Energy Efficiency in Ship Operations

Exploring Voyage Decisions and Decision-makers

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Energy efficiency in ship operations - Exploring voyage decisions and decision-makers

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ABSTRACT

To mitigate climate change due to international shipping, the International Maritime Organization (IMO) requires shipowners and ship technical managers to improve the energy efficiency of ships' operations. This paper studies how voyage planning and execution decisions affect energy efficiency and distinguishes between the commercial and nautical components of energy efficiency. Commercial decisions for voyage planning depend on dynamic market conditions and matter more for energy efficiency than nautical decisions do for voyage execution. The paper identifies the people involved in decision-making processes and advances the energy-efficiency literature by revealing the highly networked nature of agency for energy efficiency. The IMO's current energy efficiency regulations fail to distinguish between the commercial and nautical aspects of energy efficiency, which limits the ability to mitigate climate change through regulatory measures. Policymakers should expand their regulatory focus beyond shipowners and technical managers to cargo owners to improve energy efficiency and reduce maritime transport emissions.

1. Introduction

To mitigate climate change from maritime transport, the United Nations' (UNs') International Maritime Organization (IMO) requires shipowners and ship technical managers to continuously improve the energy efficiency of their ships' operations. Since 2013, the IMO has required shipowners and technical managers to carry ship energy efficiency management plans (SEEMP) onboard their ships, detailing how they and their crews manage energy efficiency in the planning and execution of ship voyages (IMO, 2016). In 2018, the IMO adopted an initial greenhouse gas (GHG) abatement strategy, aiming to lower "CO2 emissions per transport-work, as an average across international shipping, by at least 40% by 2030, pursuing efforts toward 70% by 2050 compared to 2008" (IMO, 2018). In line with this ambition, it recently tightened energy efficiency requirements for shipowners and technical managers by introducing a mandatory, annual operational carbon intensity indicator (CII). The CII measures individual vessels' annual CO2 emissions divided by

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a proxy for transport work, and shipowners and technical managers are expected to continuously improve performance regarding this metric. A detailed definition of the CII, however, has not been given (IMO, 2021).

From 2008 to 2018, the energy efficiency of international ship operations improved by one third (IMO, 2020), but scholars continue to identify inadequate energy efficiency measures. These are known as energy efficiency gaps (Jaffe and Stavins, 1994) and are particularly relevant for the achievement of the IMO GHG goal. Acciaro et al. (2013), Jafarzadeh and Utne (2014), Johnson et al. (2014), Rehmatulla and Smith (2015), Adland et al. (2017), Rehmatulla et al. (2017), and Rehmatulla and Smith (2020), among others, have attributed energy efficiency gaps to a variety of organizational, behavioral, and economic barriers, emphasizing in particular how principal–agent problems hamper the implementation of cost-effective measures. In tanker shipping, shipowners and technical managers are expected to follow instructions from powerful cargo owners, who often have objectives other than energy efficiency (Poulsen and Sampson, 2020; Poulsen et al. 2021), and in dry bulk and offshore shipping, cargo owners sometimes prefer high-powered, energy-inefficient tonnage (Adland et al., 2015, 2017). Crews have also been found to struggle with energy-efficient voyage execution because they receive unclear instructions from shore-based organizations (Armstrong and Banks, 2015; Poulsen and Johnson, 2016; Viktorelius and Lundh, 2019; von Knorring, 2019) or depend on support from a variety of port stakeholders (Poulsen and Sampson, 2020). The energy efficiency literature thus indicates complex decision-making processes for ship operations but has not adequately explored the importance of agency for energy efficiency. Agency for energy efficiency refers to organizations' and organizational departments' capabilities to make and implement decisions that improve energy efficiency in ship operations and reduce emissions per unit of transport work. Given the IMO GHG goal, the agency issue is highly relevant to policy discussions and deserves further research attention. Aiming to fill this knowledge gap in the energy efficiency literature, this study explores the following research questions:

(1) How do decisions in voyage planning and execution affect energy efficiency in ship operations?
(2) Who makes such decisions?

The two most common definitions of energy efficiency for ship operations are the Annual Efficiency Ratio (AER; IMO, 2021) and the Energy Efficiency Operational Indicator (EEOI; IMO, 2009). Both the AER and EEOI divide a ship's annual CO2 emissions by a measure of annual transport work. The EEOI uses actual cargoes carried × the distances traveled for the calculation of transport work, whereas the AER relies on a vessel's nominal cargo capacity (deadweight) × the distances traveled. The EEOI thus takes account of vessel capacity utilization, which the AER disregards. Scholars have criticized the EEOI for failing to filter out random weather and sea effects (Panagakos et al., 2019; Polakis et al., 2019) and not distinguishing between the commercial and operational aspects of energy efficiency (Poulsen et al., 2021), warning that it is not a valid metric for energy efficiency. Wang et al. (2021) also warned that the IMO's CII requirements may even incentivize emissions increases in certain situations. This study extends these discussions and explores both these energy efficiency metrics to answer the two research questions, but it mostly focuses on the EEOI because it uses a finer-grained metric for transport work than the AER.

The paper is structured as follows: Section 2 reviews the energy efficiency literature on voyage planning and execution, elaborating on knowledge gaps, and Section 3 outlines the research design and methods. Section 4 examines how the practical consequences of decisions regarding voyage planning and execution affect energy efficiency in ship operations and identifies the relevant decision-makers. Section 5 discusses study findings, and Section 6 concludes with the implications for research and policymaking.

2. Literature review

Energy efficiency scholars distinguish between technological and operational energy efficiency measures (Rehmatulla and Smith, 2020). Technological measures such as Flettner rotors, propellor boss cap fins, and main engine de-ratings require capital outlays by shipowners. Operational measures do not require major investment but focus on improved voyage execution, including speed reduction, weather routing, trim optimization, auto-pilot optimization, engine optimization, reduced ballasting, port-call optimization, and just-in-time arrival in port (Faber et al., 2011; IMO, 2016). The current review focuses on the literature on operational measures, considering energy efficiency in voyage planning and execution in the different shipping sectors because their trading patterns differ.

2.1. Voyage planning

For tankers and dry bulkers, voyage planning starts with chartering decisions made by shipping companies' chartering managers, who generally aim to maximize earnings and minimize voyage costs (including fuel costs). The charter parties, which chartering managers negotiate with charterers, determine voyage planning (Panayides, 2018; Plomaritou and Papdopoulos, 2018) and influence energy efficiency. Several studies have shown that speed choices, as defined by charter parties, have a strong bearing on fuel consumption. Rehmatulla and Smith (2015a, p. 52) found that "the speed reduction measure is considered [by shipping managers] as the most important measure that could affect the energy efficiency of ships" but observed that voyage charter party clauses requiring utmost dispatch often prevent implementation. Studying AIS data, Adland and Jia (2018) found that capesize dry bulkers did not reduce speed to save fuel in 2011–2012 despite high fuel prices and low freight rates. This counterintuitive finding was attributed to charter party clauses, which required high service speeds. For voyage charters, Jia et al. (2017) advised ship managers and charterers to include virtual arrival clauses to allow for speed reduction and fuel savings in case of port congestion, but Poulsen and Sampson (2019) found oil cargo owners reluctant in this regard due to their commercial preferences for fast transits. Adland et al. (2017) studied time charter rates for bulk carriers and observed that energy inefficient, high-powered, fast vessels achieved time charter premiums in 2003–2008. This "reflects entirely rational economic behaviour, as the value of time far exceeds any fuel savings during times of very high freight rates" (p. 10). This suggests highly complex decision-making processes in voyage planning but leaves unexplored how plans are executed. The empirical relationship between speed and fuel consumption and the energy efficiency potential of speed reduction also remain matters of debate (Adland et al., 2020).

In container shipping, voyage planning concerns the design of liner networks, the assignment of vessels to routes, and speed choices, all of which influence energy efficiency (Agarwal and Ergun, 2008; Gelareh et al., 2010; Meng and Wang, 2011; Brouer et al., 2014; Meng et al. 2019; Christiansen et al., 2020). Cariou (2011), Lindstad et al. (2011), Norstad et al. (2011), Faber et al. (2011), Comer et al. (2018), and Leaper (2019), among others, found significant energy efficiency potential in speed reduction, and fuel consumption is generally assumed to have a cubic relationship with speed (Ronen 1982, 2011; Lindstad et al., 2011; Wang and Meng 2012). Psaraftis and Kontovas (2013) outlined the important debates concerning optimum speed under different commercial and environmental constraints, including potential misalignments between profit maximization and energy efficiency. Psaraftis and Kontovas (2014) found that "solutions for optimal environmental performance are not necessarily the same as those for optimal economic performance" (p. 66). They showed how fuel prices, freight rates, cargo inventory costs, and the dependence of vessels' fuel consumption on payload affected optimum speed and energy efficiency. Cariou (2011) studied container lines' speed choices and found them slowing down in response to low freight rates and high fuel prices to reduce fuel consumption and costs. He pointed out that container lines would probably speed up if fuel prices fell and freight rates and cargo inventory costs rose. More recently, Cariou et al. (2019) found that speed reduction—combined with new ship technologies and improved network designs—had enabled container shipping to reduce CO_2 emissions per unit of transport work by 53% in 2007–2016. Due to its limited scope, voyage planning for liner-type ferries has not attracted much research. Wergeland (2012) made an important distinction between subsidized 'lifeline' routes (e.g., between Scottish or Greek islands) and commercially viable routes. Subsidized routes operate according to public tenders, which specify service frequencies and influence voyage planning (Baird and Wilmsmeier, 2011; Rehmatulla et al., 2017). Such requirements do not affect commercially viable routes, but both route types involve considerable seasonal variations in traffic volumes, which affect voyage planning (Poulsen, 2019).

2.2. Voyage execution

Concerning energy efficient voyage execution, researchers have focused mainly on seafarers. Faber et al. (2011), Poulsen and Sornn-Friese (2015), IMO (2016), Rasmussen et al. (2018), and Hansen et al. (2020) advised shipowners and technical managers to raise crew energy efficiency awareness and provide voyage execution training. Johnson et al. (2013), Rasmussen et al. (2018), Viktorelius (2020), and Hansen et al. (2020), however, found that shipping company operations managers often imposed conflicting operational and voyage plans on crews, and Viktorelius and Lund (2019) identified several operational trade-offs and goal conflicts regarding energy efficient voyage execution for ferries. They called for further exploration of crews' involvement in voyage execution and energy efficiency—calls that this paper aims to address.

Many studies (as summarized by Zis et al., 2020) have specifically recommended the use of weather routing services to save fuel. Zis et al. (2020) pointed out that improved meteorological data and advanced data analytics could guide crew's navigational decisions. Although weather routing is a rapidly growing research field, no specific studies have considered crews' use of such systems. This is an important knowledge gap, which relates directly to the issue of crews' agency regarding energy efficiency.

The IMO (2016) recommended that shipping companies improve their vessel performance monitoring systems to identify best practices for ship operations and help crews improve voyage execution. Poulsen and Johnson (2016) found that short-term time charters and temporary crew organizations challenged vessel performance monitoring and therefore energy efficiency. Johnson et al. (2014) and von Knorring (2019) documented how organizational rules and a lack of implementation capacity hampered energy-efficient voyage execution. Viktorelius (2020) argued that fuel consumption data collection could not *per se* improve energy efficiency; improvements depended on how users implemented and adopted performance monitoring systems and on the availability of time and resources for shipping organizations' data analysis.

Scholars have also studied how port-call execution affects voyage execution. Johnson and Styhre (2015) and Andersson and Ivehammer (2017) documented considerable idle time for dry bulkers and tankers in ports and advised ship managers, stevedores, and other port stakeholders to speed up port calls to save fuel. In a tanker shipping study, Poulsen and Sampson (2020) found that officials and other port stakeholders often caused delays, limiting shipping companies' and crews' leverage regarding port-call optimization. These matters, to the best of our knowledge, have not been addressed for liner shipping; hence, this paper extends the existing studies to ferries, which have very frequent port calls and would benefit from port-call optimization.

In summary, the energy efficiency literature has highlighted complex decision-making processes in the planning and execution of ship voyages, suggesting a need to further explore how energy efficiency decisions are made and executed and by whom. This study explores these questions and extends the literature by providing new insights into agency for energy-efficient ship operations.

