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Operational solutions for emissions reduction and CII estimation

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This lecture

Before break (45 min)

- Speed reduction implementation for emissions reduction
- The chokepoint case

After the break (45 min).

- CII calculations
- Review of voyage calculation example

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Learning outcomes

This lecture will help with the following learning outcomes:

Knowledge

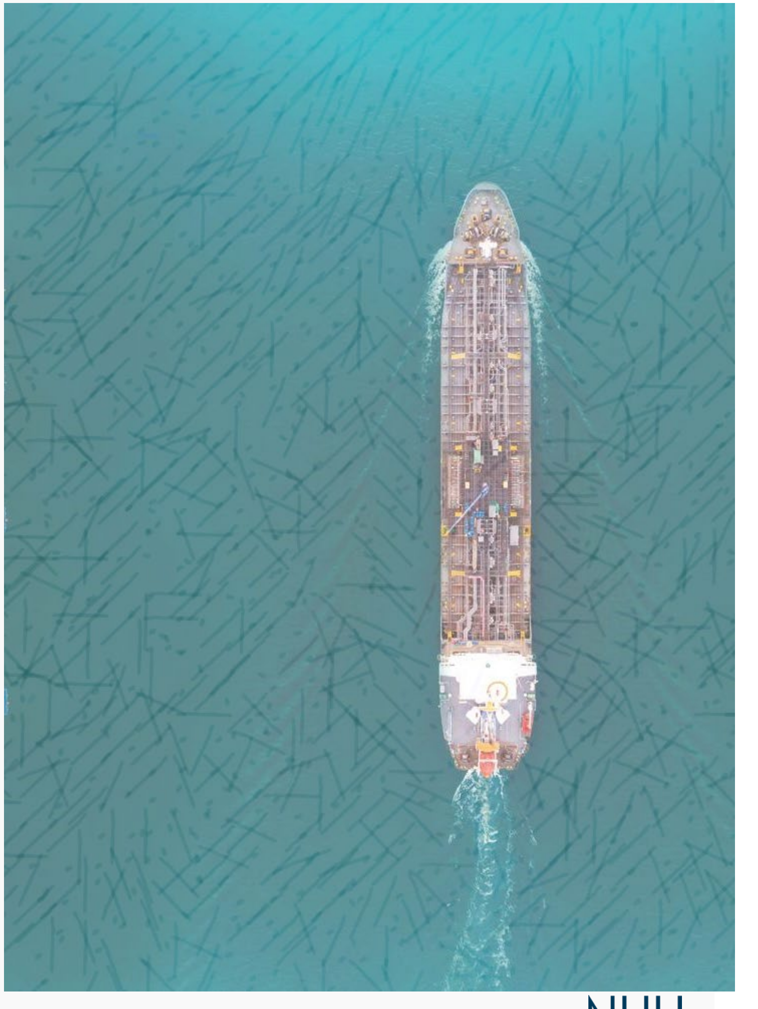
- understand the main results in recent research within shipping economics and analytics
- is familiar with recent development in data-driven analysis applied to the freight markets and ship operation.

Skills

- can communicate with industry practitioners using correct terminology

Competency

- exchanges opinions and experiences with others with a background in the field



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Available Decarbonization Options

	Pros	Cons
LNG	- Mature technology	- Still a fossil fuel, potential for methane slip - Requires significant infrastructure
Hydrogen /Hydrogen based fuel	- Can be produced from renewable energy (green hydrogen) - Water as byproduct (if proper combustion)	- High production costs (for now) - Low energy density (Hydrogen) - Explosive(Hydrogen) and Toxic (Ammonia)
Biofuels	- Can be used with existing infrastructure	- Availability and Scalability is limited - Potential competition with food production and land use

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Available Decarbonization Options

	Pros	Cons
Nuclear	- High energy density - Proven technology	- Regulatory and safety concerns, - Public resistance, - Waste disposal issues
Carbon Capture and Storage	- Allow use of existing carbon fuels	- Early stages - Infrastructure for storage or utilization of carbon captured - Potential Environmental risk
Speed Reduction	- Can be applied immediately without new technology - Reduces operational cost - Implemented as a response of high fuel prices	- Reduced global freight transport supply - Unaligned incentives - Not enough to fully decarbonize shipping

