A three-stage model to support capacity decisions in intermodal transport under uncertainty

Thibault Delbart	Hasselt University
Prof. Dr. Yves Molenbruch	Vrije Universiteit Brussel
Prof. Dr. Kris Braekers	Hasselt University
Prof. Dr. An Caris	Hasselt University

LOG
RESEARCH GROUP
LOGISTICS

UHASSELT

DISpATch

Outline

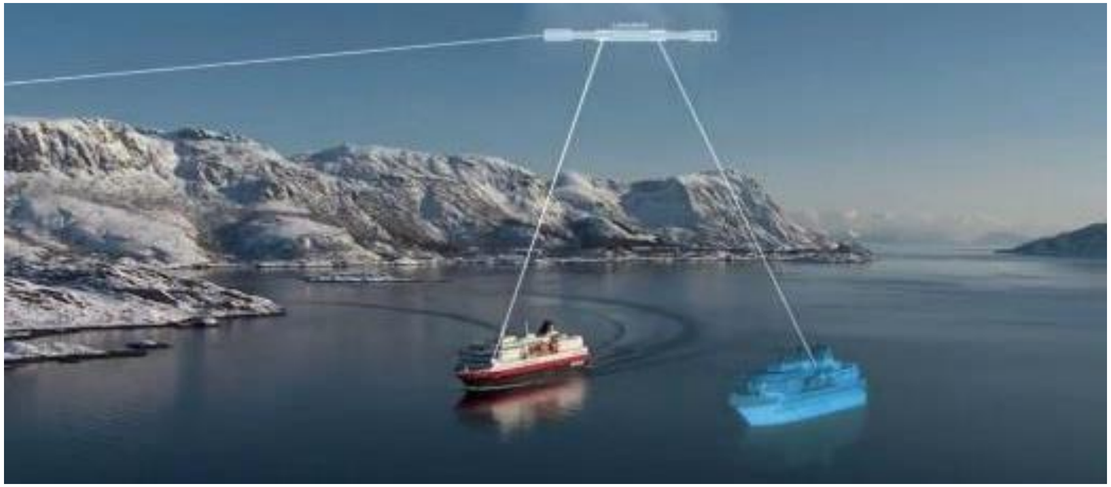
- Project summary
- Problem description
- Existing literature
- Decision support model

DISpATch project

- Digital twin for synchromodal transport
- Partners:

