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Can Crew Onboard Ships Be Incentivised to Go Green? Understanding the Role of Incentives in Nudging Behaviour for Improving Operational Energy Efficiency

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Abstract

This paper examines the measures available to improve operational energy efficiency from the perspective of onboard crew, the barriers associated with implementing those measures and how crew behaviour can be nudged using incentives. A total of 25 semi-structured interviews and subsequent surveys with 42 onboard crew were carried out to gather qualitative information on two main domains: operational efficiency and incentive schemes. In-depth thematic analysis of interviews showed the central and recurring themes such as stakeholder hierarchy, autonomy and accountability, temporal restrictions, profitability and type of charter. Due to the heterogeneity in interview responses on the topic of incentives, online surveys were conducted. The findings of the study show that whilst speed reduction was seen as the single most important measure to optimise, it was also the most difficult to implement in practice due to several barriers. These include contractual obligations, a complex web of accountability and perverse incentives to increase speed. Other measures such as trim–draft optimisation and auxiliary engine load optimisation have smaller efficiency gains but were found to have more potential for increasing implementation through behavioural changes and encouraged through incentives. Both monetary and non-monetary incentives were perceived to be important and going beyond the status quo of incentivising captains so that rewards are shared equitably amongst the crew. Whilst not generalisable, preliminary findings suggest that there is room to consider alternatives to the current approaches on incentives, which do not take advantage of the importance of acknowledgment and recognition, as well as fostering positive interpersonal relationships.

Keywords: shipping; energy efficiency; incentives; nudging; seafarer; behaviour; onboard; operations

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1. Introduction

Decarbonisation of the shipping industry, which by 2050 could account for almost 17% of world-wide GHG emissions [1], is of global relevance under the current threat of climate change. Existing policies centre around maximising energy efficiency, which is a function of both technical specification and the way in which a ship is maintained and operated. Examples include the Carbon Intensity Indicator (CII) and the Energy Efficiency

Existing Ship Index (EEXI), which supplement the goal-based fuel standard and economic instruments mentioned in the revised IMO GHG strategy [2]. A distinction, however, must be made between "technical efficiency", which refers to some baseline conditions of the vessel, and "operational efficiency", which considers the practicalities of the voyage, variability in environmental conditions, and commercial realities of operations. While technical specifications can be restricted by the infrastructure of a vessel, the dominion of human factors on operational efficiency is much more significant and the focus of this study. Research into operational efficiency measures is therefore crucial due to their potential application in facilitating reduction in fuel consumption and emissions immediately and in the short-term (reduction potential ranging from 10 to 30%), their lower need for extra capital, and the need to maximally optimise operational efficiency before a switch to more expensive zero-emission fuels [3].

The adoption of any new energy efficient protocols and adherence to these regulations, however, once in place, depends on the ship crew, whose limited autonomy of operations affecting fuel consumption is particularly compounded by long voyages away from management onshore as well as overriding commercial and safety considerations [4]. The study aims to better understand crew behaviour on board, which directly impacts the implementation of operational energy efficiency measures. The lack of understanding of the socio-technical factors contributing to operational energy efficiency has given rise to the call for more psychological and social studies within ship crews in recent years.

Incentives schemes can be one of the ways to adapt the internal and external factors pertaining to the socio-technical barriers of energy-efficient operations. Perverse incentives against energy efficiency are already woven into the market-driven framework of the shipping industry's operational practices, and this is particularly evident with certain types of charters. For example, both voyage and time charters are particularly restrictive in accommodating speed reduction measures. This can be due to "utmost despatch" clauses, strict "estimated arrival times (ETA)" [3] and expectations established by the charterer, which preclude the extra time "lost" to implementing energy efficiency measures such as "slow-steaming", for example. While there are ways to include slow steaming within contracts, the most successful slow steaming strategies consider all parts of the ship and logistics cargo chain, requiring copious advanced planning, which is true of nearly all energy-saving measures [5].

Even if contracts were to prioritise saving fuel via reduced speed, the crew who are actualising the measures aligned with better fuel efficiency are not the ones who benefit from them, leading to split incentives and the energy efficiency gap. This is the difference between the potential and the actualisation of an energy efficiency measure; i.e., those who would benefit from operational savings derived from fuel efficiency are not the ones operating those measures, and did not invest in those technologies and measures in the first place [6]. For crew, formalising the role of energy-efficiency-driven incentive schemes, both monetary and non-monetary, may be a way to tackle the energy efficiency gap to fairly distribute to them the gains of their actions on fuel efficiency. However, ship owners who invest in fuel efficiency improving measures, including investments in crew training for energy efficiency, cannot typically recoup their investment. This is unless they operate their own ships or have long-term agreements with charterers, because the charter rates of vessels do not reflect the economic benefit of their respective fuel efficiencies [3].

While the literature on technical efficiency onboard is expansive, the role of incentive schemes in promoting an energy-saving culture within the wider stakeholder network of the shipping environment needs to be further elucidated. Research needs to focus on the granularity of incentive schemes in rewarding specific energy-efficient behaviours, e.g., slow steaming and, trim–draft optimisation, in conjunction with perceived impact and awareness of these measures. Technical solutions as outlined in international and national regulations cannot be actualised if they have not in the first instance considered the socio-technical realities of operations on board. This is the case with initiatives such as the IMO's Ship Energy Efficiency Management Plan (SEEMP).

Shipping operations are complicated by a disconnected and hierarchical stakeholder network, dynamic market conditions, and a constantly changing working environment, all of which have significant effects on a ship's overall efficiency. The interplay between these factors is currently not well researched, and the lack of consideration given to these complex relationships is likely to create intrinsic contradictions which limit the true reach of regulations such as SEEMP in meeting overarching decarbonization goals, e.g., those in the IMO's GHG strategy.

This analysis, which comprises interviews and surveys, aims to gain a deeper understanding of the practices amongst different stakeholders that influence a vessel's operational efficiency. This is in order to understand the barriers to operational efficiency and subsequent areas for improvement, and what role incentives may play in the realisation of these improvements, which is an area in which there is little to no research in the maritime transport sector.

Our findings are significant against the background of shipping's current climate policies, which fail to consider the reality and complicated nature of implementing energy efficient practices onboard. Our research evidences a more integrated approach, which considers the entire ship environment as one entity with many moving parts, where no one part can be targeted without taking all the others into consideration. We hypothesise that our results will provide essential insight into how conflicting stakeholder interests and decisions limit how much crew can really achieve in terms of efficiency, particularly in the absence of well-designed incentive schemes. Furthermore, our research also aims to highlight specific and commonly occurring scenarios which increase crew agency in optimising energy efficient operations, but which crew may be underutilising due to lack of awareness or experience.

This paper is structured as follows; Section 2 provides a review of existing literature on barriers to energy efficiency measures, operational measures and incentive schemes to overcome the barriers in other sectors. Section 3 describes the data collection methods to answer the research questions. Section 4 presents the results from the semi-structured interviews and online survey. Section 5 provides a discussion of the results on energy efficiency measures and incentives. Section 6 provides concluding remarks and recommendations.

This paper aims to answer the following research questions:

1. Which operational practices/measures have the highest energy-saving potential that can be undertaken by onboard crew without compromising safety and commercial objectives?
2. Is there a role for incentives in improving operational energy efficiency?
    a. What are the current incentives and reward structures for improving performance and which ones are perceived to be most effective?
3. Which incentives and rewards are most preferred by crew in return for improving personal performance towards energy efficiency?

2. Literature Review

2.1. Energy Efficiency

2.1.1. Background

Although the definition of energy efficiency is adapted when in the context of different industries, it may be simpler to think of energy efficiency as the ratio between the useful output of a process and the energy being funnelled into it [7]. In shipping, energy efficiency can be achieved in two ways: operational and technical. Operational efficiency is more dynamic, varying with fuel consumption and the operational conditions under which human factors have more consequence, such as trim, auxiliary engine optimisation, speed optimisation, and weather routing. This can be partially measured by the Energy Efficiency Operating Indicator (EEOI), a measure used to help shipowners assess the impact of operational modifications on the fuel economy and emissions of their ships.

Technical efficiency refers to technical specifications such as engine modifications and equipment, which can be implemented at the ship-building stage or as retrofits [8]. The IMO's regulatory measure, the Energy Efficiency Design Index (EEDI), and the targets they have attached to it, help to make a ship more technically energy efficient.

The aforementioned goal-based fuel standards mentioned in the revised IMO GHG strategy [2] have established themselves within shipping regulations with the goal of prioritising energy efficiency in shipping. The transition pathway to meet these targets, such as the those for the EEOI or EEDI, are less clear. The practicalities, for example, involved in improving operational efficiency must be carried out by crew. However, the crew's realistic dominion over these practices is complicated by their downstream position in the stakeholder network which reduces their autonomy in actualising energy-efficient practices.

2.1.2. Stakeholder Network

The complex stakeholder structure of shipping is further complicated by the sea's changing environment, which necessitates a dynamic reactivity from the crew. However, the decisions on how a ship operates are made by various stakeholders including shipowners, operators and charterers, and third-party vendors and companies. Often, it may be the case that each of these agents operates with mutually exclusive goals [9]. Jaferzadeh & Utne [10] and Rehmatulla & Smith [3] have previously depicted the interrelationship between these parties.

Some of the personal choices and incentives of stakeholders onshore are driven by the shipping company's economic environment. Poulsen et al. [4] focus mainly on the decisions regarding voyage planning made in advance of the trip and the identities of these decisionmakers, split into commercial and nautical. In their study, the destination of one cargo ship was unassigned post-departure due to the charterer's deliberating between six ports during the voyage, meaning the crew had to run a "middle course" until a port was named.

It is often the case that the added effort in achieving these market-driven goals is assigned to the crew, while they are not the ones who reap the benefits. For example, many of the decisions onshore and onboard are driven by the bunker prices and consequent fuel consumption, creating an inherent attitude of saving fuel, especially in time charters. While saving fuel to increase profitability frequently aligns with boosting energy efficiency, it is often the case that the extra steps taken by crew to reduce consumption, such as efficient use of ballast or trim–draft optimisation, are not rewarded and therefore not externally incentivised. This is particularly the case in older ships with less advanced technology, which increases the manual workload of crew in achieving these goals.

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These effects of a complex stakeholder network are particularly marked on the crew due to their lower hierarchical position as the frequent operators yet seldom decisionmakers of energy-efficient measures. However, there are some cases where a ship's crew can override third party input. For example, prolonged charterer deliberation with a receiver as a vessel approaches the port may necessitate that the ship drifts or drops anchor within the outer port limit (OPL), which will stop fuel consumption almost completely, thereby increasing energy efficiency [11]. Bad weather conditions may also be another such instance, where a master can decide to take shelter and proceed only in calm conditions, instead of "full steaming" ahead in a current which does not allow sufficient forward propulsion of a ship. Such decisions can minimise aerodynamic and hydromechanical losses in bad weather conditions, while also saving fuel in the long term.