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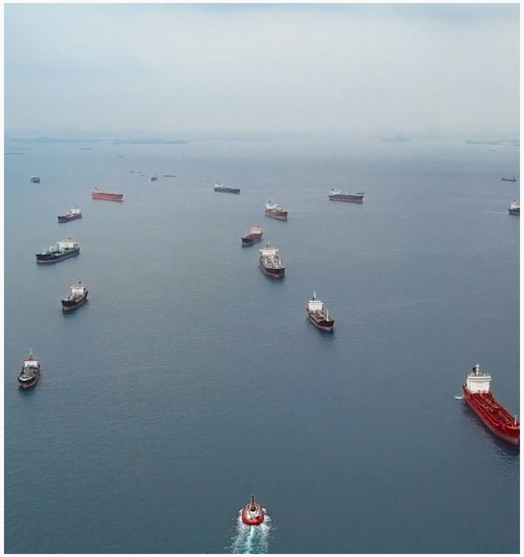
Speed Reduction Influenced by Port Efficiency

Implementation

- It is common to observe vessels sailing at full speed to then wait at anchorage for several days.
  - An attitude defined as Rush to Wait (RTW)
- Speed reduction could be implemented as:
  - Vessels arrive just at the time to be served (Just in Time)
  - Vessel slows down when information of congestion reaches them and report their arrival as if they would have kept the same speed (Virtual Arrival)
- If VA is implemented perfectly, Very Large Crude Carriers could reduce up to 20% of emissions. (Jia et al., 2017)
- Requires a tight and dynamic relationship of arriving vessels and the port management



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Speed Reduction Influenced by Port Efficiency

Barriers

- Contractual barriers
  - Vessel should sail with utmost dispatch to the port of destination
  - Tendering a Notice of Readiness upon being sighted (physical arrival)
- Principal-Agent Problems
  - Voyage charter contract, in the simple case, two parties shipowner (agent) and charterers (principal) have unaligned incentives (Rehmatulla and Smith, 2015)
  - Shipowner would like to reduce speed to save on fuels as they bear the cost
  - Charterer would prefer their vessel ready to load to queue at port (FIFO ports) or to reduce the risk of late arrival
  - Information asymmetry as the charterer can react after the shipowner acted..
  - ... and the penalties are quite heavy (e.g. canceling the voyage or claiming damages)

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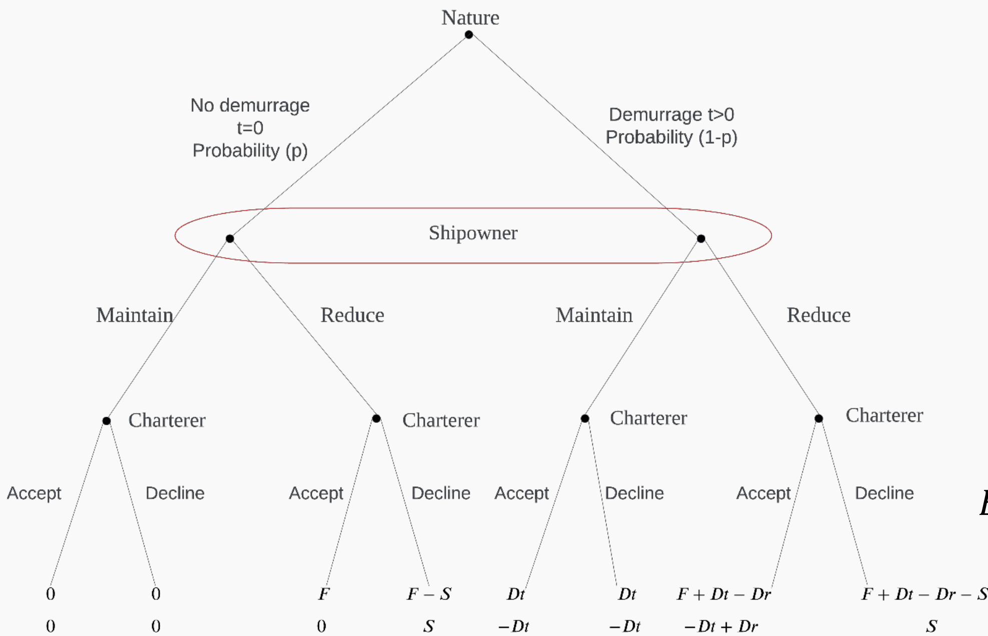
Speed Reduction Influenced by Port Efficiency