3. Methods

To explore the myriad voyage planning and execution decisions that influence energy efficiency, this study used a qualitative research design. It combined semi-structured interviews with ethnographic non-participant observation and studied both decision-makers' perceptions of energy efficiency and their actual behavior in the planning and executing of ship voyages. The authors carried out non-participant observation onboard five ferries and three tankers and conducted over 100 interviews with shipping managers and

Table 1
Interviewees (ordered chronologically).

Interviewee no.	Interview no.	Position	Type of organization	Date	Duration of recorded interview	Interviewer
1	1	Environmental Manager/Senior Sustainability Manager, CSR	Container line	August 16, 2012 May 27, 2014 June 10, 2020	0:56.31 0:55:31 1:14:00	Poulsen
2	2	General Manager, Technical	Chemical tanker shipping company	August 17, 2012	1:44:52	Poulsen
3	3	Vice President, Technical	Container line and tanker shipping company	August 28, 2012	0:49:40	Poulsen
4	4	Senior Manager, Technical	Product tanker shipping company	August 21, 2012	1:05:22	Poulsen
5	5	Chief Executive Officer	Product tanker shipping company	August 24, 2012	1:17:59	Poulsen
6	5	Senior Manager, Technical	Product tanker shipping company	August 24, 2012	1:17:59	Poulsen
7	6	Managing Director	Dry bulk shipping company	November 29, 2012	1:37:57	Poulsen
8	7	Director, Technical department	Container shipping company (tonnage provider)	November 30 – December 2, 2012	E-mail correspondence	Poulsen
9	8	Nautical School Professor, former Head of ferry line	Ferry shipping company	December 5, 2012	2:05:56	Poulsen
10	9	General Manager, Energy Efficiency/Technical	Product tanker shipping company	March 8, 2013	1:42:36	Poulsen
11	10	Director, Operations	Dry bulk shipping company	April 15, 2013	2:17:32	Poulsen
12	11	Senior Manager, Chartering	Dry bulk shipping company	April 17, 2013	1:18:16	Poulsen
13	12	Executive Vice President	Product tanker shipping company	May 3, 2013	1:13:53	Poulsen
14	13	Senior Vice President, Operations	Dry bulk shipping company	May 6, 2013	1:40:19	Poulsen
15	13	Head of Technical	Dry bulk & multi-purpose shipping company	May 6, 2013	1:29:23	Poulsen
16	14	Managing Director	Dry bulk shipping company	May 7, 2013	1:16:30	Poulsen
17	15	Chief Technical Officer	Gas shipping company	May 8, 2013	2:20:40	Poulsen
18	15	General Manager, Chartering	Dry bulk shipping company	May 8, 2013	2:20:40	Poulsen
19	15	Senior Vice President, Operations	Dry bulk shipping company	May 8, 2013	2:20:40	Poulsen
20	16	Director, Chartering	Product tanker shipping company	May 16, 2013	1:46:37	Poulsen
21	16	Director, Technical	Product tanker shipping company	May 16, 2013	1:46:37	Poulsen
22	16	Executive Vice President	Product tanker shipping company	May 16, 2013	1:46:37	Poulsen
23	17	Chief Technical Director	Product and chemical tanker shipping company	May 21, 2013	1:15:59	Poulsen
24	18	Fleet Manager, Technical	Product tanker shipping company	May 29, 2013	1:13:14	Poulsen
25	29	Chief Operating Officer	Container line	June 17, 2013	1:09:09	Poulsen
26	20	Director, CSR	Tanker and dry bulk shipping company	June 19, 2013	1:41:21	Poulsen
27	20	Head of Fuel Efficiency, Technical	Tanker and dry bulk shipping company	June 19, 2013	1:41:21	Poulsen
28	21	Vice President, Fleet Management	Gas shipping company	June 24, 2013	2:36:19	Poulsen
29	22	Fuel Optimization Manager, Technical	Product, crude oil and gas tanker shipping company	June 27, 2013	1:33:19	Poulsen
30	23	Vice President, CSR	Container line	May 21, 2014	0:56:34	Poulsen
31	24	Sustainability Manager, CSR	Product tanker shipping company	May 28, 2014	1:07:12	Poulsen

(*continued on next page*)

Table 1 (*continued*)

Interviewee no.	Interview no.	Position	Type of organization	Date	Duration of recorded interview	Interviewer
28	26	Executive Vice President, Technical	Product tanker shipping company	March 24, 2018	E-mail correspondence	Poulsen
32	25	Senior Manager, Operations	Product tanker shipping company	April 17, 2018	Telephone interview, with concurrent notes	Poulsen
33	27	Vice President, Chartering	Chemical tanker shipping company	June 26, 2018	1:18:59	Poulsen
17	27	Vice President, Technical	Chemical tanker shipping company	June 26, 2018	1:18:59	Poulsen
2	28	Head of Projects, Technical	LPG shipping company	July 4, 2018	1:23:14	Poulsen
34	29	Head of Chartering	Product tanker shipping company	July 10, 2018	1:02:49	Poulsen
15	29	Vice President, Technical	Product tanker shipping company	July 10, 2018	1:02:49	Poulsen
35	30	Technical Superintendent	Chemical and product tanker shipping company	July 18, 2018	0:55:24	Poulsen
36	31	Chief Executive Officer	Gas tanker shipping company	July 24, 2018	0:53:41	Poulsen
37	32	Chief Operating Manager	Chemical tanker shipping company	August 20, 2018	1:09:40	Poulsen
38	33	Vice President, Operations	LNG, chemical and product tanker shipping company	August 21, 2018	0:52:56	Poulsen
39	34	General Manager, Chartering	Chemical and product tanker shipping company	August 29, 2018	0:53:09	Poulsen
40	35	CEO	Supplier (Energy saving equipment)	February 18, 2019	01:39:17	Varvne
41	35	Sales manager	Supplier (Energy saving equipment)	February 18, 2019	01:39:17	Varvne
42	36	CEO	Product tanker shipping company	March 20, 2019	Meeting like dialogic interview, approx 2hrs + 1hrs lunch, concurrent notes	Varvne
43	36	Board member, Senior advisor	Product tanker shipping company	March 20, 2019	Meeting like dialogic interview, approx 2hrs + 1hrs lunch, concurrent notes	Varvne
44	36	Board member	Product tanker shipping company	March 20, 2019	Meeting like dialogic interview, approx 2hrs + 1hrs lunch, concurrent notes	Varvne
45	36	Board member	Product tanker shipping company	March 20, 2019	Meeting like dialogic interview, approx 2hrs + 1hrs lunch, concurrent notes	Varvne
46	37	Manager, Technical	Product tanker shipping company	March 20, 2019	01:17:45	Varvne
47	38	Manager, Chartering	Product tanker shipping company	May 14, 2019	00:56:28	Varvne
48	39	Manager, Operations	Product tanker shipping company	May 15, 2019	00:56:28	Varvne
49	40	Master on product tanker	Product tanker shipping company	May 16, 2019	01:02:21	Varvne
50	41	Production planner	Port authority	June 13, 2019	01:11:01	Varvne
51	42	Shipping Manager	Cargo owner (oil major)	June 18, 2019	01:17:57	Varvne
52	43	Master on product tanker	Product tanker shipping company	June 23, 2019	01:11:56	Varvne
53	43	Chief Officer on product tanker	Product tanker shipping company	June 23, 2019	01:11:56	Varvne
54	44	Chief Engineer on product tanker	Product tanker shipping company	June 23, 2019	00:32:40	Varvne
55	45	Plant Energy Manager	Cargo owner (oil major)	November 22, 2019	01:16:10	Varvne
56	45	Plant Development Engineer	Cargo owner (oil major)	November 22, 2019	01:16:10	Varvne
57	46	CEO	Product tanker shipping company	March 6, 2020	Meeting like dialogic interview, approx 2hrs + 1hrs lunch walk and talk, concurrent notes	Varvne
58	46	Board member		March 6, 2020		Varvne

(*continued on next page*)

Table 1 (*continued*)

Interviewee no.	Interview no.	Position	Type of organization	Date	Duration of recorded interview	Interviewer
			Product tanker shipping company		Meeting like dialogic interview, approx 2hrs + 1hrs lunch walk and talk, concurrent notes	
59	46	Sustainability Coordinator	Product tanker shipping company	March 6, 2020	Meeting like dialogic interview, approx 2hrs + 1hrs lunch walk and talk, concurrent notes	Varvne
60	47	Sustainability Coordinator	Product tanker shipping company	April 17, 2020	00:46:13	Varvne
61	48	Logistics Manager, Logistics	Consumer goods manufacturer (major container shipper)	May 29, 2020	0:53:37, online	Poulsen
62	49	Director, Sustainability	Container line	June 2, 2020	0:53:16, online	Poulsen
63	50	Sustainability Manager, Logistics	Consumer goods manufacturer (major container shipper)	June 5, 2020	0:35:15, online	Poulsen
64	51	Senior Manager, Sustainability	Container freight forwarder	June 14, 2020	0:37:34, online	Poulsen
65	52	Director, Sustainability	Container freight forwarder	June 23, 2020	0:55:56, online	Poulsen
66	52	Manager, Sustainability	Container freight forwarder	June 23, 2020	0:55:56, online	Poulsen
67	53	Manager, Sustainability	Container freight forwarder	July 2, 2020	0:57:29, online	Poulsen
68	54	Former Director, Technical	Ro/ro and ropax shipping company	July 14, 2020	0:58:32, online	Poulsen
69	55	Director, Sustainability	Consumer goods manufacturer (major container shipper)	July 23, 2020	0.46:19, online	Poulsen
70	56	Production planner	Port authority	September 18, 2020	00:17:50	Varvne
71	57	Sustainability Manager, Sourcing & Logistics	Consumer goods manufacturer (major container shipper)	September 28, 2020	0:56:06, online	Poulsen
72	58	Infrastructure manager	Port authority	November 13, 2020	00:26:08 online	Varvne
73	59	Loading masters	Cargo owner (oil major)	November 16, 2020	00:57:13 online	Varvne
74	60	Sustainability manager	Port authority	November 17, 2020	00:26:58 online	Varvne
75	61	Shipping coordinator	Cargo owner (oil major)	December 3, 2020	00:53:05 online	Varvne
76	62	Sustainability manager	Port authority	December 7, 2020	00:54:10 online	Varvne
77	63	Head of Newbuildings and Projects, Technical	Dry bulk shipping company	January 15, 2021	Online interview, concurrent notes	Poulsen

Interviewees (ordered by type of organization)

Interviewee no.	Interview no.	Position	Type of organization	Date	Duration of recorded interview	Interviewer
9	8	Nautical School Professor, former Head of ferry line	Ferry shipping company	December 5, 2012	2:05:56	Poulsen
68	54	Former Director, Technical	Ro/ro and ropax shipping company	July 14, 2020	0:58:32, online	Poulsen
8	7	Director, Technical department	Container shipping company (tonnage provider)	November 30 – December 2, 2012	E-mail correspondence	Poulsen
1	1	Environmental Manager/Senior Sustainability Manager, CSR	Container line	August 16, 2012 May 27, 2014 June 10, 2020	0:56.31 0:55:31 1:14:00	Poulsen
25	29	Chief Operating Officer	Container line	June 17, 2013	1:09:09	Poulsen
30	23	Vice President, CSR	Container line	May 21, 2014	0:56:34	Poulsen
62	49	Director, Sustainability	Container line	June 2, 2020	0:53:16, online	Poulsen
3	3	Vice President, Technical	Container line and tanker shipping company	August 28, 2012	0:49:40	Poulsen
17	15	Chief Technical Officer	Gas tanker shipping company	May 8, 2013	2:20:40	Poulsen

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Table 1 (*continued*)

