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KNOWLEDGE IN ACTION

Long-term capacity planning in rail-road networks under demand uncertainty

Thibault Delbart
Prof. Dr. Kris Braekers
Prof. Dr. An Caris

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Research focus

Support logistics service providers in their transition towards synchromodal transport

“Synchromodal transport is **real-time**, **dynamic** and **optimised** intermodal transport” (Ambra et al., 2019)

How?

Research focus

Decision support model to assist capacity decisions under uncertainty

(1) Which capacity?

- Train slots on the long/medium term
- Trucking capacity in the short term

(2) Which uncertainty?

- Demand volume
- Available train slots over time
- Train slot prices over time

Network assumptions

Train services

- Offered by rail operators
- LSPs can book slots between each terminal pair
- Fixed schedules
- Can be booked in advance

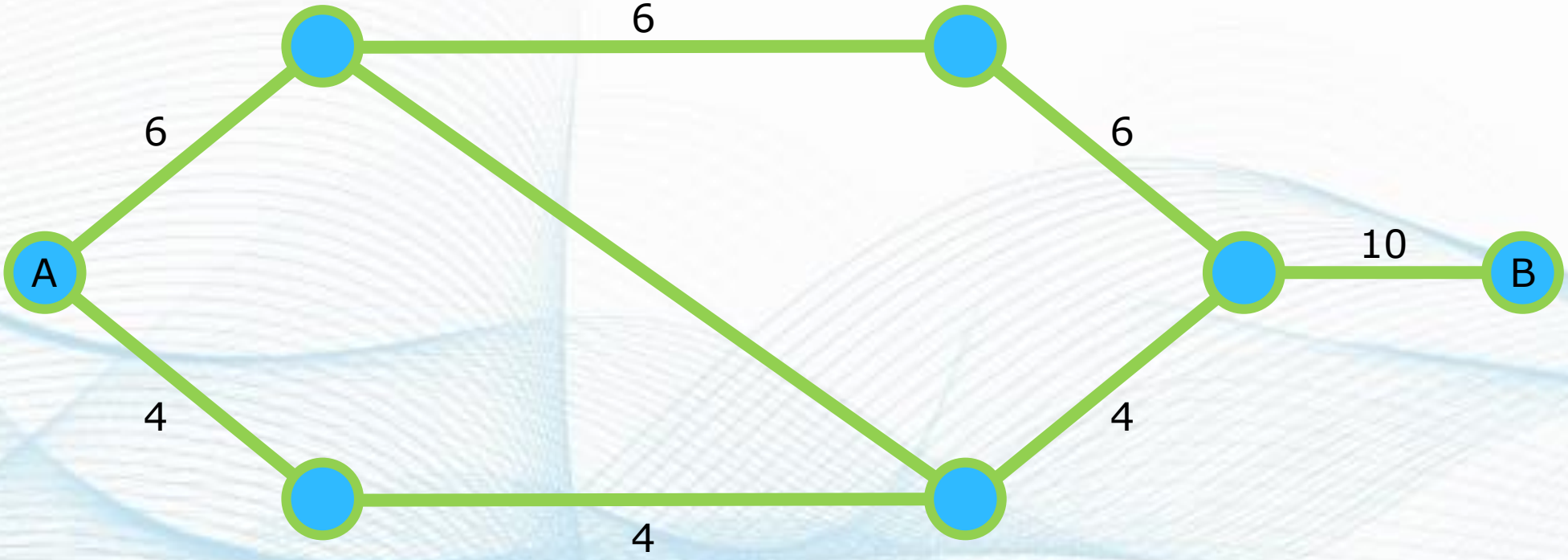
Truck services

- Unlimited number
- More expensive and faster than trains
- Only booked in the short term