VUB mobi MOBILITY, LOGISTICS & AUTOMOTIVE TECHNOLOGY RESEARCH CENTRE   KU LEUVEN

- Objective: Facilitate synchromodal transport



Source: mfame

DISpATch

UHASSELT KNOWLEDGE IN ACTION

Introduction

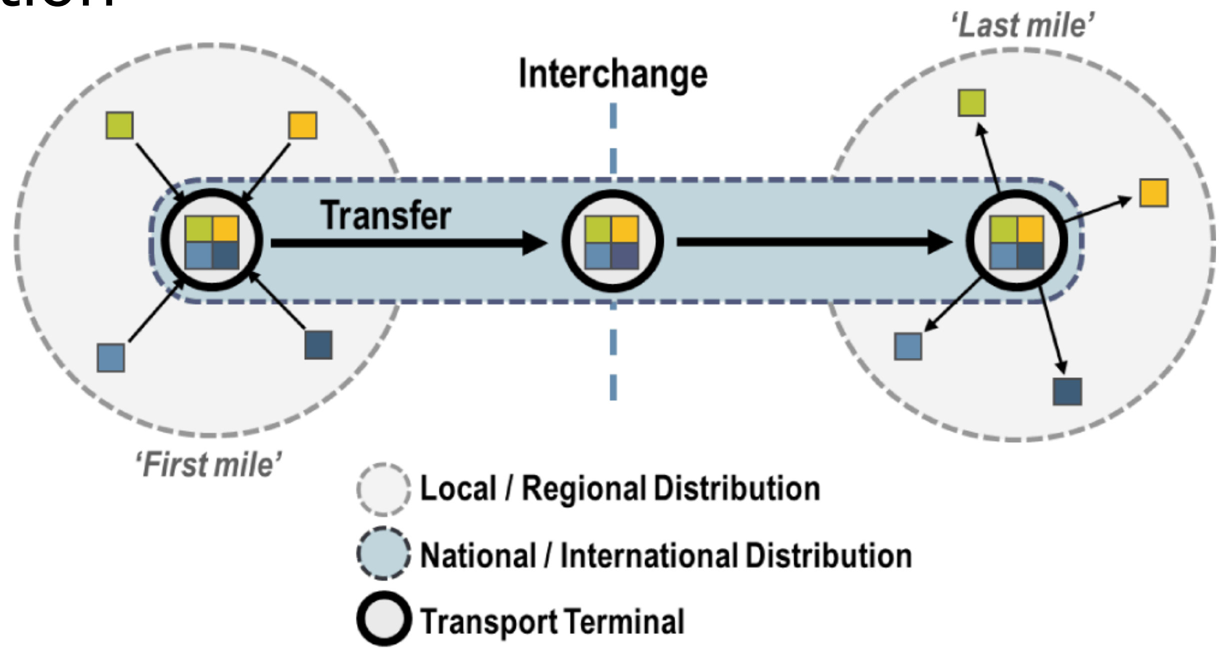
Support logistics service providers in their transition towards synchromodal transport.

- Multimodal: multiple transport modes
- Intermodal: same loading unit
- Synchromodal: complete integration and flexibility

Rationale:

- Increased freight consolidation
- Higher vehicle fill rates
- More environmentally friendly transport modes

Introduction



Source: transportgeography

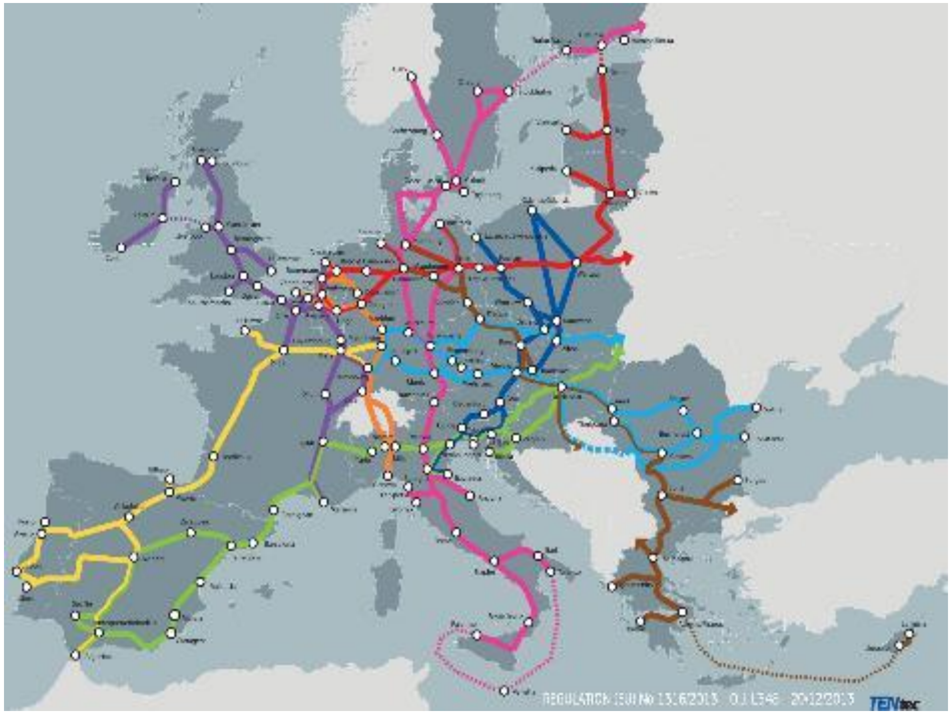
- Trucks can be booked at the last minute
- Other modes are booked in advance before demand is known

