INTRODUCTION AND ASSESSMENT OF BASIC DESIGN CONCEPTS FOR AUTONOMOUS SHIPS IN MARITIME TRANSPORT SYSTEMS FOR SHORT SEA SHIPPING

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Revitalization of Coastal and Short-Sea Shipping through Autonomous Transport Systems – SATS

- We ask in which segments of shipping autonomous vessels can be a contributing factor to:
  - Enhance the competitiveness of maritime shipping
  - Reduce shipping's GHG emissions
  - Reduce total GHG emissions from transport.

SATS

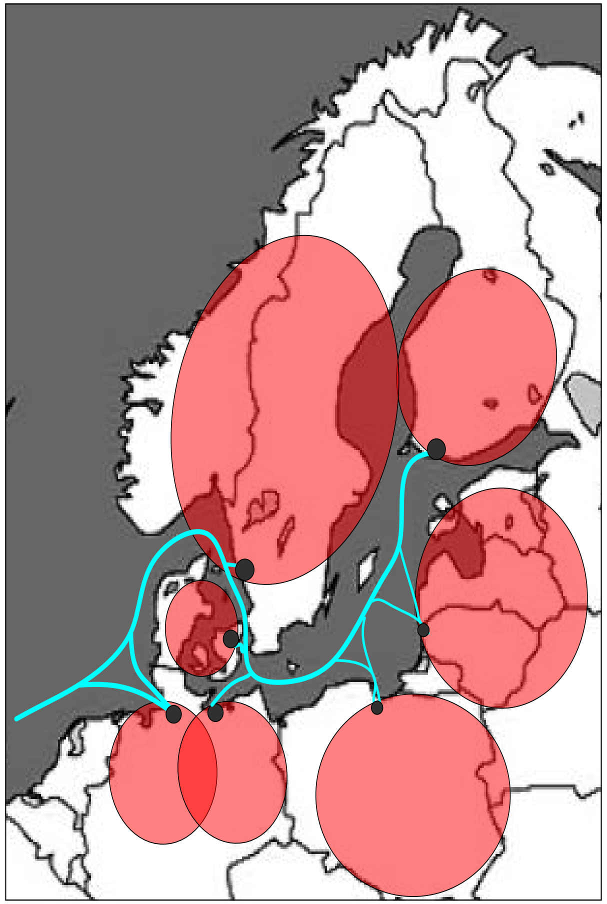
- Autonomous ships may have their first commercially viable applications where personnel costs are important
- Unmanned ships can enable more efficient designs.

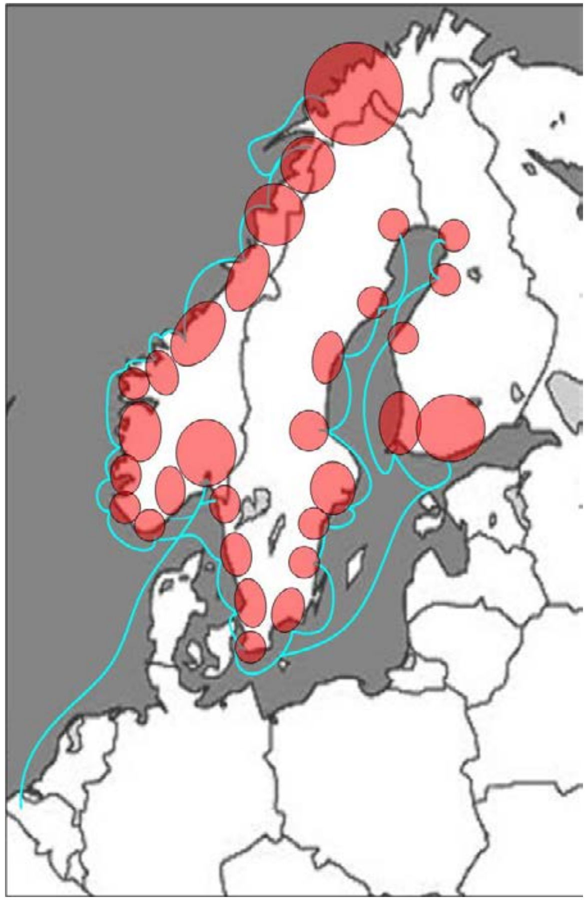
Compared to USA and Canada, Europe in general and Norway in particular has more ports

- Norway with 5 million people has nearly 80 commercial cargo ports, which is more than you will find along the whole West coast of USA and Canada.
- In addition Industrial companies and Fish processers tends to have their own quays/ports
- Some of these ports have major volumes and are served with large vessels (Cape size and VLCC), but the majority of the ports are served with small, general cargo vessels.

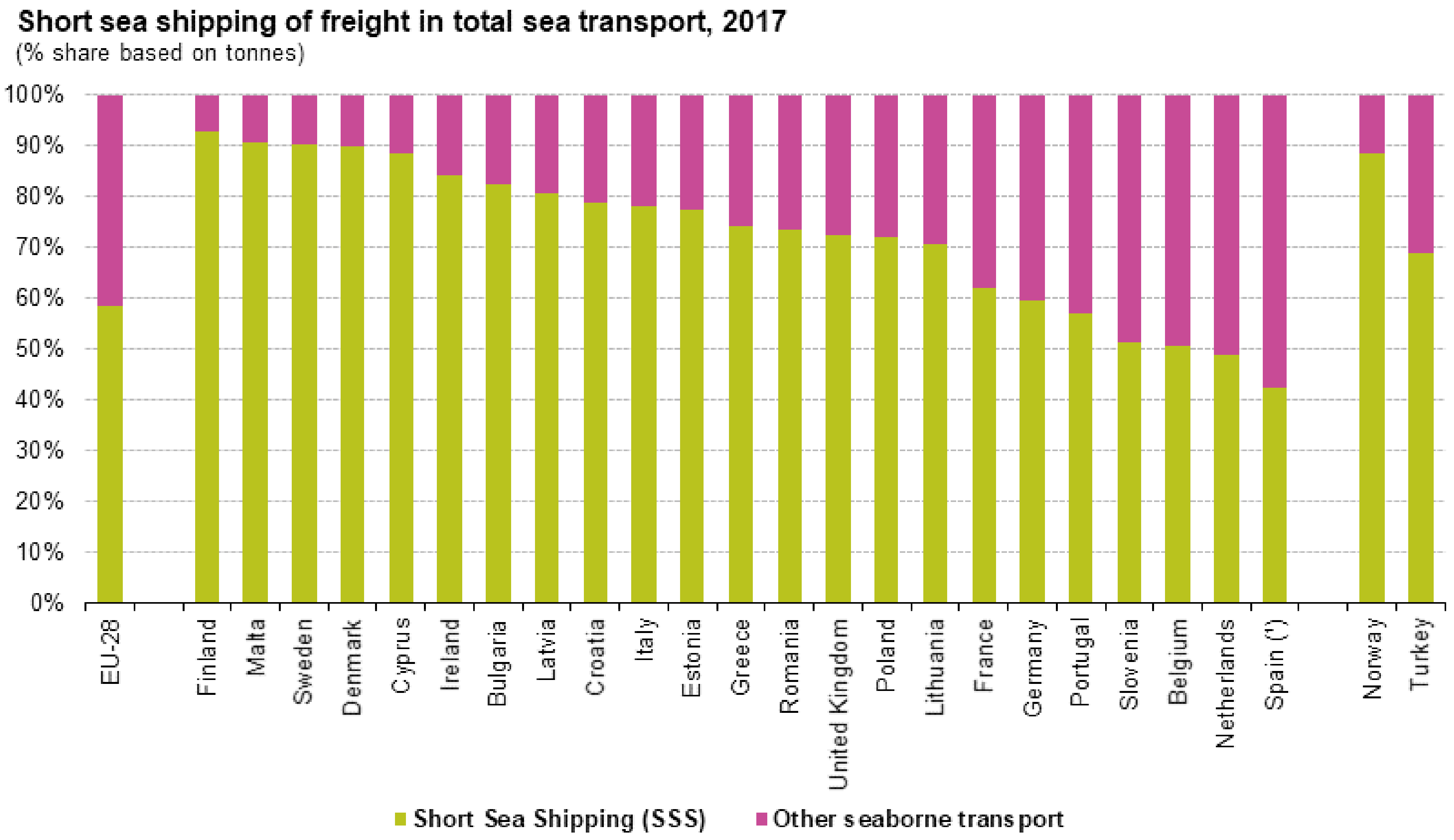
MoS (Motorways of the seas) vs Autonomous vessels serving several small ports

