EMISSION-AWARE DECISION-MAKING METHODS FOR INLAND VESSELS

WP3 – T3.1

Ir. Simeon Slagter
Dr. Ir. Yusong Pang
Prof. Dr. Rudy Negenborn

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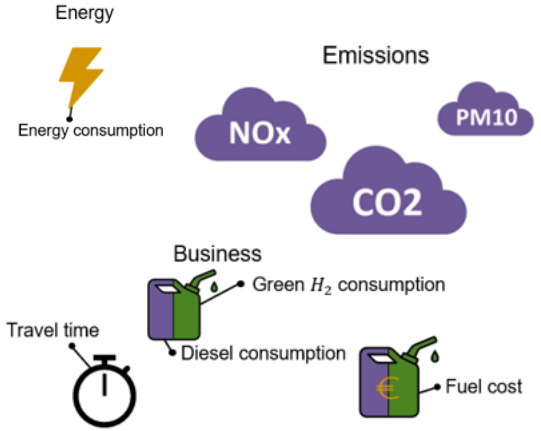
Agenda

- RECAP
- DATA SETS
- ROBUST SPEED PLANNING
- BATTERY SWAPPING + ENERGY MANAGEMENT SYSTEM
- INTEGRATION OF WP3.1 IN THE DIGITAL TWIN

RECAP: Speed planning

EMISSIONS PLANNING

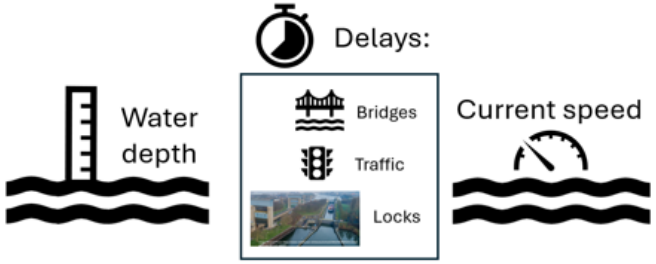


Energy	-7.26 %
Emissions CO2	-5.37 %
NOx	-3.85 %
PM10	-6.77 %
Fuel	-5.37 %

*Journal paper: S. Slagter, M. Jiang, Y. Pang, K. Visser, M. van Koningsveld, R. R. Negenborn (2025). Impact of Speed Planning for Inland Vessels with Alternative Power Systems on Energy Efficiency and Emissions. Energy Conversion and Management: X

ADAPTIVE PLANNING

Dynamic fairway conditions:



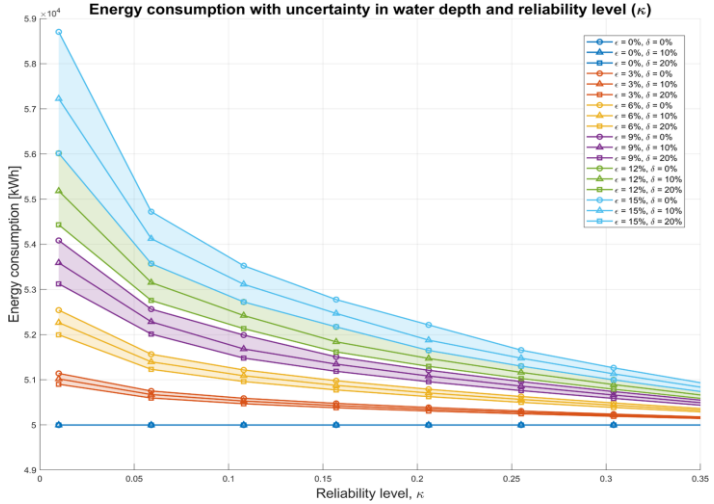
Main objectives:
1. Minimize energy consumption
2. More reliable arrival times
3. Improved safety

Avg. Speed	- 3.67 %
Energy	- 8.33 %
Travel time	+ 4.46 h

Conference paper: Slagter, S., Pang, Y., & Negenborn, R. R. (2024). Energy-Efficient Speed Planning Considering Delay and Dynamic Waterway Conditions for Inland Vessels. Proceedings of the International Ship Control Systems Symposium, Article 11161. https://doi.org/10.24868/11161

ROBUST PLANNING

Main objectives:
1. Robustness against uncertainty; 'plan for worst-case scenario'
2. Guarantee Reliable & safe planning