Introduction

Address capacity planning under uncertainty from the perspective of LSPs

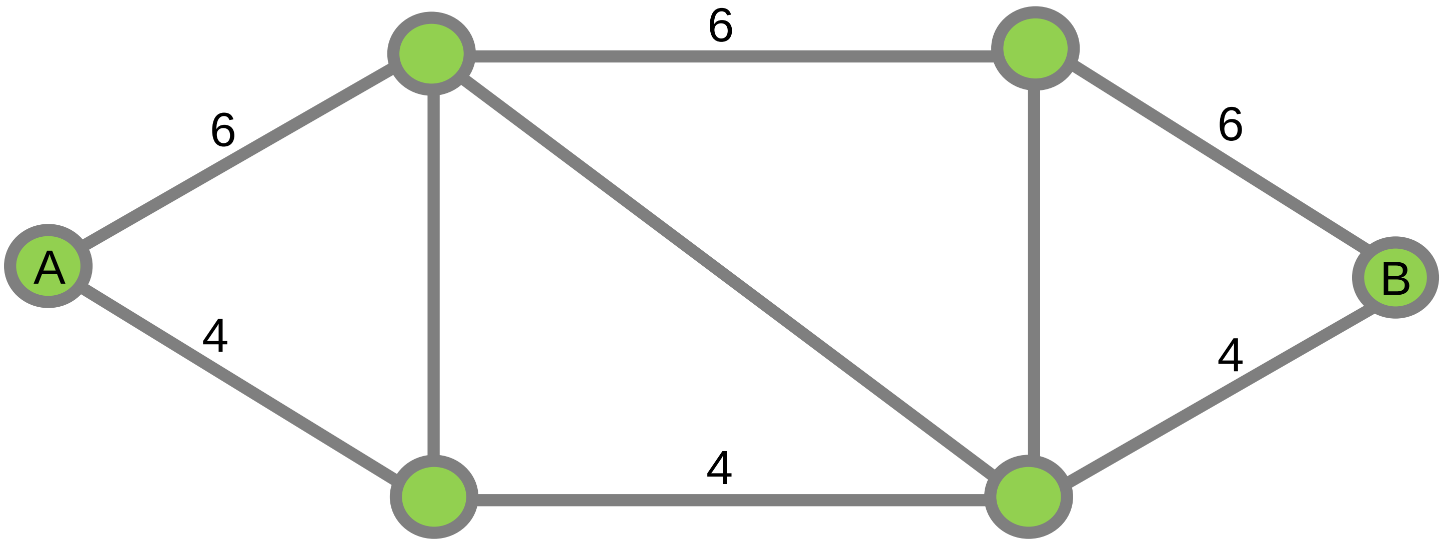
Only container transport

Scope: single corridor



Source: European Commission

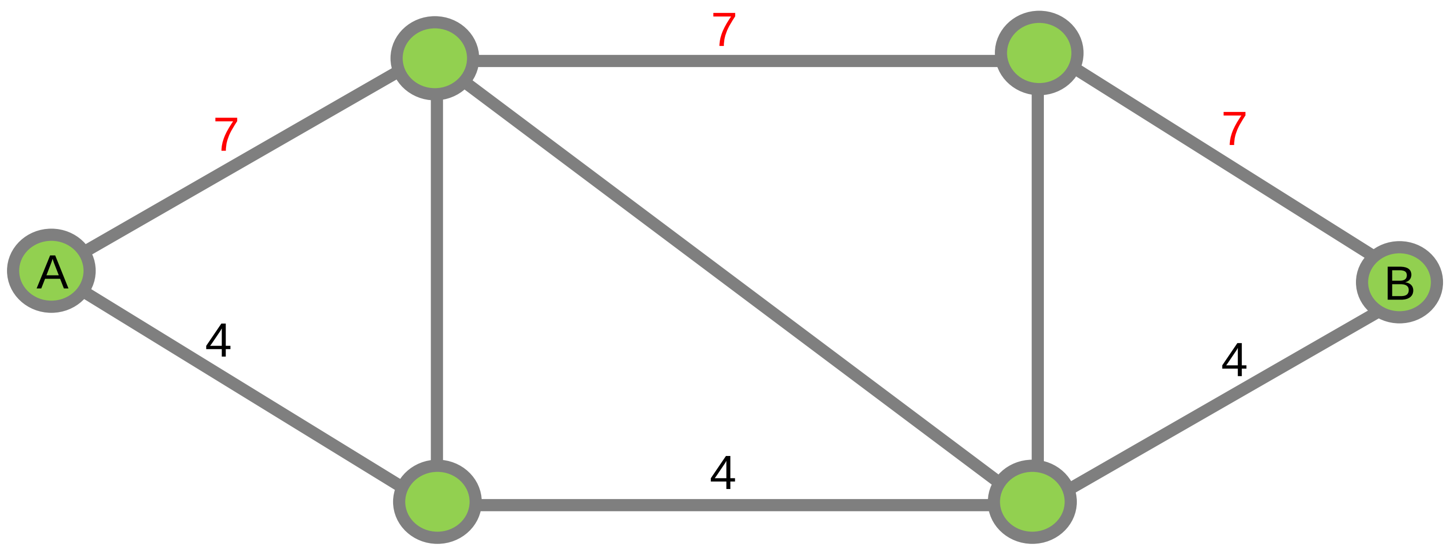
Transport planning



Tactical planning

- Capacity decisions

Transport planning