- MoS require concentration of cargo -> few ports -> much road transport
- Autonomous SSS -> more ports -> less road tranpsort





Short sea shipping in Europe



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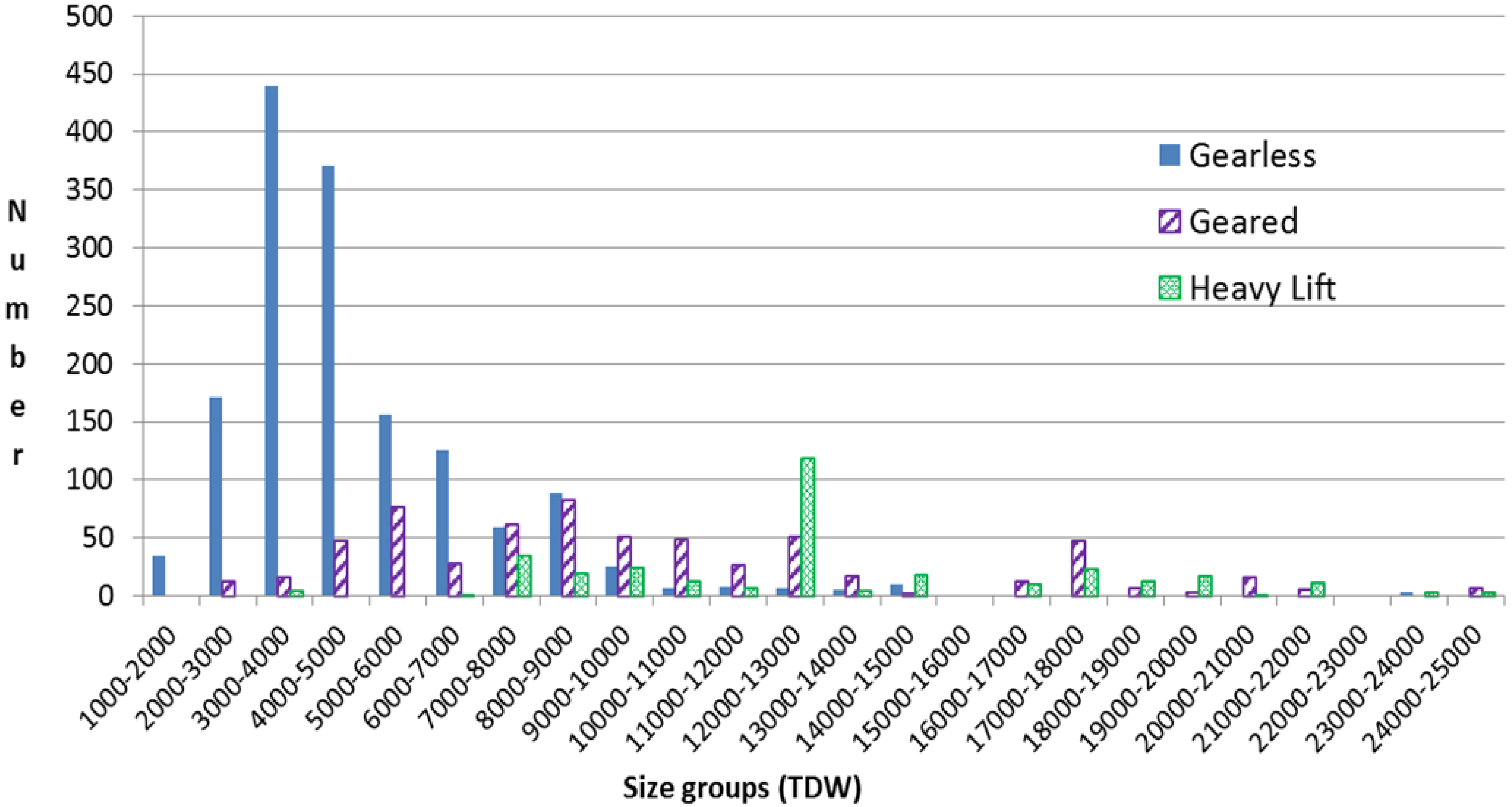
The North European General Cargo Fleet



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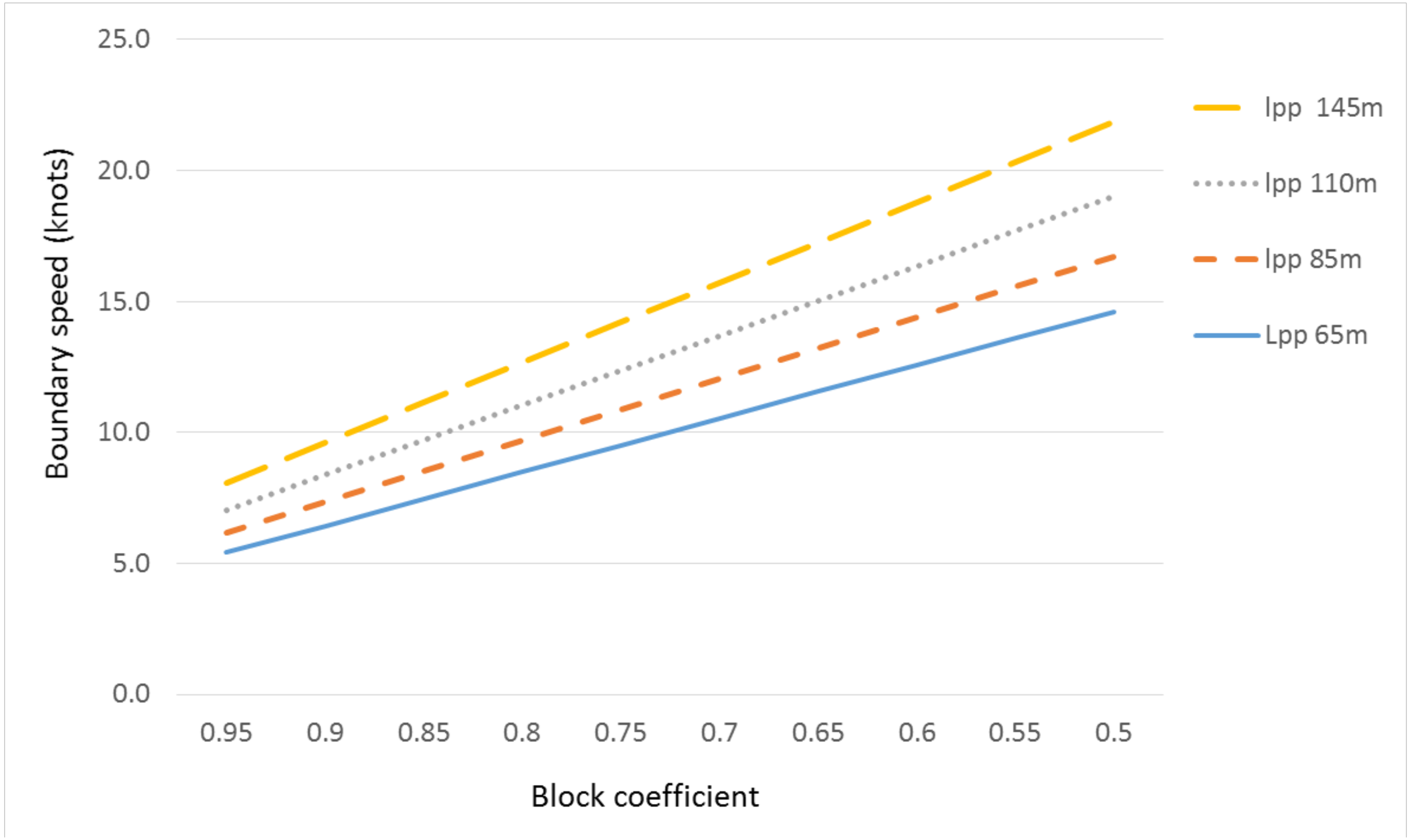
Boundary speed (going faster means much higher energy consumption) as a function of vessel length and block coefficient