However, it must be noted that crew are not the only ones who are affected by this extensive network. Contradicting goals also persist between ship owners and charterers; for example, in voyage charters where it is the charterer who requires high speeds while the shipowner bears the cost of fuel.

2.1.3. Operational Efficiency

Seafarers, when asked which known operational measures had the highest potential for CO_2 emission reduction cited the following: fuel consumption monitoring, weather routing, speed reduction 'slow steaming', and crew awareness and training [12]. The majority of these measures are in line with the literature on the operational measures with the highest GHG abatement potential [8,13,14].

However, for the crew, the reality of implementing these measures is complicated by vessel structure, international guidelines, charter clauses, and the wider stakeholder network. When vessel structure is considered, slow steaming, for example, is not always an efficient measure. Each vessel's operating system is built to accommodate an optimum speed, which may not always align with what is most energy efficient. Engine operation at lower engine load may result in deterioration of the main and auxiliary engines, including cold corrosion and fouling on the exhaust gas boiler, paradoxically consuming more fuel to cover a smaller distance at lower speed. To avoid such efficiency variations while operating outside specified design parameters, extra engine maintenance is required, which is just one of the hidden costs of slow steaming, which is often presented as a cost-free implementation. Eventually, these efficiency variations may mean that the expected fuel consumption savings may not even be realised [15].

There are some energy-efficient adjuncts which help the master and crew to navigate an optimum sailing course, such as weather routing systems. Such systems increase the effectiveness and efficiency of current ship operations by achieving just-in-time (JIT) arrivals while considering real-time ETAs. Some define Ship Weather Routing as a system which takes into account forecasted conditions in conjunction with the captain's experience and ship infrastructure to sail an optimum course. However, it is often the case that the captain's judgement and experience may be at odds with weather routing suggestions, which may compound existing and intrinsic resistance to change on the part of the staff [16].

Similarly to such systems, the development of regulatory tools such as IMO's mandatory SEEMP also appear to forgo crew and master involvement in their conception. SEEMP can guide a crew's best energy-efficient practices, such as better voyage planning, weather routing, speed optimisation, reduced power consumption, optimised ship handling, enhanced fleet management, and cargo handling [17,18]. However, it is often the case that crew have not been involved in the development of a vessel's SEEMP [17] and therefore it may be difficult for them to be aware of its benefits, therefore reducing motivation to implement its suggested measures [18].

The SEEMP also does not isolate the effects of individual nautical and operational parameters on energy efficiency [18], which means that individual practices cannot be targeted for change easily. Some claim that this is further expounded by lack of precise monitoring equipment to provide the granular data required to isolate the effects of crew behaviour on efficiency. However, the lack of precise fuel consumption data is less a valid argument against incentive schemes and more for the creation and legitimisation of more fine-grained vessel performance data and real-time energy consumption monitoring, a sentiment echoed by ship masters in multiple surveys [18,19].

While the implementation of such technology is becoming more widespread, the shipowners who invest in this technology will not always be the ones benefiting from the resultant boost in efficiency, creating a split incentive against such investments, which is discussed in the next section. Furthermore, such technology may not even be the central prerequisite to incentivise energy-efficient behaviours [20]. The International Seafarer's Wellness Association Network's (ISWAN) recent survey on seafarers' challenges with decarbonisation found that seafarers wanted to be "acknowledged and valorised, both in terms of remuneration and job security" for their contributions to decarbonisation. The validity of monitoring data sets did not appear in this report as a priority or obstacle for seafarers [21].

2.2. Incentives Schemes in Shipping

Incentive schemes in shipping are mostly rooted at the organisational level, where shipping companies are incentivised to reduce pollution and accidents to improve water quality [22]. These incentive structures have extended to energy efficiency in shipping, such as the implementation of lower port dues for vessels which score highly on the Environmental Ship Index (ESI) [23]. However, personal incentives for crew within the ship environment are less known, with this being an area where there is almost no research pertaining to shipping specifically.

The Principal–agent problem, derived from the Theory of the Firm [24] describes a situation where the delegation of a task from a principal to the agent, accompanied by a granted capacity to the latter to perform said task, is nuanced with the conflicting interests of, and the asymmetry of information between, the two parties. In shipping, this can be called a split incentive [25]. A common example of the split incentive problem is where one who must invest and implement the energy efficiency measure is not the one benefiting from the improvement in energy efficiency, e.g., a time charterer who benefits from reduced fuel consumption when a shipowner invests in technical energy efficiency. Blumstein et al. [26] refers to these as landlord–tenant problems [27]. Johnson et al. [27] further highlight the importance of identifying or creating personal incentives for "investing" in energy efficiency, where investing extends to even day-to-day activities which could nurture individual personal accountability for energy efficiency. Realising incentive structures for propagating energy-efficient behaviours could both invest and empower crew in their role as agents of energy-efficient and sustainable shipping.

There are four types of incentive schemes: (a) cost incentives, (b) schedule incentives, (c) performance incentives, and (d) safety incentives [28,29], and the manner in which these can be delivered can be monetary or non-monetary [30,31]. Incentive schemes can retain an employee by boosting their satisfaction and compensate and improve their performance through the theory of expectancy. It is then predicted that the individuals will make conscious choices (such as improving their performance to meet incentive-driven targets) in order to maximise their gain (further incentives) [31]. It has also been shown that in addition to improving job performance, contractual incentives can result in a better alignment of owner and contractor objectives [30]. It is possible that this may address the issue of split incentives in the complex chain of stakeholder relationships. The impact of incentives on a crew's energy efficiency in shipping has, to date, not been widely researched. However, treatments applied in other transport sectors, such as aviation and road freight, as shown below, can be useful to understand their impact on behaviour.

In their field experiment in partnership with Virgin Atlantic airways, Gosnell et al. [20] used firm level incentives for workers as a pathway towards nurturing energy efficient behaviours over a 27-month period. The impact of three treatments on the fuel efficiency behaviours of captains was measured: personalised information (on fuel consumption), performance targets (on fuel consumption and other measures implemented), and prosocial incentives. Results relevant to this study stated that the inclusion of personalised targets increased captains' implementation of their three measured behaviours: performance reports sent to captains, personal targets in addition to performance reports, and prosocial incentives such as charity donations subject to meeting targets. Overall, the effects for all three behaviours were statistically significantly different from the study's control group for nearly every behaviour–treatment combination.

In the road freight transport sector, up to 91% of total trucking fuel consumption in the U.S. is affected by "usage" Principal–agent problems, where the driver does not pay fuel costs and lacks incentive for fuel-saving operation [32]. In a study focusing on light commercial vehicle drivers in a logistics company fleet, comparing the significance of monetary vs. non-monetary incentives on fuel efficiency and eco-driving, participants in the non-monetary group exhibited a much higher reduction in average fuel consumption than the monetary treatment group [33]. In this study, non-monetary incentives included vouchers in the same value as the monetary treatment for attending wellness activities such as the cinema. The same phenomenon was exhibited when comparing monetary and non-monetary incentives for energy conservation in a Dutch firm as well as a trucking company in Norway, with public and social rewards outperforming monetary rewards, even if monetary rewards were initially perceived as more popular with the workers [34,35]. This suggests that there may be a disconnect between perception and practice when it comes to incentivising sustainable practice.

In the discussion of non-monetary and monetary incentives, it must be postulated whether the existence of monetary incentives as extrinsic motivation creates a habit of perverse financially driven practices which ruin intrinsic motivation, often known as the "motivation crowding effect" [36]. In shipping, seafarers' personal pride when it comes to energy efficiency, and the impact of incentivising performance via extrinsic measures, must be considered. However, Deci & Ryan's cognitive evaluation theory [37] predicts that "rewards only reduce intrinsic motivation when they are perceived as controlling the behaviour" [38]. Even when they do reduce intrinsic motivation, the factors contributing to this are not well understood. Similarly, the possibility of perverse incentives is not an argument against exploring incentive schemes in shipping, especially given their efficacy in other transport sectors such as aviation and road freight. On the other hand, they highlight the importance of carefully constructed incentive structures which minimise perverse incentivisation in the realm of operational efficiency. Table 1 summarises some of the seminal literature on the topic of operational efficiency which employ interviews and/or surveys with stakeholders in the transport sector. This analysis is the first to focus on the use of incentives for maritime crew to increase their operational energy efficiency in shipping, with the wider aim of shedding light on the potential role of incentives in the transport sector to increase global sustainability.

Table 1. Literature review table: studies employing interviews and/or surveys in understanding operational efficiency measures, crew behaviour and incentives.

Authors	Title	Design Type	Interviews/Surveys	No. of Participants	Results
Zoubir, 2019 [39]	Onboard energy-efficient operations and decision-making of ship crews.	Qualitative and Quantitative	Yes	15	Facilitating energy-efficient operations can be accomplished through increasing crew understanding of ship functions, more efficient navigation, improved personal attitudes and better incentives.
Poulsen et al., 2022 [4]	Energy efficiency in ship operations: Exploring voyage decisions and decision makers	Qualitative	Yes	77	Principal–agent problems hamper energy efficiency in ship operations. Policymakers should consider the limited autonomy of crew in executing energy-efficient nautical decisions given commercial constraints, and instead broaden their regulatory focus, including stakeholders with more significant autonomy in implementing energy efficient decisions, such as cargo owners.
Hansen et al., 2020 [40]	Making shipping more carbon-friendly? Exploring ship energy efficiency management plans in legislation and practice	Qualitative	Yes	30	Wider range of stakeholders must be involved in the vessel-specific SEEMP in order to define unambiguous goals which allow the entire system around the ship to cooperate in meeting these goals.

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Table 1. *Cont.*

Authors	Title	Design Type	Interviews/Surveys	No. of Participants	Results
Gonsnell, List and Metcalfe, 2019 [20]	A new approach to an age-old problem: solving externalities by incenting workers directly	Quantitative and Qualitative	Yes	335	Providing basic informational feedback to crew, setting personalised exogenous targets, and providing prosocial incentives can increase fuel-efficient behaviours.
Viktorelius and Lundh, 2019 [41]	Energy efficiency at sea: An activity theoretical perspective on operational energy efficiency in maritime transport	Quantitative and Qualitative	Yes	40	A better understanding of socio-technical change processes at a local level is required to address energy efficiency gaps, and international and national guidelines are not likely to be enough. Existing contradictions in current practice relating to energy efficiency must be understood and addressed contextually, and this can be achieved through new forms of collaboration between ship and shore.
Hammander et al., 2015 [42]	How Do You Measure Green Culture in Shipping? The Search for a Tool Through Interviews with Swedish Seafarers	Qualitative	Yes	13	Lack of information transferability and transparency within the ship environment may prevent a proactive green culture.

