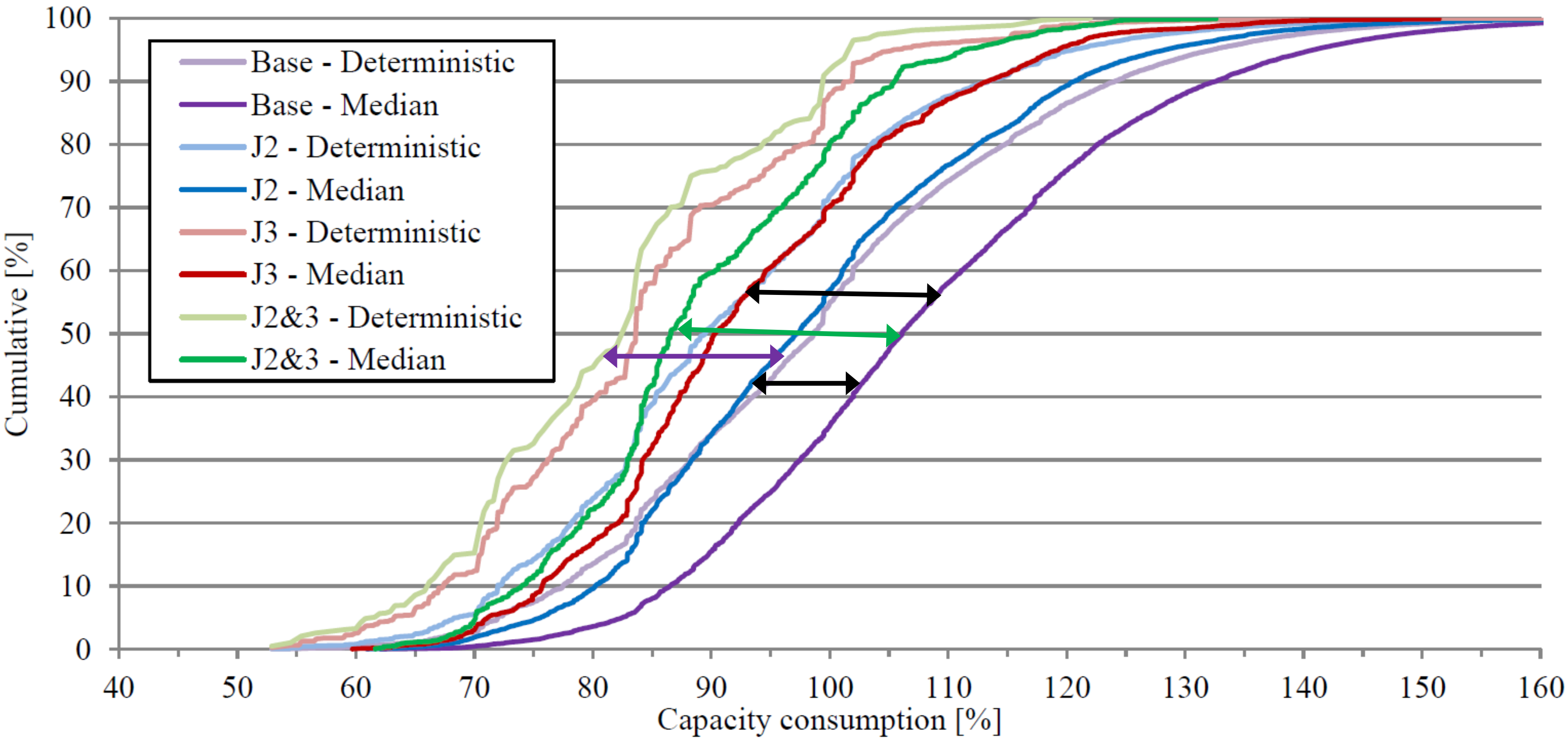
Stochastic results

- Variance of results over all iterations (60)



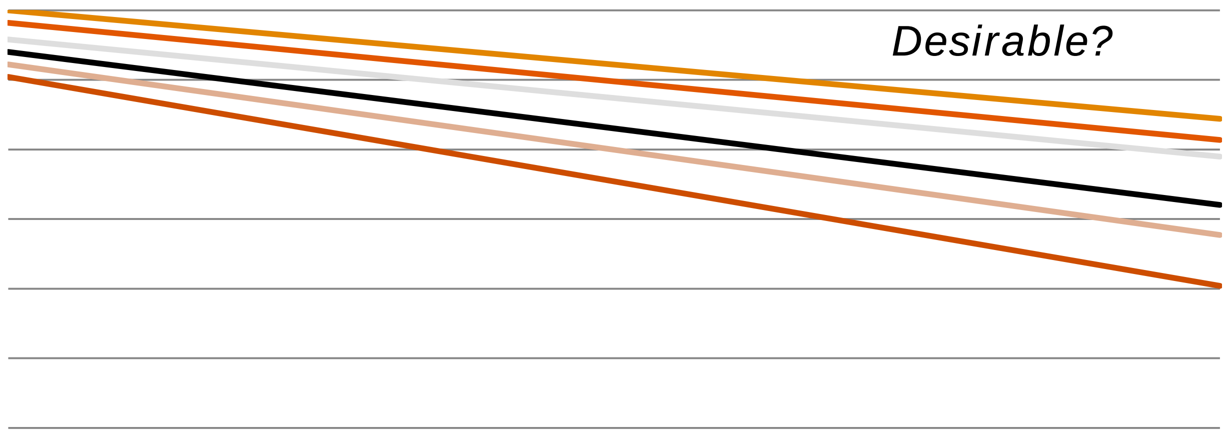
Stochastic results

- Four different scenarios:



Exclusion of certain sequences

Does it make sense to consider all sequences of train runs?