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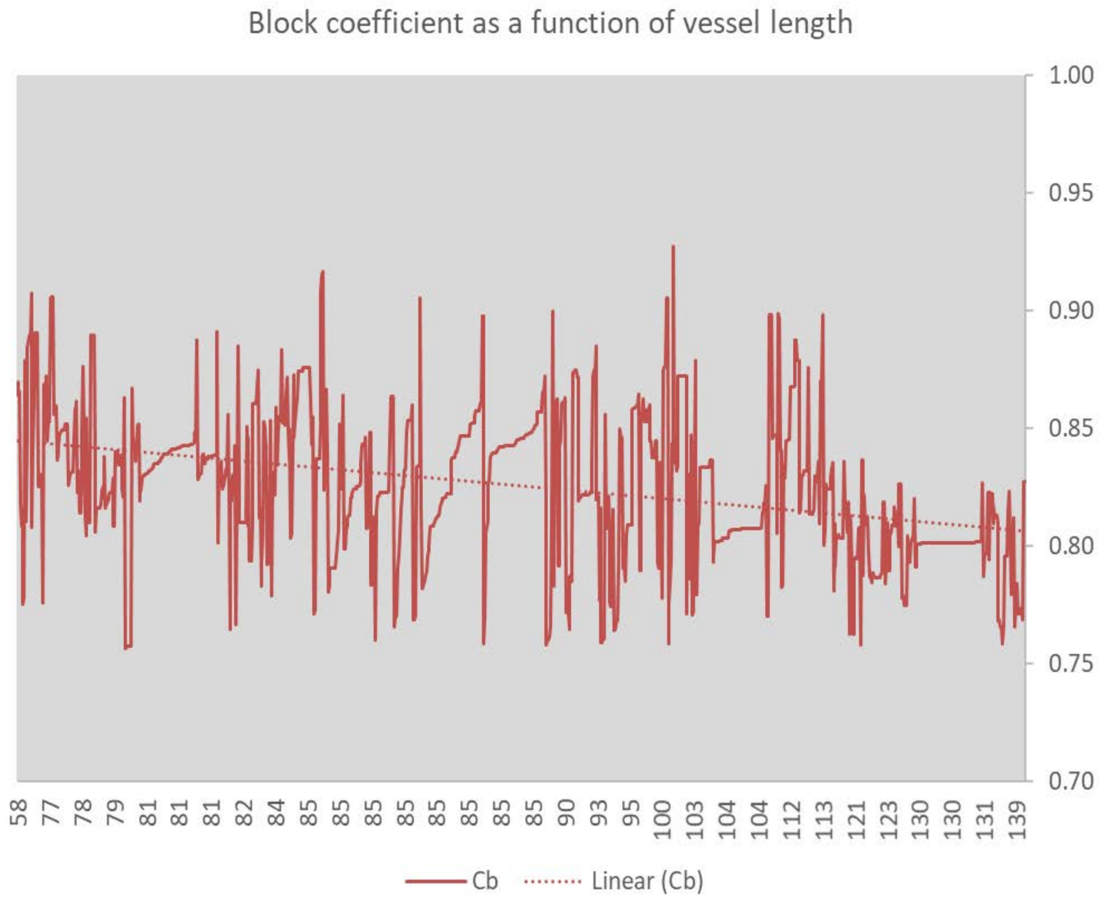
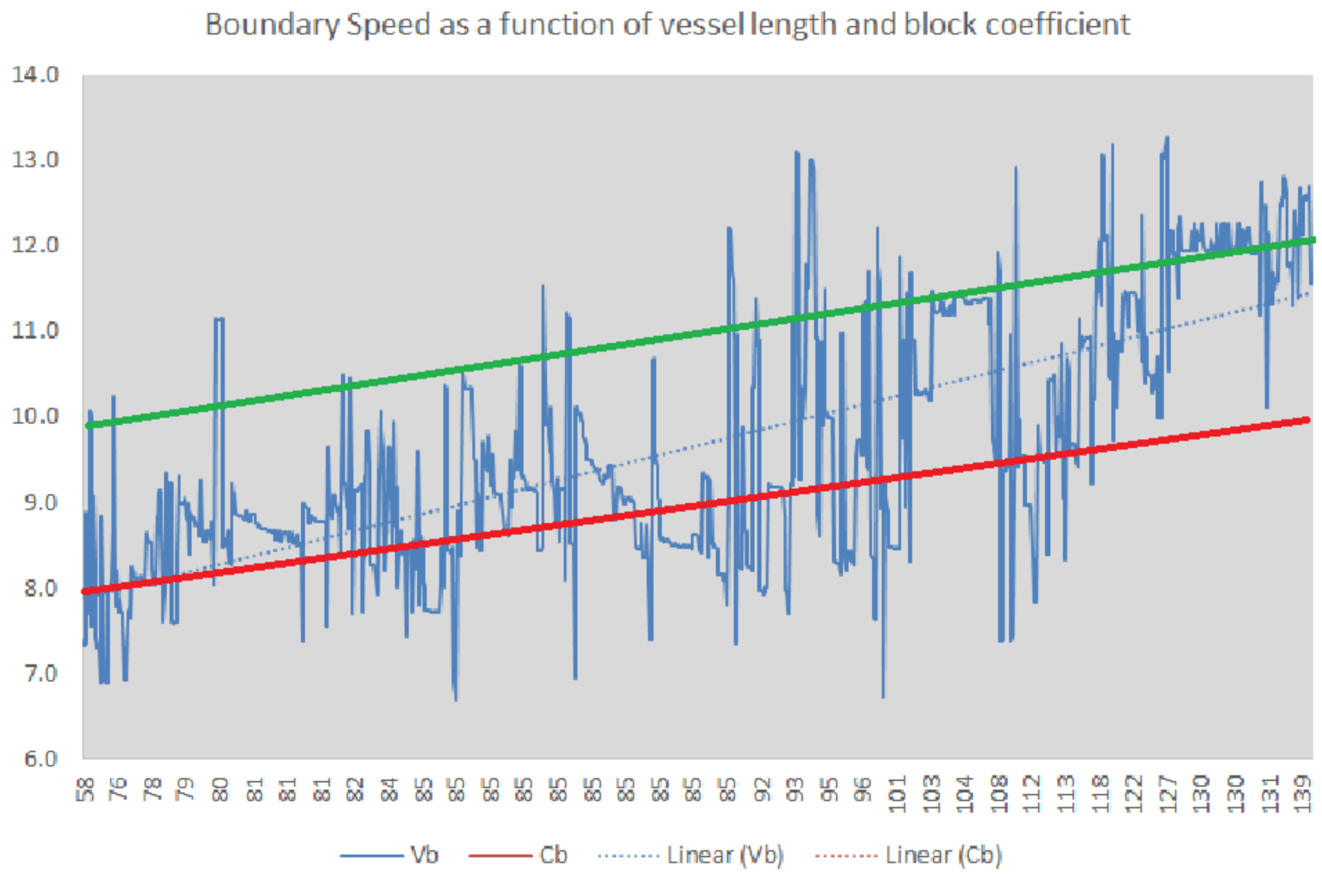
North European General Cargo fleet – Boundary speed as a function of block coefficients and vessel length (1169 gearless vessels)





Low Block coefficients (Slender hull forms)

Very high Block coefficients (Shoe box)

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Yara Birkeland – Fully autonomous and electrical