Table 1. *Cont.*

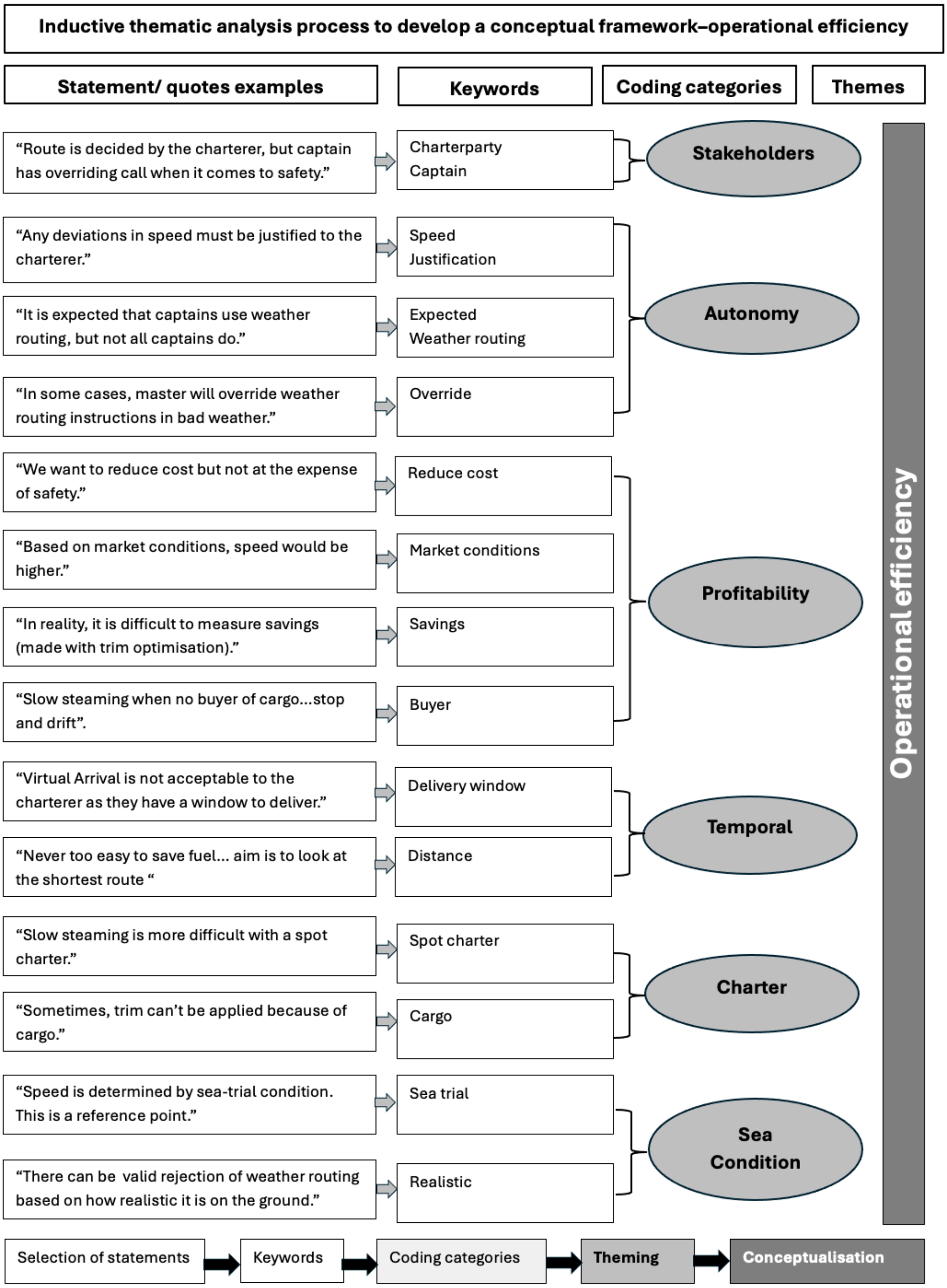
Authors	Title	Design Type	Interviews/Surveys	No. of Participants	Results
Rasmussen et al., 2018 [43]	Energy efficiency at sea: Knowledge, communication, and situational awareness at offshore oil supply and wind turbine vessels	Qualitative	Yes	49	Operations on board are affected by a system of factors including ship design and individual factors such as crew ability, experience and training. SEEMP is non-concordant with the realities of operating patterns onboard.
Dewan et al., 2018 [44]	Barriers for adoption of energy efficiency operational measures in shipping industry	Qualitative and Semi-Quantitative	Yes	118	The main barriers to cost-efficient, energy-efficient measures are limited information and awareness of the measure as well as lack of crew competence. While these can be addressed by crew, the ship-owner's interest and financial barriers complicate the implementation.

3. Methods

Qualitative research in the form of semi-structured, in-depth interviews was deemed most suitable for an initial exploration that helped to meet the aforementioned aims. Twenty-five in-depth interviews were undertaken with nine captains, eight chief engineers and five operators, one technical manager and two policy experts (with seafaring experience), from a diverse range of shipping companies and sectors (tanker, dry bulk and ferries) mostly headquartered in Europe with international operations. Since this is a preliminary study with the objective of understanding a phenomena, i.e., first-order understanding of the subject of incentives, the aim is not to reach generalisable results; hence we used purposive sampling for effective use of limited resources [45] and identified and selected individuals based on their knowledge and experience with the phenomenon of interest [46].

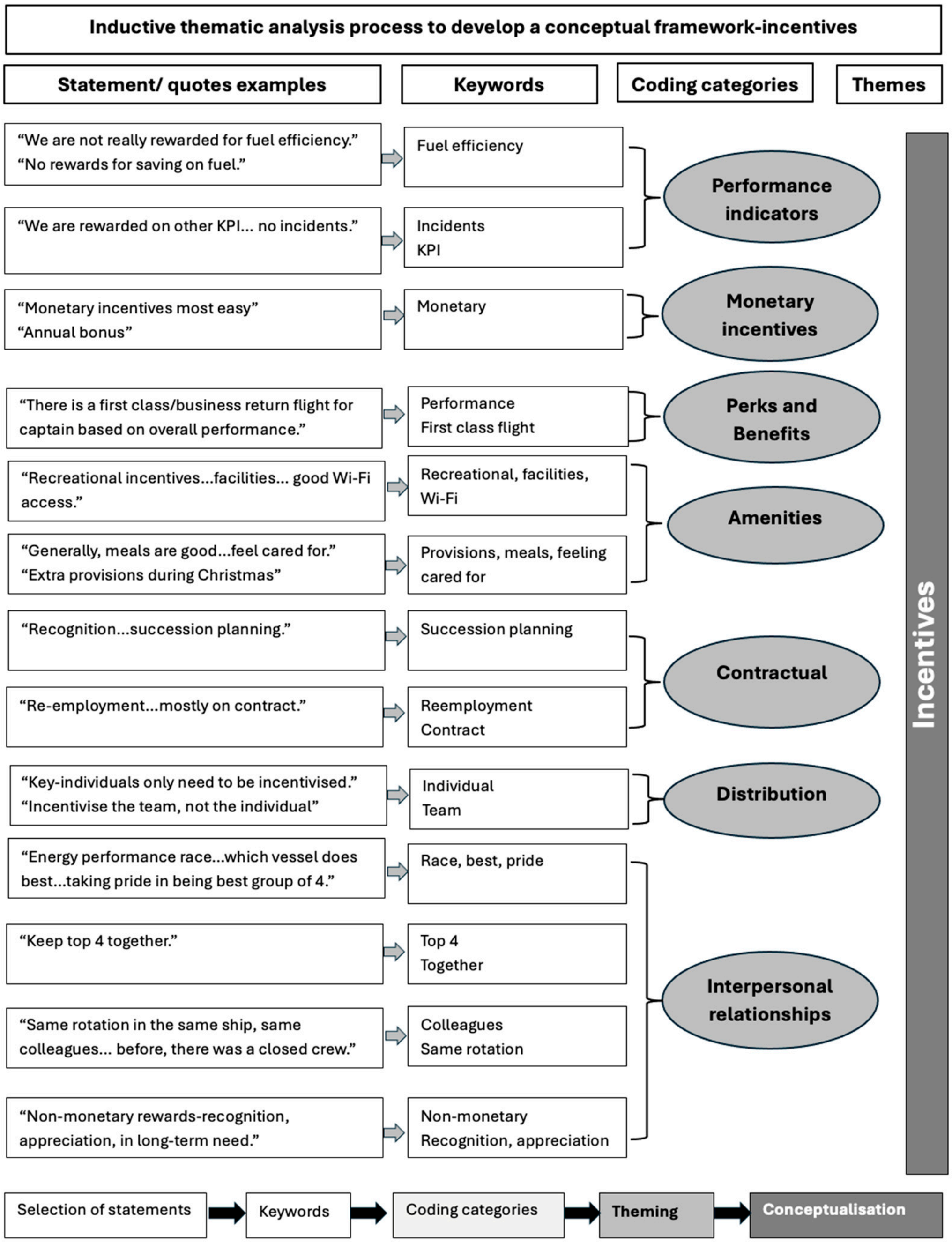
As per Braun and Clarke [47], the study divides the analysis into two separate 'global themes': operational measures and incentives. Within each one of these global themes, various 'organising themes' were defined, which effectively organised the individual findings into relevant categories.

In-depth thematic analysis was carried out through first- and second-order coding of interview transcripts, from which arose central themes relevant to each of our two global themes—operational efficiency and incentives—with the shipping stakeholder network being deeply embedded in both of them, similar to our literature review. Summaries of our first- and second-order coding is available in Appendix B (Operational Efficiency) and Appendix C (Incentives). We have also provided two conceptual frameworks as adapted from Naeem et al. [48] to visually represent our inductive analysis for the global themes of Operational Efficiency (Figure 1A) and Incentives (Figure 1B).



(**A**)

Figure 1. *Cont.*



(**B**)

Figure 1. (**A**) Thematic analysis on operational efficiency adapted from Naeem et al. [48]. (**B**) Thematic analysis on incentives adapted from Naeem et al. [48].

The use of interviews and subsequent surveys is based on recommendations to use a diverse array of methods to investigate underexplored or new subject areas [49]. The study employs a sequential exploratory design, starting with a qualitative interview which builds onto a quantitative survey. Qualitative data provides the opportunity to explore barriers from the respondents' perspective, allowing them to control the narrative, as opposed to a questionnaire which limits them in their answers [17]. Individual interviews are also a frequently used data-collection method [50] and have previously been used in other studies focusing on seafarer perspectives on energy efficiency [51].