Interviewees (ordered by type of organization)						
Interviewee no.	**Interview no.**	**Position**	**Type of organization**	**Date**	**Duration of recorded interview**	**Interviewer**
28	21	Vice President, Fleet Management	Gas tanker shipping company	June 24, 2013	2:36:19	Poulsen
36	31	Chief Executive Officer	Gas tanker shipping company	July 24, 2018	0:53:41	Poulsen
2	28	Head of Projects, Technical	Gas tanker shipping company	July 4, 2018	1:23:14	Poulsen
29	22	Fuel Optimization Manager, Technical	Product, crude oil and gas tanker shipping company	June 27, 2013	1:33:19	Poulsen
38	33	Vice President, Operations	Chemical, product and gas tanker shipping company	August 21, 2018	0:52:56	Poulsen
23	17	Chief Technical Director	Chemical and product tanker shipping company	May 21, 2013	1:15:59	Poulsen
35	30	Technical Superintendent	Chemical and product tanker shipping company	July 18, 2018	0:55:24	Poulsen
39	34	General Manager, Chartering	Chemical and product tanker shipping company	August 29, 2018	0:53:09	Poulsen
2	2	General Manager, Technical	Chemical tanker shipping company	August 17, 2012	1:44:52	Poulsen
33	27	Vice President, Chartering	Chemical tanker shipping company	June 26, 2018	1:18:59	Poulsen
17	27	Vice President, Technical	Chemical tanker shipping company	June 26, 2018	1:18:59	Poulsen
37	32	Chief Operating Manager	Chemical tanker shipping company	August 20, 2018	1:09:40	Poulsen
4	4	Senior Manager, Technical	Product tanker shipping company	August 21, 2012	1:05:22	Poulsen
5	5	Chief Executive Officer	Product tanker shipping company	August 24, 2012	1:17:59	Poulsen
6	5	Senior Manager, Technical	Product tanker shipping company	August 24, 2012	1:17:59	Poulsen
10	9	General Manager, Energy Efficiency/Technical	Product tanker shipping company	March 8, 2013	1:42:36	Poulsen
13	12	Executive Vice President	Product tanker shipping company	May 3, 2013	1:13:53	Poulsen
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22	16	Executive Vice President	Product tanker shipping company	May 16, 2013	1:46:37	Poulsen
24	18	Fleet Manager, Technical	Product tanker shipping company	May 29, 2013	1:13:14	Poulsen
31	24	Sustainability Manager, CSR	Product tanker shipping company	May 28, 2014	1:07:12	Poulsen
28	26	Executive Vice President, Technical	Product tanker shipping company	March 24, 2018	E-mail correspondence	Poulsen
32	25	Senior Manager, Operations	Product tanker shipping company	April 17, 2018	Telephone interview, with concurrent notes	Poulsen
34	29	Head of Chartering	Product tanker shipping company	July 10, 2018	1:02:49	Poulsen
15	29	Vice President, Technical	Product tanker shipping company	July 10, 2018	1:02:49	Poulsen
42	36	CEO	Product tanker shipping company	March 20, 2019	Meeting like dialogic interview, approx 2hrs + 1hrs lunch, concurrent notes	Varvne
43	36	Board member, Senior advisor	Product tanker shipping company	March 20, 2019	Meeting like dialogic interview, approx 2hrs + 1hrs lunch, concurrent notes	Varvne
44	36	Board member	Product tanker shipping company	March 20, 2019	Meeting like dialogic interview, approx 2hrs + 1hrs lunch, concurrent notes	Varvne
45	36	Board member		March 20, 2019		Varvne

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Table 1 (*continued*)

Interviewee no.	Interview no.	Position	Type of organization	Date	Duration of recorded interview	Interviewer
			Product tanker shipping company		Meeting like dialogic interview, approx 2hrs + 1hrs lunch, concurrent notes	
52	43	Master on product tanker	Product tanker shipping company	June 23, 2019	01:11:56	Varvne
53	43	Chief Officer on product tanker	Product tanker shipping company	June 23, 2019	01:11:56	Varvne
54	44	Chief Engineer on product tanker	Product tanker shipping company	June 23, 2019	00:32:40	Varvne
46	37	Manager, Technical	Product tanker shipping company	March 20, 2019	01:17:45	Varvne
47	38	Manager, Chartering	Product tanker shipping company	May 14, 2019	00:56:28	Varvne
48	39	Manager, Operations	Product tanker shipping company	May 15, 2019	00:56:28	Varvne
49	40	Master on product tanker	Product tanker shipping company	May 16, 2019	01:02:21	Varvne
57	46	CEO	Product tanker shipping company	March 6, 2020	Meeting like dialogic interview, approx 2hrs + 1hrs lunch walk and talk, concurrent notes	Varvne
58	46	Board member	Product tanker shipping company	March 6, 2020	Meeting like dialogic interview, approx 2hrs + 1hrs lunch walk and talk, concurrent notes	Varvne
59	46	Sustainability Coordinator	Product tanker shipping company	March 6, 2020	Meeting like dialogic interview, approx 2hrs + 1hrs lunch walk and talk, concurrent notes	Varvne
60	47	Sustainability Coordinator	Product tanker shipping company	April 17, 2020	00:46:13	Varvne
26	20	Director, CSR	Product tanker and dry bulk shipping company	June 19, 2013	1:41:21	Poulsen
27	20	Head of Fuel Efficiency, Technical	Product tanker and dry bulk shipping company	June 19, 2013	1:41:21	Poulsen
7	6	Managing Director	Dry bulk shipping company	November 29, 2012	1:37:57	Poulsen
11	10	Director, Operations	Dry bulk shipping company	April 15, 2013	2:17:32	Poulsen
12	11	Senior Manager, Chartering	Dry bulk shipping company	April 17, 2013	1:18:16	Poulsen
14	13	Senior Vice President, Operations	Dry bulk shipping company	May 6, 2013	1:40:19	Poulsen
16	14	Managing Director	Dry bulk shipping company	May 7, 2013	1:16:30	Poulsen
18	15	General Manager, Chartering	Dry bulk shipping company	May 8, 2013	2:20:40	Poulsen
19	15	Senior Vice President, Operations	Dry bulk shipping company	May 8, 2013	2:20:40	Poulsen
77	63	Head of Newbuildings and Projects, Technical	Dry bulk shipping company	January 15, 2021	Online interview, concurrent notes	Poulsen
15	13	Head of Technical	Dry bulk & multi-purpose shipping company	May 6, 2013	1:29:23	Poulsen
51	42	Shipping Manager	Cargo owner (oil major)	June 18, 2019	01:17:57	Varvne
55	45	Plant Energy Manager	Cargo owner (oil major)	November 22, 2019	01:16:10	Varvne
56	45	Plant Development Engineer	Cargo owner (oil major)	November 22, 2019	01:16:10	Varvne
73	59	Loading masters	Cargo owner (oil major)	November 16, 2020	00:57:13, online	Varvne
75	61	Shipping coordinator	Cargo owner (oil major)	December 3, 2020	00:53:05 online	Varvne
61	48	Logistics Manager, Logistics	Consumer goods manufacturer (major container shipper)	May 29, 2020	0:53:37, online	Poulsen
63	50	Sustainability Manager, Logistics	Consumer goods manufacturer (major container shipper)	June 5, 2020	0:35:15, online	Poulsen

(*continued on next page*)

Table 1 (*continued*)

Interviewee no.	Interview no.	Position	Type of organization	Date	Duration of recorded interview	Interviewer
69	55	Director, Sustainability	Consumer goods manufacturer (major container shipper)	July 23, 2020	0.46:19, online	Poulsen
71	57	Sustainability Manager, Sourcing & Logistics	Consumer goods manufacturer (major container shipper)	September 28, 2020	0:56:06, online	Poulsen
64	51	Senior Manager, Sustainability	Container freight forwarder	June 14, 2020	0:37:34, online	Poulsen
65	52	Director, Sustainability	Container freight forwarder	June 23, 2020	0:55:56, online	Poulsen
66	52	Manager, Sustainability	Container freight forwarder	June 23, 2020	0:55:56, online	Poulsen
67	53	Manager, Sustainability	Container freight forwarder	July 2, 2020	0:57:29, online	Poulsen
70	56	Production planner	Port authority	September 18, 2020	00:17:50	Varvne
50	41	Production planner	Port authority	June 13, 2019	01:11:01	Varvne
72	58	Infrastructure manager	Port authority	November 13, 2020	00:26:08, online	Varvne
74	60	Sustainability manager	Port authority	November 17, 2020	00:26:58, online	Varvne
76	62	Sustainability manager	Port authority	December 7, 2020	00:54:10, online	Varvne
40	35	CEO	Marine equipment supplier (Energy saving equipment)	February 18, 2019	01:39:17	Varvne
41	35	Sales manager	Marine equipment supplier (Energy saving equipment)	February 18, 2019	01:39:17	Varvne

Interviewees (ordered by type of organization)

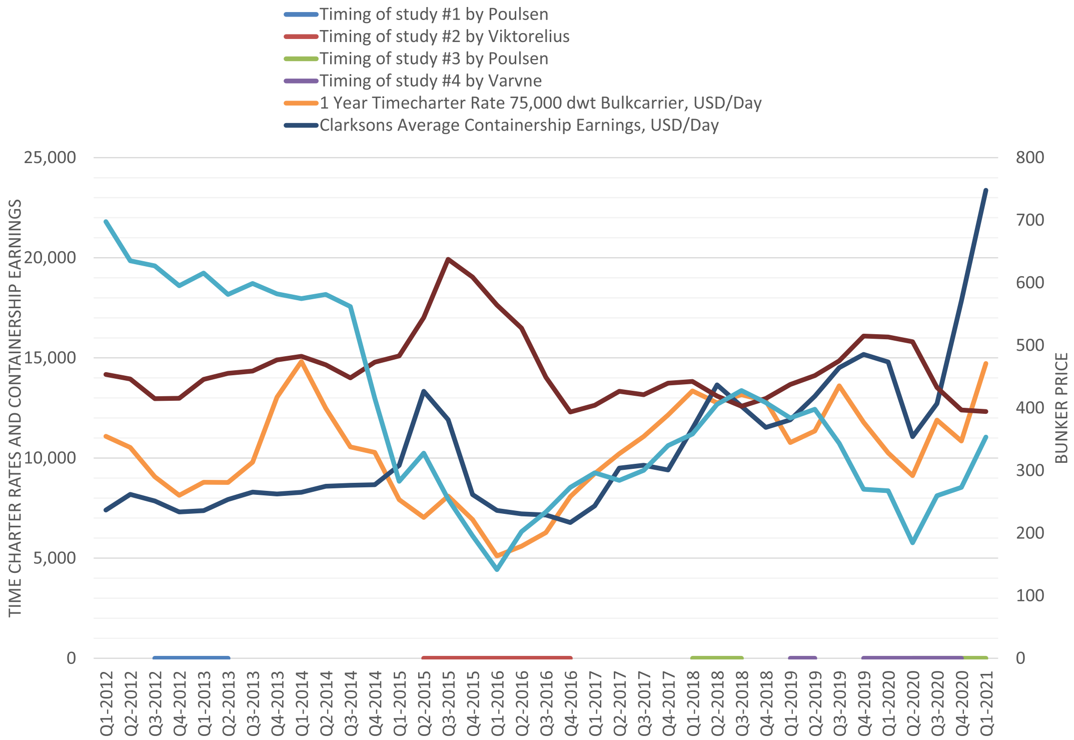

Fig. 1. Shipping intelligence network timeseries.

seafarers in tanker, dry bulk, container, and ferry shipping over eight years (Table 1). Ethnographic studies are particularly suitable for understanding how people conduct their work and how they account for their reality and present these accounts (Czarniawska, 2014). Such studies are useful for exploring the experiences and practices of specific groups, such as chartering, operations, and technical managers and crews, who are all involved in decision-making regarding energy efficiency.

The study employed team ethnography (Evans et al., 2016) and multi-site ethnography (Marcus, 1995; Malhotra and Majchrzak, 2014; Luff and Heath, 2019) to observe voyage planning and execution at different sites and different times. It therefore consolidated four separate studies on energy efficiency, carried out in 2012–2021 (Poulsen and Sornn-Friese, 2015; Poulsen and Johnson, 2016; Poulsen and Sampson, 2019; Viktorelius and Lundh, 2019; Viktorelius, 2020; Poulsen and Sampson, 2020). Acejo and Abila (2016) and Sampson et al. (2019) provided the inspiration to consolidate ethnographic studies conducted onboard several merchant ships.

The field material provided a unique opportunity to compare energy efficiency decisions in different shipping sectors and to study not only shipping managers' and crews' perceptions but also their behavior. The longitudinal nature of the field material (Fig. 1) covered periods of high and low freight rates and fuel prices. The researchers specifically investigated the effects of these particular market conditions on energy efficiency, thus controlling for the time-dependent effects of freight rates and fuel prices on decision-making.