Notation	Description
F	Fuel savings
D	Demurrage benefit/cost
t	Maximum time of demurrage
r	Time lost of demurrage for reducing speed
S	Damages claimed by the charterer to the shipowner for deviating
p	Probability of dealing with a charterer that will allow the vessel to reduce speed

$$E[MaintainingSpeed] \leq E[ReduceSpeed]$$

$$F \geq Dr + S - pDr$$

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Chokepoints: An Interim Implementation Strategy

- Speed reduction is implemented at a chokepoint, and not at a port
- As NOR is only to be tendered at port, there is no incentive to RTW to get to a chokepoint. Poulsen and Sampson, 2019 presented some arguments on RTW to be a rational behavior in the maritime industry (based on uninterrupted port to port trips),
- As per the incentives, the shipowner reduces speed (operational cost) while the charterer remains unaffected as the decision of passing the vessel is exclusive of the chokepoint operator
- This assumes that the chokepoint is the scheduling manager and the only that instructs vessels to reduce speed
- We explored implementation if by the Panama Canal

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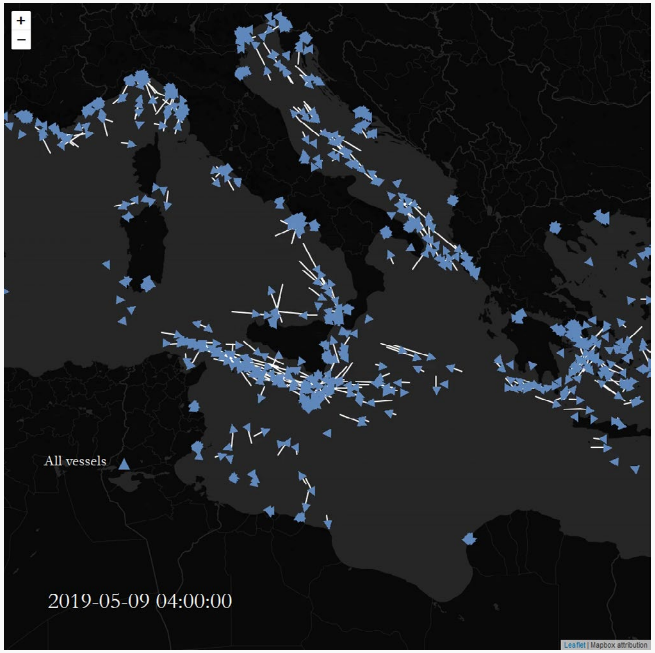
Chokepoints: An Interim Implementation Strategy

Benchmark

- Energy demand estimation and emissions factors sourced from IMO GHG study 4th (IMO benchmark)
- Waiting times and transit times estimated with own algorithms fed with Automated Identification System (AIS) high frequency data and M/L methods
- AIS are satellite/radio signals with vessels positions and positions timestamp, among other variables
- Generated statistics verified against official monthly aggregated statistics (98% of transits)
- The study contributed to the method on how to estimate waiting times at canal with high accuracy.