Online surveys allow a “rapid turnaround in data collection” and subsequent cross-sectional collection and analysis without necessitating heavy human resource requirements [46]. Qualitative data in the interviews is supplemented by quantitative data from surveys, which were undertaken due to heterogeneity in interview responses on the topic of incentives. This quantitative data is retained to allow for a general quantification of seafarer priorities and perceptions when it came to the type of incentives, monetary and non-monetary, and to identify any patterns in their ranking of given options on distribution of incentives, which were the main areas for which interviews showed wide-ranging responses. No statistical tests have been applied to this data due to the small sample size (n = 42) and because it is first important to understand the data thoroughly through descriptive analysis [52,53]. Furthermore, we are cognisant of the sample and therefore are not making any inferences to the population, ensuring that we caveat our findings and discussion based on this [54].

Whilst the focus of the research is onboard energy efficiency and the role of incentives in its optimisation, there are two reasons for including shore-based staff in the interviews: to corroborate the statements of onboard crew and to identify the limits and orders placed by shore-based staff on the commercial aspects of the voyage. Each interview built on the understanding gained from the previous ones, and some key conclusions emerged. The respondent demographics are presented in Appendix D and the interview guide can be found in Appendix A.1. The interviews were recorded and transcribed for analysis.

The lack of consensus and heterogeneity in responses when it came to the subject of incentives warranted a further exploration and online ‘anonymous’, self-administered surveys were deemed most suitable, as they would circumvent any potential interview bias, especially around perception of incentives. The online survey was designed using the Tailored Design Method (TDM) guidelines [55], which was distributed through the authors networks and garnered 42 responses over a period of 3 weeks (refer to Appendix A.2 for full list of questions). In addition to the Table provided in Appendix D, further respondent demographics are presented in Figures 2–4. Note the totals do not reach 42 due to non-responses in the demographic questions; this is expected because TDM guidelines suggest including demographic questions at the end and not forcing responses, in order to overcome survey attrition and increase total response size. Figure 2 shows that most responses were from captains, who were the target sample, and the majority had over ten years’ service with their current company (Figure 3). Other respondents included superintendents and operations staff ashore. In terms of the sector coverage, there was good representation across the sectors, and the other category included respondents from offshore oil and gas and car carriers (note responses exceed the number of respondents as multiple responses were allowed). The survey consisted of questions around motivations, rewards and incentives. The aim of the survey was exploratory, and not to obtain statistically significant results, therefore the response rate achieved was deemed appropriate.

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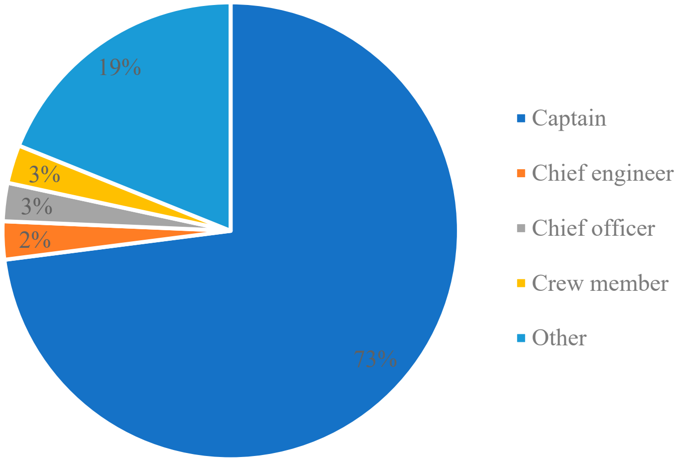

Figure 2. Rank of survey respondents (n = 37).

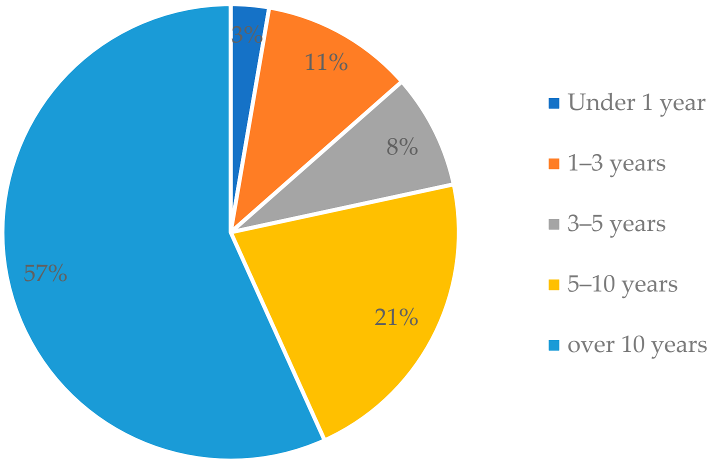

Figure 3. Length of service with the company (n = 37).

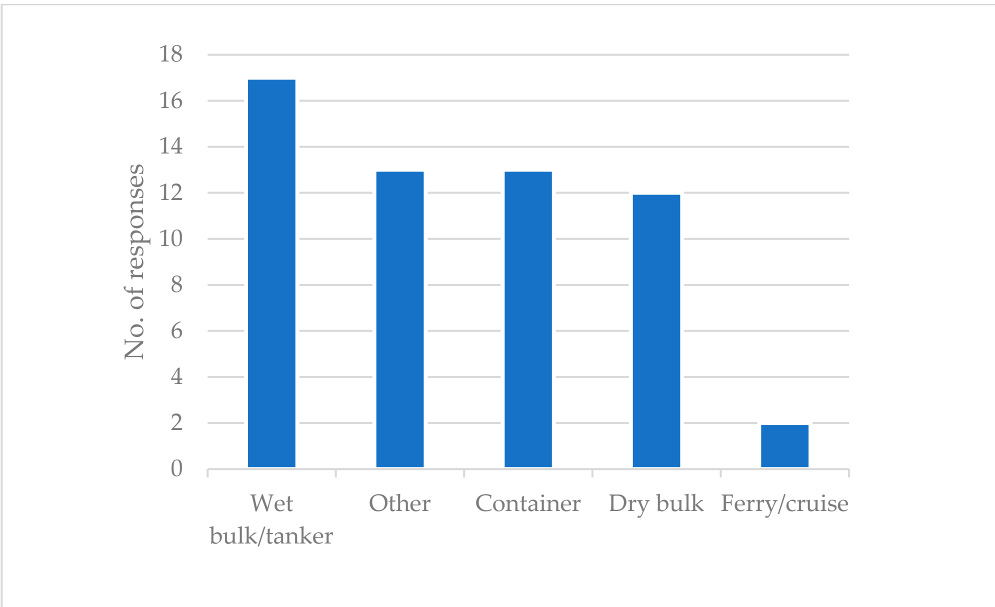

Figure 4. Shipping sector represented by respondents (n = 37).

4. Results

After conducting interviews and surveys, the data revealed a number of new insights in the behaviour and operational practices of shore-based and onboard crew around operational measures and perception of incentives.

A theme that underpins many of the respondent comments revolved around data for fuel-consumption monitoring. There is some variability in the degree to which operational efficiencies are optimised from one company to another. Interviewees admit that while noon reports are important, more modern tools, such as flow meters and sensors onboard, would allow for more real-time and continuous monitoring of fuel consumption. Although it appears that crew are keen to save fuel using systems and tools, as this also cuts costs, the new technology required to monitor this would come with an expectation of enabling further savings:

> "*After three months you're going to be asked how much you've saved with the system*" (B-CAP).

Any system, therefore, which manages operational measures, e.g., weather routing software, autopilot adjustments and trim–draft optimisation, must be "*user friendly*" as a requirement (A-OP).

4.1. Operational Measures

4.1.1. Speed Reduction

In almost all interviews, speed as an energy-saving measure was brought up by the interviewees without requiring any prompts. Speed forms the basis for determining efficiency:

> "*From a commercial standpoint, it is the basis that everything comes from. When they are working out the voyage, they figure out which speed is most efficient.*" (Q-POL)

Speed is closely related to, and influences, fuel consumption:

> *"Speed is controlled by the engine department based on the fuel ceiling."* (G-ENG)

Decisions around optimising speed can also be driven by savings:

> *"If there are no savings to be made, there is no need to play with speed range."* (X-ENG)

The interviews confirmed that the captain and chief engineer are key entities pertaining to operational efficiency, especially around speed reduction. However, maximising energy efficiency through speed reduction requires a degree of autonomy which seems to be limited due to the charterparty's overarching influence on operational decisions, which often considers market conditions as well.

> *"Market conditions sometimes mean speed would be higher."* (A-OP).

Any deviations from pre- and in-voyage imposed orders must be justified to the charterer by the captain:

> *"There is a choice, as long as there is a justification."* (G-ENG).

The margins of manoeuvring with some autonomy are minute. An example of this is the deviation allowances of present voyage speeds being as small as "Plus or minus 0.5 knots".

> *"You can get away with half a knot"* (B-CAP).

However, despite this allowance, interviewees felt that in practice it was difficult to take this as an opportunity to reduce fuel consumption. The only cases in which these prerequisites can be overridden are for safety reasons:

> *"Permitted deviation, when something goes wrong."* (F-CAP).

The complex web of accountability makes it such that some of the autonomy on operational measures is dependent on charterparty instructions, how well the cargo receivers are prepared, and what the owners prefer:

> *"When you are explaining your decisions to the charter party, also keep your managers and owners in copy so they get it."* (D-OP)

4.1.2. Weather Routing

In terms of the energy-saving potential of weather routing, the interviewees considered it to be of importance (after speed reduction), but as with speed reduction, highlighted several barriers that hinder its implementation. On one hand, the autonomy of the ship master with regard to weather routing was said to be limited by the risk of not meeting ETA requirements.

> *"There is little autonomy with weather routing"* (K-CAP).

> *"Speed reduction is based on expected time (ET) requirement"* (N-CAP).

> *"The charter party does not take into account currents"* (A-OP).

There is also a lack of trust, as there are varied levels of certainty on the weather conditions assumed to deliver savings and rules of thumb which were cited by several captains, e.g., sailing on previously calm/safe routes:

> *"The choice of most fuel-efficient route must be balanced against the safest route and quickest route"* (U-CAP).

Captains are not only exposed to strict instructions from the charter, but also from secondary authorities such as meteorological experts for weather routing. Weather routing suggestions can be at odds with judgements made by key decisionmakers on the vessel:

> *"Meteorological don't know what's happening on the ground but people on the vessel know"* (M-CAP).

However, this restricted autonomy was questioned in one interview with an engineer:

> *The master has the overriding authority to follow or not to follow the recommendation from the weather routing companies. If they don't agree, the final word is with the master, because he's responsible for the safety."* (I-ENG)

4.1.3. Trim–Draft Optimisation

Another measure that was consistently mentioned by the interviewees of having potential for improvement was trim–draft optimisation. The trim represents the difference between a ship's forward and aft draft. A vessel's hull is designed and optimised for the fully loaded condition, therefore the trim that is optimal for a vessel under the different conditions varies based on cargo. Trim by aft/stern is preferred to increase the aerodynamic resistance of the vessel, as well as to allow adequate propeller immersion for efficient propulsion.