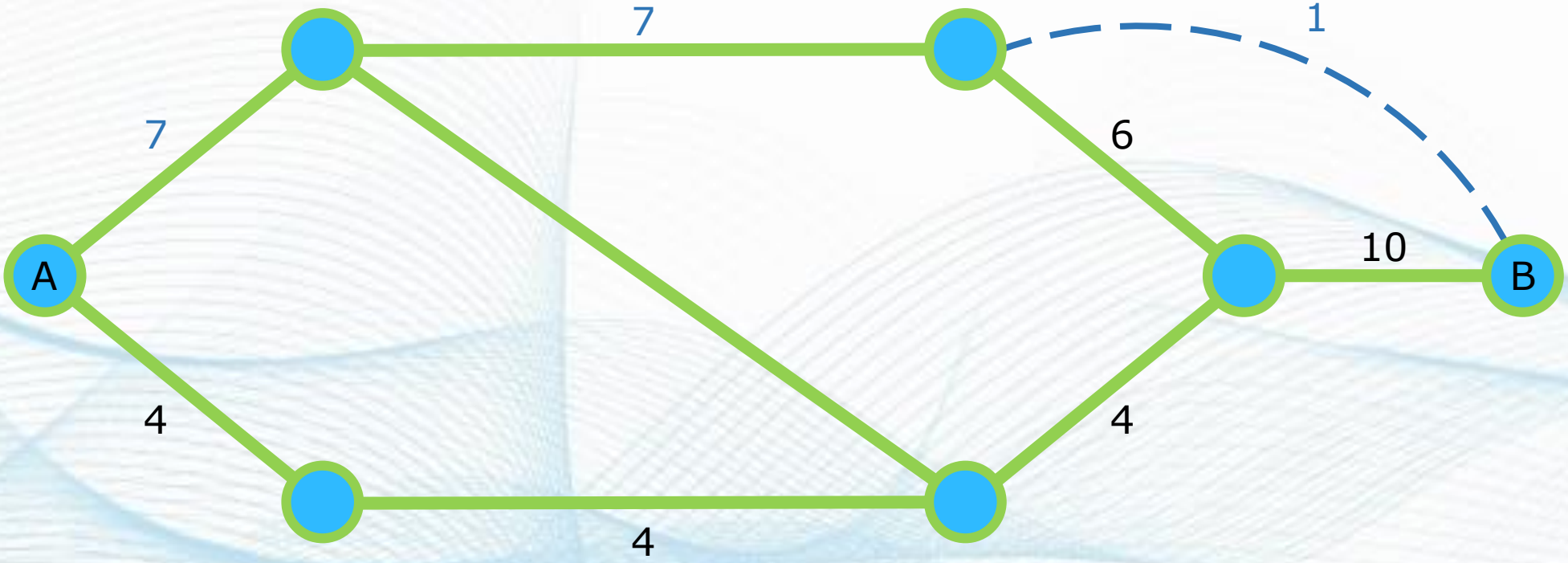
Terminals

- Cost per transhipped container
- Transhipment time

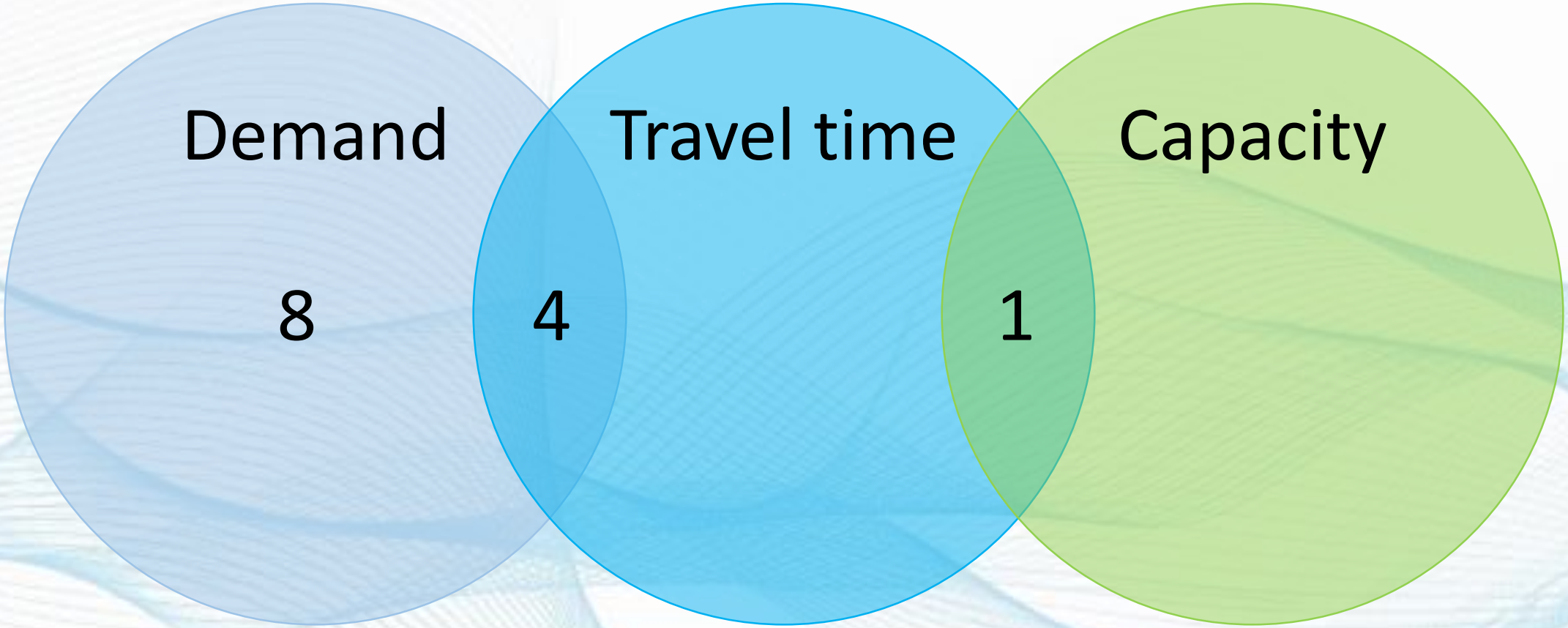
Network example



Network example



Literature results: uncertainty



Literature results: modelling approach

Modelling approach	Capacity and travel time	Demand	Demand and travel time
Chance-constrained mixed integer programming			1
Fuzzy chance-constrained mixed integer programming	1		
Mixed integer linear program		1	1
Simulation optimisation			1
Two-stage chance constrained programming			1
Two-stage robust programming		1	
Two-stage stochastic programming		6	
Total number of studies	**1**	**8**	**4**