*Currently writing journal paper about this topic

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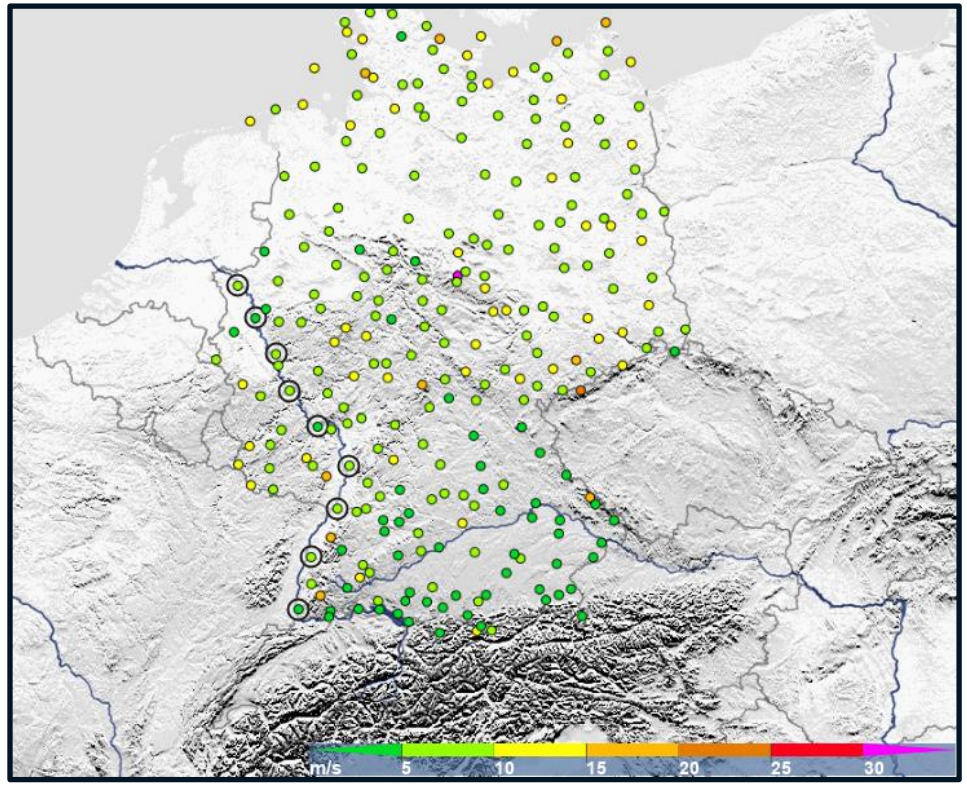
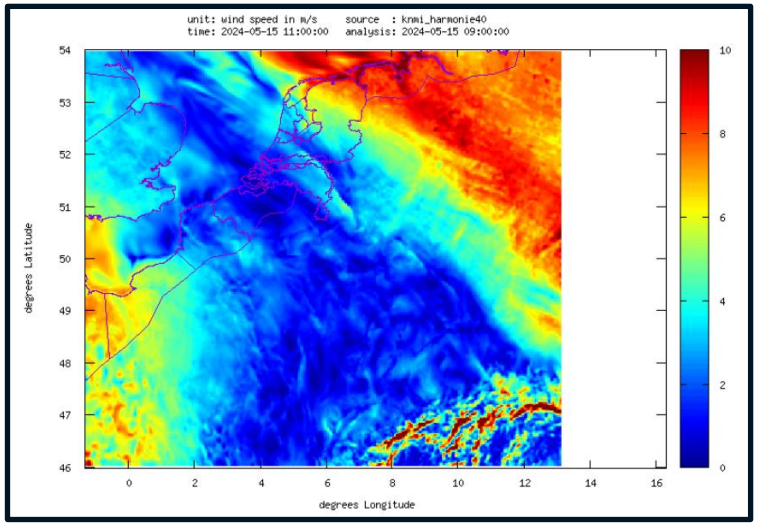
DATA: Wind