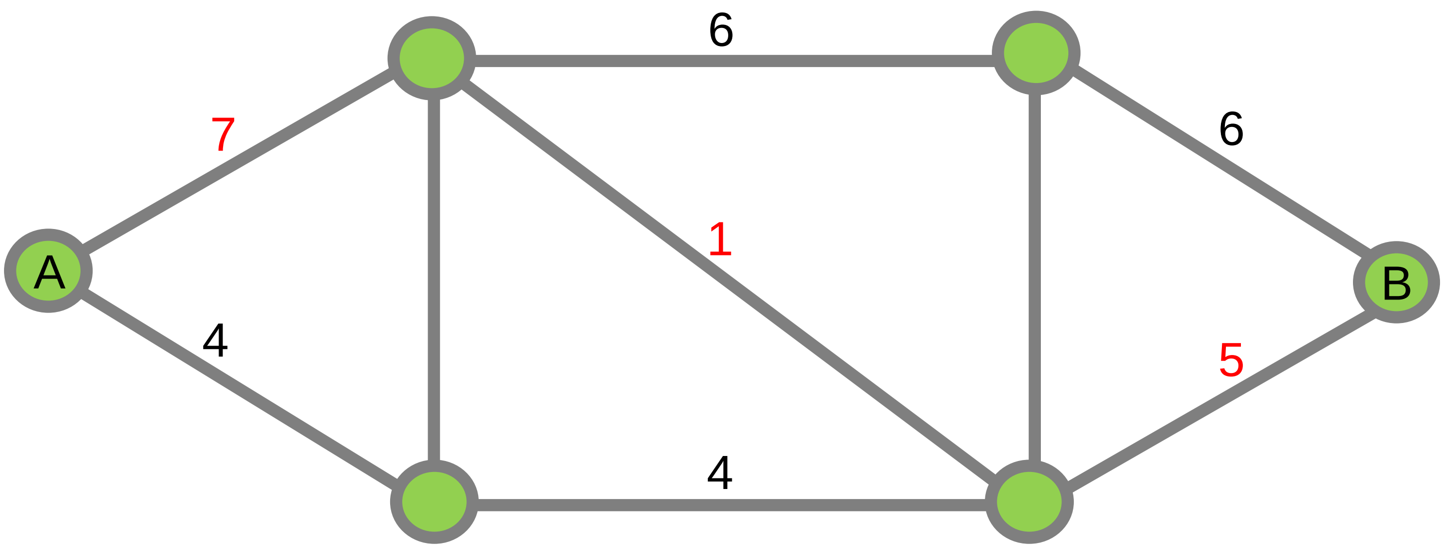
Tactical planning

- Capacity decisions

Operational planning

- Short-term capacity adjustments
- Container routing

Transport planning



Tactical planning

- Capacity decisions

Operational planning

- Short-term capacity adjustments
- Container routing

Types of uncertainty

- Stochastic demand