Model description

Integer programming model

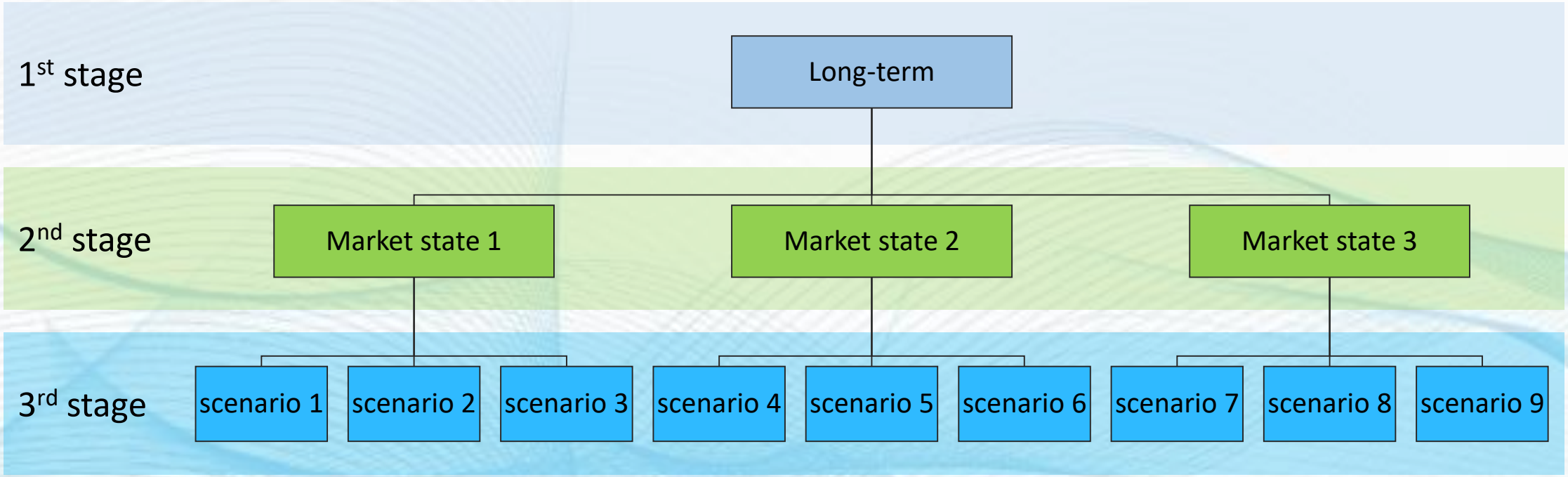
Minimise costs

- Train slots at each stage
- Trucking at the operational stage
- Transhipment

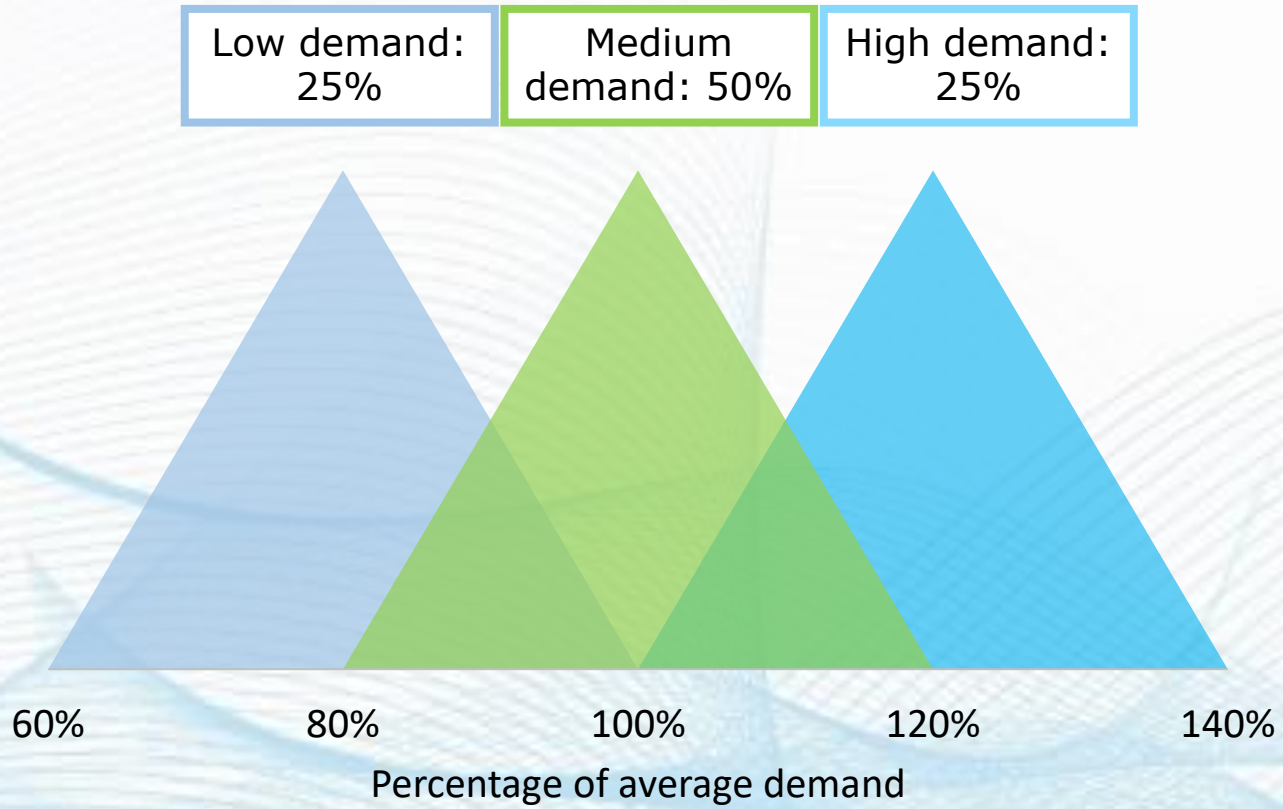
Planning timeline

	First stage	Second stage	Third stage
Decisions	Train slots to book	Train slots to book Train slots to cancel	Train slots to book Train slots to cancel Trucks to book Container routing
New information		Available capacity Improved demand forecasts	Available capacity Demand volume Order sizes Time windows