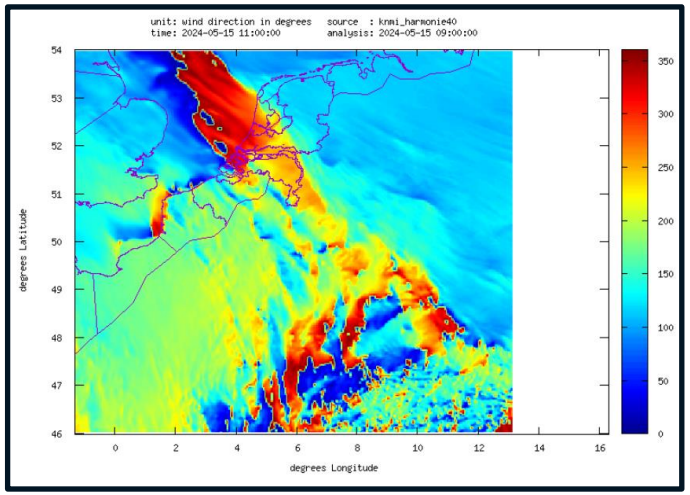
Measurement locations



Wind Speed

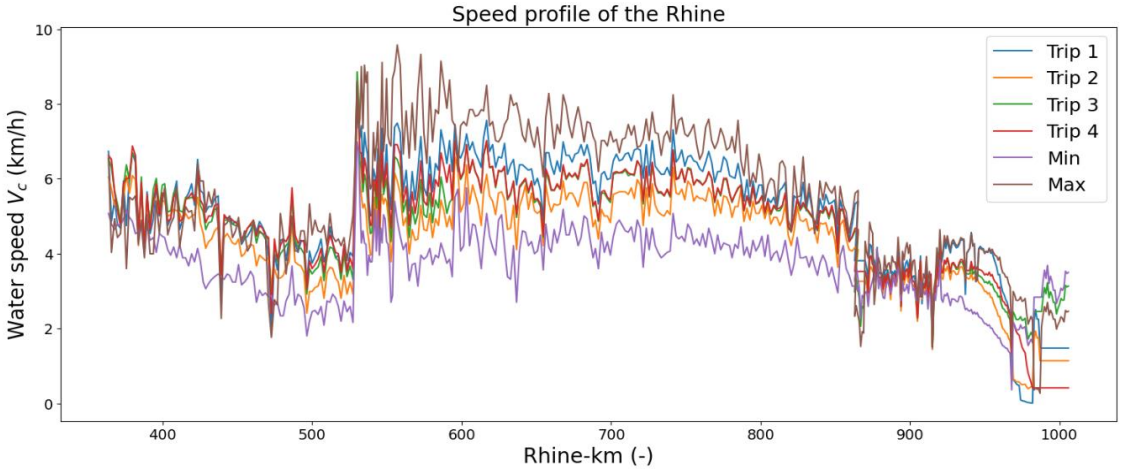


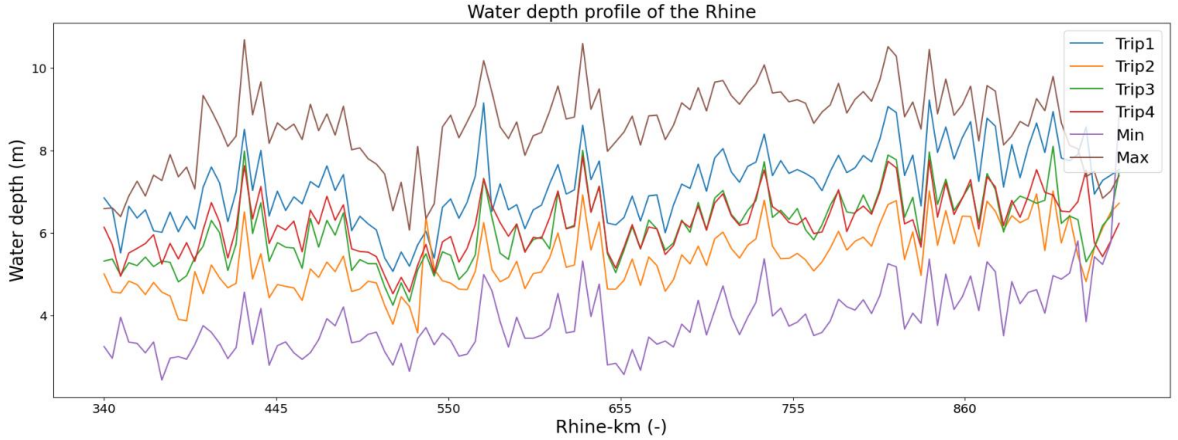
Wind direction

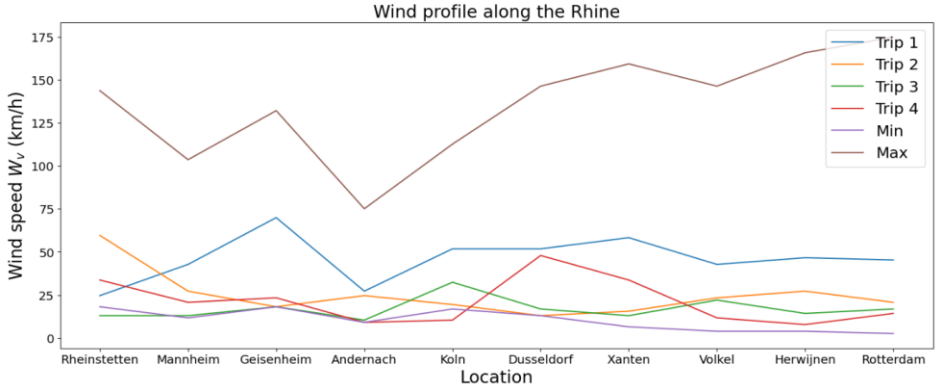