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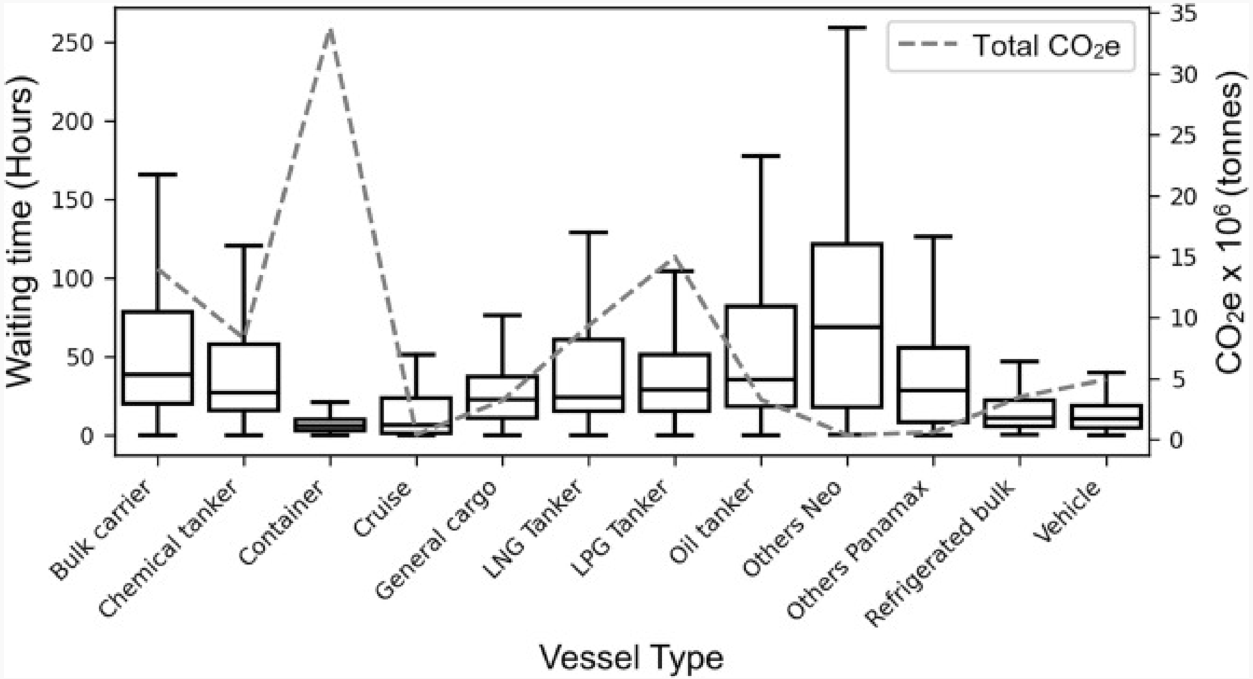
Chokepoints: An Interim Implementation Strategy

Waiting times vs CO_2e emissions



Source: Fuentes and Adland, 2023

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Chokepoints: An Interim Implementation Strategy

Most emitting routes

Origin	**Destination**	**CO_2e $x10^6$ (tonnes)**	**Main vessel type**
Busan port	Port of New York and New Jersey	2.23	Container
Busan port	Port of Houston	1.98	Container
Xiamen	Port of New York and New Jersey	1.35	Container

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Chokepoints: An Interim Implementation Strategy

Implementation strategies

Strategy	Description	Red.	Complexity
Coordinated voyage	Vessel reduce speed from origin up to the Canal	5.2%	- Vessels' arrival uncertainty due to external effects (e.g., weather)
JIT 48 hours	Vessel reduce speed 48 hours before arrival	1.7%	- Lower arrival uncertainty but significantly less impact
Green slots	Works on existing JiT slots assigned by the Canal. It just assign all slot opportunity to the best (GHG reduction) prospect	0.3%	- Limited slots and small reduction potential. - The simplest
Green slots + JiT 24 hrs	Do same as Green slots and instruct speed reduction for vessels 24 hours before arrival	1.2%	- Hybrid between the last two options. - 24 hours before arrival allows information to settle

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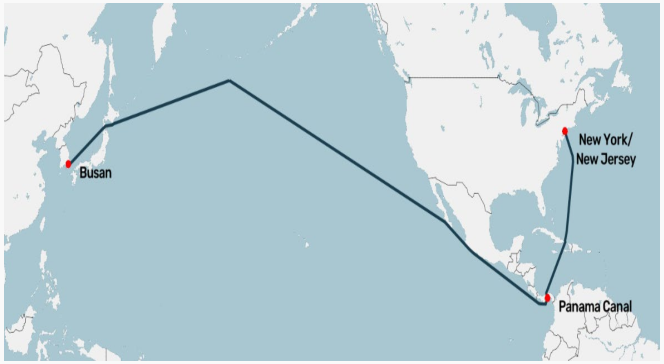
Focused Green Corridor Strategy