Scenario tree



Stochastic demand

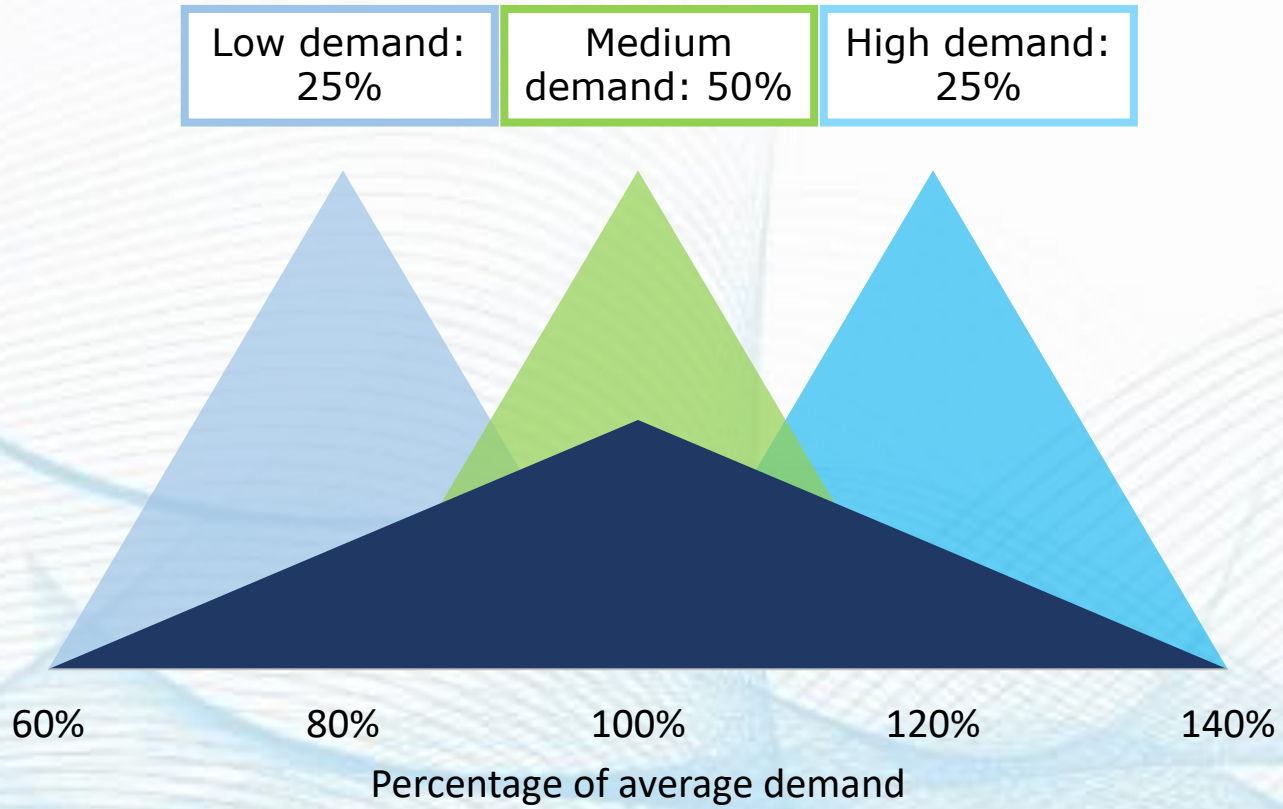


Each terminal pair has its own average demand

2nd stage demand distributions depend on the **total demand in the market**

Each market state has its own probability

Stochastic demand



Each terminal pair has its own average demand

2nd stage demand distributions depend on the **total demand in the market**

Each market state has its own probability

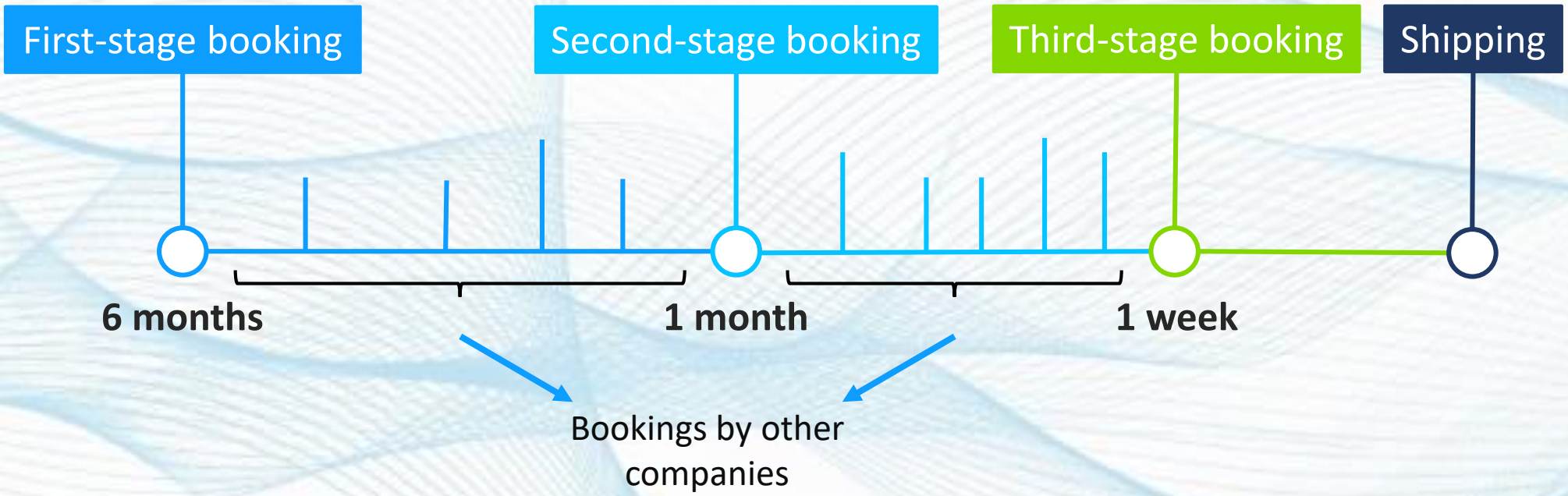
Long-term demand distribution is the weighted sum of the 2nd stage distributions