Trim can be improved by arranging bunkers, by positioning cargo or by varying the amount of ballast water, which will affect displacement and resistance and thus have a direct impact on fuel consumption.

> *"Even keel and relation with cargo measurement... trim by stern."* (F-CAP)

There are also other ship-specific and voyage-related factors that contribute towards optimal trim, such as operation difficulties, lack of awareness of ship crews and lack of information. In order to compute the effect of these variables, software packages/decision support systems can analyse and facilitate counter measures. Trim tables play a key role within the trim–draft optimisation measure and are usually managed by the chief engineer.

A trim table informs on how every 100 tonnes of cargo per cargo hold affects the forward and aft draft, and consequently the change on trim, for a certain initial draft.

> *"Trim is used to improve performance."* (A-OP).

The interviews confirmed that the effectiveness of this measure requires agreement and cooperation from the whole crew onboard, especially between the deck, cargo handling and the engine room teams. This measure is also where the discrepancies in beliefs also lie and there is a need for individually tailored systems for each vessel's operational profile. While some respondents claim that all vessels have trim tables, others explained that optimisation was not readily available for all respondents:

> *"All vessels have trim tables—for saving bunkers."* (D-OP)

> *"Don't currently have it but it's in the plan."* (P-OP)

4.1.4. Auxiliary Engines Load Optimisation

Auxiliary engines generate power for non-propulsive energy required onboard, including electricity for lighting and heating, cargo/crane functions, pressure systems, etc. The interviews confirmed that many vessels run more auxiliary engines simultaneously than is required by the vessel.

> *"Ideally, we don't have to be running more than 1 aux engine. However, because engines are not performing, the crew may be forced to run both engines which may cause consumption to hit the roof."* (S-ENG)

> *"Generally I feel auxiliary engine consumption gets overlooked, especially from the operator side."* (J-ENG)

Further insight into the deciding body of this behaviour came from P-OP, who reveals that the chief engineer is an important entity when it comes to operational measures like the auxiliary engine:

> *"Chief engineer is in charge of everything in engine room."* (P-OP)

Communication between the deck and the engine room may be a key deciding factor in the unnecessary operation of auxiliary engines.

> *"Those in the engine room don't know what's going on above, if we don't tell them the engines aren't needed because there's been a change in plans, the engines keep running…"* (P-OP)

Aside from taking on the extra workload of the ship where required, auxiliary engines are also responsible for other non-propulsive energy usage requirements.

There is an awareness onboard that that personal usage of electricity can influence fuel consumption through auxiliary engine usage and that therein lies room for optimisation:

> *"AC load, blower, lights on board, cooking, electricity use when it comes to the meat room, fish room and veg room… what should I set my thermostat at? Optimising there can be done."* (J.ENG).

4.2. Incentives

4.2.1. Perception of Incentives

Incentives proved to be the topic where there was significant variation in the interview responses. The question on what respondents would like to see as incentives for improved performance on energy efficiency was met with a lot of hesitation by them. This is why we attempted to supplement interview data with surveys in order to gain a more comprehensive understanding of interviewee responses. For example, in the interviews, some respondents claimed that there was not an explicit need to reward positive behaviour with incentives in the matter of energy efficiency because it was

"Part of the job description... everyone is a part of saving." (M-CAP).

Others in the interviews highlighted that there were: *"Company-based rankings of the vessel"* (W-CAP), which was enough of an incentive to improve performance. However, in the surveys, the majority of the respondents thought that they should be rewarded over and above their salaries for good performance (Figure 5), with 58% of respondents believing that individuals should be rewarded over and above their salary for good performance on their jobs. No respondents disagreed or strongly disagreed, which suggests rewards and incentives for good performance should be explored further.

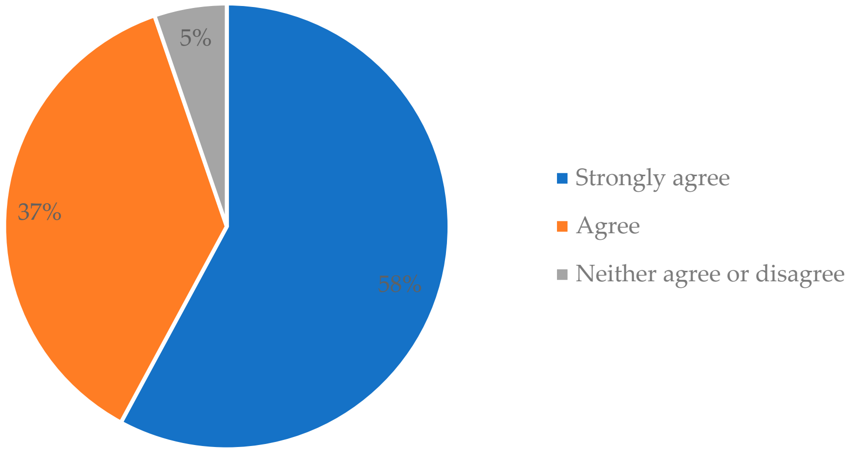

Figure 5. Respondent views on whether individuals should be rewarded over and above their salary for good performance in their jobs (n = 38).

Direct monetary incentives or in-kind, e.g., business-class flights, were preferred by some respondents while others argued that this should be avoided as it could diminish returns of the company and the bonuses for all staff and for creating a culture of staff being accustomed to incentives to drive good performance:

"Incentives taken for granted... must be careful in their design" (L-CAP).

Competition with other ships was also cited by one captain as an incentive for efficiency:

"We need to do the voyage as efficiently and beat the competitors" (M-CAP),

However, one captain deemed it as unhealthy and mentioned:

"Perverse incentive of competition... should not incentivise unsafe operations" (K-CAP).

4.2.2. Incentives for Fuel Efficiency

Despite this significant heterogeneity of opinion regarding incentives, there was agreement in the interviews that no specific incentives are in place for fuel efficiency.

"We are not really rewarded for fuel efficiency" (U-CAP).

This contradicts survey data where a minority of respondents reported being rewarded for fuel efficiency (Figure 6). The survey results do show, however, that crew and captains are aware and do receive incentives for other key performance indicators such as safety, as shown in Figure 6. Other responses from the survey showed that some received rewards for cargo handling operations, optimising maintenance schedules and following successful vetting/inspections.

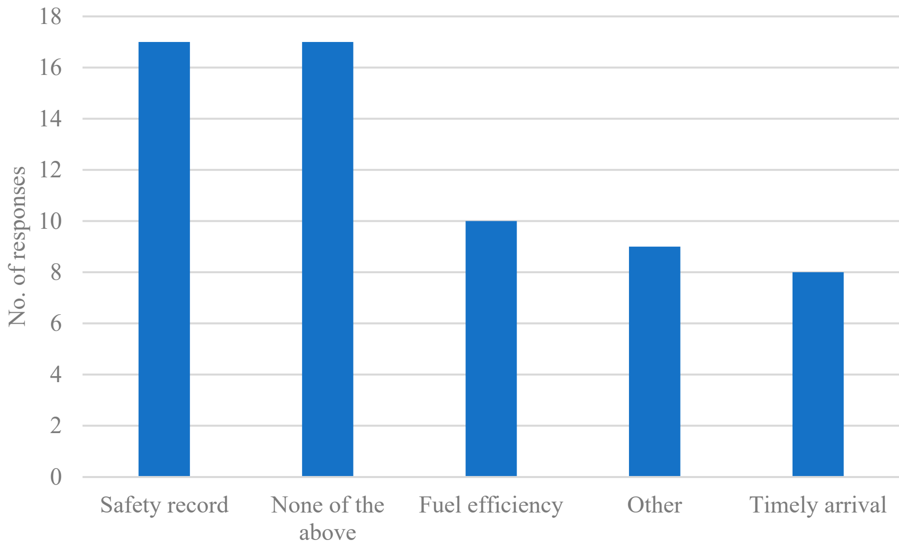

Figure 6. Measures or behaviours for which respondents are rewarded for (over and above your salary/remuneration) (n = 38).

4.2.3. Distribution of Incentives

Captains are most commonly incentivised for good performance, with direct cash or annual bonuses forming the bulk of their incentives. Regarding the captain's monopoly on monetary incentives, interviewees were at odds, with some feeling that this should at least be shared with the chief engineer, while others wanted a ship-wide distribution.

"Bonus to master and crew should be considered; for, e.g., a cash bonus." (Y-OP)

"Ship bonus like a karaoke machine where everyone gets a little something." (R-ENG)

Survey results confirmed this view on equitable distribution, with 59% of responses preferring rewards should be tied to performance beyond the individual (i.e., team and vessel performance) (Figure 7). (note the results are not cumulative because the question allowed for multiple responses). Specifically on rewards for fuel efficiency, 54% of respondents remained in favour of sharing equally between the captain and the crew (Figure 8).

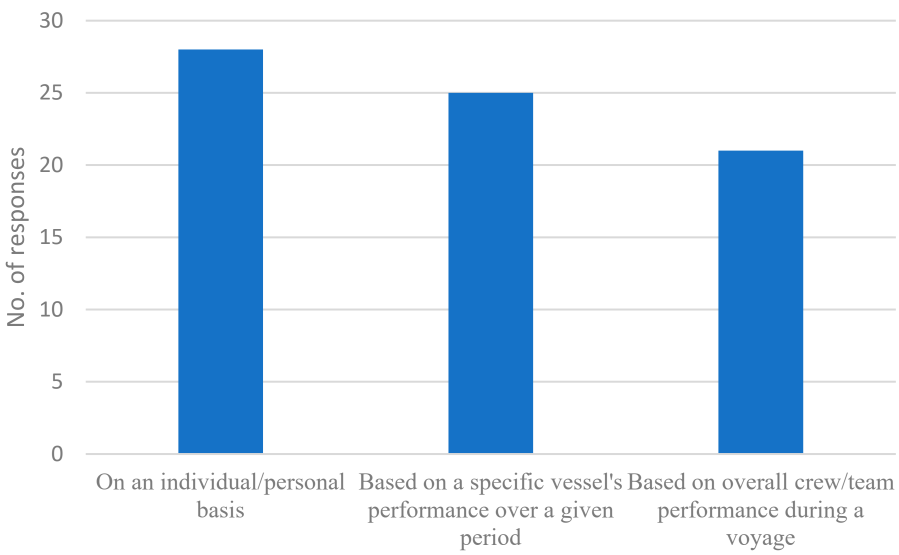

Figure 7. Preferences on distribution of rewards (n = 38).