Length o.a.: 80 m
Service speed: 6-7 knots
Max speed: 13 knots
Cargo capacity: 120 TEU
Deadweight: 3 200 mt

Conventional reference container ship

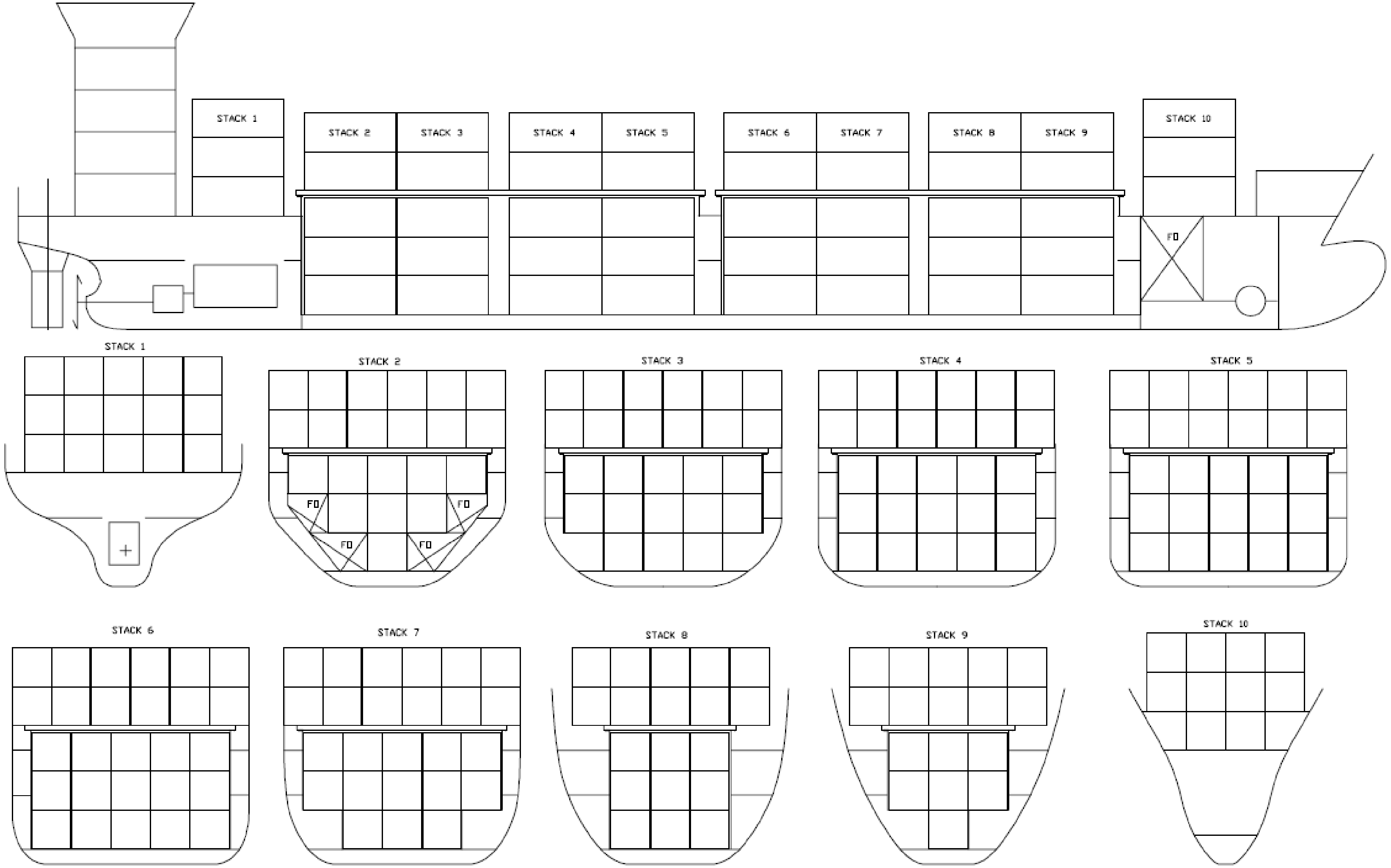
- A traditional general cargo vessel
  - 85 m
  - Boundary speed: 9,5 knot
  - CB: 0,83
  - 4200 DWT
  - 221 TEU

Slender container ship concepts

- Boundary speed of 12 knots for all variants
- Base design is 85 meters
- Scaled down versions: 75% to 37% of the base design dead weight

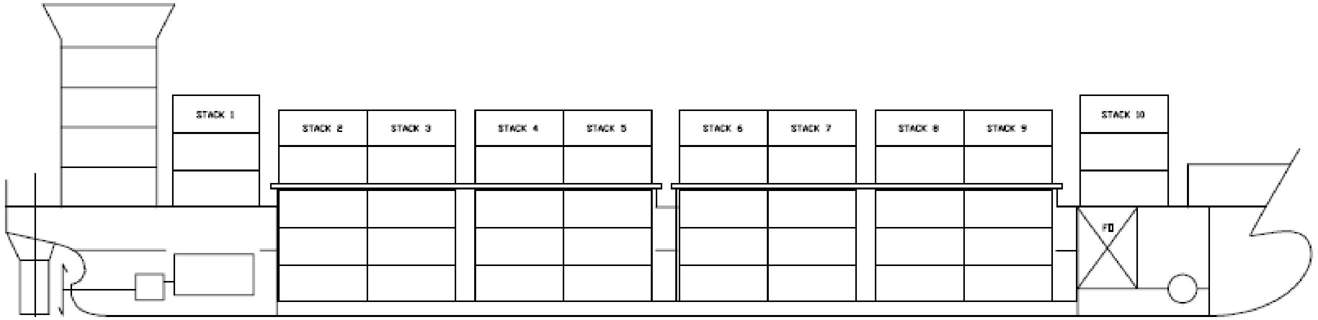
Base concept ship

- Main dimensions
  - Lpp 85m, LOA 90.4m
  - B 15.8 m T=5.4m
  - Cb=0.7
- Service speed 12 knots
- Cargo capacities
  - 190 14t TEU
  - DW 3550t

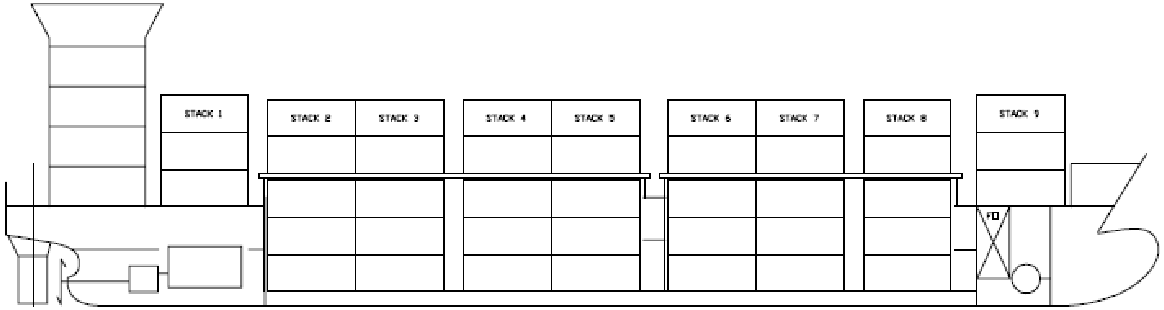


Smaller variants

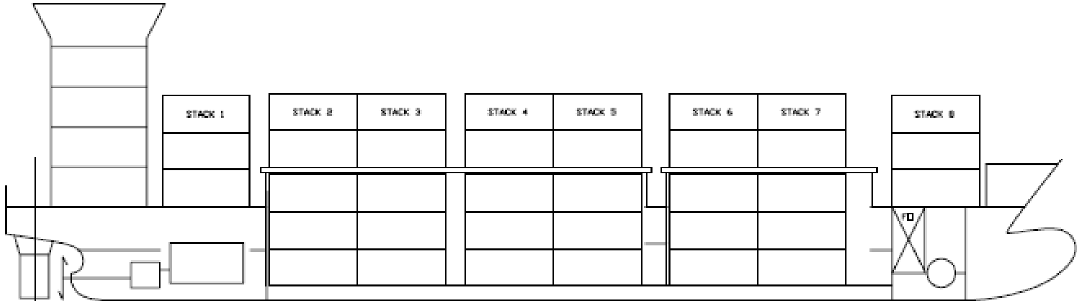
- 75% of ref. DW variant
  - Lpp 74,5m, B 15.8m T=4.9m Cb=0.67
  - Service speed 12 knots
  - DW 2660t, 158 14t TEU