Source: KNMI & DWD

DATA: Water speed & depth







*Min/Max over 2024

Source speed: Bafg & RWS
Source depth: Covadem

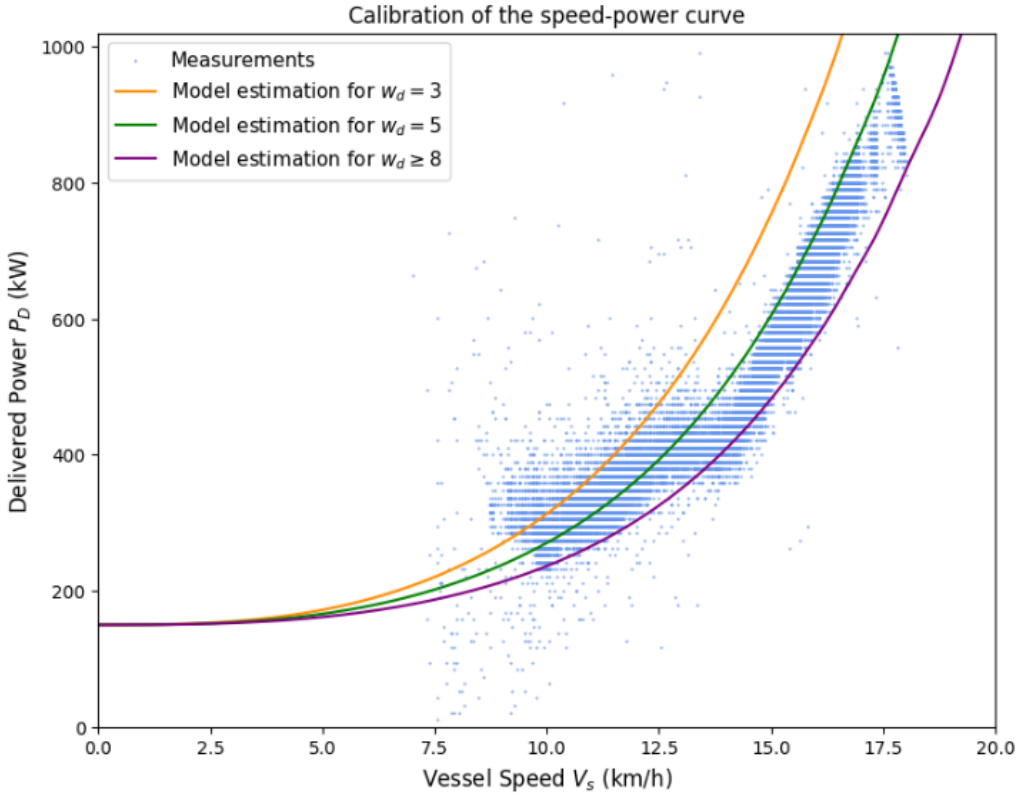
DATA: Vessel

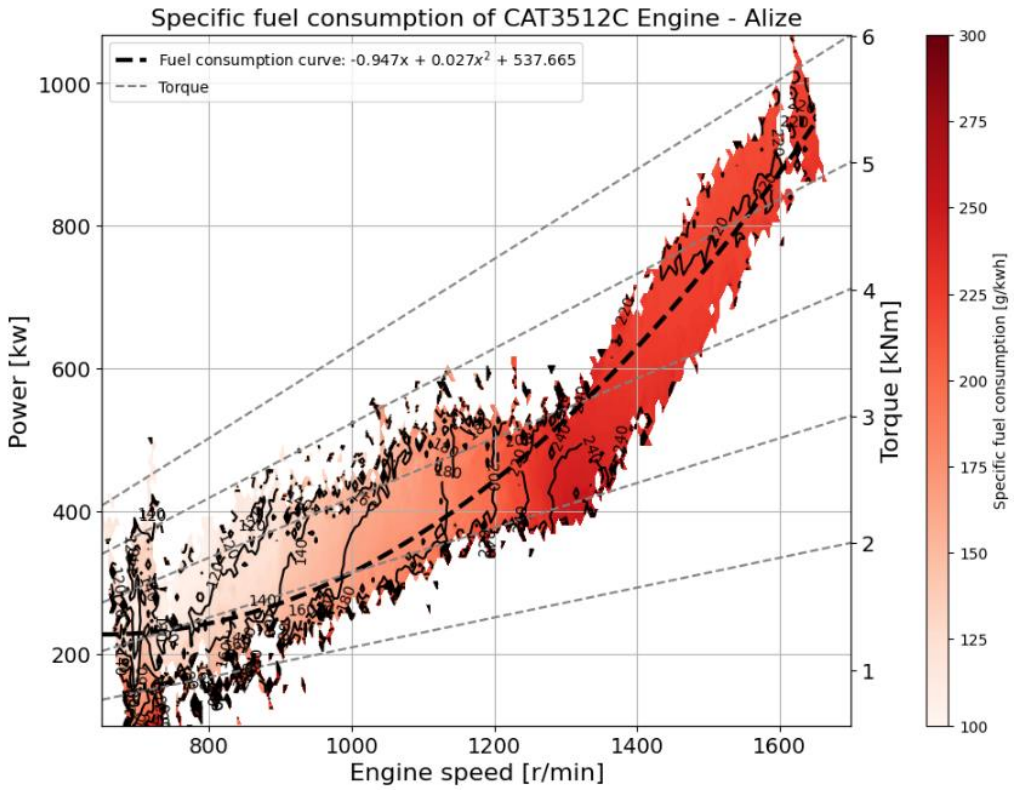
Data features:

1. AIS data
2. Engine load
3. Engine speed
4. Fuel rate
5. Wind speed & direction
6. Draught
7. Cargo load

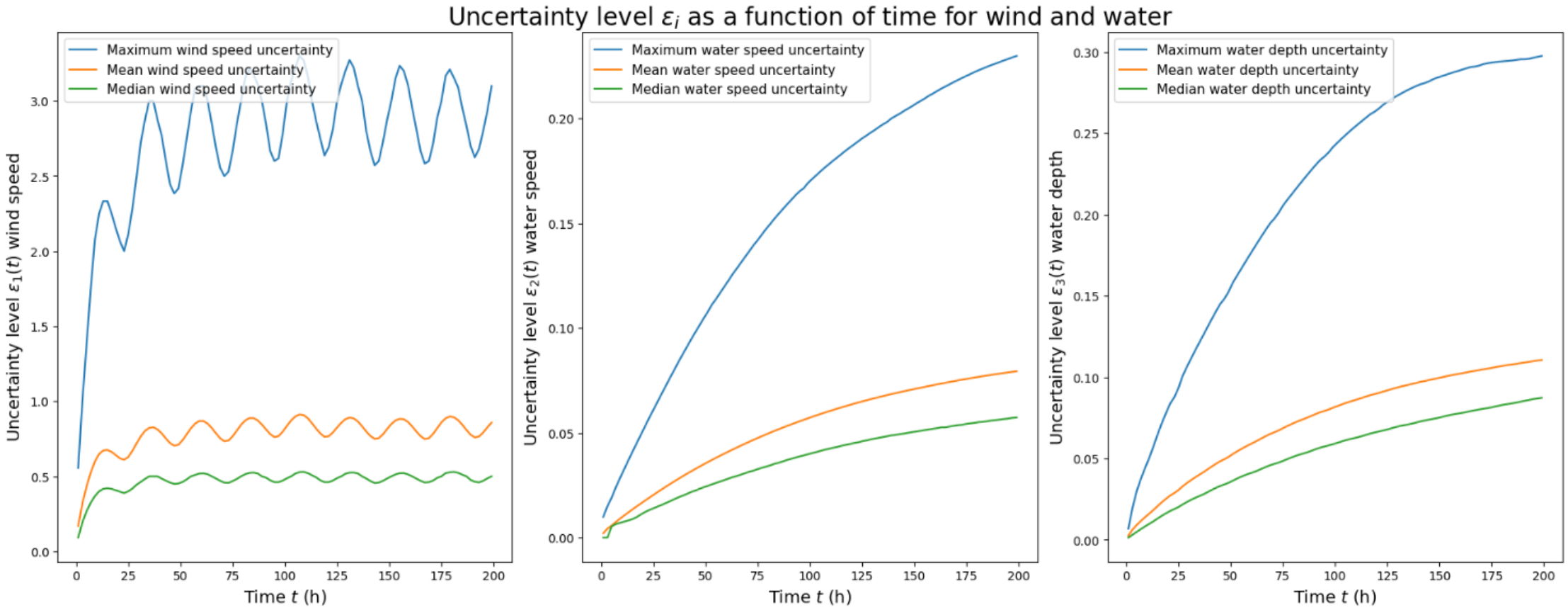
Source: Techbinder

DATA analysis: Vessel