3.1. Collection of field material

During the field material collection, the focus was specifically directed toward energy efficiency measures identified from the energy efficiency literature.

For the first study, Poulsen conducted semi-structured interviews with 31 technical, operations, and chartering managers and shipping company CEOs in 2012–2014, when high fuel costs and depressed freight markets coincided with the IMO's introduction of SEEMPs and the diffusion of 'slow-steaming' (Interview guide 1, Appendix 1).

For the second study, Viktorelius carried out interviews and observations onboard five medium-sized and large ferries and in the shore-based organization of a major European ferry company. He undertook a total of 28 sea voyages in 2015–2016 (approximately 195 h in total), each of which included one round trip (back and forth between destinations, with durations of 10–39 h). During this period, fuel prices were low, and Viktorelius interviewed approximately 40 masters, bridge officers, marine engineers, and shipping managers (Interview guide 5, Appendix 1).

In 2018, Poulsen conducted the third study with non-participant observation onboard a 40,000-dwt product tanker (330 h). The vessel was employed in the short-haul Northern European trade under Contracts of Affreightment. In 2018–2021, he did a round of interviews with tanker, bulk, container, and ferry shipping managers and major container shippers/cargo owners (Interview guide 2, Appendix 1), during a period of highly variable freight rates and fuel prices. Finally, Poulsen also attended several webinars in 2021 at which classification societies and ship-owner associations presented the newly adopted CII to shipping managers.

For the fourth study, Varvne conducted 27 semi-structured interviews with managers in tanker shipping companies, oil majors, and ports and carried out observations onboard two 18,000-dwt product tankers employed in the Northern European short-haul, spot-market trade (175 h, including one short visit in port and two voyages), in a port (1 work week), and at a crewing conference (24 h; Interview guide 3, Appendix 1). This coincided with a period of falling and then rising fuel prices and tanker freight rates.

Poulsen, Viktorelius and Varvne made extensive field notes during the onboard observations. Combining and comparing field notes from several researchers increased transparency and reduced the risk of personal bias. The researchers used the field notes extensively throughout the analysis, and some of the excerpts in this paper were translated from Scandinavian languages to English by the authors. The observations on the five ferries and three tankers, combined with the interviews with managers in tanker, dry bulk, container, and ferry companies, represented the highly diverse vessels in world fleets—both in terms of designs and trading patterns. Product tankers and bulkers are produced in long series of identical vessels with highly standardized designs, and they predominantly tramp globally. By contrast, ferries are tailor-made specifically for relatively short routes and operate scheduled pendulum services between the same

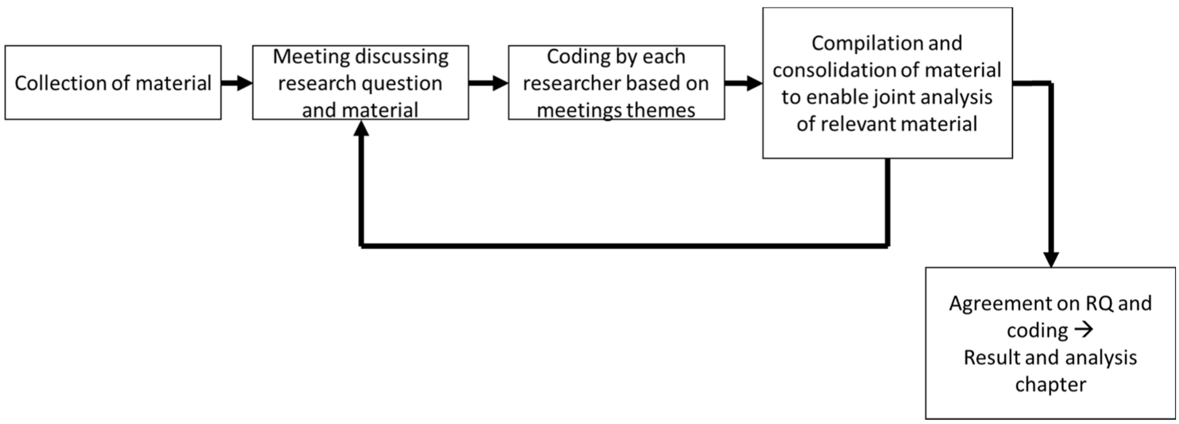

Fig. 2. Research process.

two or three ports, whereas container ships have more complex scheduled trade routes with many port calls per route. These differences allowed the authors to explore the research questions in the context of distinctive ship operations. The study included oil tankers, dry bulkers, container vessels, and ferries, which are the major carbon emitters in shipping and account for 14.6%, 17.8%, 21.3%, and 3.4% of shipping GHG emissions, respectively (IMO, 2020).

3.2. Analysis of the field material

The authors transcribed the field notes from each study and individually analyzed the material they had collected. In joint meetings, the authors discussed the field material to identify similarities and differences between shipping sectors at different points in time (Fig. 2). At these meetings, the authors developed a joint coding framework, and each researcher subsequently reviewed the material and compiled relevant quotes, which were then made available to all the researchers. All the researchers thus shared and discussed each other's material to establish joint findings and agree what themes, codes, and research questions to pursue. After repeating this process, the final questions guiding the coding and analysis were:

(1) Who are the stakeholders involved in voyage planning and execution?
(2) When are decisions with energy efficiency effects made?
(3) What objectives do the stakeholders pursue while making such decisions?
(4) How do different stakeholders affect the EEOI nominator (CO2 emissions) and the EEOI denominator (cargoes carried times distances travelled)?

4. Results

4.1. Voyage planning: Matching ships and cargoes, and route choices

Regardless of their idiosyncratic trading patterns, all shipping sectors start voyage planning by making commercial decisions that match ships and cargoes. These decisions, as will be explained, greatly influence the amount of cargo carried (i.e., one of the two components of the EEOI's denominator, transport-work) and therefore energy efficiency.

In tanker and dry bulk shipping, chartering managers explained that they aimed to maximize a ship's time charter equivalent (TCE), defined as the gross freight income less voyage costs (fuel, port, and canal charges) divided by the round-trip voyage duration in days. TCE maximization establishes voyage planning goals and influences priorities for all shipping company staff, both onshore and at sea. In the words of the vice president of a technical department in a tanker ship-owning company:

> That's our golden number, right, and the better we are at optimizing that number, the better it gets. That's the number we are all measured against. (Interviewee 15)

To achieve this, chartering managers aimed to maximize the utilization of ships' cargo capacities and the time spent under laden conditions. Such conditions had a positive impact on energy efficiency, lowering emissions per unit of transport work. As pointed out by a Corporate Social Responsiblity director with a seafaring background, "If the vessel is not full … the number [the EEOI] quickly moves in the wrong direction" (Interviewee 26). In line with this, a vessel performance manager with a seafaring background, responsible for energy efficiency, explained why he saw high vessel utilization as the key aspect of energy-efficient ship operations: "For the EEOI, you cannot tell whether the main engine is adjusted correctly. You can make only a marginal improvement there, but it means a great deal if you can reduce your ballasting" (Interviewee 29). The operational measure of engine fine-tuning will be discussed in Section 4.3, but the important point to note is the huge importance for energy efficiency that the technical expert assigned to commercial decisions.

Many tankers and dry bulk carrier trades had very pronounced head- and back-hauls, which caused vessels to reposition from discharging ports to loading ports under ballast conditions. Such voyages did not involve transport work and adversely affected the EEOI. Triangulation (i.e., using a triangular trading pattern, rather than a pendulum pattern) was widely known as a feasible strategy for improving vessel utilization by facilitating two consecutive voyages under laden conditions, followed by only one ballast voyage. Ship owners with small fleets might face challenges with triangulation due to their limited fleet sizes, and thus assign vessels to pool managers, who could more easily triangulate with the large fleets they managed commercially on behalf of several ship owners.

Although chartering managers generally aimed to improve vessel utilization, interviewees also mentioned voyage planning decisions with negative EEOI effects. These specifically concerned route choices that increased fuel consumption without improving transport work. A head of tanker operations pointed this out when he explained the company's chartering policy: "We should not use a short ballast [voyage] if a longer ballast [voyage] pays more money" (Interviewee 38). During periods of relatively low oil prices, voyage planners were willing to choose long routes with high fuel consumption to avoid short routes with costly canal fees. This often happened for transit from the Baltic to the North Sea, with route planners often preferring the Skaw route over the shorter, but more expensive, Kiel Canal route (field notes, Poulsen, and Varvne). A dry bulk performance manager pointed out an extreme example, where a vessel sailed the Cape Horn route from the Caribbean to Peru to avoid the expensive Panama Canal transit charges (Interviewee 50).

In container shipping, liner companies assigned their large fleets of vessels to vast global route networks to match them with cargoes. Striving for high-capacity utilization, their commercial scheduling departments faced the complex task of optimizing networks, which was critical for profitability. Incidentally, the commercial efforts greatly affected transport work (the EEOI denominator). In 2012, a technical director emphasized that "the way we design our network and assign the individual ships is extremely important for energy efficiency" (Interviewee 3). Similarly, the chief operating officer of another container line explained that the company's goal of high-capacity utilization contributed to improving the EEOI:

> Our claim to fame … is that we run operations as efficiently as possible. We do believe a lot in technical solutions [to save fuel], but the greatest potential [for fuel savings] comes from having the right scale and sailing the shortest distances possible with containers … so we get the right vessel sizes for the right trades and keep them as full as possible. (Interviewee 25)

These two excerpts encapsulate how crucial commercial decisions are for energy efficiency in ship operations. A sustainability manager for another container line shared this view and explained that a combination of commercially motivated speed reductions, network optimization, and the employment of larger vessels with scale advantages had enabled significant EEOI improvements from 2008 to 2020 (Interviewee 1).

In ferry shipping, shipowners tended to assign tailor-made ferries to specific routes that they operated for many years. Traffic typically flowed in both directions with no pronounced head- or backhauls, but volumes varied considerably according to season (e.g., many tourists during the summer). To some extent, ferry lines could offer seasonal discounts to attract traffic, but such strategies did not entirely balance volumes across the year. Ferry lines could also reduce service frequency, but service considerations often limited their options in this regard. Customers expected a certain frequency, even during the low season. Moreover, public procurement contracts for subsidized ferry routes typically specified service frequency, which limited ferry companies' control of energy efficiency. Fuel consumption was seen as largely independent of the number of passengers carried (Interviewee 46), so the EEOI varied considerably over the year in terms of traffic volumes.

4.2. Voyage planning: Speed choice

Once a ship is assigned to a particular cargo and route, the key voyage planning decision concerns service speed. This choice greatly affects fuel consumption (the EEOI denominator) and has a minor effect on the distances traveled per year (one of the two components of the EEOI denominator), as will be shown.

In tanker and dry bulk shipping, cargo owners' commercial priorities regarding transit times and fuel consumption (as specified by charter parties) define the tasks for voyage planning. For vessels on voyage charters, voyage route instructions, such as expected time of arrival (ETA), average speed, and maximum daily fuel consumption, were given directly by operations managers to masters, since shipowners paid for fuel (field notes, Poulsen). On time-chartered vessels, charterers' operations managers provided voyage instructions. Voyage plans reflected cargo owners' preferences for transit time, and vessels often sailed at 'charterer speed', as explained by a pilot (field notes, Poulsen). In 2012, a product tanker shipping pool director described speed choices under different commercial conditions and different charter types:

> This is very dependent on the market. What does an individual voyage pay? What are the fuel costs? We factor these things into our daily chartering when choosing voyages. We find out what we pay for fuel and what we can fix the vessel for … As far as ballast is concerned, if the vessel is not fixed, then we go at 10 knots … When we are under laden conditions, we do not decide how fast we sail. The charterer will usually have a clause specifying 12–13 knots, depending on delivery time, so we are not in control of speed. (Interviewee 22)

Speed decisions thus changed with freight rates and oil prices, and shipping managers often found themselves limited by charterers' decisions. In explaining how freight rates influenced speed choice via TCE maximization, the same interviewee added: "The starting point is today's market. What pays the best? If the market is 40,000 dollars per day, we obviously go at full speed to make as many voyages as possible" (Interviewee 22).