Stochastic capacity

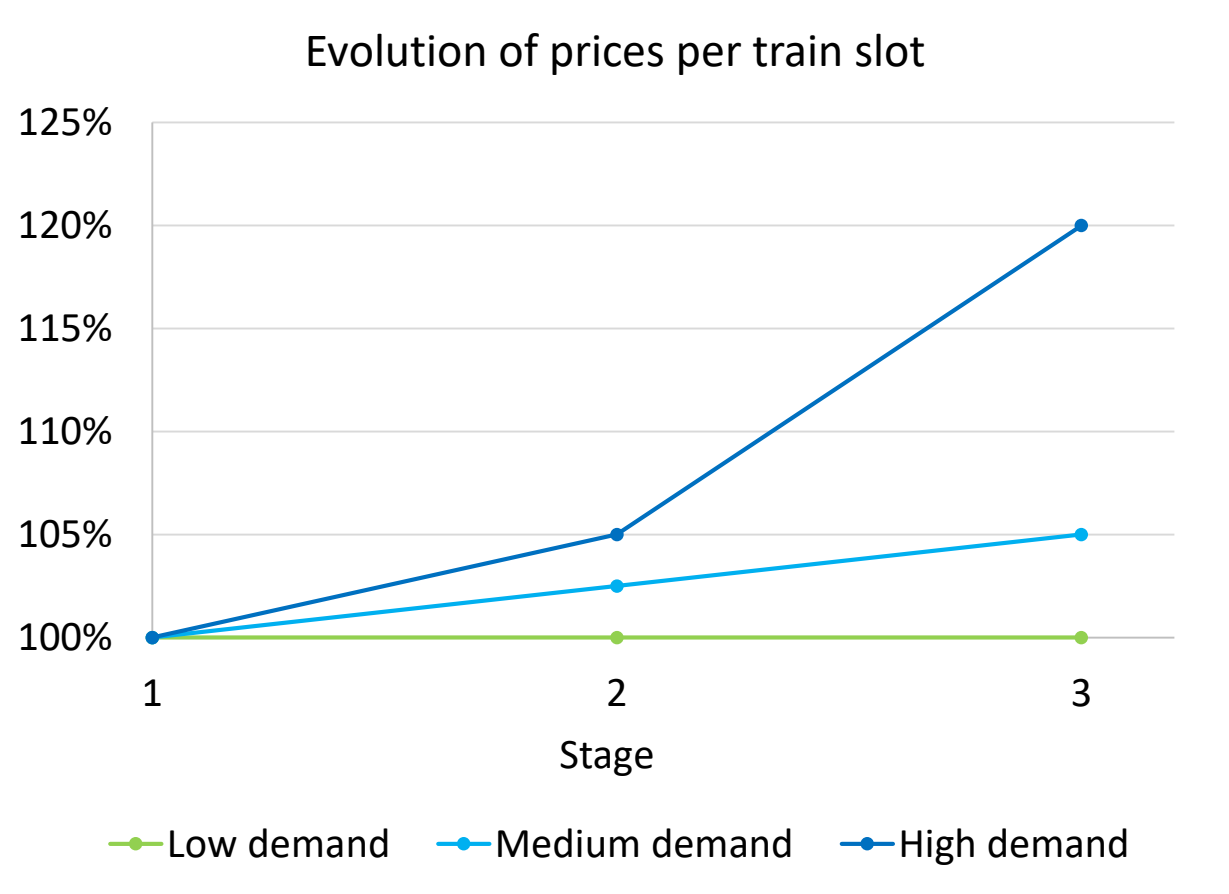
Fixed number of train slots in the first stage

Second and third stages:

- Stochastic capacity decrease per connection
- Distribution mean depends on the market state



Train slot prices



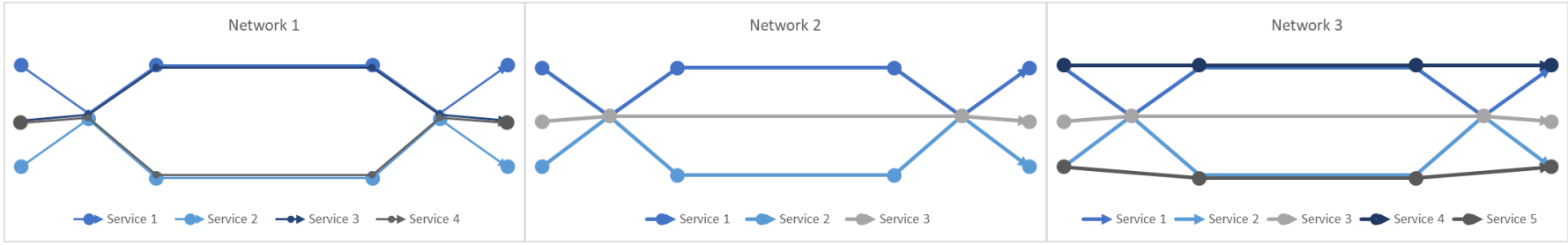
Fixed increase compared to initial prices