- 50% of ref. DW variant
  - Lpp 68m, B 13.3m T=4.6m Cb=0.64
  - Service speed 12 knots
  - DW 1780t, 86 14t TEU



- 37% of ref. DW variant
  - Lpp 60m, B 13.3m T=4.6m Cb=0.61
  - Service speed 12 knots
  - DW 1300t, 71 14t TEU



Automation concept AL4: Constrained Autonomy

Definitions from Rødseth et al. 2018:

Autonomy level AL4

- All functions executed autonomously
- Pre-programmed limits:
  - Maximum deviation of arrival time
  - Maximum deviation from planned route
  - Maximum weather condition

Automation and manning concept for the test case

Bridge Periodically unmanned

- Qualified navigation and control personnel onboard
- Normally the control positions are unmanned
  - Crew work dayshift only
  - Mustered to control stations if needed
- Degree of autonomy AL4
- No shore based control centre needed – onboard crew is the fallback

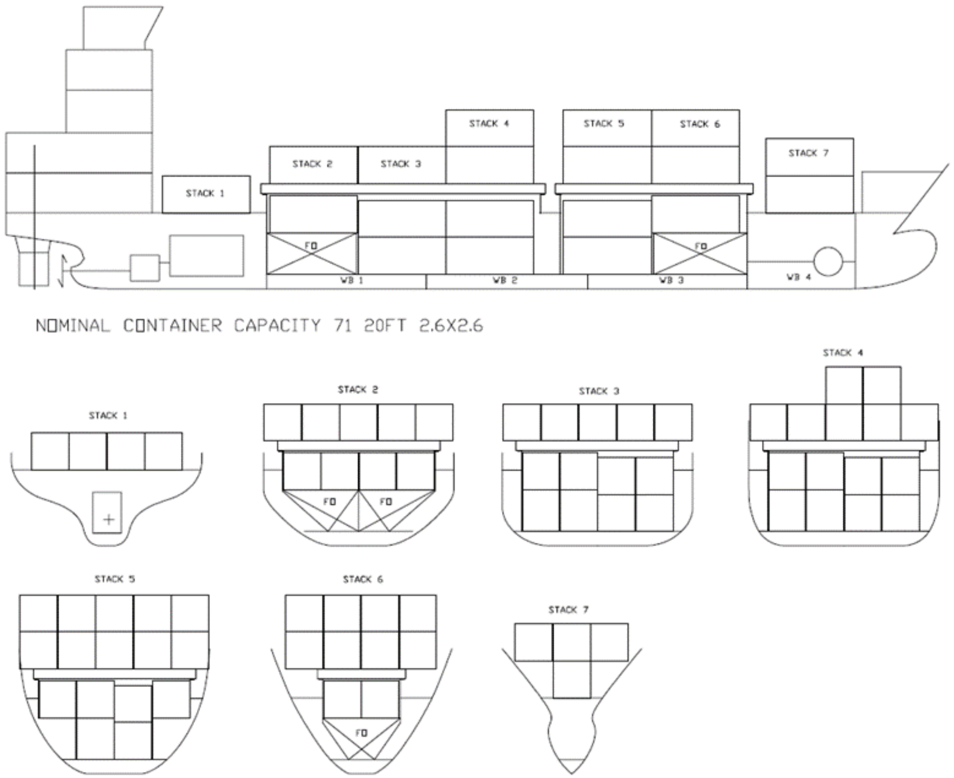
Bridge removed

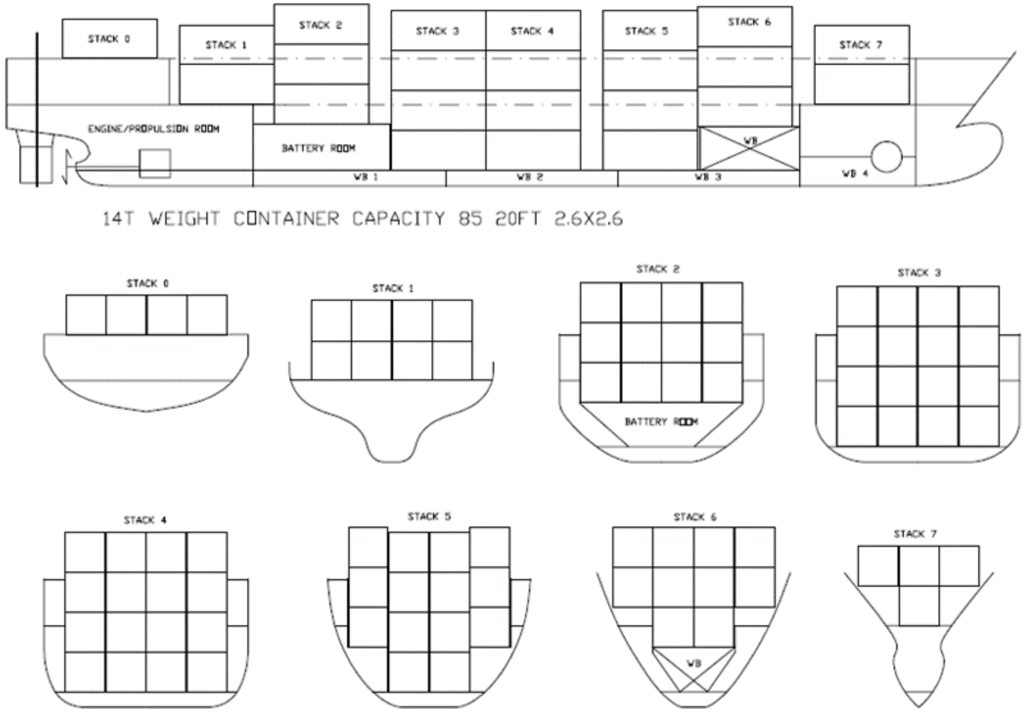
- control station below deck

Cost impact for chosen concept

- Increase in CAPEX for state-of-the-art technology
- Reduction in CAPEX due to removal of superstructure
- Reduction OPEX from reduced manning
- Increase in load capacity due to removal of superstructure