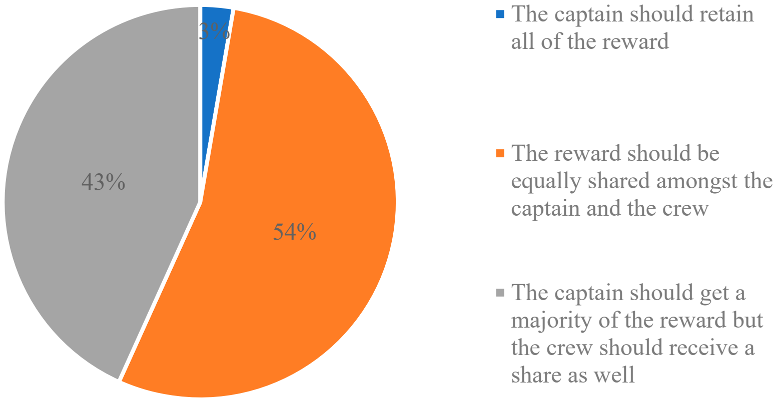

Figure 8. Preferences on distribution of rewards for improving fuel efficiency (n = 37).

4.2.4. Incentive Categories

Monetary and annual bonuses were the most commonly preferred incentives for improving performance in interviews, which matches survey data, with monetary incentives being the most administered, followed by recognition and welfare onboard; the least commonly administered rewards were vouchers and pro-social incentives (Figure 9). The priority of provision of these by the company, as well as the performance rewards offered specifically for the interviewed roles, relatively matched worker preference, with monetary bonuses over salary, welfare onboard, and recognition constituting three out of the four top most commonly reported incentives. However, 14% of respondents were not aware of any rewards, meaning that there is a faction of workers working with no additional incentives or not aware of incentive structures in their company. This was the second most picked option after monetary rewards (Figure 9).

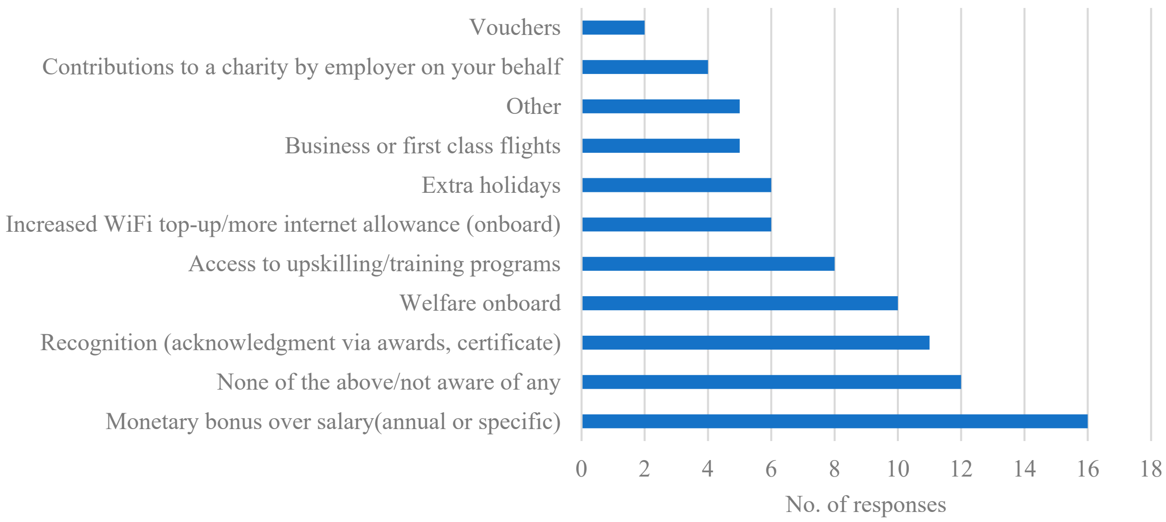

Figure 9. Type of performance rewards provided by companies (across all types of roles).

In terms of what factors would improve job motivation on a 1–5 Likert scale, with 5 being “very much” and 1 being “not at all”, recognition and upskilling opportunities were valued more than perks and benefits, which may open the path for non-monetary incentives, of which access to training programmes, welfare onboard and recognition followed secondary preferences (Figure 10).

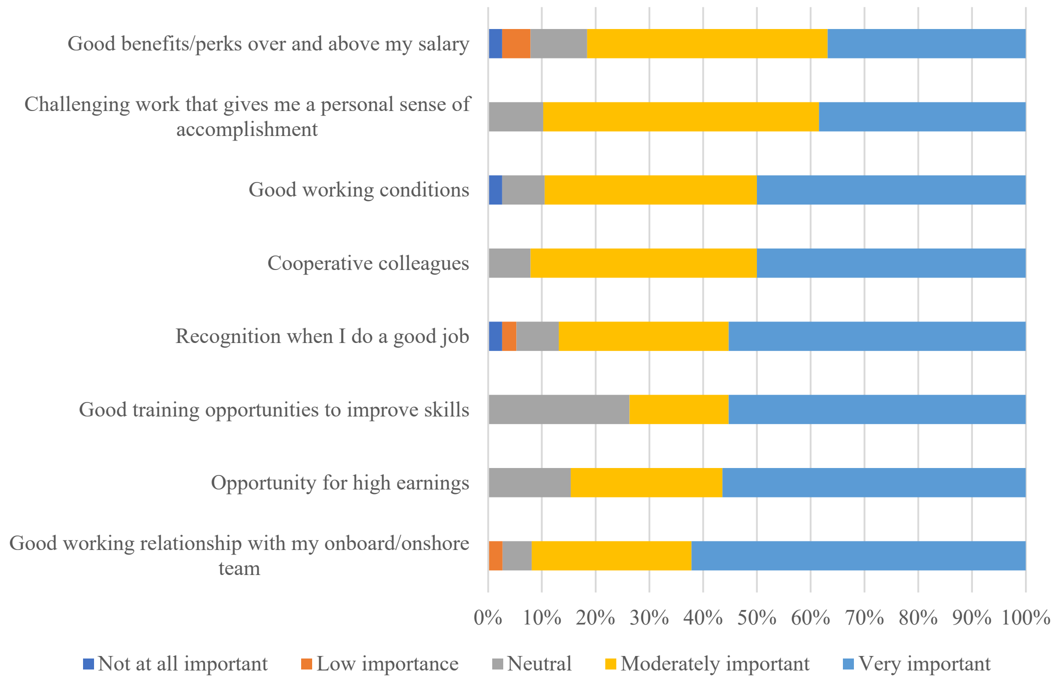

Figure 10. Importance of different factors affecting motivation.

Unsurprisingly, in response to the question "How much would the following performance rewards motivate you to improve your performance", with 1 being not at all, and 5 being very much, 'monetary bonus over salary' again was most preferred by respondents, followed by access to training programmes and upskilling (Figure 11).

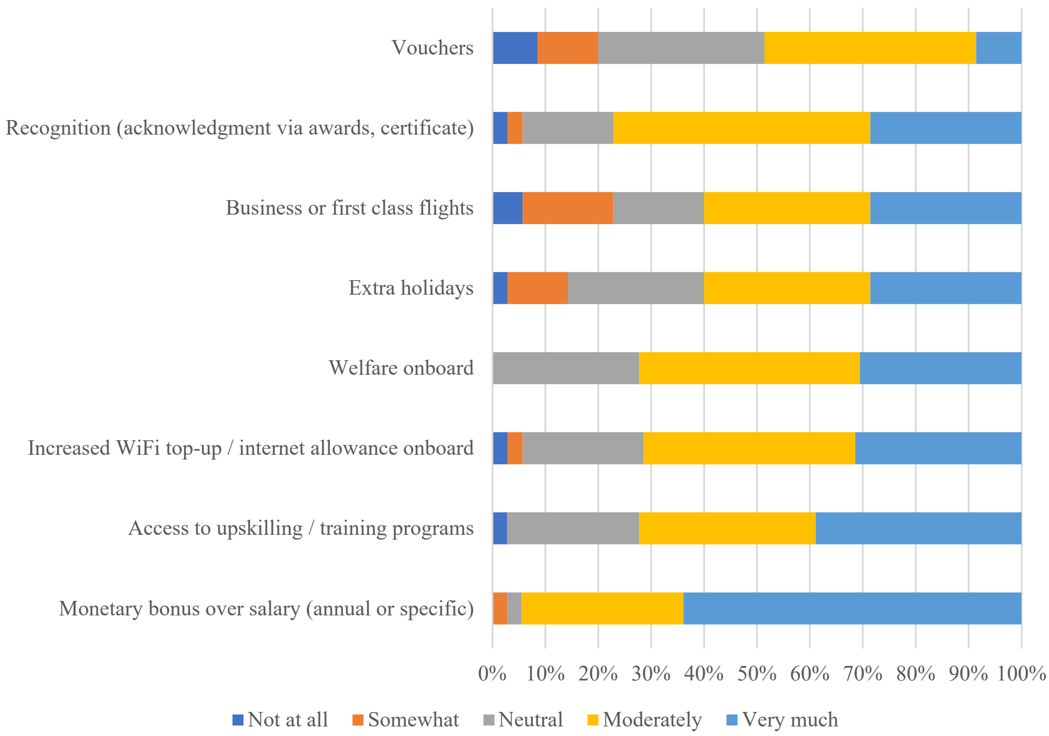

Figure 11. How much would the following performance rewards motivate you to improve your performance?

Recognition as a non-monetary incentive was mentioned the most frequently in response to: "What do crew want?" in interviews:

"Acknowledgment and recognition." (U-CAP).

The same captain also commented that he has found this acknowledgment more easily in companies with fewer employees as he was in

"... the same rotation in the same ship, same colleagues." (U-CAP).

Another captain supplemented this by specifying that this acknowledgement could specifically be catered towards operational efficiency,

"... as per indicators such as EEOI" (K-CAP).

To correlate with survey data, first-class flights were reported as existing reward schemes by 5.9% of respondents, while welfare onboard was reported by 11.8% (Figure 8). Hybrid non-monetary incentives were also cited as attractive options:

"First class return flights... generally the meals on the ship are good" (K-CAP)

"I've been offered upgraded flights home..." (A-OP)

"Feel good, being cared for e.g., meals" (F-CAP)

"Free internet provision to the crew onboard could also be provided as a reward" (W-CAP)

5. Discussion

The fact that the crew's justification of their decisions to charter and their own managers and owners comes retrospectively leads us to hypothesise whether, rather than the current consensus of restricted autonomy, it may be that crew has "answerable autonomy". This would mean that the limitation lies in the expectation to successfully justify any autonomic decisions to higher-ups, rather than the inability to make decisions at all. Empowering the function and expanding the limits of this autonomy in favour of energy efficiency may be achieved by educating crew in and involving them in each ship's SEEMP [17], which can allow them to make energy-efficient decisions and justify to their shipowner, operators and charterers how these decisions are also in line with their cost-management plans.