Depends on the market state

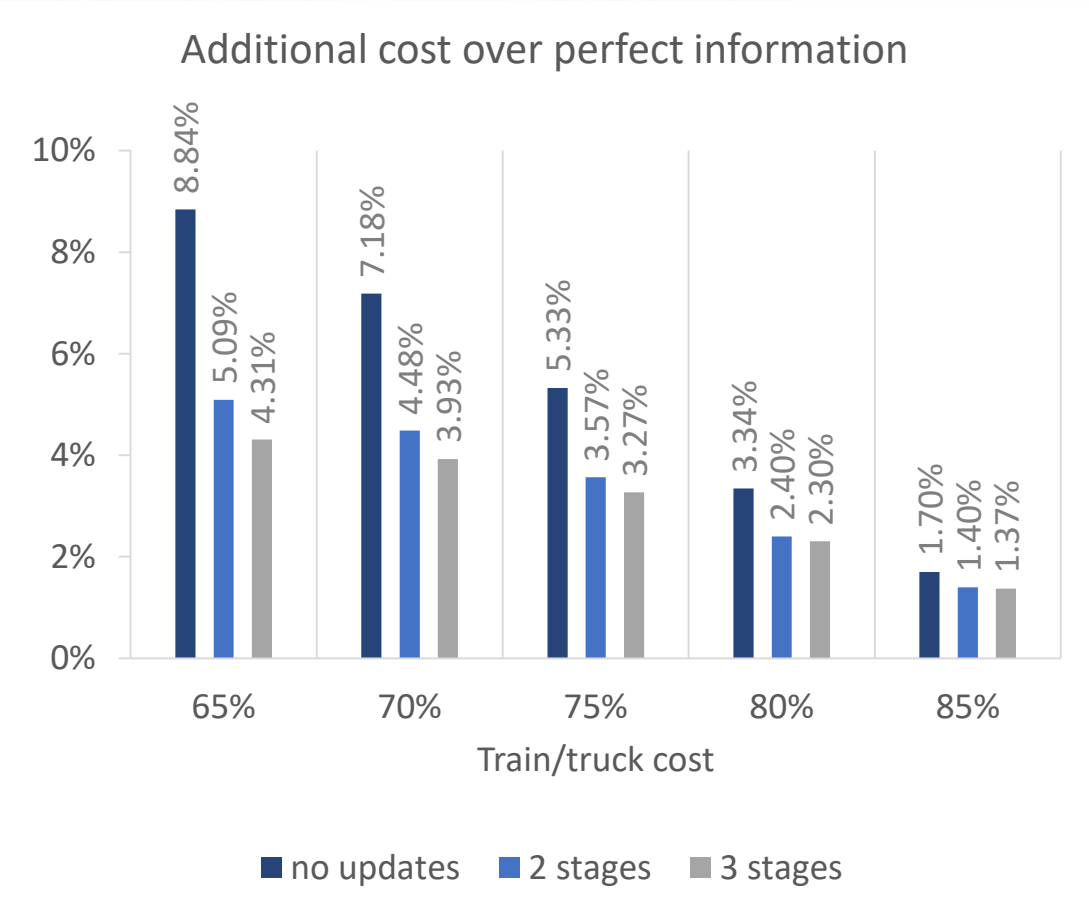
Methodology

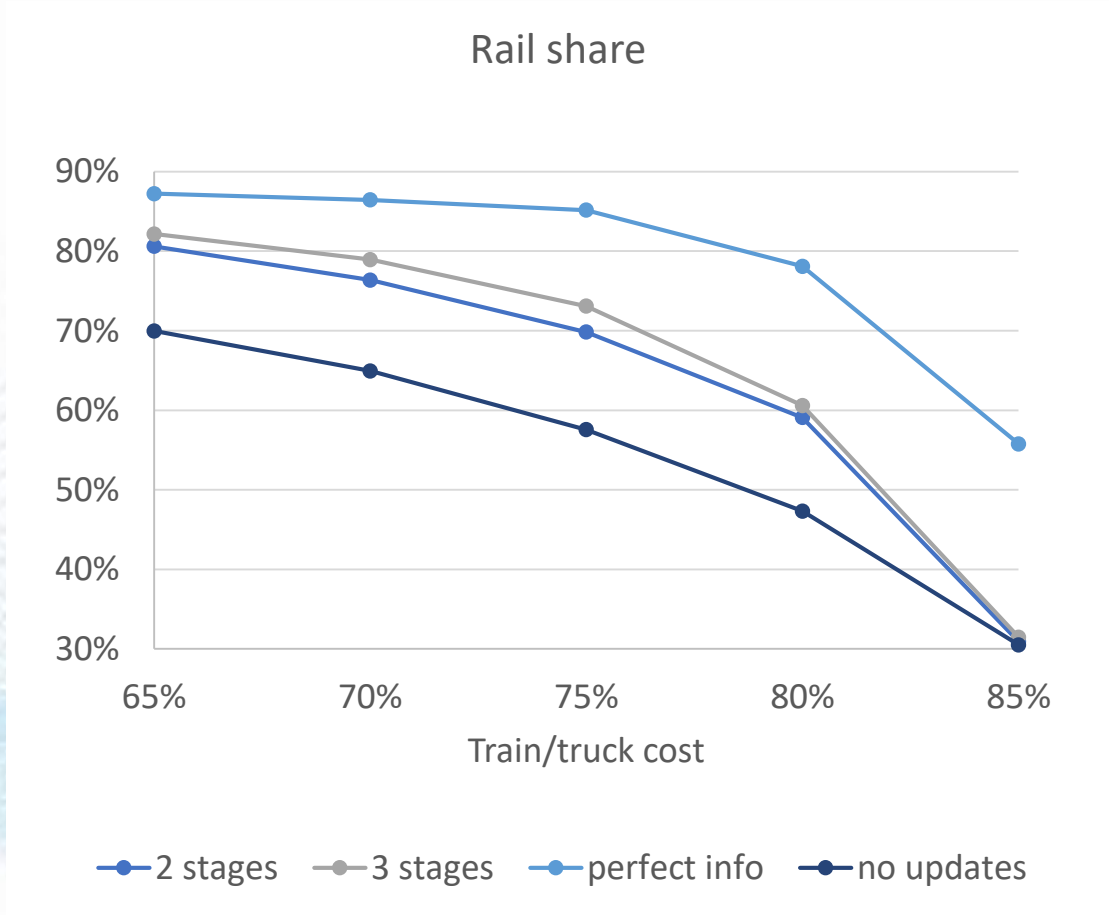
- Exact solver with a time limit and minimum optimality gap
- Factorial design
- Tested models:
  - Three-stage
  - Two-stage
  - Without replanning
  - Perfect information

Factorial design

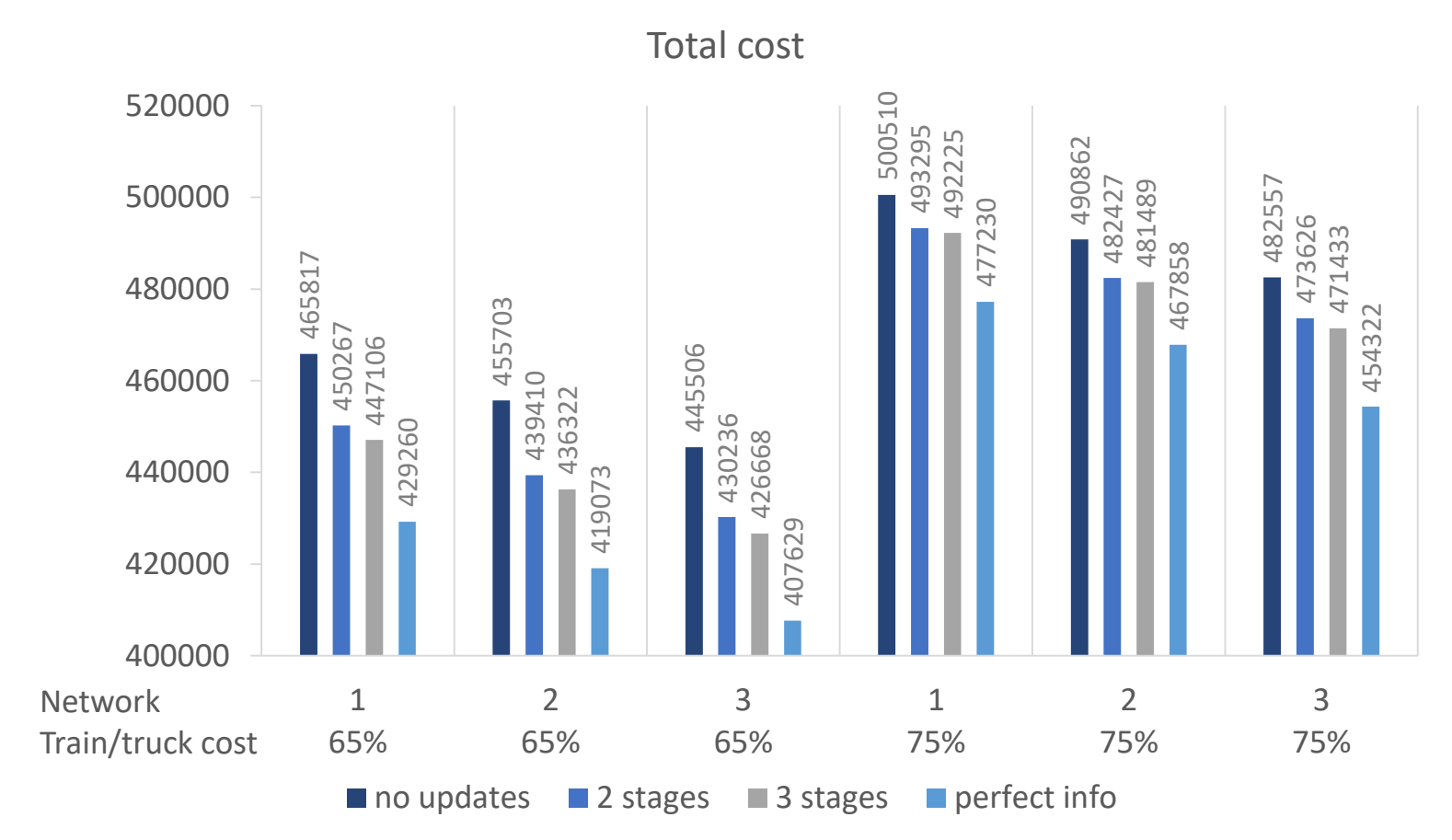
Network					
First-stage train capacity/demand ratio	120%		150%		180%
First-stage train slot prices as % of truck cost	65%	70%	75%	80%	85%
Width of demand distributions as % of average demand	20%		40%		60%
Difference between market state demand volumes as % of average demand	10%		20%		30%