- Stochastic travel times
- Remaining available capacity
- Deviations between actual capacity and booked capacity
- Sudden disruptions

Problem description

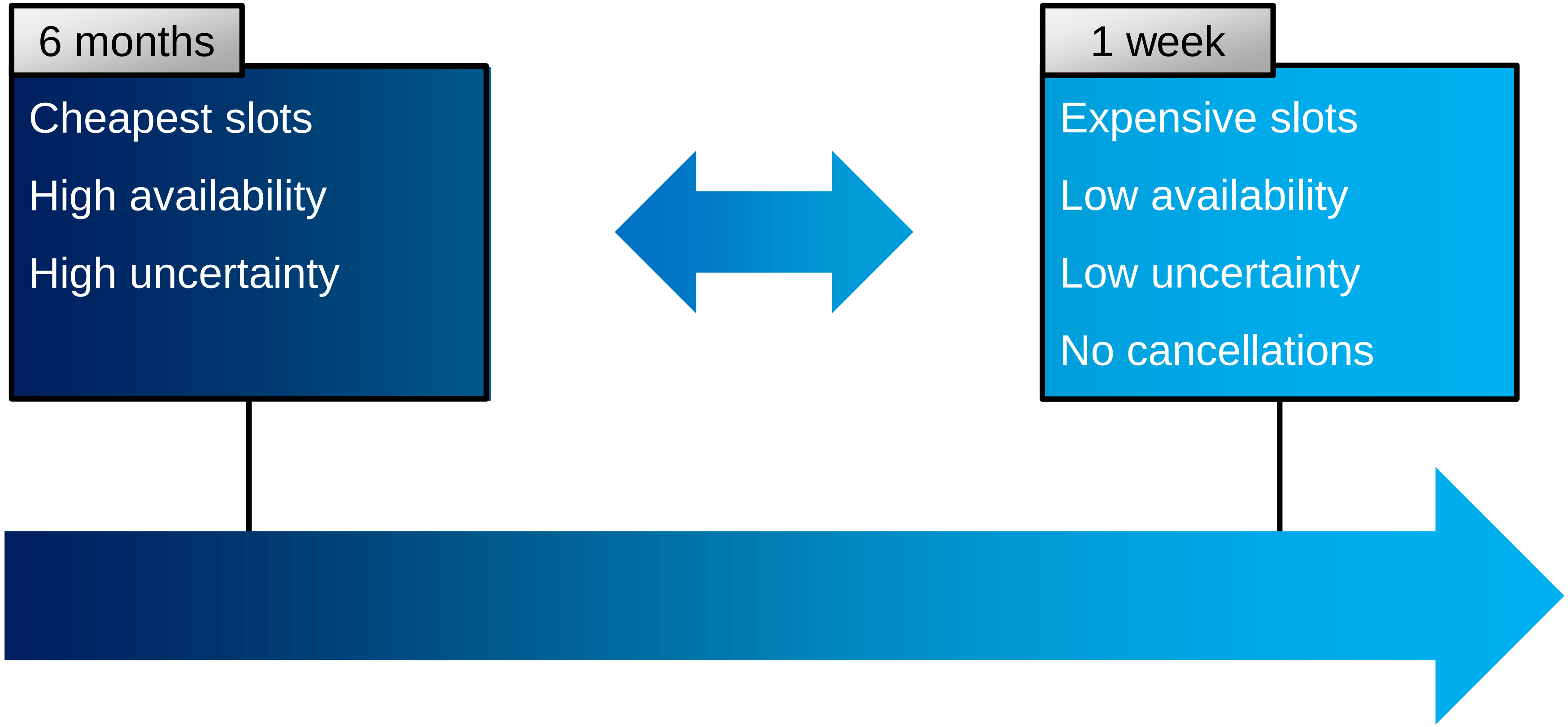
- Challenges faced by LSPs
  - How much capacity should be booked in advance?
  - How many trucks to keep?
  - How to deal with disruptions in real-time?