- Exclude “infeasible” train sequences before calculation
  - Using e.g. heterogeneity indicators
  - Exclude certain sequences
    - E.g. all sequence where train A follows train B
  - Use only certain sequences
    - E.g. consider only sequences where train C follows A
    - Can be used to model turn-arounds, couplings and overtakings

Constrain sequences

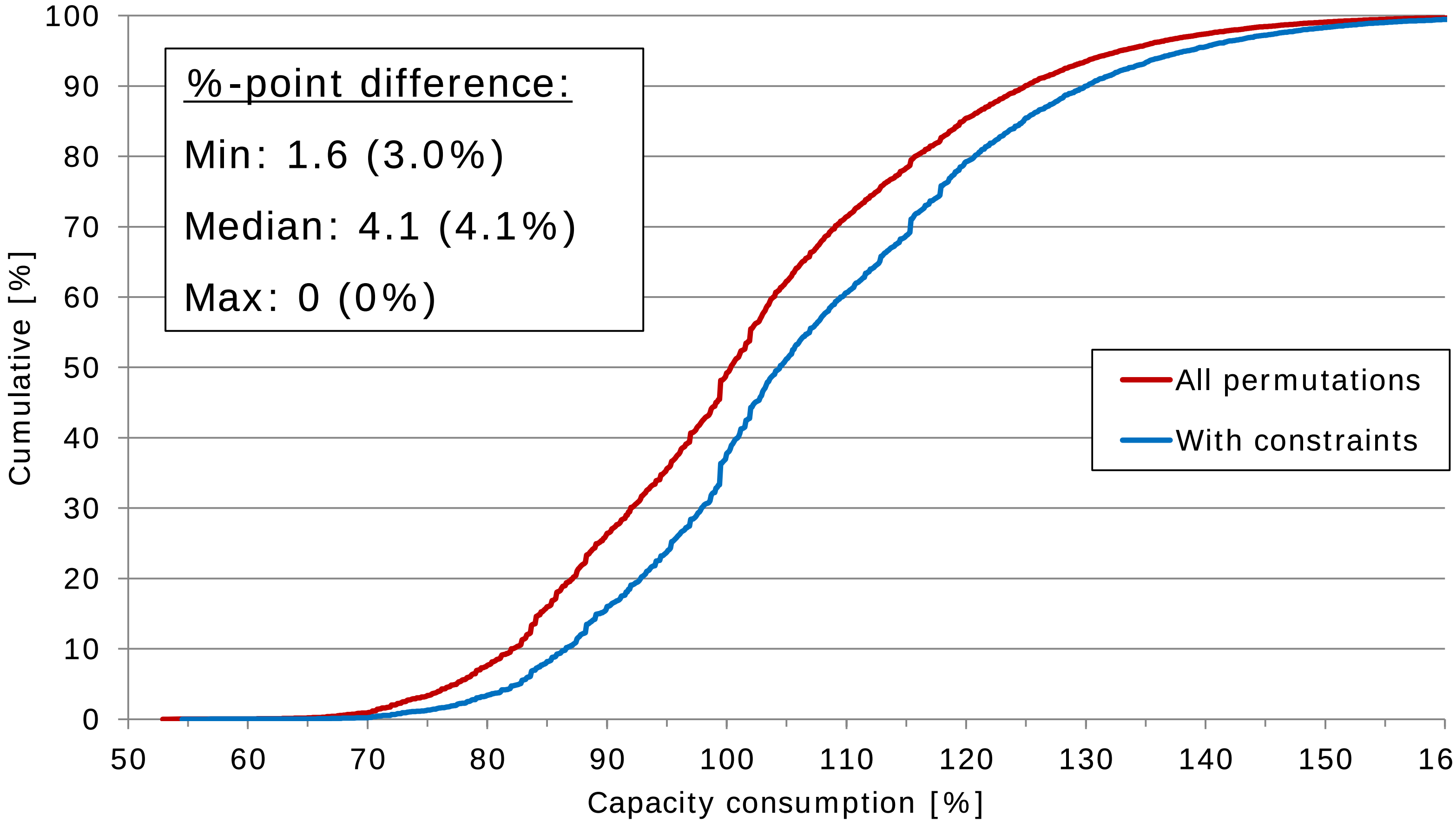
- 2 types:

  1. A < X < B: train type A cannot flow train type B

  2. A < C: train type C must follow train type A

Network capacity consumption results

- Results for constrained vs unconstrained case:



Conclusions

- Model framework developed for capacity consumption assessment in railway networks
  - No timetable needed
  - Possible to account for delays (stochastic assessment)

- Capacity assessment is very much dependent on the size of the network considered

- Improvement (decrease) in network capacity consumption observed in case when some junctions are upgraded
  - Better improvement for stochastic case than in the deterministic case

- Constrain sequences in case
  - Results are shifted to the right (higher capacity consumption)

Thank you for your attention!

Lars Wittrup Jensen
Department of Transport
Technical University of Denmark
lawj@transport.dtu.dk