- Coordinated voyage strategy on the highest emitting route (Busan to NY/NJ)
- Use the existing framework of Green Corridors implemented by the Getting to Zero Coalition
  - Selected shipping routes with low and zero-emission vessels can operate efficiently.
- If implemented, it would rank 9th in terms of carbon intensity compared to existing routes
- Centralization of authority matters. The Canal has control of a large part of their operations.
- Infrastructure developed in a chokepoint could easily adapt to other routes
- Changing Mindsets
  - Starting with Speed Reduction, Gradually Escalating to Clean Fuel Routes
- It is not only about the emissions reduced by speed reduction but the catalyst effect it could have on scalability of green fuels



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AER and CII

- **Carbon Intensity Indicator** (CII)
- **Annual emissions rating** (AER) is a type of CII metric to calculate carbon efficiency. It is estimated as $\frac{CO_2}{DWT x\ distance\ sailed}$
- Capacity Gross Ton Distance (cgDist) – another type of CII and is estimated as $\frac{CO_2}{GT x\ distance\ sailed}$
- CII applies to all vessels above 5,000 GT, on some vessel types (bulk carriers, gas carriers, tankers, container ships, general cargo ships, refrigerated cargo carriers, combination carriers, LNG carriers, vehicle carriers, Ro-Ro cargo vessels, Ro-Ro passenger vessels and cruise ships)
- CII is reported on a yearly basis!
- Distance only from sea passage, no anchorage
- Corrections are allowed due to ice navigation, cargo ops, dynamic position, reliquefaction, refrigerated containers

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Steps for AER and CII estimations

1) $AER\left(\frac{g}{ton\ mile}\right) = \frac{CO_2}{DWT x\ distance\ sailed} x10^6$

2) $CII_{ref} = a\ x\ Capacity^{-c}$

Ship Type		Capacity	a	c
Bulk Carrier	DWT ≥ 279,000	279,000	4745	0.622
	DWT < 279,000	DWT	4745	0.622
Gas Carrier	DWT ≥ 65,000	DWT	14405E+7	2.071
	DWT < 65,000	DWT	8104	0.639
Tanker		DWT	5247	0.610
Container ship		DWT	1984	0.489
General cargo ship	DWT ≥ 20,000	DWT	31948	0.792
	DWT < 20,000	DWT	588	0.3885
Refrigerated cargo carrier		DWT	4600	0.557
Combination carrier		DWT	40853	0.812
LNG Carrier	DWT ≥ 100,000	DWT	9.827	0
	100,000 > DWT ≥ 65,000	DWT	14479E+10	2.673
	DWT < 65,000	65,000	14479E+10	2.673
Ro-ro cargo ship (VC)		GT	5739	0.631
Ro-ro cargo ship		DWT	10952	0.637
Ro-ro passenger ship		GT	7540	0.587
Cruise passenger ship		GT	930	0.383

Source: ClassNK

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1 g $=10^{-6} ton$

AER and CII estimations

3) $CII_{required}(2024) = CIIref\ x\ \left(\frac{100-7}{100}\right)$

Year	Reduction Factor (Z)
2023	5%
2024	7%
2025	9%
2026	11%
2027	**
2028	**
2029	**
2030	**