Literature results

Reference	Stochasticity	Approach	Recourse actions
Lium et al. (2009)	Demand	Two-stage stochastic programming	Ad hoc capacity increase
Hoff et al. (2010)	Demand	Two-stage stochastic programming	Ad hoc capacity increase
Crainic et al. (2011)	Demand	Two-stage stochastic programming	Ad hoc capacity increase
Bai et al. (2014)	Demand	Two-stage stochastic programming	Ad hoc capacity increase and rerouting
Meng et al. (2015)	Demand	Two-stage stochastic programming	Ad hoc capacity increase
Zhao et al. (2018)	Demand and transportation time	Two-stage chance constrained programming	

Delbart, T., Molenbruch, Y., Braekers, K., & Caris, A. (2021). Uncertainty in Intermodal and Synchromodal Transport: Review and Future Research Directions. Sustainability, 13(7), 3980.

Planning timeline



Planning timeline

6 months

- Cheapest slots
- High availability
- High uncertainty

1 month

- More expensive slots
- Intermediate availibility
- Less uncertainty

1 week

- Expensive slots
- Low availability
- Low uncertainty
- No cancellations

First stage

Objective function:

Minimise costs $\begin{cases} Capacity\ costs\ in\ the\ first\ stage \\ Expected\ additional\ capacity\ costs \\ Expected\ penalty\ costs \end{cases}$

Decisions variables:

Booked slots per service

Constraint:

Booked capacity ≤ available capacity

DISpATCh

UHASSELT

KNOWLEDGE IN ACTION

Second stage

Decisions variables:

- Booked slots per service
- Cancelled slots per service

Constraints:

- Extra capacity ≤ remaining available capacity
- Cancelled slots ≤ previously booked slots

Third stage

Decisions variables:

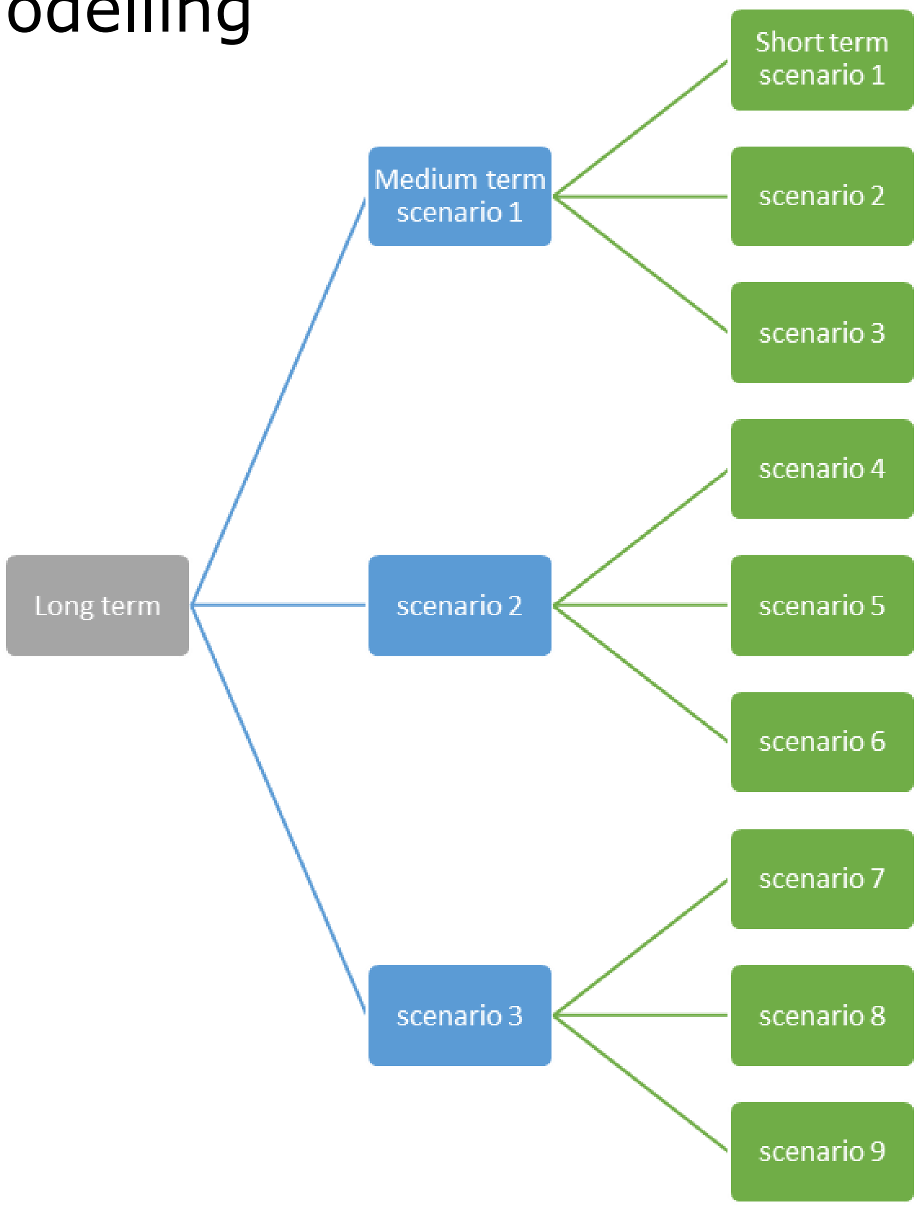
- Booked slots per service
- Emergency capacity
- Containers per order assigned to each service

Constraints:

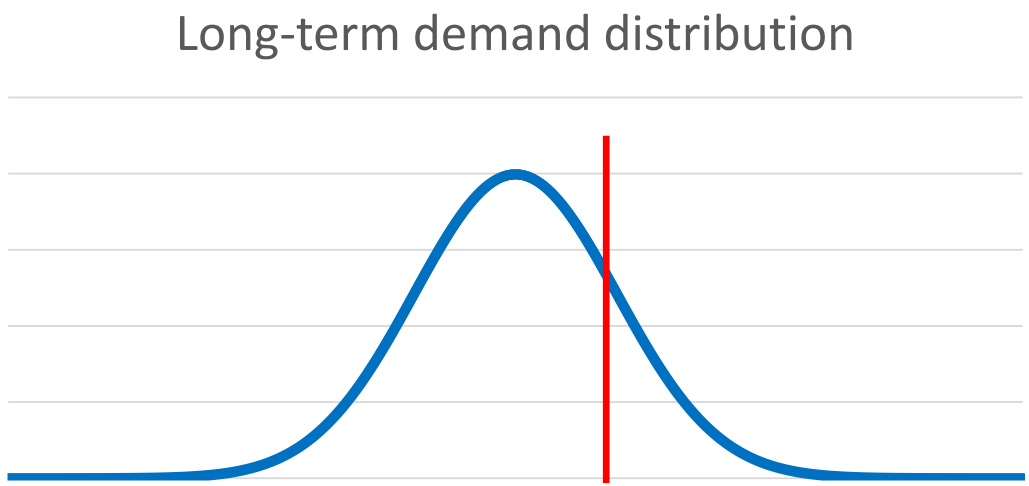
- Booked capacity ≤ remaining available capacity
- Time window constraints
- Flow conservation constraints