In other studies, energy-saving checklists developed based on audits, and incentive or bonus schemes have been suggested as ways of tackling crew awareness and training [44], which are essential prerequisites to involving crew in a ship's SEEMP. However, it may seem that by proposing that crews' only incentive in fuel consumption is extrinsic, e.g., monetary, we are neglecting any intrinsic incentives, e.g., personal pride they may have as seafarers in fuel consumption. This is an important dilemma and is addressed in the discussion in Section 5.2.

The decisionmakers themselves may also fall short in the optimality of the decisions, which depend on the quality of the input data they receive from the voyage. Not only the crew who are closest to the real-time decisions made during the charter, but also the charterers themselves could be educated in the assessment of available measures in the market to make the most optimal decisions which align both energy efficiency as well as cost and safety [56].

5.1. Operational Measures

Our study finds that although the crew does have autonomy in operational measures, particularly the chief engineer, the limits of this rely on the ability to justify any deviances from charter instructions to the charterparty and managers, and their distance from the decision-making hubs which control the recourses to implement energy efficiency processes.

Speed is the operational measure most closely related to fuel consumption, and this is decided by market conditions, cost, and fuel consumption ceilings. Other measures include auxiliary engine load, trim–draft optimisation, weather routing, and fuel consumption monitoring, the use of which is determined primarily by the chief engineer and sometimes captain. with regard to incentivising green behaviours, monetary rewards were most popular, and it was believed that they should be shared with a larger proportion of the crew and not only the captain. Fuel efficiency was infrequently incentivised, while safety was the most incentivised behaviour.

5.1.1. Speed

The interviews helped with creating a shortlist of operational-efficiency measures or interventions that can be targeted for improvement. Speed reduction was deemed to have the most energy saving, which is validated by other data confirming an 18% net reduction in CO_2 emissions alone which could be achieved by slow steaming [8]. However, there was a limited range for further improvement due complex accountability, contractual constraints and even perverse incentives to increase speed, such as

(i) speeding up to gain demurrage income
(ii) speeding up to tender Notice of Readiness (NOR) to avoid the risk of tendering NOR outside the stipulated charterparty times/port times

Slow steaming or using information from fuel meters to adjust speed is also limited by predefined speeds in the charter contracts, which may demotivate crew to implement any energy efficiency initiatives [43]. If slow steaming clauses are not already included in the charter agreement, e.g., as proposed by Baltic and International Maritime Council (BIMCO), it can be difficult for the crew to implement slow steaming within the charter [57].

In addition, there may be some cases where the “slow steaming mode” is not always efficient. Bad weather conditions in particular may complicate the implementation of slow steaming as an energy-efficient measure. Insufficient speed against a strong current or adverse conditions may result in insufficient forward propulsion of a vessel or “rolling”, which creates unsafe operation conditions. In such cases, slow steaming could mean that the transport fuel consumption in tonne/nm ends up being significantly higher than the hourly fuel consumption in tonnes per hour, and paradoxically, lower speeds result in less efficient fuel consumption.

Just-in-Time Arrival (JIT)

The current state of port call in global shipping is largely inefficient. While the master will do their best to meet expected charterer arrival times while providing accurate ETAs, the port and associated market conditions may mean that even when a vessel arrives at the port within the agreed time window, berth may not be available. This will result in either waiting outside of the OPL at anchorage or idle drifting offshore while waiting for berth. JIT of ships can address this by maintaining the optimal ship operating speed to ensure arrival coincides with availability of berth, fairway and nautical services, without any effect on the overall length or duration of a voyage, thereby reducing fuel consumption.

However, for a vessel to slow down mid-voyage, predetermined charter clauses must be used to allow for a more coordinated ETA aligned within port availability at arrival time, by way of port call optimisation. Some respondents claimed that JIT may not be acceptable to higher stakeholders, such as shipowners, possibly due to the fact that, without change in contract, shipowners of ships under voyage contract could lose out on demurrage (penalty from the charterer to the ship owner following the late arrival of the ship at the place of tendering NOR). Furthermore, the responses suggest that not many ports currently offer

JIT, with the exception of a few, such as Australian ports, which mirrors the literature on this topic [58].

Although the port and charterer could greatly benefit from JIT, there is no clear incentive for crew to suggest its implementation. While the port and terminal operators also face additional workload in providing real-time updates, charters need to ensure that the crew and captain are also motivated to carry out JIT.

5.1.2. Weather Routing

Based on interview responses, it appears that the route which the vessel takes is influenced by several key factors: the shortest distance, safety, and cost. These key factors are deliberated by key stakeholders such as the charterer, ship owner, third-party input (e.g., routing systems), as well as the master to reach a consensus. While some interviews showed that the master will listen to most weather routing suggestions with limited autonomy, others stated that weather routing systems are only used when something goes wrong, i.e., to avoid bad weather. The route itself is given by the charterer.

Like the other operational measures, safety considerations greatly increase the master's autonomy in overriding weather routing suggestions. From interviewee responses, it appears that masters will choose to navigate high-traffic areas such as Taiwan straits based on experience rather than weather-routing suggestions. While reducing cost is a priority using weather routing systems as an adjunct, this is not performed at the cost of safety, suggesting that crew will trust their experience over technology, particularly where safety is concerned. While some services such as skysails, which were often mentioned, will give hourly advice, this advice may still be at odds with what is going on at sea in real-time, resulting in possible rejection of weather-routing suggestions by the master. However, such rejections must also come with justifications to the shore-based staff.

It appears that a possible solution to the disconnect between weather routing systems and real-time sea experience may be addressed by integrating weather routing systems with the judgement of experienced masters. Currently, such systems are created using sophisticated algorithms, meteorological data, and performance models. Combining this with the first-hand experience of masters could create a hybrid efficiency tool which considers the expert first-hand knowledge beyond prediction models. This could be crucial in gaining the trust of masters as well as aligning sustainable technologies more closely with the intricacies of real-world navigation [59].

5.1.3. Trim Draft

Another measure that was consistently mentioned by the interviewees of having potential for improvement was trim–draft optimisation, which some interviewees reported was not in use at their companies currently. One can assume that this refers to automated systems of optimisation, as all vessels should come with trim tables, although manual optimisation using cargo/ballast can be human-resource heavy. Crew need training in the use of automated systems, and not all ships have the software/capability to allow the use of automated trim–draft optimisation.

In addition to the above, the ship's specifications may also affect the viability of trim–draft optimisation. The fluctuating under keel clearance (UKC) for each vessel is based on its structure and water conditions which affect the ship draft. The UKC is therefore a further determinant of the operational reality of trim–draft optimisation, e.g., amount of aft draft which a ship can maintain while following UKC guidelines. This is particularly important in shallow waters, e.g., near ports, which typically mandate their own specific UKC.

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The fact that some respondents reported not having trim–draft optimisation at all is therefore concerning, as aside from being an energy-efficiency measure, it is an essential safety aspect of manoeuvring in shallow waters, especially near the port, with this having knock-on effects on speed and cargo handling.

Furthermore, trim optimisation cannot be considered in isolation and there are limits to its potential as a result of safety considerations for the ship itself. Bending and shearing forces mean that a trim which is optimal for energy efficiency may not be optimal for safety. While optimising trim using ballasting or cargo, it is important to consider trim effects of load distribution on bending and shearing forces which can cause cracks in the ship's infrastructure through hogging or sagging. This can be accomplished by using the suggestions of trim tables in conjunction with the stability parameters taken into account by the ship's loadicator to ensure safe and efficient operations.

5.1.4. Auxiliary Engine Load Optimisation

Following speed, the operational measure that was deemed most significant was auxiliary engine optimisation, a measure over which crew, particularly the chief engineer, has almost total control, without the need for any additional capital investment. The interviews confirmed that many vessels run more auxiliary engines simultaneously than is required by the vessel. This is related to risk aversion of blackout, i.e., the only running auxiliary engine dropping out and to provide a safety margin against blackout and at times adhering to manufacturer guidelines [39]. There is also a perverse incentive of turning on auxiliary engines and boilers well in advance of the required need to make sure that they are ready. In Hansen et al.'s 2020 study [17], it was said that offshore sites claim a distance of 500 m as a 'safety zone' where vessels entering this zone must meet certain safety standards: 'We have everything up and running [. . .] we must be sure [. . .] that we have enough power to get away' (Navigator). Although in other studies some tanker engineers are prepared to turn off engines between uses, they admit that safety will always come first. In addition to the significant energy saving potential of up to 20% per auxiliary engine [14] where safety permits, lowering the number of auxiliary engines within safety limits also leads to monetary savings as a result of reduced engine hours, the rate of wear and tear per hour, lubrication oil consumption and consequently work needed to do maintenance.

While the argument can be made that the personal usage of crew on board only contributes to a minute percentage of total ship's energy usage, crew awareness of how their personal usage affects efficiency is telling of an inner drive to increase energy efficiency through any and all avenues. While some of the measures mentioned, such as thermostat comfort settings, are not technically considered personal usage, crew appears to be willing to optimise efficiency even at the cost of personal comfort. Discounting personal usage due to its small contribution to overall consumption neglects the cumulative effects of personal usage on the global fleet, which can have significant effects. Personal usage is the measure that crew has the most direct autonomy over. By discounting its potential as an energy-saving measure, one also ignores its value in empowering crew in their role in energy efficiency and instilling energy-efficient behaviours in their day-to day lives on board. Furthermore, this is a key area where split incentives can manifest themselves, as crew onboard are not directly paying for the fuel and can be akin to guests at a hotel [60] or renters where energy bills are included in rental contracts [61].

5.2. Incentives

5.2.1. Current Practice

The mix of answers in interviews and surveys suggested that a review of both the types of incentives offered and their distribution across the vessel is needed. While safety was mentioned in both interviews and surveys, no interviewee reported being rewarded for fuel efficiency even though both the charter and crew recognise that 'profitability' is associated with efficiency. Contrary to this, 16% of respondents in the survey did report fuel efficiency as an incentivised measure; however, considering the important role of operational energy efficiency, this is still a minority.

5.2.2. Incentive Categories

Though overwhelmingly monetary bonuses were offered, preferred, and available to the respondents, there was an awareness that their higher offering and anticipation could in time diminish returns. However, it can be argued that these returns are offset if they incentivise money-saving measures such as optimising auxiliary engine load and personal usage onboard. Regardless, where this is a concern, respondents' focus on "recognition and acknowledgement" as well as welfare onboard highlights a place for non-monetary incentives as an area requiring little to no capital investment. When asked about acknowledgement within their companies, a Swedish crew exclaimed: "We have that, it's not like working for a large company" which suggests that closer working relationships, and a close relationship from further up the stakeholder chain may be key to perpetuating this incentive [62]. In interviews, crew mentioned internet access, meals onboard, and feeling cared for under the umbrella of onboard welfare as other preferred options, which also rated highly in the surveys.