Source: ClassNK

4) $ratio = \left(\frac{AER}{CII_{required}}\right)$

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AER and CII estimations

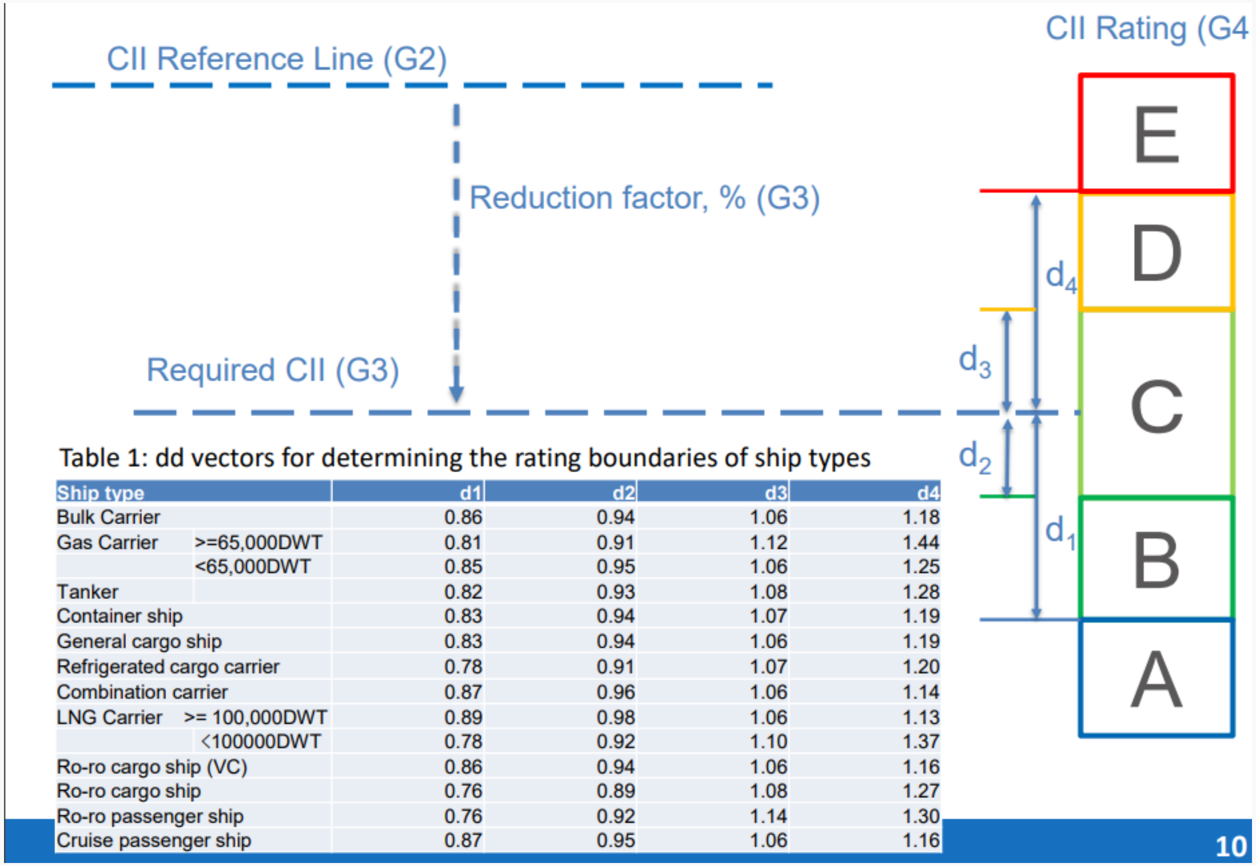

Table 1: dd vectors for determining the rating boundaries of ship types

Ship type		d1	d2	d3	d4
Bulk Carrier		0.86	0.94	1.06	1.18
Gas Carrier	>=65,000DWT	0.81	0.91	1.12	1.44
	<65,000DWT	0.85	0.95	1.06	1.25
Tanker		0.82	0.93	1.08	1.28
Container ship		0.83	0.94	1.07	1.19
General cargo ship		0.83	0.94	1.06	1.19
Refrigerated cargo carrier		0.78	0.91	1.07	1.20
Combination carrier		0.87	0.96	1.06	1.14
LNG Carrier	>= 100,000DWT	0.89	0.98	1.06	1.13
	<100000DWT	0.78	0.92	1.10	1.37
Ro-ro cargo ship (VC)		0.86	0.94	1.06	1.16
Ro-ro cargo ship		0.76	0.89	1.08	1.27
Ro-ro passenger ship		0.76	0.92	1.14	1.30
Cruise passenger ship		0.87	0.95	1.06	1.16

Source: ClassNK

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AER and CII estimations

- We have an Aframax of 80k DWT that have travelled for 59,000 nautical miles and produced 22,250 tons of CO2 in 2025. Estimate its AER and CII ranking.
- If the vessel has the same performance on 2026 what would be the rating?
- What could they do to improve its rating?

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References

Fuentes, G., & Adland, R. (2023). Greenhouse gas mitigation at maritime chokepoints: The case of the Panama Canal. *Transportation Research Part D: Transport and Environment*, *118*, 103694.

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