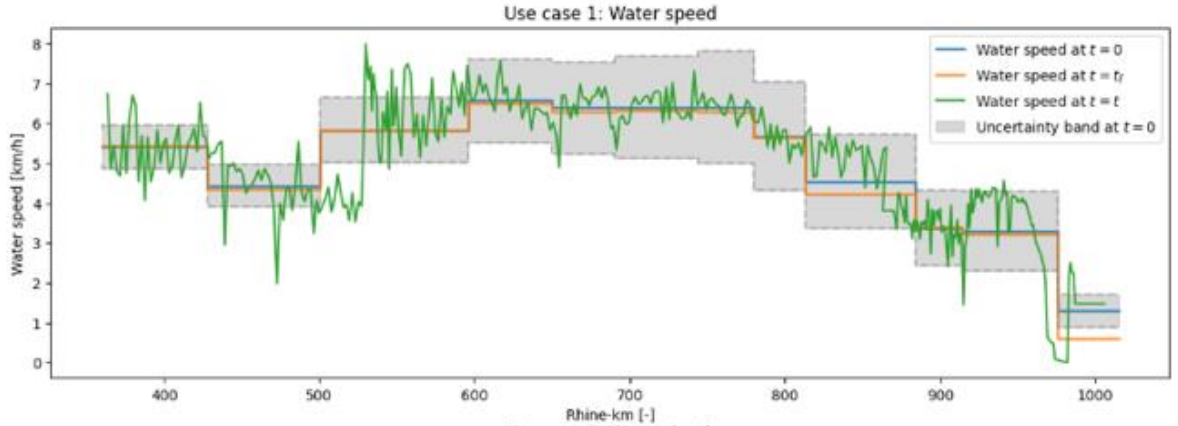


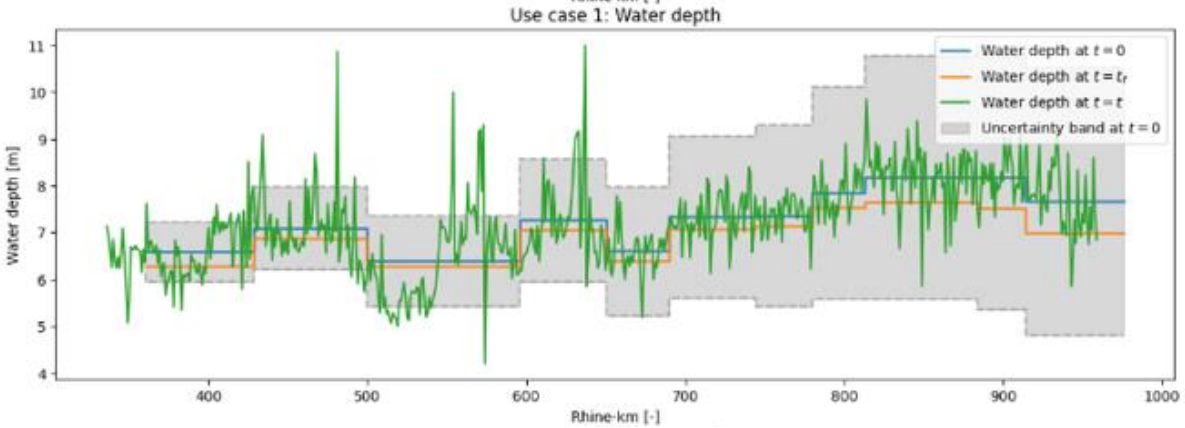
ROBUST SPEED PLANNING: Uncertainty

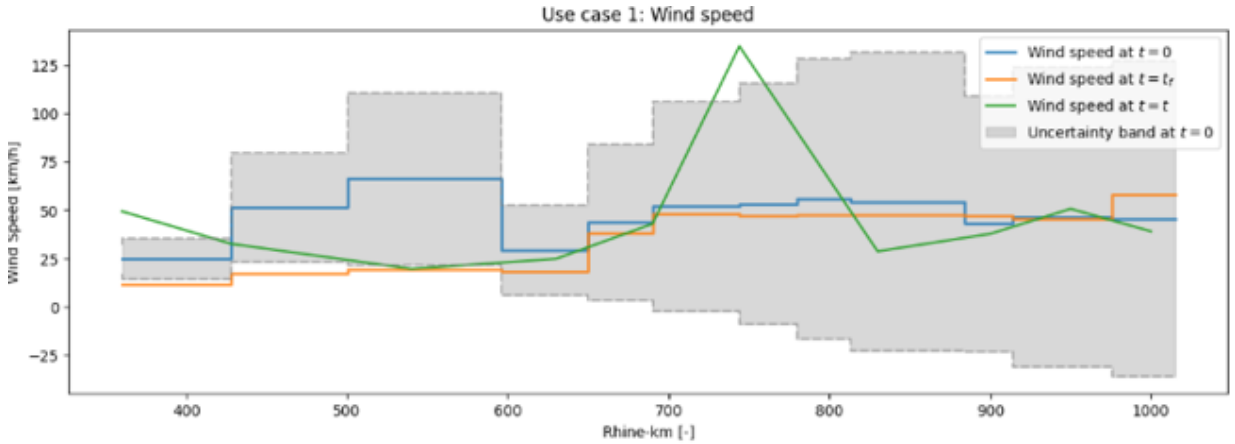


Assumption: additive additional uncertainty of 5% due to measurement.