These excerpts show that changing market conditions regarding freight rates and fuel prices influenced speed choice in highly dynamic ways. High freight rates justified higher speeds and fuel consumption, although this inevitably caused the EEOI to deteriorate. In 2013, a CSR director explained that a tanker and dry bulk ship-owning and -operating company achieved substantial fuel savings and improved EEOI during a period of very high fuel prices and low freight markets. The interviewee pointed out that speed reduction had contributed to this:

> Slow-steaming is very important and we save a lot of energy on this. This is the part where we have to be realistic and say that it will be compromised [speed will increase] if freight markets go up or fuel prices go down. (Interviewee 26)

The interviewee distinguished between the commercial and operational components of energy efficiency and explained that the company's ships 'right-steamed'. 'Right-steaming' refers to economically optimal speed choices, which depend on freight markets and fuel prices and therefore vary over time. Neither in the authors' 2012–2014 nor 2018–2020 interview rounds did EEOI improvement appear to be an objective for voyage planning for tankers and bulkers; it was effectively determined by shipping companies' TCE maximization and charterers' voyage planning demands.

Based on speed and maximum daily fuel consumption instructions from operations managers, masters made detailed voyage plans, including route way-points and service speeds, prior to departure (field notes, Poulsen). This is an IMO requirement (IMO, 1999), and a bridge officer explained that "[ships often] receive complaints from the operations' department if daily consumption exceeds the specified limit but will hear nothing in the opposite case." He said that operations managers in shipping companies frequently had sometimes provided him with unhelpful speed instructions, focusing too much on the theoretical speed-bunker consumption curve and blindly providing speed instructions on this basis. He felt that they often failed to consider good seamanship (field notes, Poulsen).

This excerpt illustrates the diverse economic and nautical perceptions of optimum speed held by operations managers and crews, and the limited leverage that crews felt they had over speed.

In liner shipping, voyage planning translates publicly available sailing schedules into detailed speed choices. In 2013, a container line with a large fleet of chartered vessels experienced communication challenges regarding crews and speed choices. To save fuel costs, which were very high at the time, the chief operating officer explained that the company had defined a simple speed limit of 17 knots for all chartered vessels, which crews had to seek permission to exceed (Interviewee 25). This again illustrates the limited leverage that crews had over speed and therefore energy efficiency.

A former ferry-shipping technical manager explained that a shipping company adjusted the schedule on an overnight route to save fuel during a period of rising fuel costs. Due to relatively long port stays on this route, the company could extend voyages by approximately one hour, which had allowed for significant fuel savings. However, for most ferry routes, he argued that such schedule adjustments were unfeasible because of the logistical requirements of freight customers, who themselves worked with tight schedules in their shore-based logistics operations (Interviewee 46). This illustrates the networked nature of decision-making for voyage planning and speed choices, which also depended on cargo-owner transit time preferences.

For ferries, schedule reliability was also seen as a key commercial concern for voyage plans, which dictated service speeds and often undermined energy efficiency. It was important for crews to avoid late arrivals in port, and officers explained that their expectations of the workload in the next port could cause them to plan voyages that would involve speeding up to arrive early in port, to leave enough time for the anticipated complex cargo operations (field notes, Viktorelius).

4.3. Voyage execution

After departure, crews translate voyage plans into numerous nautical choices that affect fuel consumption (the EEOI denominator). Nautical decisions to reduce fuel consumption are important under all market conditions, but a combination of dynamic commercial decisions and safety considerations limits crews' agency over voyage execution and reduces energy efficiency.

Avoiding departure delays: In ferry shipping, all the crews interviewed saw punctual departure as one of the most important energy efficiency measures available to them, since it would affect service speeds and be important regardless of fuel price changes. Masters and other bridge officers explained that they would always depart earlier than scheduled, if all pre-booked cars/trailers/trucks were onboard (field notes, Viktorelius); however, a complex cargo mix (with many unaccompanied trailers) or a lack of staff on car decks or in terminals often caused delays, as did many last-minute booking changes by freight customers (field notes, Viktorelius). Several times, masters postponed departures because they waited for loyal customers' delayed trucks, meaning that commercial service objectives undermined energy efficiency, as did the priority assigned to 'bonus' passengers with cars. Paying higher ticket prices, 'bonus' customers assumed the right to priority disembarkation upon arrival, adding complexity to the loading process and increasing the risk of delays. In such cases, officers used all main engines to catch up for lost time in port, although this added considerably to fuel consumption (field notes, Viktorelius).

Constant speed during the voyage: In both ferry and container shipping, commercial decisions made in the scheduling department changed with market conditions and influenced voyage execution. A former technical manager explained that constant speed during a voyage would save fuel as opposed to an operational profile with variable speeds over different voyage stages (Interviewee 46). During the 1990s and early 2000s, when fuel prices were very low, "masters learned that they must never arrive late in port. Never!" (Interviewee 3). Service considerations vis-à-vis cargo owners dictated such practices, and masters consequently opted for high service speeds in the early voyage phases to ensure a safety margin against bad weather and delays in the final voyage phases. This led to high fuel consumption, and a technical director explained that a container liner succeeded in changing the culture for voyage execution in response to the rapidly rising oil prices in the early 2010s by maintaining constant speed during voyages (Interviewee 3).

In tanker and dry bulk shipping, the volatile nature of freight markets also affected speed choice during the voyage, as operations managers updated the voyage instructions given to masters. A tanker shipping CEO explained changing speed instructions during ballast voyages:

> Usually, our instructions are to sail at 10 knots, and … we will follow the market. Then we ask ourselves whether it makes sense to step up the speed to 13 knots, so that we can reach the window in which the next cargo is available. We follow this day after day. (Interviewee 5)

This encapsulates how freight market dynamics affected speed choice during voyages and challenged efforts to maintain constant speeds during voyages. The dynamic nature of tanker markets could also cause charterers to change discharge ports after departure. Cargo owners might sell cargoes in transit and therefore require ships to change their courses and discharge ports. Our field notes read:

> The senior officer explained that the destination is not always known [even after departure] and recalled a voyage from Algeciras [in the Gibraltar Straits] to the Atlantic Basin. The crew did not know where the ship was going. Six different ports—from New York in the north to Houston in the south—were on the table while the ship was *en route*. He explained that the vessel steered "a middle course," until the crew received instructions about which port the cargo had been sold [to]. (Field notes, Poulsen).

Such practices could add considerable distances to a voyage and increase fuel consumption with adverse effects on the EEOI, but shipowners were bound by charterers' instructions. This indicates that the commercial decisions of cargo owners influenced voyage execution and illustrates the networked nature of agency for energy efficiency in ship operations.

Weather routing: During the onboard studies, crews explained that adverse weather and sea conditions increased fuel consumption. A marine engineer said that a tanker regularly conducted sea trails at full speed in calm weather and flat seas to minimize the effects of these factors on the fuel consumption data (field notes, Poulsen). Several performance experts in technical departments confirmed that changing weather and sea conditions caused considerable levels of “noise” in the performance data, thereby affecting the EEOI (Interviewees 10, 27, and 77). To some extent, crews could mitigate weather effects by weather routing, but not entirely eliminate them. Outside narrow fairways and traffic separation zones, they could use updated weather information to avoid areas with adverse weather and sea conditions to save fuel. A bridge officer explained that he took currents into account to optimize route choice: “When the waves come from the stern of the ship, ships benefit from the current, which provides extra speed. Our course is planned so that the vessel benefits from the current [and saves fuel]” (field notes, Poulsen).

For crews, weather routing was often an important source of professional pride (field notes, Varvne, and Poulsen), and a master explained that he preferred to rely on his nautical experience rather than weather routing services to choose routes. He took pride in finding routes with favorable currents and explained how he used his nautical experience to “chase a mythical current along the coast. I know it should be there, and I think I have found traces of it, and then you get at least 0.3–0.4 [knots] while sailing northbound” (field notes, Varvne).

He only relied on weather routing services in areas that he was unfamiliar with. In promotional material, software companies often present strong cases for fuel savings via weather routing, but a technical manager explained that success depends on system implementation and technical departments’ communication with crews. In retrospect, he regretted a top-down approach used to implement such a system, because crew involvement suffered. Software problems further contributed to crew resistance, and the system failed to deliver the expected fuel savings (Interviewee 46). This illustrates that weather routing and voyage execution depend not only on advanced technology, but also require effective ship–shore communication and intra-organizational trust.

Optimizing trim and ballast: Crews explained that they used ballast water to improve stability when vessels were empty or under partly laden conditions; an empty vessel with large volumes of ballast water pitched less in high waves than a vessel with less ballast water, but large volumes of ballast water increased fuel consumption. Several technical managers and crew members explained that they sometimes carried large ballast volumes to ensure passengers’ comfort (field notes, Viktorelius). They also pointed out that trim, defined as the difference between forward and aft drafts, influenced fuel consumption. Optimizing trim by using ballast water could reduce fuel consumption, although the optimum point differed between ships. For ferries, crews saw trim optimization and cargo planning/loading as closely related challenges. An ideal cargo distribution on car decks was often difficult to plan and realize, since cargo lists often changed shortly before departure (some vehicles did not show up, and the exact weight of the different cars, trucks, and lorries were seldom specified). Optimizing trim could take time before departure and compromise the scheduled departure time. Crews on ferries with hectic schedules and short voyages tended to pay less attention to trim optimization than to commercially important schedule reliability (field notes, Viktorelius).

Optimizing the use of ships’ equipment: A nautical instructor explained that crews should minimize unnecessary rudder corrections during ocean navigation, since constant corrections increase fuel consumption. Crews should give the autopilot slightly more freedom in open water than they would do in coastal waters to avoid frequent and unnecessary rudder corrections (Interviewee 9). Ferry crews could also reduce fuel consumption by minimizing the use of thrusters during port maneuvers, but safety considerations were always paramount, and masters used their professional judgment to balance wind and maneuvering conditions with thruster use time (field notes, Viktorelius). Similarly, tanker engineers explained that they optimized the use of auxiliary engines and shut them off whenever possible (field notes, Poulsen). Bridge and engine officers often mentioned fuel consumption (field notes, Poulsen, and Viktorelius), but

Table 2
Key decisions in voyage planning and execution affecting a ship’s EEOI and other factors with EEOI effects.

VOYAGE PLANNING	VOYAGE EXEUCTION
COMMERCIAL DECISIONS	**NAUTICAL DECISIONS**
Matching vessels and cargoes (affects cargoes carried) • Maximize the utilization of a ship’s cargo capacity • Minimize the time spend in ballast condition • Optimize route network – to allow for speed reduction and maximize vessel utilization • Triangulate voyages – to minimize time in ballast condition • Use the services of commercial managers – to improve vessel utilization	**Ship handling (affects fuel consumption)** • Optimize trim • Optimize ballast • Optimize use of auxiliary engines and other marine equipment • Avoid unnecessary rudder corrections (optimize auto-pilot usage)
Route choice (affects fuel consumption) • Use canal transits, when possible – to reduce distance sailed and fuel consumption	**Route choice (affects fuel consumption)** • Weather routing – to reduce effects of counter currents and adverse weather
Speed choice (affects fuel consumption and distances travelled) • Reduce service speed – to save fuel • Adjust liner schedules – to allow for longer transit times and speed reduction • Use virtual arrival – to allow for speed reduction in case of port congestion	**Speed choice (affects fuel consumption)** • Ensure punctual departure – to ensure low service speed • Equalize speed over voyage – to avoid energy consuming speed changes • Take shallow water effect into consideration – to reduce fuel consumption • Arrive to port just in time – to avoid idle time at anchorage and ensure low service speed
	OTHER FACTORS **Weather and sea conditions (affect fuel consumption)** • Calm seas – reduce fuel consumption • Favourable currents – reduce fuel consumption • Calm weather – reduce fuel consumption • Tailwinds – reduce fuel consumption

Note: The grey shading marks wind and sea factors, which are external to decisions in voyage planning and execution. These factors also influence a ship’s EEOI.
Source: Authors’ analysis.

their discussions on the matter showed that the optimal use of engines was often not a straightforward matter and safety considerations always came first (field notes, Viktorelius).

Safety considerations: During the field observations, there were several instances of safety priorities overruling energy efficiency considerations. Poulsen experienced this for anchoring operations:

> As the vessel approaches the anchorage point … the wind and the waves have gathered strength. According to one of the bridge officers, wave heights are currently around three to five meters. As the vessel turns around 180 degrees [up against the wind and waves, at the anchorage point], it lists heavily … Even though the deck crew stands ready on the forecastle to release the anchor, the vessel has to abandon this plan. Instead, it now sails at a speed of approximately three knots, circling around the anchorage point. (Field notes, Poulsen).