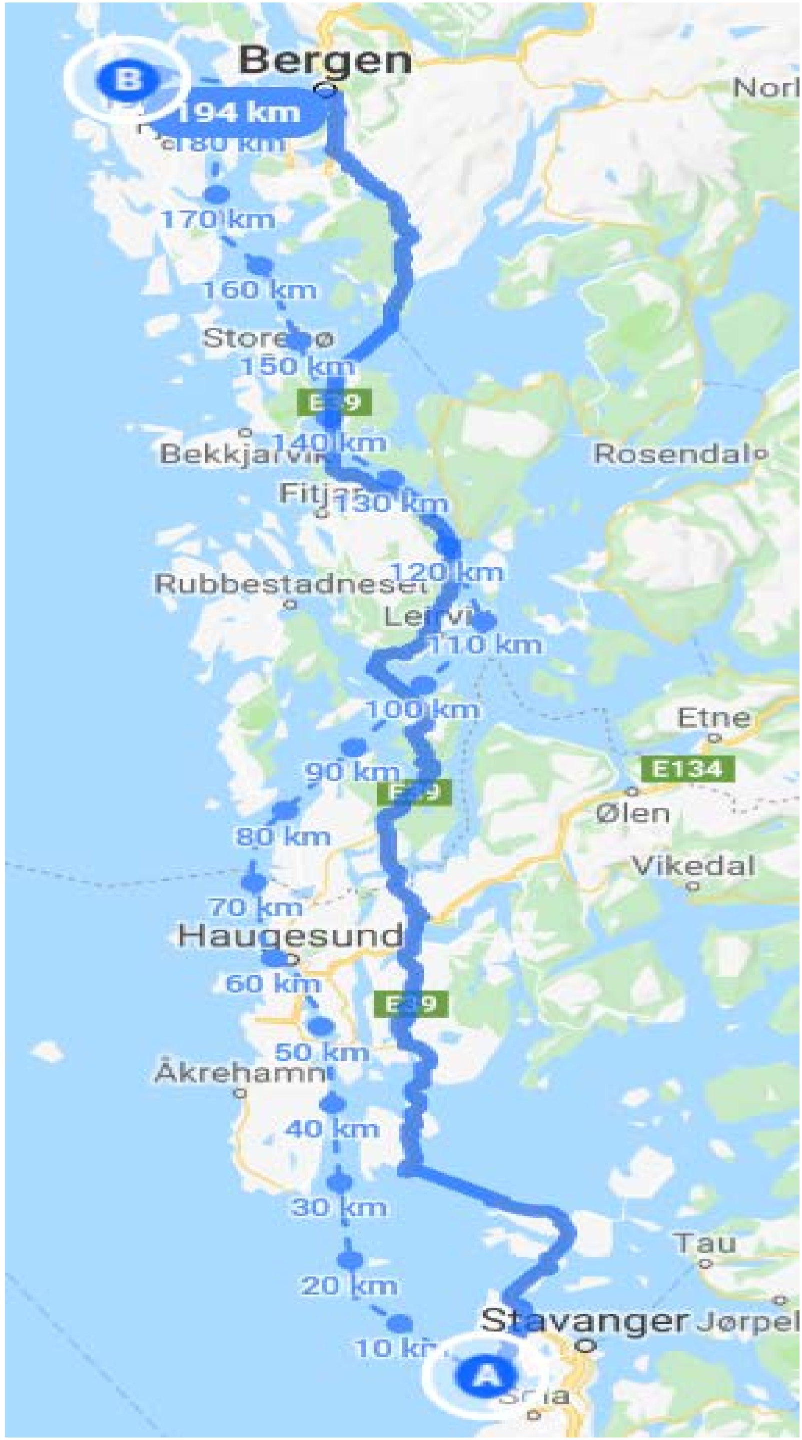
From conventional to autonomous increases capacity with 20% on a 60m container vessel





Test case

- Transport of containers between two Norwegian ports
- Road route:
  - 236km of which 205km on road and 31km of ferry crossings
  - **Cost: 284 EUR/TEU**
  - **C02: 150 kg/TEU**
- Sea route:
  - 194km coastal route = (105nm)



Test case

Two scenarios:

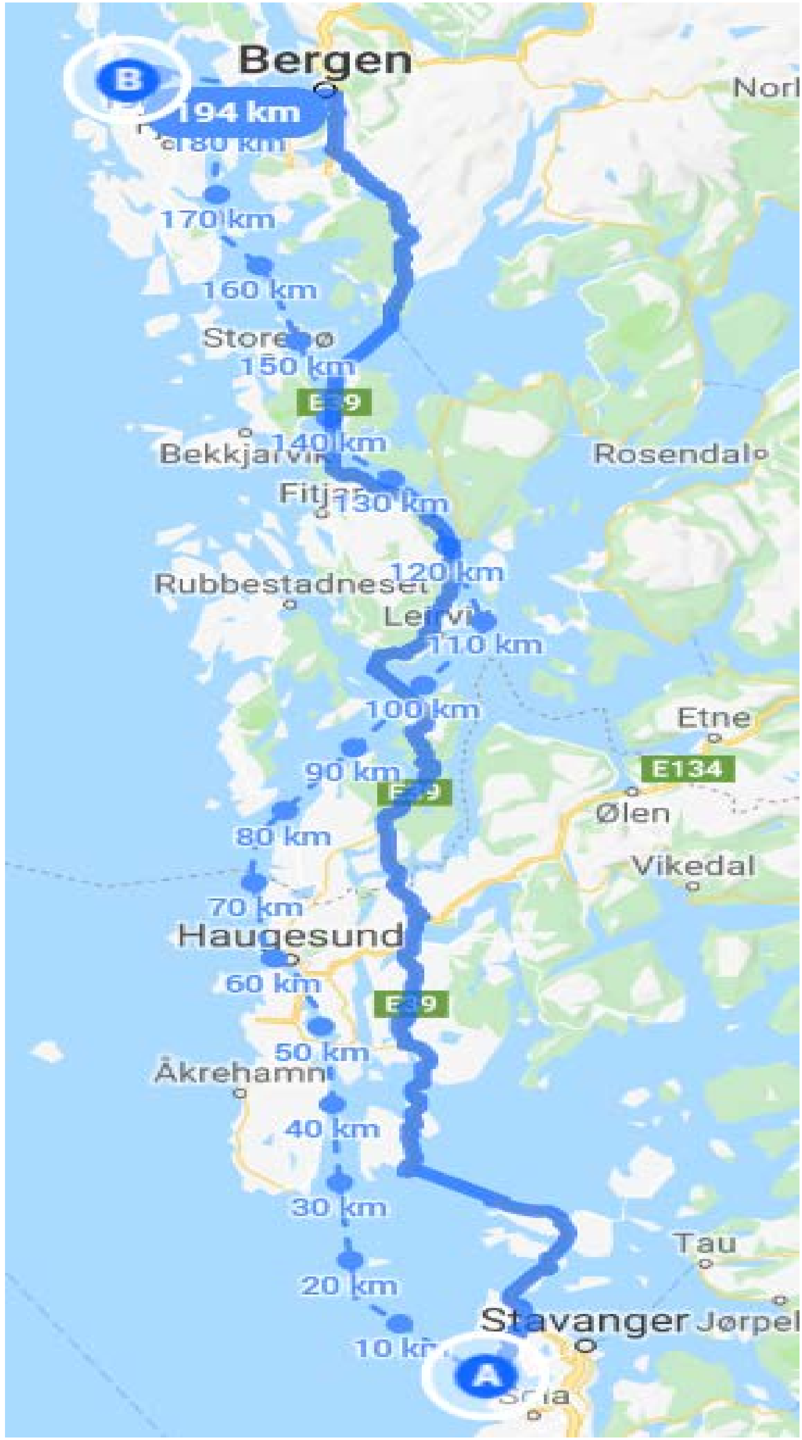
A: Effects of slender ship design and no autonomy