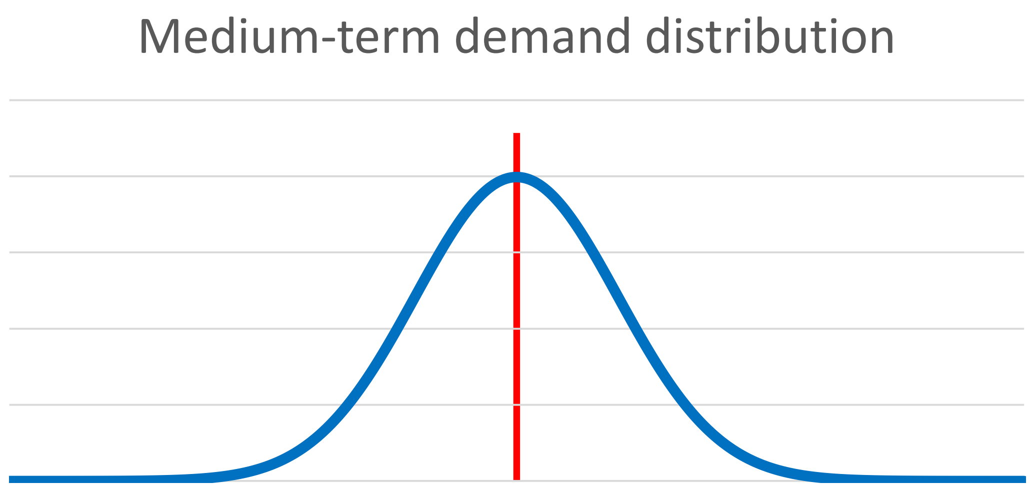
DISpATCh
UHASSELT
KNOWLEDGE IN ACTION

Demand modelling



Demand modelling





UHASSELT
KNOWLEDGE IN ACTION

Next steps

- Determine how to model demand
- Develop a solution method
- Apply the model with company data
- Expand the model with additional sources of uncertainty

References

Bai, R.;Wallace, S.W.; Li, J.; Chong, A.Y.-L. Stochastic service network design with rerouting. Transp. Res. Part B Methodol. 2014, 60, 50–65.

Crainic, T.G.; Fu, X.; Gendreau, M.; Rei,W.;Wallace, S.W. Progressive hedging-based metaheuristics for stochastic network design. Networks 2011, 58, 114–124.

Delbart, T., Molenbruch, Y., Braekers, K., & Caris, A. (2021). Uncertainty in Intermodal and Synchromodal Transport: Review and Future Research Directions. Sustainability, 13(7), 3980.

Hoff, A.; Lium, A.-G.; Løkketangen, A.; Crainic, T.G. A metaheuristic for stochastic service network design. J. Heuristics 2010, 16, 653–679.

Lium, A.-G.; Crainic, T.G.;Wallace, S.W. A study of demand stochasticity in service network design. Transp. Sci. 2009, 43, 144–157.

Meng, Q.; Hei, X.;Wang, S.; Mao, H. Carrying capacity procurement of rail and shipping services for automobile delivery with uncertain demand. Transp. Res. Part E Logist. Transp. Rev. 2015, 82, 38–54.

Zhao, Y.; Xue, Q.; Cao, Z.; Zhang, X. A two-stage chance constrained approach with application to stochastic intermodal service network design problems. J. Adv. Transp. 2018, 2018.

DISpATCh

UHASSELT

KNOWLEDGE IN ACTION

Thank you for your attention

Questions are welcome

thibault.delbart@uhasselt.be

Thibault Delbart — *Hasselt University*

Prof. dr. Yves Molenbruch — *Vrije Universiteit Brussel*
Prof. dr. Kris Braekers — *Hasselt University*
Prof. dr. An Caris — *Hasselt University*

UHASSELT

KNOWLEDGE IN ACTION