Another safety concern related to other shipping traffic in narrow fairways. The field notes read:

> The pilot wants our vessel to overtake a bulk carrier, which is steering a [parallel] northward course. He asks the master to adjust speed from the current 13.5 knots to the maximum. Apparently, his pilot counterpart on the bulk carrier, which does not decrease its speed as expected, annoys him. We cannot overtake the bulk carrier in the narrow strait, and he therefore asks the master to reduce speed. We will overtake the bulk carrier later. (Field notes, Poulsen).

This excerpt encapsulates the complexities and dynamics of voyage execution, whereby safety concerns and other ship movements limit crew's agency for energy efficiency.

4.4. Summary of findings

Table 2 summarizes the key decisions that affect energy efficiency in ship operations and thus the different EEOI components. It distinguishes between commercial decisions in voyage planning and nautical decisions in voyage execution and takes into consideration the idiosyncratic trading patterns of different shipping sectors. In all sectors, commercial decisions have by far the greatest influence on energy efficiency via the matching of ships and cargoes and speed and route choices, and they are dynamic and highly market dependent. In tank and bulk shipping, chartering managers and charterers make such decisions; in container and ferry shipping, decisions are made by scheduling departments, which emphasize customer preferences (cargo owners or governments for tendered routes). Nautical decisions to reduce fuel consumption are relevant under all market conditions, but commercial decisions often hinder their implementation. Crews and their colleagues in technical and operations departments often depend on changing voyage plans given by chartering managers, who respond to charterers' or other cargo owners' expectations. Safety considerations also trump energy efficiency in voyage execution. No single shipping department or organization is in full control of energy efficiency in ship operations, because agency for energy efficiency is highly networked.

5. Discussion

Energy efficiency scholars have often attributed energy efficiency gaps in shipping to the principal–agent problem, since agents who determine fuel consumption do not have incentives to save when principals pay for fuel (Acciaro et al., 2013; Jafarzadeh and Utne, 2014; Johnson et al., 2014; Rehmatulla and Smith, 2015a; Adland et al., 2017; Rehmatulla et al., 2017; Rehmatulla and Smith, 2020). This paper, however, moves beyond the binary principal–agent framework to explore decision-making for voyage planning and execution phases and illustrates the highly networked and dynamic nature of agency for energy efficiency in both phases. The decisions that affect energy efficiency are made by several departments within shipping organizations, as well as by charterers and other cargo owners/customers. A binary theoretical framework therefore cannot fully account for the complexities of decision-making processes, which start with chartering negotiations and continue until vessels arrive at discharge ports.

Poulsen et al. (2021) argued that several organizations in tanker shipping—in particular, powerful oil majors—influence energy efficiency in ship operations and distinguish between the technical, commercial, operational, and sea/weather aspects of energy efficiency. This study extends these findings by documenting such decision-making processes in voyage planning for bulkers, container vessels, and ferries. Regardless of idiosyncratic trading patterns, highly dynamic commercial decisions affect energy efficiency in all shipping sectors. The study has highlighted the primacy of commercial decisions for energy efficiency and linked these decisions to highly dynamic shipping and oil markets.

Rehmatulla and Smith (2015a) found that shipping company managers and crews perceived speed reduction to be their most important leverage point for energy efficiency. Although Adland et al. (2020) questioned the fuel-saving potential of speed reduction for tankers, this study found that both shipping managers and crews perceived speed reduction as an important energy efficiency decision—besides the matching of ships and cargoes. The high fuel prices and low freight rates over long periods in the 2010s, as pointed out by Cariou (2011) and Cariou et al. (2019), motivated speed reductions, which contributed to energy efficiency improvements.

Psaraftis and Kontovas (2014) found that optimum speeds from a profit-maximizing perspective did not necessarily lead to optimal environmental performance for ships, and this study provides new empirical evidence in support of this conclusion for the four studied sectors. Speed choice, as also pointed out by Rehmatulla and Smith (2015a), Adland et al. (2017), Adland and Jia (2018), Adland et al. (2019), and Poulsen and Sampson (2019), often depends on instructions from cargo owners, who might have preferences other than for fuel savings. But chartering managers in shipping companies also indicated their willingness to speed up if shipping markets rewarded fast transits. The IMO (2020) recently highlighted a latent risk of emissions increases, which seems warranted:

> Under certain market conditions, operating speeds could increase again and the associated increases in average fuel consumption and emissions … could return. If their return is sustained, some, or all, of the reductions in carbon intensity [the EEOI] achieved to date could be reversed (p. 11).

For improved voyage execution, the IMO (2016) provided extensive advice to crew and technical managers on operational or nautical measures. Although such measures are relevant under all market conditions, the agency of crews and technical managers is often greatly limited for voyage execution due to overriding commercial and safety considerations. The literature on voyage execution (Poulsen and Sornn-Friese, 2015; Rasmussen et al., 2018; Hansen et al., 2020; Viktorelius, 2020) has directed attention toward seafarers, but this study shows that the commercial aspects of energy efficiency take priority over nautical aspects. Concerning voyage execution, Zis et al. (2020) highlighted the considerable energy efficiency potential of weather routing. This study showed that crews took pride in nautical choices that factored in currents, waves, and wind directions. Crew involvement appeared vital for successful implementation of weather routing, and this topic deserves further attention from weather routing researchers.

Regarding port-call optimization, this study extends work on bulk and tanker shipping (Johnson and Styhre, 2015; Poulsen and Sampson, 2020) to ferry shipping. Unlike tankers and bulkers, ferries call regularly at the same ports, do not require tug and pilot assistance, and do not need to wait for government officials. These factors facilitated port-call optimization. Nevertheless, delays often occurred in ports due to complex loading operations and company service policies vis-à-vis delayed priority customers. These commercial factors limited crews' agency regarding voyage execution and often undermined energy efficiency.

Polakis et al. (2019), Panagakos (2019), Poulsen et al. (2021), and Wang (2021) were skeptical about the validity of the EEOI and AER as energy efficiency metrics, and this study adds new evidence to support this skepticism. When benchmarking vessel performance and energy efficiency, it is important to separate the effects of commercial decisions from those of nautical decisions. The EEOI does not make this important distinction. The AER relies on nominal vessel capacity, not actual cargo carried, and therefore also fails to consider the question of vessel utilization, which is extremely important for energy efficiency.

6. Conclusion

To mitigate climate change due to international shipping, policymakers require shipowners and ship technical managers to continuously improve energy efficiency in their ship operations. Energy efficiency scholars, however, have found that cost-effective measures are underutilized in ship operations and have discussed the causes of this problem. They have pointed out that complex decision-making processes, including principal–agent problems, hamper energy efficiency in ship operations. This paper sheds new light on the decision-making processes for energy efficient ship operations and identifies the key decision-makers who are involved in them. Exploring voyage planning and execution, the paper goes beyond the binary understanding of principal–agent problems for energy efficiency by documenting the highly networked nature of agency for energy efficiency and the very dynamic decision-making processes that affect voyage planning and execution. No single shipping department or organization has full control over energy efficiency in ship operations.

The paper highlights the differences between the commercial and nautical aspects of energy efficiency. Commercial decisions in voyage planning—relating to the matching of cargoes and ships, routes, and speed choices—have the greatest impact on energy efficiency, and shipping companies' chartering and scheduling managers make such decisions in close dialogue with influential cargo owners. These decisions greatly depend on the state of the freight markets, fuel prices, and cargo-owner transit time preferences; hence, they change with market conditions. Nautical decisions for voyage execution, by contrast, are relevant under all market conditions, but crews and technical managers who make such decisions are limited by commercial constraints and safety considerations, which often undermine energy efficiency.

Indices that aggregate the commercial, nautical, and weather/sea aspects of energy efficiency into one metric fail to provide valid measures of energy efficiency in ship operations. Both the IMO's AER and the EEOI suffer from this shortcoming. Observers cannot separate the effects of the different commercial and nautical decisions and changing weather and sea conditions on these two metrics, which limits their value for benchmarking vessel performance and energy efficiency. Future research should study large and fine-grained data sets for vessel fuel consumption, transport work, and weather/sea conditions to separate the different components of energy efficiency and develop more valid metrics for energy efficiency in ship operations.

The IMO intends to improve energy efficiency in ship operations with the new mandatory CII, which has yet to be precisely defined. Its practical value, however, is likely to be limited by the low validity of the current energy efficiency metrics of the AER and EEOI. The new regulation encapsulates the IMO's ship-focused regulatory approach, which targets shipowners and ship technical managers to mitigate climate change due to international shipping. They and their crews, however, are not in full control of energy efficiency, and the CII's impact on decision-making in ship operations remains to be seen. Policymakers, however, should acknowledge the limitations of the ship-based regulatory approach and direct more attention toward cargo owners, since they significantly influence energy efficiency and emissions. It is important to broaden the regulatory focus from shipping industry emissions to maritime transport emissions and the markets that condition them to mitigate climate change.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix

Interview guide 1
For vessel performance manager and executive in a tanker shipping company (2012–14)
Business practices

- Could you please explain briefly the main activities of your company?
- Do you have long-term relations with cargo-owners or charterers?
  - o What expectations do cargo-owners (oil majors) have for your services?
- Do you charter vessels in or out?
  - o What types of charters to do you engage in?
  - o And with what durations?
  - o If you charter in vessels, how do you select them?
  - o Do you observe differences between chartered and owned vessels?
  - o If yes, which and why?
- How do you crew your vessels?
  - o Do you employ your own crews onboard the vessels or use third part ship managers?
  - o Why?
  - o What are the advantages and disadvantages of using in-house crewing and third party ship management, respectively?
  - o How frequently do crews change?
- What are the key sources of corporate competitiveness in tanker shipping?
  - o Who pays the fuel costs?

Potential for fuel saving

- In your annual report you provide information on fuel saving initiatives in your company in the last couple of years:
  - o What are your experiences in this regard?
  - o How did you achieve the savings?
  - o What were the major challenges in this regard?
  - o Have the initiatives surprised you in any way?
- Have you now realized the full potential for cost effective fuel saving measures?
  - o If no, why not?
  - o And where does a potential exist?
  - o Are you sure such initiatives are cost effective?
  - o What is the fuel saving potential with regard to operational measures? Speed reduction, voyage execution, power management, performance monitoring?

How and why energy consumption monitoring is performed

- How do you monitor fuel consumption onboard your fleet?
  - o How frequently do you monitor vessel fuel consumption?
  - o What are the procedures you employ for monitoring of vessel fuel consumption?
  - o For how long have you done so?
  - o What is the level of detail in your fuel consumption monitoring? What is monitored?
- How do you analyze the fuel consumption data that you gather?
  - o What methods do you employ to analyze data?
- What do you use energy consumption monitoring data for? Why?

- o Did you ever consider implementing fuel saving competitions between your vessels? Why/why not?
- o Do you provide crews with feedback based on the energy consumption monitoring data analysis? Why/why not?
- o In case you provide feedback, how do crews react to this?

- Do you observe any difference in terms of energy efficiency performance within your fleet?
  - o If yes, how big are the differences?
    - ■ Are they also observable between sister ships?
  - o If yes, which ships are best in class and which are the worst performers?
    - ■ Why?
  - o How do you address differences in performance between vessels?
- Do you have a SEEMP?
  - o If yes, who formulated it?
  - o Why did you establish it?
  - o Do your ships have individual SEEMPs or are SEEMPs identical for all vessels?
  - o What effects (if any) do the IMO SEEMP requirements have on your business?
- How do you perform in terms of fuel saving and energy efficiency when compared to competing shipping companies?
  - o How do you know?
  - o In the case of a performance difference, what is the reason for this?