B: Effects of improved ship design with autonomy

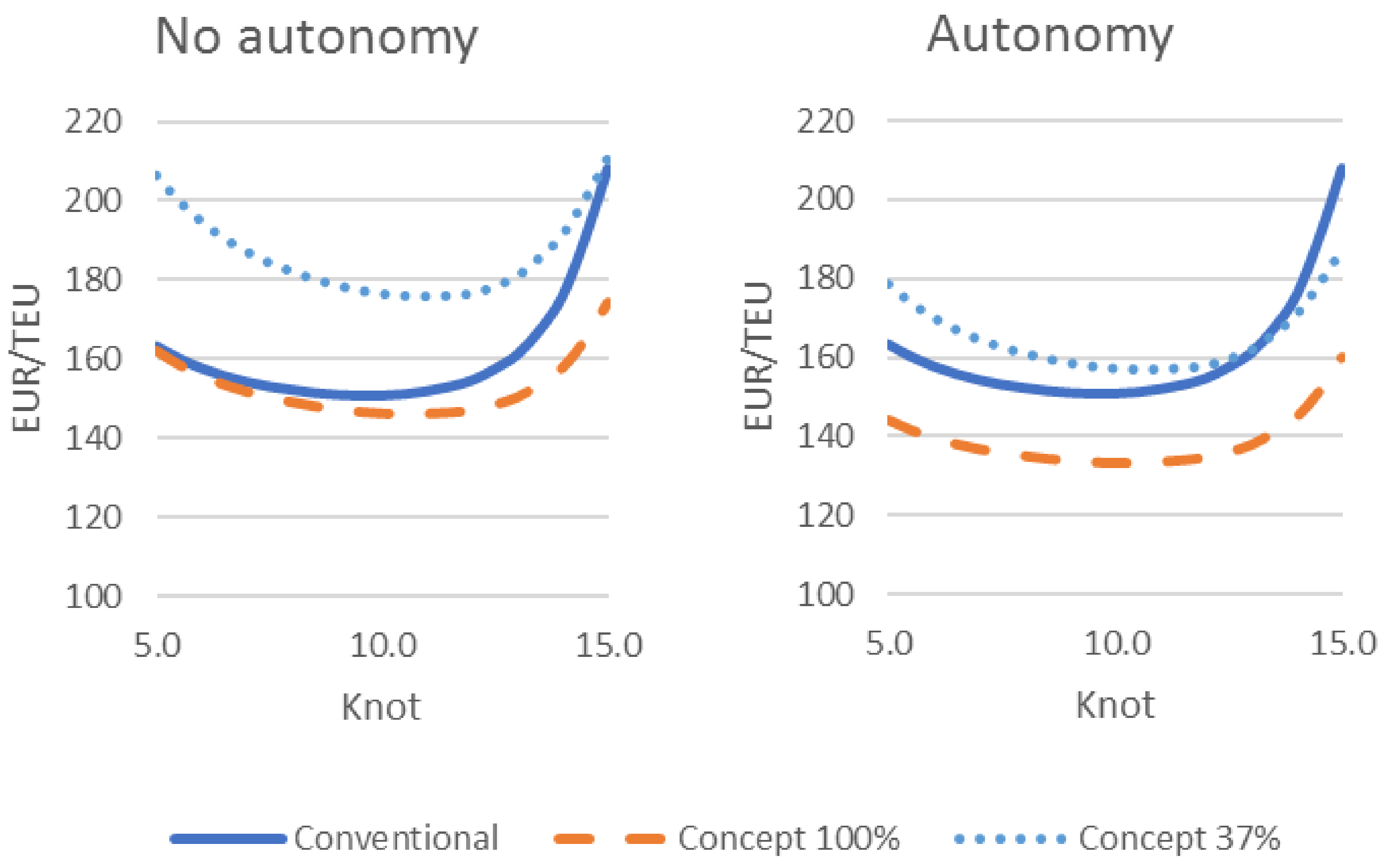
Two load cases:

50% load of total capacity

50TEUs regardless of total capacity



Cost per TEU with 50% load – function of speed



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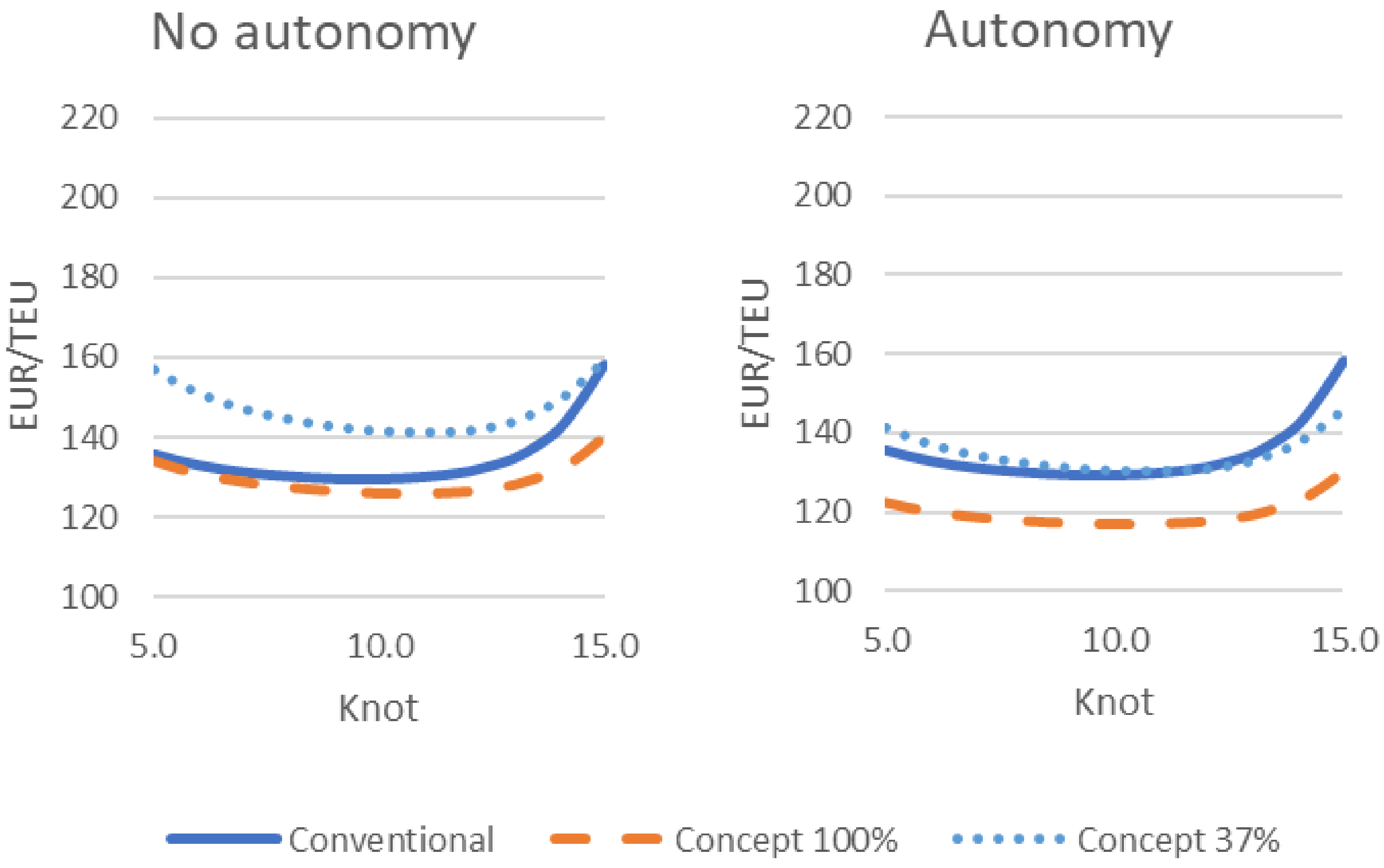
Cost per TEU with 100% load – function of speed