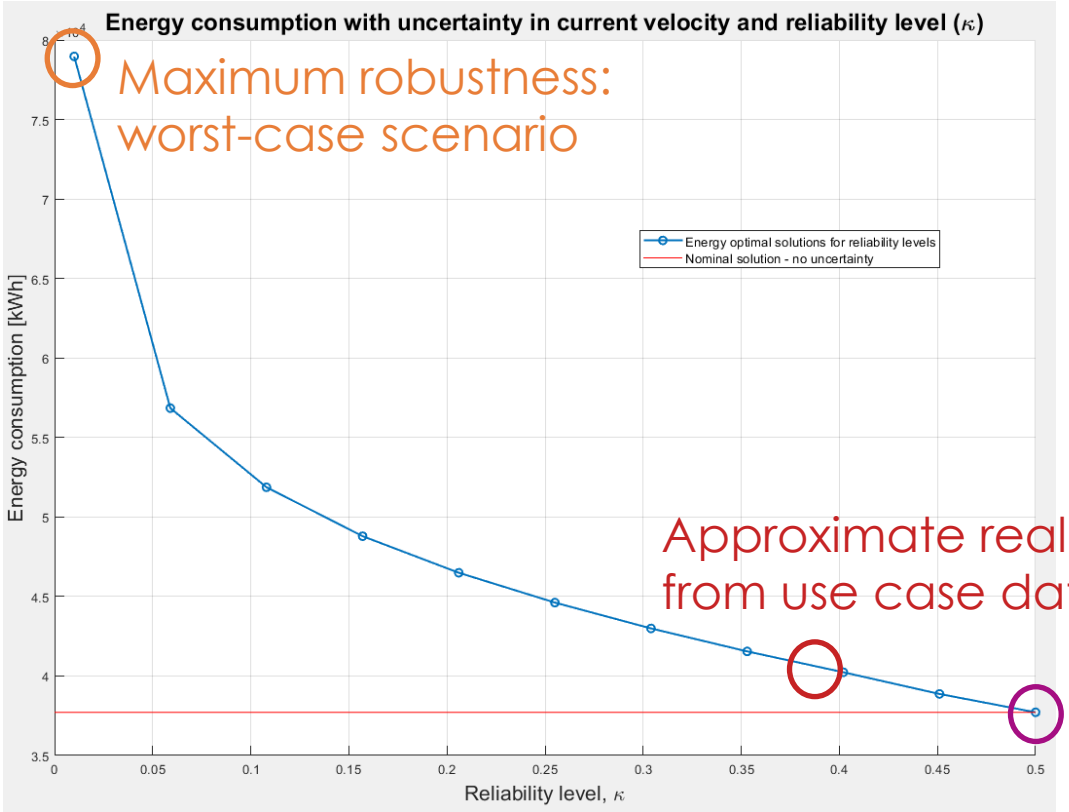
ROBUST SPEED PLANNING: use case







ROBUST SPEED PLANNING: results



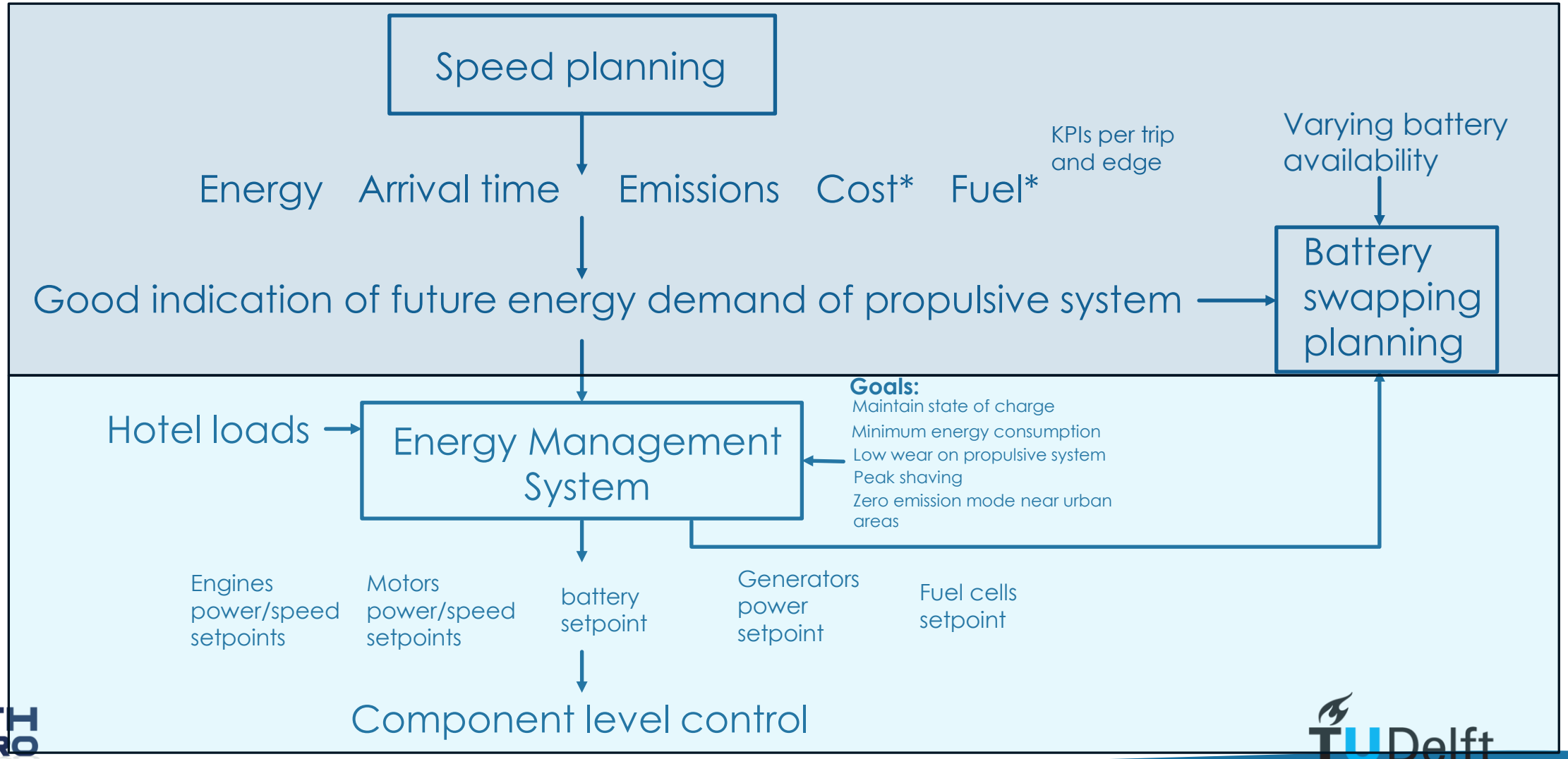
Maximum robustness: worst-case scenario

Approximate real energy consumption from use case data

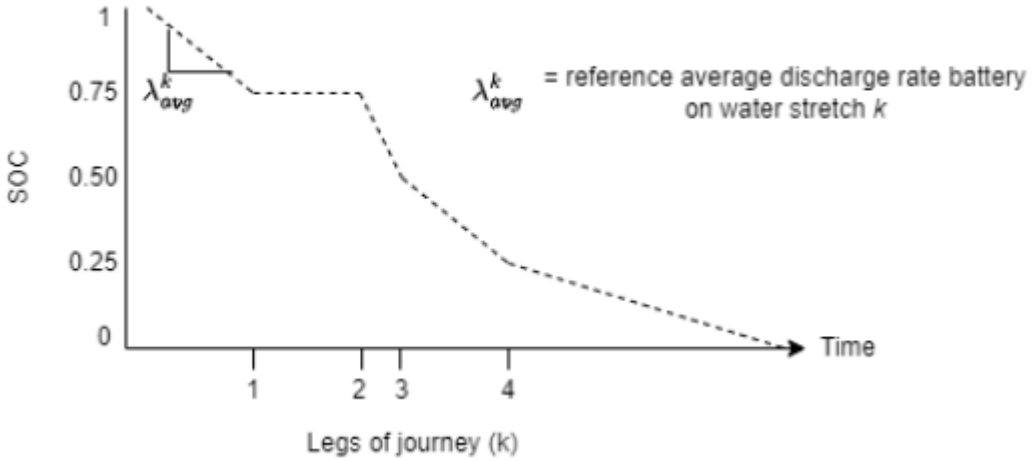
Optimal solution without robustness

*Results for single optimization (not yet adaptive structure)

Energy Management System