Validity and reliability of energy consumption monitoring data and best practice

- What is the quality of the energy consumption monitoring data you receive from ships?
  - o Other interviewees have explained that they observe significant noise in energy consumption monitoring data: Is that also the case for you?
  - o Does energy consumption monitoring data quality vary? If yes, when and why?
  - o How do you assess the quality of noon reporting systems and auto-logging systems?
    - ■ Which of the systems do you prefer? Why?
  - o Do you have flow meters installed onboard your vessels?
- What is best practice energy consumption monitoring for you?
- Interviewees in other companies have explained how they experiment with various fuel saving measures, such as the ones mentioned below. Would they be relevant for your?
  - o Continuous energy consumption monitoring and auto-logging systems?
  - o Vessel fuel saving competitions?
  - o Energy efficiency training courses for crews?
  - o If no, why not?
- Which roles do crews and shore organizations have in regard to fuel saving?
  - o How do you engage crews and shore employees in fuel saving efforts?
  - o Do you train employees on shore and at sea?
- What are the ideal conditions for fuel saving?
  - o Does outsourcing of ship management influence fuel consumption?

Interview guide 2

For chartering, operations and technical managers in tanker shipping companies (2018)

In my **e-mail approach to the interviewees**, I explain my interest in the potential for reduction of GHG emissions from shipping. I explain that my research concerns the question of how shipping can achieve the GHG goals agreed at the IMO MEPC meeting in April. I reveal my two key questions below (but not more than that):

1. What is the potential for time savings in tanker operations (in port and at anchorage)? Could reduce turn-around time in port and reduced time at anchorage enable ships to slow-steam further and achieve emission abatement?
2. What is your view on the GHG data collection systems from the EU (MRV) and the IMO (DCS)?

The interviews will be **semi-structured** (and ideally take at least one hour). Preferably I will target heads of operations and chartering departments in tanker companies (product, chemical, LPG, and LNG). The interviews will fall in two parts:

1. Time savings potential, because this question is focused on the shipping companies' own operations.
2. The MRV and DCS discussions, because they are both concerned with shipping companies' own operations and environmental regulation. I expect the latter aspect to be more controversial in the view of the interviewees than the discussion on time savings.

The overall structure of the interviews will be the following:

1. Start with open-ended questions: Please describe what you do. How you do it? How does regulation affect your company?

2. Gradually follow up with more testing questions: Did you consider the following aspects and factors? If you see an improvement potential, why has this potential not already been achieved? How can shipping achieve significant GHG emission reductions?
3. Ending with clarifying questions about the business model of the shipping company: What are your competitiveness factors? (In order to supplement the information which is available in company annual reports and on corporate website).

PART 1 – POTENTIAL FOR TIME SAVINGS

Do you see a potential for **time savings** in the operation of tankers, which could allow for service speed reductions?

- If yes, where?
  - How large is the potential?
  - How to achieve it?
  - Why has it not been achieved already?
- If not, why not?

Port turn-around time

- What are the factors, which influence a ship's turn-around-time in port?
  - Do you see variation in the duration of port calls?
    - If yes, what in your experience is the shortest and what is the longest?
      - What causes such variation?
- What are the main activities during a tanker's port call?
  - Could you please describe the different activities and processes that take place during a tanker's port call?
    - How long time does each activity take?
      - Which of these activities is the crew or the shipping company in control of?
      - How do bunkering, provisioning, garbage and sludge handling, crew changes or other activities influence the time spent in port?
        - Would it be possible to save time on any of the activities?
          - Which and how?
          - How can achieve such time saving measures?
      - How do customs clearance, immigration, signing of bills of lading etc. influence the time spent in port?
- Port turn-around time saving measures
  - What can you, in the chartering (or operations) department of a tanker shipping company do to reduce port turn-around time?
    - Do you have experiences with this?
  - What can seafarers onboard the ships do to reduce time in port?
  - Who are the other key stakeholders, who can ensure short turn-around time in port?

Time spent at anchorage

- Do any of your ships spend time in laden condition at anchorages, while waiting for berth?
  - If yes:
    - Where?
      - Is there any difference in the waiting time between different geographies, terminals or ports?
        - If yes, what causes this variation?
    - For how long do the ships wait?
    - Is waiting time at anchorage affected by the ship's charter party? Or type of charter (voyage vs. time charter)?
    - Does waiting time at anchorage affect your earnings in any way?
      - Under voyage charters?
        - When will you start earning demurrage?
        - Does demurrage rate differ from the voyage charter rate?
          - If yes, how and why?
      - Under time charters?
    - Can you minimize or avoid the waiting time?
      - Would you want to do that?
      - What would be required to minimize waiting time?
- **Virtual arrival schemes**
  - Do you use virtual arrival schemes in your company today?
    - If yes, where and when?
      - Do you propose to charterers to use virtual arrival clauses to your voyage charterers?
    - If not, why not?
      - Do you have experiences with virtual arrival schemes from the previous shipping companies that you worked in?

- Would implementation of virtual arrival clauses not enable shipping to reduce its fuel consumption and achieve emission abatement?

o Are you familiar with the BIMCO virtual arrival clause for voyage charters, which was developed in 2012?
- ▪ What is your view on the clause?
- ▪ Do you use it? Or offer your charterers to use?
  - If yes, who use it?
    - o And how frequently is it used?
  - If not, why not?

o Do you see a potential for implementation of virtual arrival schemes?
- ▪ If yes, what would it require?
- ▪ And who should be involved for it to succeed?

PART 2 – DATA SETS ON GHG EMISSIONS
Shipping company **performance monitoring system**

- How do you **measure the fuel consumption of your ships**?
  - o Which onboard energy consumers do you focus on?
  - o Do you use noon reports?
  - o Do you use auto-logging systems?
  - o Do you have flow meters onboard?
  - o How frequently do you collect data?
  - o What do you use the data from the systems for?
  - o Have you changed your systems in recent years?
  - o What are the key factors, which influence a ship's fuel consumption?
    - ▪ Which of these factors do you have an influence on?

View on **EU MRV**

- How does the EU MRV affect the work you do and your shipping company?
- How do you **collect data for MRV**?
  - o Which data do you collect?
  - o Where do you collect the data from?
  - o Who collects the data?
- **Resources for MRV** data collection
  - o Who is responsible for MRV data collection in your company?
  - o Did you allocate additional resources to the data collection process, in terms of:
    - ▪ Human resources,
    - ▪ New IT-infrastructure, or
    - ▪ Monitoring equipment onboard the ships in your fleet?
  - o How much does the MRV data collection require of your company in terms of man-hours per year/human resources?
    - ▪ To comply with EU MRV did you need to make any changes in the collection of fuel consumption data from your fleet (i.e., amend or revise your vessel performance monitoring systems)?
      - If yes, which, how and why?
- Did you use consultants or other external experts for the design or implementation of your MRV data collection system?
  - o How do you **quality control** your MRV data?
    - ▪ Who is verifying your MRV data?
    - ▪ How does verification take place?
      - How frequently does it take place?
      - Can you use the process of data verification to improve your data quality?
- How does company's fleet performance monitoring system compare with the data collection for the MRV and DCS systems?

View on **IMO DCS**

- How do you collect data for the IMO DCS?
  - o Which data do you collect?
  - o Where do you collect the data from?
  - o Who collects the data?
  - o How frequently do you collect data?
- Could you please compare the IMO DCS and the EU MRV?
  - o What are the key differences between the two systems?
    - ▪ Do these differences affect your work or data collection in any way?

o Do you see any differences between the systems in terms of data quality?
▪ If yes, where and why?

Internal use of MRV and DCS data

- How do you use MRV and DCS data within your shipping company?
  o For what purposes? Why?
  o Can you use the MRV data to identify a potential for energy efficiency or other types of improvement potentials within your fleet?
  o Can you use the MRV or DCS data to identify fuel inefficient ships in your fleet?
    ▪ Have you actually done so?
- To what extent can you and your colleagues in the shipping company affect the efficiency measurements in the MRV and DCS systems?
  o Can you make changes in the operations of your ships, which would improve the performance measurements of your ships in the MRV and DCS systems?
    ▪ If yes, how?
    ▪ If no, why not?
- Do the MRV or DCS data convey the same message with regard to the efficiency of individual ships?
  o If not, what are the causes for the observed differences?
    ▪ Do the MRV and DCS systems reflect the true performance differences between individual ships?
    ▪ Do the MRV and DCS data sets align with the performance metrics that you use in your internal fleet performance monitoring system?
      • If yes, what are the key performance metrics?
      • If not, why not?

External use of MRV and DCS data

- **Who** do you expect to use the MRV and DCS data, when data sets become publicly available?
  o Will charterers use them for chartering decisions?
    ▪ Can they identify the most fuel efficient ships in the market?
  o Will you or your company use the data sets, when chartering ships?
    ▪ Can you use the MRV or DCS data sets for guiding your own chartering decision?
  o Could other stakeholders have an interest in using the MRV data?
    ▪ Who? Why?
    ▪ For instance:
      • Port authorities (for green port fee reductions)?
      • Policy makers?
        o For implementation of Market-Based Measures in the future?
        o What is your view on MBMs?
      • Journalists?
      • NGOs?
      • Others?
- Does the MRV or DCS systems provide you with any **business opportunities**?
- Does the MRV or DCS force you to reveal **commercially sensitive information**?
  o If yes, which information?
  o And what effects do you foresee from MRV and DCS?

Link between **MRV, DCS and private eco-rating** schemes

- Are you familiar with private eco-ratings in shipping?
  o If not: CCWG, CSI, ESI, Rightship, BetterFleet, EVDI
  o If yes, which ones?
    ▪ Do you use them?
      • If yes, what for?
    ▪ Do you know of other using it?
  o How do the eco-ratings affect the work you do, your company and the business of tanker shipping more broadly?
- From you point of view, how do the MRV, DCS and the private eco-rating schemes (CCWG, ESI, CSI, Green Award, Rightship/EVDI and BetterFleet) compare?
  o Are they measuring the same factors?
  o Or are there important differences between any of the ratings?
    ▪ If yes, which?
  o Are there any overlaps between the private eco-ratings and the MRV and DCS systems?

- If yes, which?
- In your opinion, which of the systems provide the best measurement of a ship's energy efficiency?
  - And of its overall environmental performance?

- Do cargo-owners ask you questions regarding your CO2 emissions or any other aspects of your environmental footprint?
  - o If no, why not?
  - o If yes, what do they ask?
    - And who asks?
    - What do they use the information for?

View on the **air emission regulation in shipping**

- What is your view on regulation of air emissions in shipping?
  - o Regulation from the IMO? The EU? And others?
  - o **How is regulation affecting your business** and your company?
    - What regulation is affecting you the most?
    - How is regulation on air pollutants and regulation on GHG affecting your company? And the shipping markets?
    - What are the costs associated with compliance for you?
  - o In your opinion, **how can shipping achieve the GHG emissions reductions** agreed at the April 2018 MEPC by 2050 (i.e. a 50 per cent reduction in absolute GHG emission levels relative to 2008)?
    - To what extent can these ambitions be achieved through efficiency improvements in the shipping sector?
    - In your opinion, does shipping need a new type of fuel to achieve the goals?
- From you point of view, why did the MRV and DCS systems come into existence?

Shipping company strategy

- In addition to the information available on your web-page and in your annual report, so short follow up or clarifying questions about:
- Which **trades** are you active in?
  - o In terms of geography?
  - o In terms of vessel sizes?
  - o In terms of contract types and contract durations?
    - Use of spot, time charter, bareboat charters and Contracts of Affreightments?
  - o Do you engage in asset play?
  - o Do you contract newbuildings or buy second-hand vessels?
- How are ships **managed**? In-house or outsourced set-up for:
  - o Chartering
  - o Operations
  - o Technical management
  - o Crewing
  - o Why? What is the motivation behind this set-up?
- What are the key **sources of competitiveness** for your company?

Interview guide 3:

For sustainability or transport procurement managers in consumer goods companies, which ship substantial volumes of containers, (2020)

Your emissions and abatement goals

- What are your goals for abatement of air emissions from your company?
- What are your main sources of emissions?
- For GHG and air pollutants?
- How important are emissions from container shipping for your firm's emissions footprint?
- How are you reporting on your emissions? Do you report on GHG Scope 1, 2 and 3 emissions?
- Have you formulated specific goals for abatement of container shipping emissions?

Your **transport needs**

- Cargo characteristics
- Which cargoes do you ship in- and outbound, respectively?
- What are your annual cargo volumes (in teus and weight)?
  - How much do volumes change from month to month?
  - How predictable are volumes?

- What is the value of your cargoes?
- What is the average parcel sizes?
- Frequency of shipments: How often do you ship?
- Geography of shipments:
- What are the most common origin-destinations for your cargoes?
- Major trade-lanes used?