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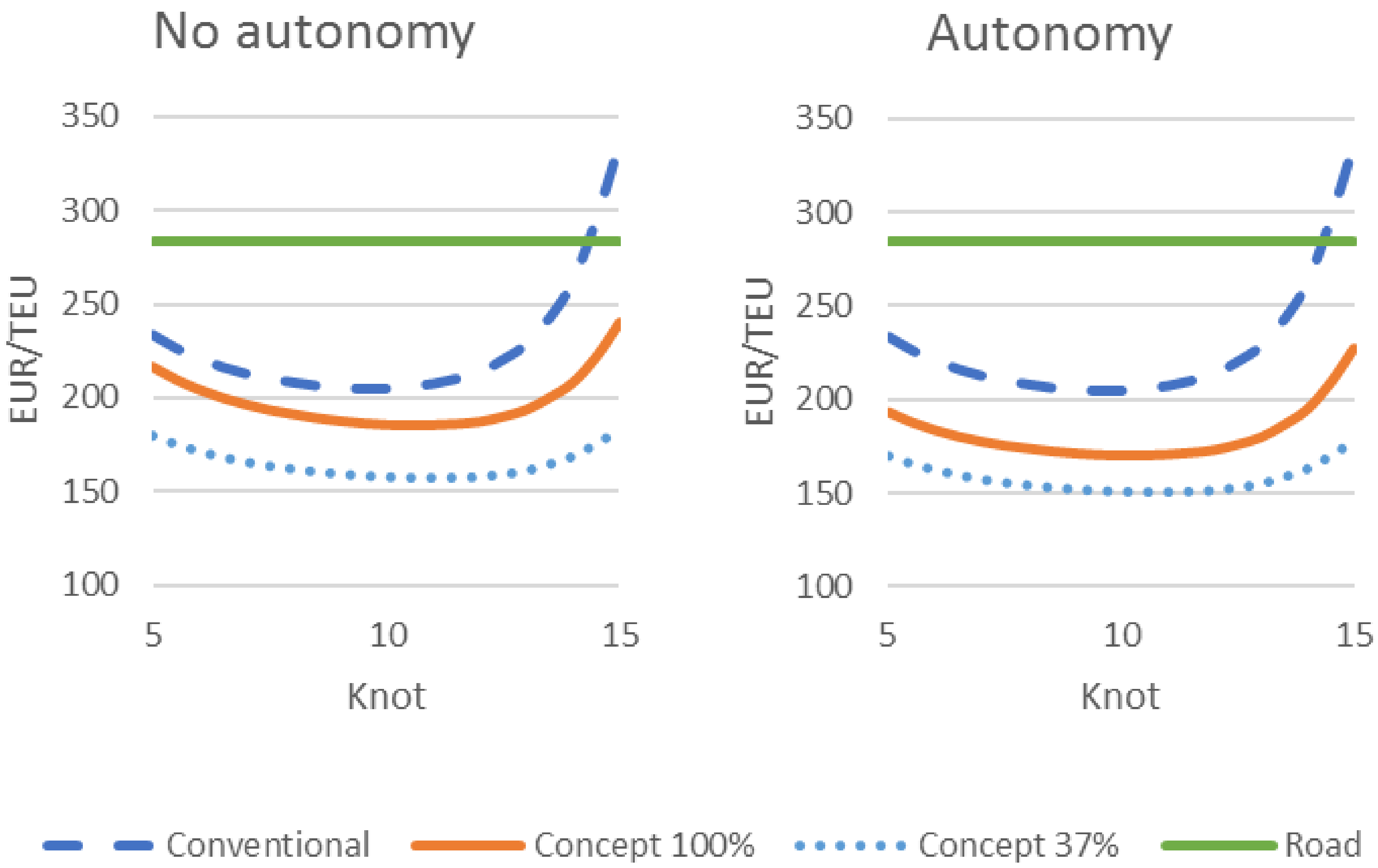
Cost per TEU with 50TEU load – function of speed



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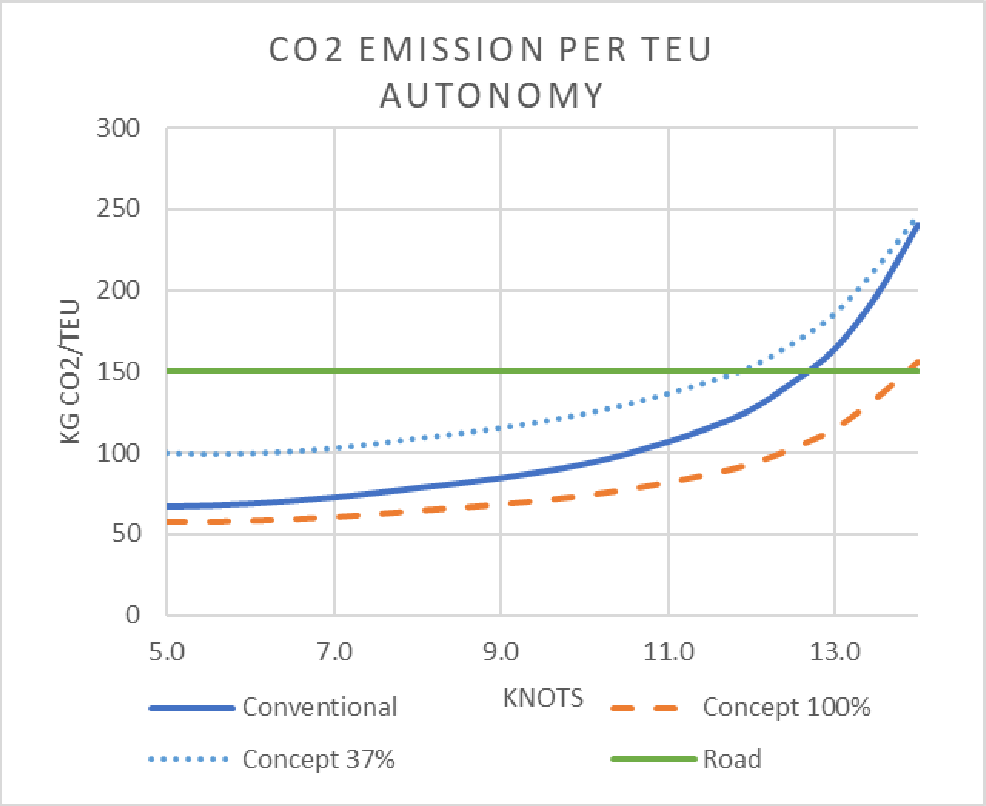
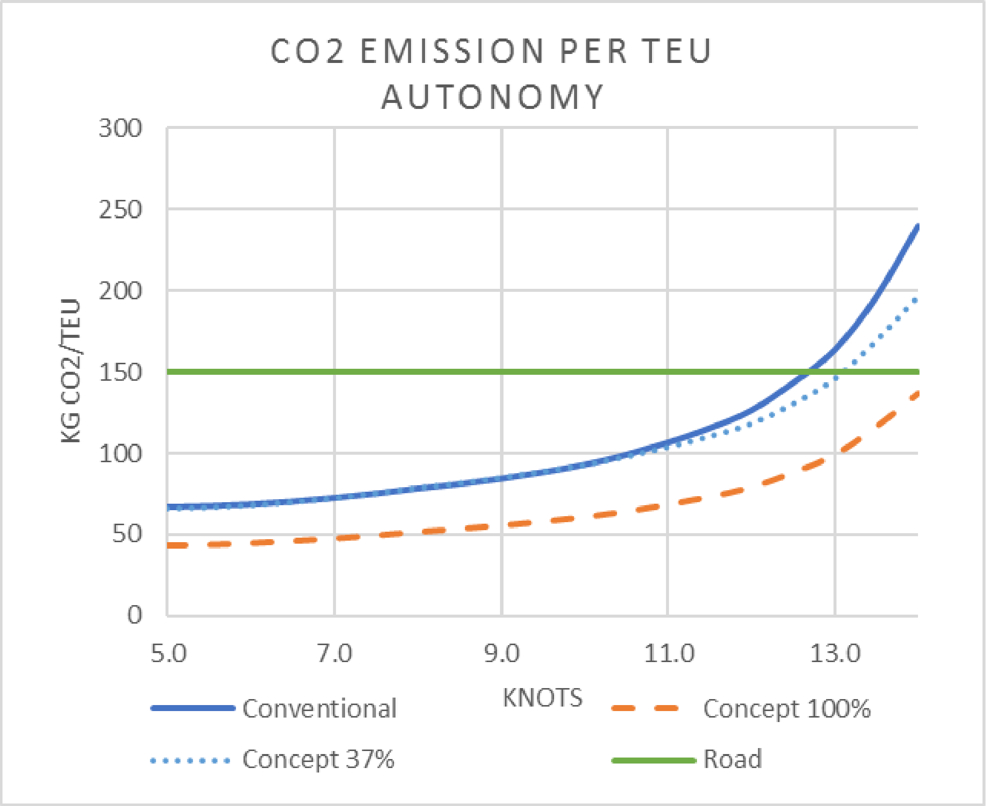
CO2 emissions per TEU at 50% load

No-Autonomy – Scenario A



Autonomy – Scenario B



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Conclusion

Our results show that:

- Ships can compete with trucks: Slender and autonomous designs have lower **emissions** and transport **cost**
- Autonomy makes smaller ships competitive

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