Train cost ratio

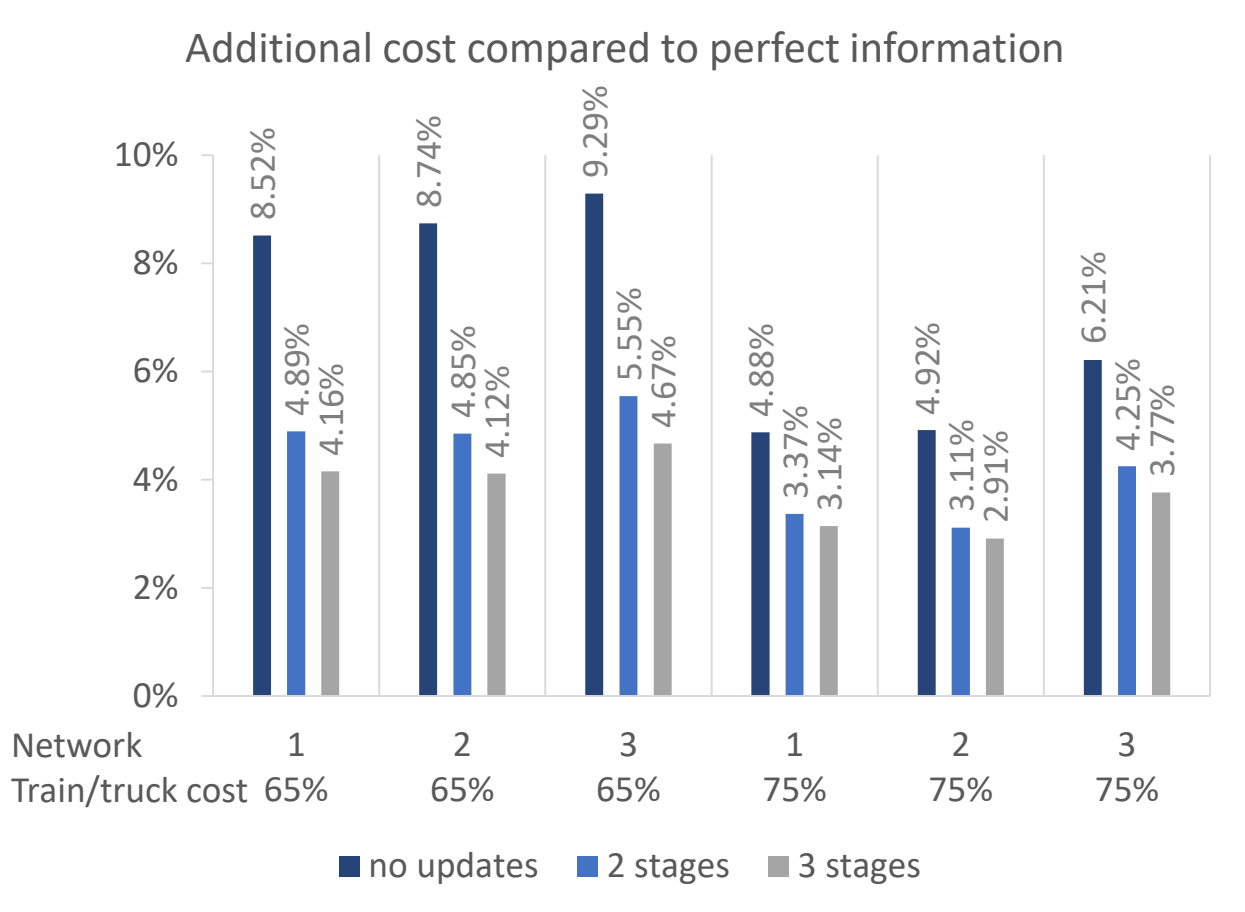


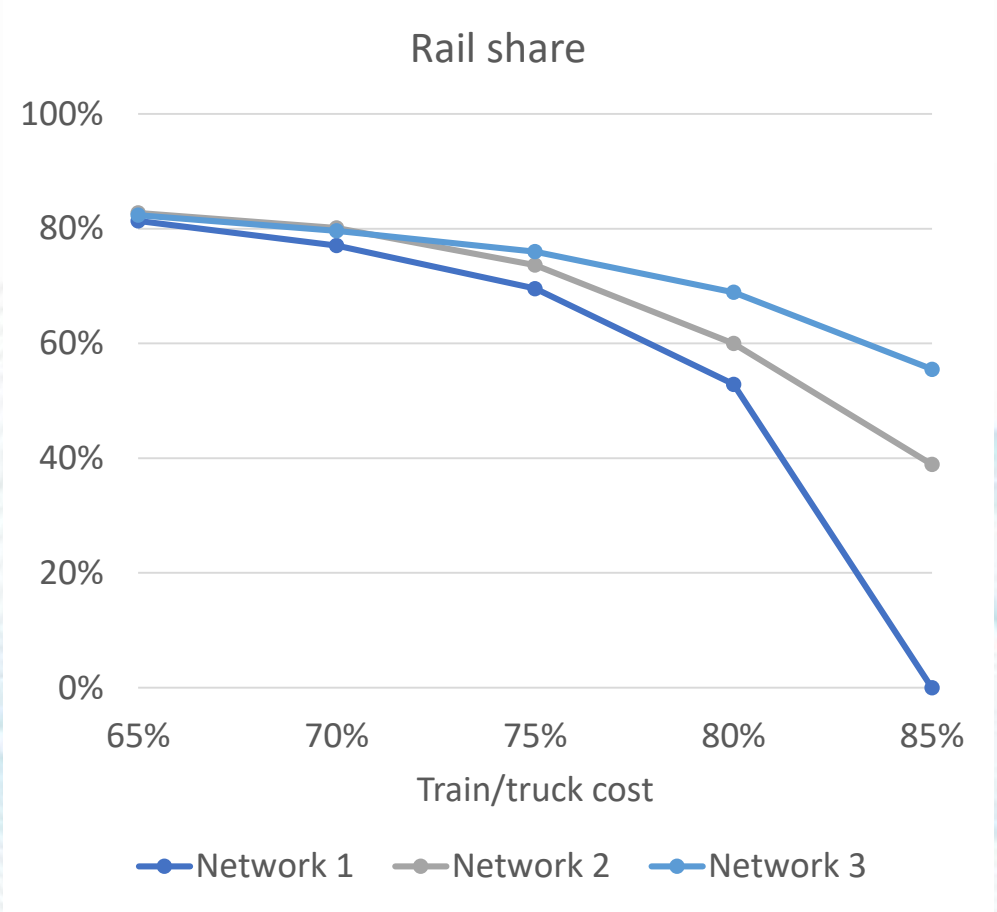


Network

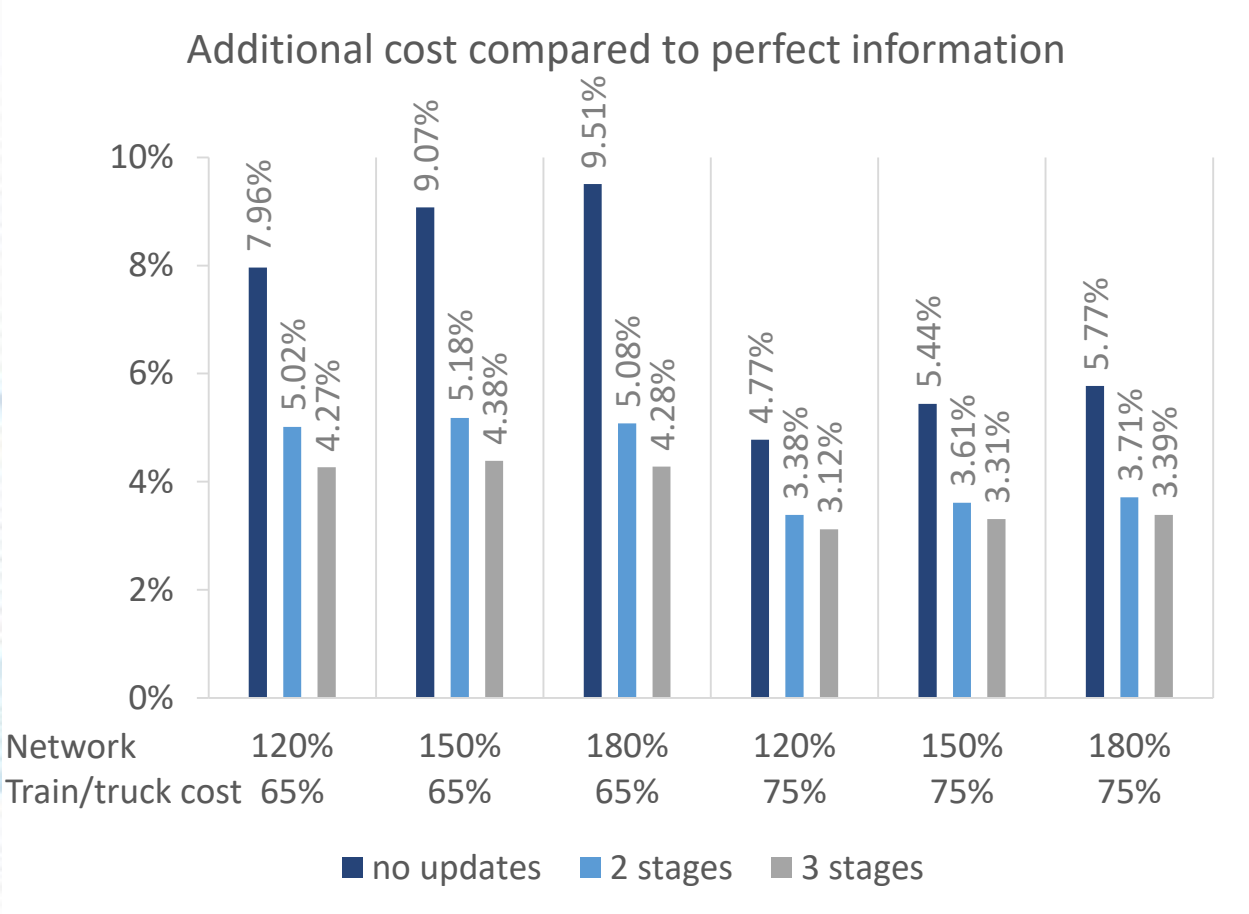

Total cost
520000
500000
480000
460000
440000
420000
400000
465817
450267
447106
429260
455703
439410
436322
419073
445506
430236
426668
407629
500510
493295
492225
477230
490862
482427
481489
467858
482557
473626
471433
454322
Network
1
2
3
1
2
3
Train/truck cost
65%
65%
65%
75%
75%
75%
no updates
2 stages
3 stages
perfect info