Energy Management System



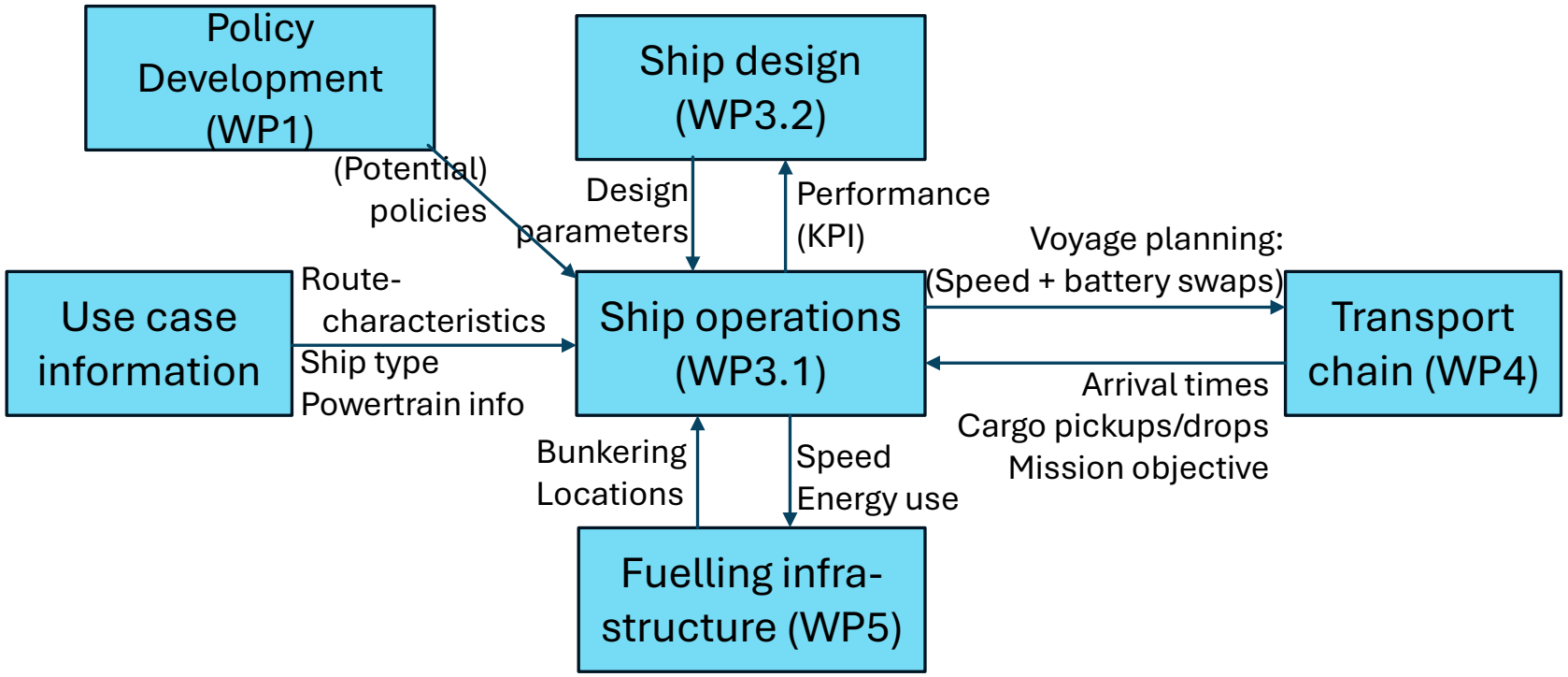
Possible optimization formulation (min)

$$(\lambda(t) - \lambda^k_{avg}(t))^2$$

$$(\int_{k-1}^{k} \lambda(t) - \lambda^k_{avg}(0)\, dt)^2$$

$$(\int_{k-1}^{k} \lambda(t) - \lambda^k_{avg}(t)\, dt)^2$$

Digital Twin



Thank you!

Contact:
Simeon Slagter
s.slagter@tudelft.nl

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