Your **shipping procurement**

- How do you choose between transport modes?
- What is the modal distribution for your cargoes?
- What are the key considerations for you regarding modal choice?
- How do you procure container shipping services?
- Do you have direct contact with carriers? Or do you go through forwarders?
- Do you use spot or period contracts for your shipments?
- What are your main concerns/priorities for your transport service procurement?
- What are your key carrier choice criteria?
- For instance: Price, speed, frequency, network coverage, onshore transport services, transparency/cargo traceability, environmental performance….?
- How many different carriers do you use?
- Do you use emissions considerations in your carrier choice? If so, which and how?

Current drivers for emissions abatement

- In your opinion, what are the **key drivers** for the abatement of emissions from container shipping?
- Which measures are available?
    - ▪ Efficiency measures? Which?
    - ▪ Slow-steaming?
    - ▪ New technologies or alternative fuels? Which?
    - ▪ Regulatory measures?
    - ▪ Other measures?

Clean Cargo: Why did you join?

- When did you join?
- What do you gain from the membership?
- What does membership require from you?
- Which departments from your organization are involved in Clean Cargo? CSR, transport/logistics or any other departments? Why?

CC work: Could you please describe the Clean Cargo's work? What are the main activities?

- The Clean Cargo webpage describes its four **main activities** – could you please elaborate on them?
  - Measuring emissions
  - Sharing best practices
  - Catalyzing partnerships to improve sustainability performance in supply chains
  - Supporting responsible business practices

CC measuring emissions: What is the purpose of this?

- What does Clean Cargo measure?
  - o Exactly **what data** do members report to Clean Cargo?
    - ▪ How frequently do they report?
    - ▪ How is data quality ensured?
  - o Do carriers report, for instance?:
    - ▪ Container shipping lines' annual emissions per teu-mile on trade lane basis?
    - ▪ Emissions from individual ships? On a per voyage basis? Or per year? Or per teu-mile per year?
    - ▪ Absolute emission levels for container shipping lines?
    - ▪ Absolute emissions from shippers?
    - ▪ Emissions per teu-mile for shippers?
    - ▪ Other something else?
  - o The measurement focuses on GHG as well as air pollutants? Why? What is the most important?

- How do you **use data** from Clean Cargo?
  - o Which data sets do you use?
    - ▪ How? For what purpose? Why?
    - ▪ How are you working with Clean Cargo data?
    - ▪ Do you use it to estimate your own firm's emissions?
    - ▪ Do you use it for transport procurement decisions? If so, how?
    - ▪ Do you use Clean Cargo data for pricing negotiations?
    - ▪ Internally, in your organization? For which purposes?
    - ▪ Externally, in your communication with different stakeholders?
  - o How do other members of Clean Cargo use the data?
    - ▪ Who else can or should use the data?
    - ▪ Would it make sense to make detailed emissions data publicly available? Why/why not?
- How much do carriers **differ in terms of environmental performance**, fuel consumption or CO2 per teu-mile?
  - o Why do they differ? For instance, due to:
    - ▪ Ship-designs/technologies (newbuildings and/or retrofits)?
    - ▪ Use of alternative fuels?
    - ▪ Scrubber, vs. LSFO choice?
    - ▪ Vessel operations (trim optimization, hull cleanings, weather routeing etc.)?
    - ▪ Average service speed?
    - ▪ Vessel capacity utilization?
    - ▪ Network-designs?
    - ▪ Carrier business model?
    - ▪ Carrier horizontal integration (from carrier to forwarding and terminal operations)?
    - ▪ Membership of shipping alliances?
    - ▪ Other factors?
  - o Do the carriers differ in terms environmental aspirations or goals?
    - ▪ If so, how? And why/why not?
  - o In your view, what is the best metric for environmental performance in container shipping?
    - ▪ On a carrier basis?
    - ▪ On a trade-lane basis?
    - ▪ On a ship basis? Or on a fleet basis?
    - ▪ On an annual basis? Or with a more fine-grained data set, per month or on a per voyage basis?
    - ▪ On an origin-to-destination basis, including land transport?
    - ▪ How to measure and produce reliable, valid data sets on carrier and vessel emissions?
      - What are the key determinants of the emissions from individual ships?
    - ▪ How much do individual ships differ in terms of emissions/environmental performance? Why do they differ?
- **Do you provide data** to Clean Cargo?
  - o If so, which data sets do you provide?
    - ▪ How do you gather and quality control data?
    - ▪ For what purposes is this data used?
  - o It not, why not?
    - ▪ Would it make sense to collect and compare cargo-owners' emissions data?
    - ▪ For instance, would it be feasible to identify shippers with the lowest CO2 footprint per ton-mile procured?
- **Other data available**: What is your view on emissions data sets gathered for the EU **MRV** and IMO DCS, respectively?
  - o Do you use it? If so, for what purpose?
  - o In essence, does the MRV and CC provide similar or supplementary metrics?
    - ▪ Do they show the same? Why/why not?
    - ▪ Or is MRV more comprehensive in its GHG data reporting than Clean Cargo?
  - o What is your experience with **other private eco-rating initiatives**?
    - ▪ Such as the Environmental Ship Index, Rightship and Clean Shipping Index?
    - ▪ Did you consider to join or use any of these?
    - ▪ Why have these schemes and initiatives come into existence?
    - ▪ How do they differ from Clean Cargo?
    - ▪ How would you characterize them in terms of ambitions level?
    - ▪ Would it make sense to merge CC with them? Why/why not?
- Some observers claim that private green shipping initiatives are designed to **make life easier for business managers** – would you agree with this observation?
  - o If not, why not?

CC sharing best practices

- Could you give examples of what is shared?
- What have you shared yourself?
- What have you gained form others' sharing of best practices?

CC catalyzing partnerships to improve sustainability performance in supply chains

- How can Clean Cargo do this?
- What does this involve?
- Could you give examples of this?

CC supporting responsible business practices

- What are the main ways in which Clean Cargo seeks achieves this?

CC summing up

- Who are the main leaders of Clean Cargo? – Cargo-owners, forwarders or carriers?
- What are the main limitations of Clean Cargo, with regard to emissions abatement?

Looking ahead

- How can container shipping **achieve the IMO GHG goals**?
  - o Which of the IMO GHG goals is most difficult to achieve?
    - To reduce CO2 footprint per ton-mile, by 40 % by 2030 and 70 % by 2050
    - To reduce absolute emissions by 50 % by 2050;
    - To phase out fossil fuels in second half of this century?
  - o How can shipping achieve each of the goals?
    - Via efficiency improvements?
    - Via alternative fuels?
    - Via other measures?
    - Which measures are currently contributing the most to emissions abatement for container shipping?
  - o How do the goals **affect your business** and container shipping in general?
  - o How can **your company contribute** to the achievement of the goals?
- Which **regulation** is most likely to abate container shipping emissions?
  - o What is your view on the following measures?
    - Current SEEMP – and a possible, future, more rigorous SEEMP
    - Current EEDI - and a possible, future, more demanding EEDI
    - Current MRV – and possible, future, more demanding MRV
    - Global Sulphur cap
    - Speed limits
    - A ban on fossil fuels (e.g., by 2050)
    - Market based measures
      - Bunker tax
      - Emissions Trading Scheme – including an EU ETS
    - Do you see any alternative regulatory measures?
    - Regional measures, e.g. from the EU? For instance, MRV and an inclusion of hipping into an EU ETS?

Interview guide 4:
For ropax crew members (2015–16)
What role does energy efficiency play in your work?
What does energy efficiency mean for you?
How do you define energy efficiency?
How to achieve energy efficiency? What are the most important factors?
How to reduce fuel consumption on board? (progress, operation)
How do you know what is energy efficient?
Is it possible to reduce fuel consumption on board?
Do you feel that you have the right resources to weigh the factors that affect energy efficiency?
Do you feel that you have the opportunity to influence energy efficiency on board?
Are there any obstacles or difficulties in reducing fuel consumption?
What types of decisions on board and at the shipping company affect energy consumption?
Do you feel that you have the right information or data to make decisions regarding energy optimization?

Is there the equipment required to analyze and optimize energy consumption?
Do you see any obstacles to analyzing and optimizing energy consumption?
Are there any organizational or technical aids that would have facilitated the analysis and optimization of energy consumption?
What analyzes or studies have been done to evaluate energy efficiency?
What (operational) measures have been implemented to increase energy efficiency?
How have the measures been evaluated?
Are any measures planned to increase energy efficiency?
Are suggestions for improvement in the energy field encouraged?
Do you feel that there is room for improvement? Which?
Do you feel that there is an opportunity to test different working methods to investigate what is most energy efficient?
What kind of cooperation between different parts of the crew is required to be fuel efficient?
What kind of cooperation between crew and shipping company is required to be fuel efficient?
If you could describe your work to a person who has never worked on a boat, what would you say?
What are the positions on board and what is their role?
What role does SEEMP play?
How do you experience the shipping company when it comes to supporting you?
How many helmsmen and masters are there in the organization who work on board X?
What does the work organization look like? How long do you work together? What do the bikes look like?
What role do you think the crew on board has for EE?
What role do you think the shipping company has for EE?
How would you describe your routines on board?
What would you say is the reason for the routines you have?
What does the job as a helmsman / commander require? What challenges do you face? What difficulties are you challenged by?
What decisions are the most difficult to make in your job?
How would you describe your work situation?
What conditions must be met for you to be able to do your job?
Do the machines run optimally? How can you optimize the machines so that they consume as little fuel as possible given the timetable?
Loading:
Who is involved? What does the configuration look like? What is communication about?
What information is needed? Is this most common? What aids are used? What difficulties can arise? How long will it take?

Interview guide 5

For chartering, operations and technical managers in tanker shipping companies (2019)

Presentation of the company

- Including personal introduction and role description

How do you work with energy management today?

- Internally, are they a department or part of a larger group's work?
- Collaboration with any suppliers, customers, researchers or other external contacts?
- Examples of ongoing projects?
- Information retrieval and what factors are important to you when choosing a project to work with.
- Do you see any additional benefits, in addition to fuel savings, of working with energy management?

How do you report your energy consumption and your environmental footprint today?

- Is this information used for any other purpose than the reports?

How do you see the future work with energy management?

- Possibilities?
- Difficulties?
- IMO's target of 50% reduction in GHG by 2050?
- Convert and improve existing boats against investments in new construction?
- Are the technologies available today sufficient?
- The interplay between technology development and commercial and operational interests?

Is the research that is happening today relevant to you?
What would you like to see for future research?
What motivates you to work with sustainable shipping?

Interview guide 6
For crew on oil tankers (2019)
What is your personal background and role onboard?
What is your view of energy consumption?

- From an engineer perspective
- From bridge perspective
    - Voyage planning
    - Speed
    - Laycan
- Calculation of consumption

What are you able to influence and control in terms of energy consumption'?
How do you measure energy consumption?
Would you like to do something different?
Interview guide 7
For ship operators and managers in fuel companies (2019–2020)
Presentation of the company

- Including personal introduction and role description

How do you work with transport? (Focus on shipping)

- Internal, department etc.
- Suppliers
- Procurement
- Long / short term

How is a port call planned?

- Planning
- Arrival
- Speed adjustment
- Prioritization scheme
- JIT
- Virtual arrival

How do you see your role in enabling change in the transport sector?
How do you work with energy management today?

- Internally, are they a department or part of a larger group's work?
- Collaboration with any suppliers, customers, researchers or other external contacts?
- Examples of ongoing projects.
- Information retrieval and what factors are important to you when choosing a project to work with.
- Is this a job that you are involved in when planning transports?

Do you have any cooperation with shipping companies and actors regarding transport?
How do you think about the fuel of the future?

- Reduced demand
- New sources
- Bio fuel

Interview guide 8
For ship operators and managers in ports (2019–2020)
Presentation of the company

- Including personal introduction and role description

Can you describe the work that takes place in the port?

- Which actors are in the port?
- Who works in the port?
- What operations are performed?

What are your most energy-intensive surgeries?

- Measurement of energy consumption?
- What type of challenges do you have?
- What factors influence that process?

How do you work with energy related issues?

- Internally
- Externally

How are the goals set for your energy consumption?
How is a port call planned?

- JIT
- Virtual arrival
- Prioritization scheme

How do you see your role in enabling change in the transport sector?
Cooperation with other shipping companies and actors?

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