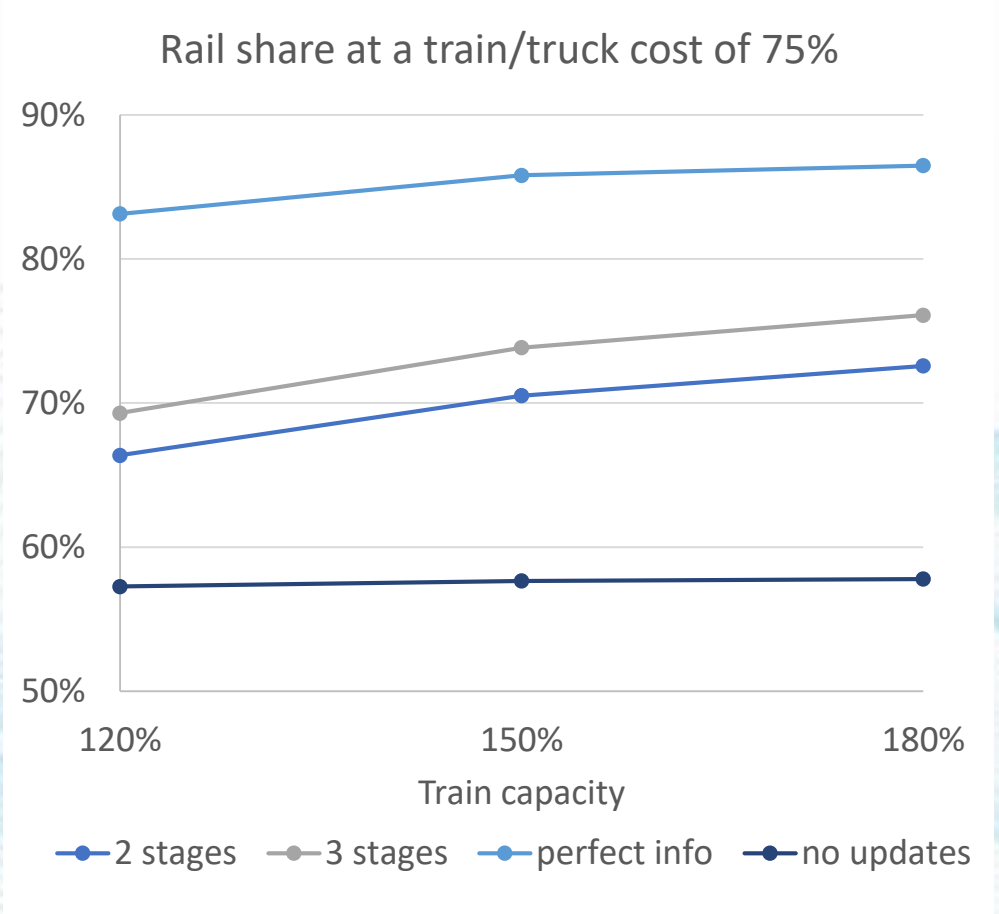
Network - continued





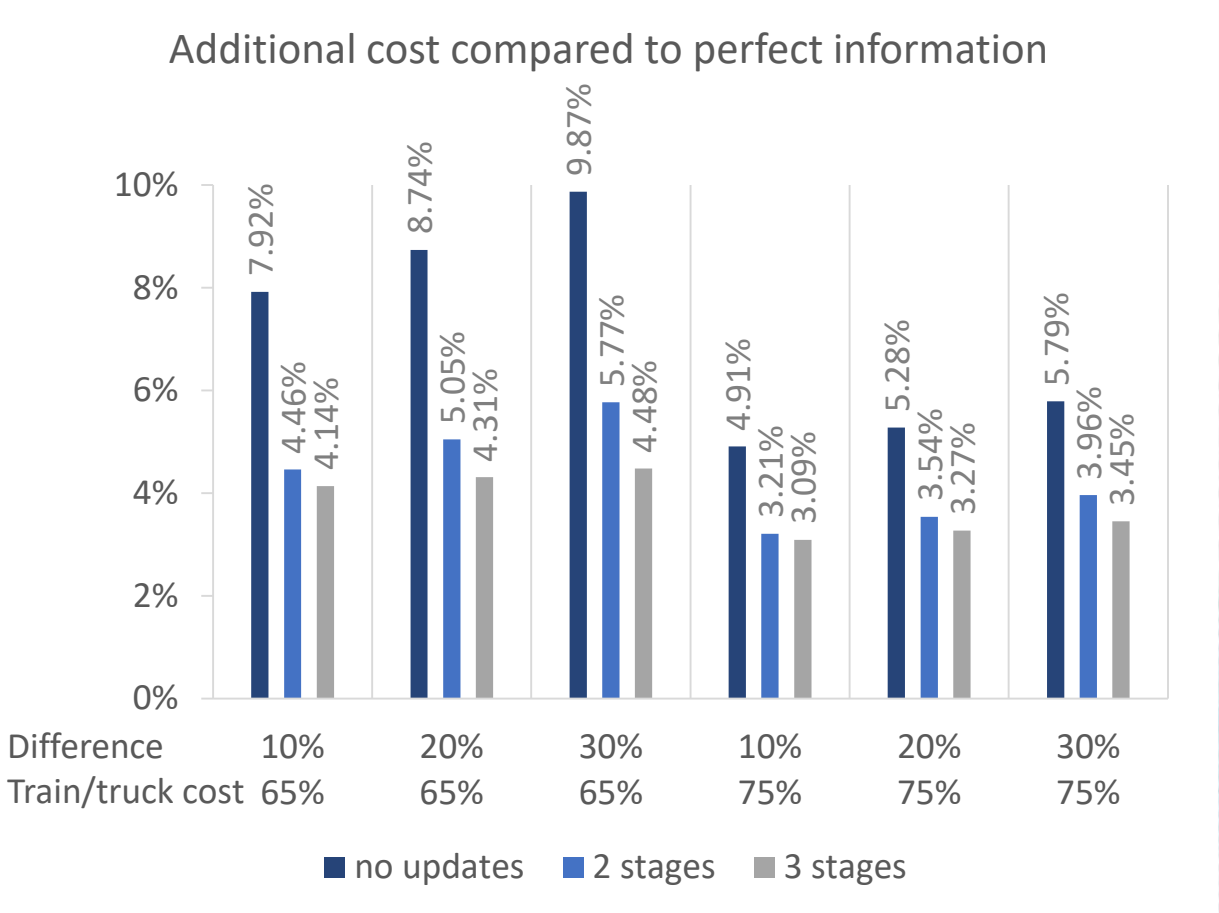
Capacity

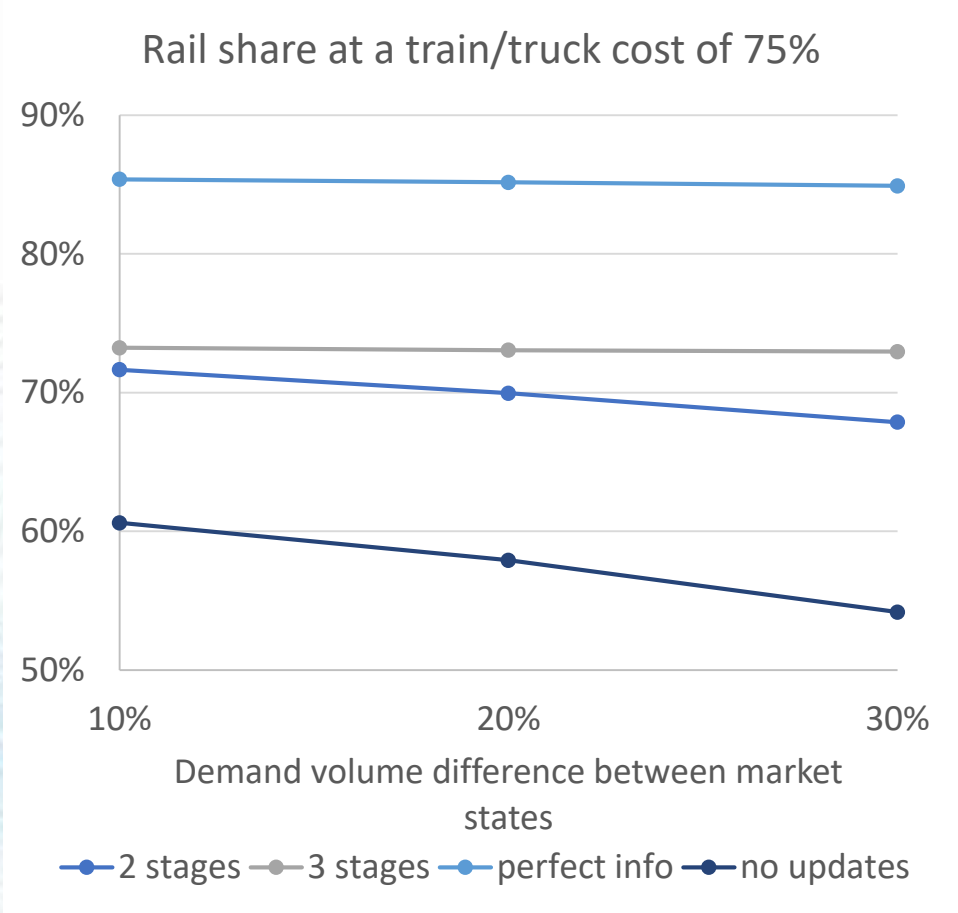

Additional cost compared to perfect information
10%
8%
6%
4%
2%
0%
7.96%
5.02%
4.27%
9.07%
5.18%
4.38%
9.51%
5.08%
4.28%
4.77%
3.38%
3.12%
5.44%
3.61%
3.31%
5.77%
3.71%
3.39%
Network
120%
150%
180%
120%
150%
180%
Train/truck cost
65%
65%
65%
75%
75%
75%
no updates
2 stages
3 stages


Rail share at a train/truck cost of 75%
90%
80%
70%
60%
50%
120%
150%
180%
Train capacity
2 stages
3 stages
perfect info
no updates

Capacity – slots booked

Market states demand differences





Discussion

Factors that improve the cost and rail share over a two-stage model

- Lower train cost compared to trucks
- More flexible network
- Information quality when updating capacity decisions

Challenges

- Data requirements
- Computational complexity

Future research

- Horizontal cooperation

Thank you for your attention

thibault.delbart@uhasselt.be

Thibault Delbart — *Hasselt University*

Prof. dr. Kris Braekers — *Hasselt University*
Prof. dr. An Caris — *Hasselt University*

Research group website:
https://www.uhasselt.be/en/onderzoeksgroepen-en/research-group-logistics