Despite the technical capability of ships to provide internet [62], many companies do not provide easily accessible nor affordable internet to the crew [63]. The agreement in May 2022 on the introduction of mandatory internet provision, under the Maritime Labour Convention (2006) by the International Labour Organisation, which came into force in December 2024 will go some way to overcoming this challenge [64]. Improving social connectivity for seafarers and in turn their social wellbeing and mental health, which are a cause for concern, could lead to better on-the-job performance as well as retaining a highly motivated crew [51,62,65].

The linear alignment between what our sample knows and prefers, such as that observed with monetary incentives, may be used to advance pro-social incentives into the narrative. Although interviewees did not fail to mention prosocial incentives, there was little specification of what they meant by them. It can be questioned whether this is because they are not common or known and examples could not be given because crew had not experienced these. However, it is difficult to draw any conclusions due to their minority status being an industry wide status quo, although their efficacy has been proven in other transport sectors such as aviation [51,66].

5.2.3. Incentive Distribution

The current reward structure is at odds with equity and fairness within the ship setting, as it seems that the highest ranked and paid, i.e., ship's captain, are rewarded the most for the efforts of a team. Although this may be justified by the fact that it is the captains and chief engineers who are usually in charge of these operational measures (see the captain's dominion on weather routing, and the chief engineer's control of auxiliary engines), the fact that it is the captain who is most commonly incentivised for performance was not popular with either interviewees or survey respondents, who believed that incentives should be shared with the crew.

A first-step solution to this could be revisiting incentive structures and redistributing funds initially by the top four ranks on a ship (captain, chief engineer, chief mate and second engineer), which could allow for a relatively similar amount of funds to be distributed to a larger percentage of the work force, which feeds better into interviewee preference of 'team/vessel recognition' instead of individual awards. However, incentivising only the "top four" may alienate other members of the crew who are the ones carrying out the optimisation, even if the ultimate responsibility and control lie in the hand of the top four.

Another reason for rewarding only the captains may be because of the regularity with which a captain would sail on the ship, usually in rotation with one or two other colleagues, compared to the rest of the crew, who could change from one voyage to another, and their short-term contracts.

The discrepancy in the tenure of the onboard crew also presents a challenge to effectively rewarding performance rightfully to the crew member who caused the efficiency gain. A vessel's key performance indicator (KPI) is on a per-voyage basis but also on a yearly basis, and who should be rewarded for good performance at the end of the year can be tricky, as crew members may have already left or are onboard another vessel.

The policy of employee retention, as opposed to employment by voyage [66] and longer contractual obligations [67], can be ways to allow for ship-wide distribution of monetary incentives which are fair and proportional to individual efforts within the team.

The next step would be targeted ship-specific incentive structures. If a chief engineer is the main entity responsible for the optimisation of operational measures, such as their involvement in auxiliary engine usage, the adoption of this measure by the chief engineer could be personally targeted. If captains have tools at their disposal but are not aware of them, their incentives could be targeted towards the adoption of these tools.

Finally, intrinsic (experienced meaningfulness) and extrinsic (pay satisfaction) motivators/incentives are complementary to one another [68], and when beginning to implement extrinsic incentive schemes, seafarer's personal pride and intrinsic motivations for improving energy efficiency must not be discounted. In interviews, the fact that energy efficiency is already "part of the job" came up more than once. Crew are contractually obliged to optimise performance to the maximum extent; however, energy efficiency does not always explicitly fall under the umbrella of "performance". By making energy efficiency's role in the measuring of performance more explicit, crew's intrinsic motivations to "do well" can be targeted more closely towards optimising energy efficiency on board.

6. Conclusions

This study employed a sequential exploratory design to investigate the under-researched area of barriers to operational efficiency measures, which have the potential for significant energy and emissions savings, from the perspective of crews combined with an exploration of existing incentive structures and crew perception towards incentives. Whilst the study's sample size and geographic spread (mainly European) limit its generalisability, a number of key findings emerge with potential relevance for policy and practice. Cognisant of these limitations, we have found that there is an absence of an explicit narrative around optimising operational efficiencies to save fuel and benefit the environment in the workplaces of our respondent seafarers. That is simply assumed to be a byproduct.

Energy efficiency and benefits to the environment can be woven into the existing priorities communicated to key decisionmakers on board a vessel; for example, through the mandated SEEMP. While the captain and key decisionmakers have first-hand control and agency over operational measures, their actual power to influence some of the measures, especially those with significant energy efficiency savings, such as speed reduction, are situated within a complex web of accountability that needs to, but cannot, significantly prioritise the environment. This therefore leaves only a handful of other measures to optimise, such as auxiliary engine load optimisation, trim–draft optimisation and weather routing, which have smaller efficiency gains, but if aggregated and consistently applied through behavioural changes and practices, encouraged through incentives, can lead to significant fuel savings over time. Our recommendation is that these smaller number of measures should be supplemented with explicit educational and training programmes, including the use of fuel consumption monitoring systems. These should be included in the ship's SEEMP with crew involvement/consultation.

Other than inclusion in mandatory measures, incentives can be much more effectively utilised to promote the uptake of these measures; for example, through company- or vessel-linked KPIs that align behaviours of onboard crew with shipowner or operators. Both monetary incentives such as bonuses (annual or specific) over and above salary and non-monetary incentives, requiring little capital, such as recognition and acknowledgment, fared highly in both interviews and surveys. Incentives should therefore be considered seriously if shipping companies are to go further than compliance with regulations and reap the full potential of energy-efficiency measures. Companies can use performance-based contracts linked with monetary incentives, with staff within their remit and ideally teams, both onboard and onshore, to align them towards common goals. Although there is a positive correlation between the preferred incentives and those which are offered, their distribution appears to be an area for further implementation. This is especially pertinent since it is clear that shipping companies have autonomy in setting incentives relative to other sectors such as aviation, where industry regulations restrict the ability of individual companies to incentivise employees over and above their salaries.

The distribution of incentives must be expanded. Exclusively directing incentives to the captain or the 'top four', as seems to be current practice, is likely to make the rest of the crew feel that they do not have much of a role to play when it comes to saving fuel. Distributing incentives to include the crew coupled with the inclusion of reducing emissions and saving the environment into the set of priorities will ensure that every member of the crew feels that they have a role to play in reducing fuel consumption. This sense of agency can lead to positive spillovers, where even seemingly insignificant behaviours like air conditioning use and fridge temperature can lead to significant gains when aggregated.

Lastly, the potential oversaturation feared when it comes to introducing incentives is less likely to pose a problem, as a sizable percentage of the sample were not aware of any incentives being available to them at all for good performance on energy efficiency or other areas, e.g., safety. Incentives are not just about the 'what', but also about the 'who' and the 'how', and therefore need to be looked at as a holistic package of these three factors. These three aspects have revealed themselves as dimensions of significance through the interview and survey data.

Our study is limited in its small sample size; however, we believe that this is offset by the minimal existing research on incentives, which we hope will grow in the future. Although this limits the study's generalisability, as one of the first papers on the topic of incentives, we are posing the question of the feasibility of the possible role of incentives in shipping. Our findings on incentives are mirrored in other studies on road freight and aviation, which support our claims.

This study presents a preliminary set of incentive structures that can be compared to one another in a Randomised Control Trial. This should be supplemented by further qualitative work to better understand survey results on incentives. Some of the results suggested incentive structures involve the crew and are tied to performance or behaviours that go beyond just the individual. Therefore, further work can help understand if an increase in efficiency was also correlated with an increase in crew engagement, and overall wellbeing and satisfaction, which are also key metrics to consider.

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Institutional Review Board Statement: This study is waived for ethical review as Research involving the use of non-sensitive, completely anonymous educational tests and surveys when the participants are not defined as "vulnerable" and participation will not induce undue psychological stress or anxiety by Institution Committee.

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Appendix A

Appendix A.1. Interview Guide

Part 1: Areas where there may be potential for improving operational energy efficiency

Main q: In which areas of operation, where you have the most control, of the ship do you think there may be potential for improving energy efficiency/fuel efficiency?

Speed reduction

1. How does a master achieve 'average speed' instructions in practice (e.g., do they speed up initially, slow down later, constant speed, variable speed? i.e., is there room for improvement in how speed instructions are actually enacted
2. How much of a restriction is this on the mind of a master during a voyage?
3. How do you currently address the incentive to speed up under FCFS and utmost despatch and its significant impact on speed/efficiency? What are the trade-offs assessed to decide to go ahead or not with arriving on time?
4. How is the assessment of the repercussions of a "late arrival to the queue" carried out?
5. How do crew perceive slow steaming (more work? Lack of a break?)

Applies to shore-based staff

6. Do inventory costs influence decisions on speed?
7. If slow steaming is chosen how is this communicated to the crew?
8. What factors influence the instructions on speed?

Weather routing

1. What is the perception of the crew on using weather routing versus rule of thumbs (sailing on previously calm/safe routes)?
2. How much can a master decide on whether the route he/she sails is of a particular nature/how much autonomy do they have?

Just In Time arrival (applies to shore-based staff)

1. How do charterers/operators currently obtain information on port status (congestion, unexpected delay, etc.) and what do they do with this information?
2. Do any of the routes in your operations have ports that can/do share information for virtual arrival

Trim-draft optimisation/loading profile

1. Where a trim/draft optimisation software exists, does it get used on every voyage and what do you think are the key barriers to its effective usage?
2. How is the safety of a specific trim assessed in your vessel?
3. How could the loading plan steps be improved to optimise trimming as an option?
4. In the context of trimming, How much room for improvement is there on ballast loads given restrictions by environmental regulation?

Improving auxiliary engine loads

1. Is there room for energy efficiency gains in the management of auxiliary machinery at optimal loads? And what are the barriers to achieving those gains

Operation of other energy efficiency devices on board

1. What energy efficiency technologies have been implemented in your vessel? Are they being used optimally? What could be done to improve their utilisation.
2. Do you think there are new EETs that have the potential to reduce a workload (passage planning, route monitoring, better information about optimal trim/speed/autopilot setting, power management systems etc.).
3. What are the incentives to using autopilot during every voyage, what might be the barriers to its use

Part 2: Incentives
What types of rewards and incentives are you offered at work?

1. What types of rewards and incentives are seagoing staff/crew onboard offered at work?
2. What types of incentives, in your opinion, are most meaningful to crew/what type of incentives do crew want?

Appendix A.2. Survey Questions

1. How important are the following in motivating you in your job?

	Not at All Important	**Low Importance**	**Neutral**	**Moderately Important**	**Very Important**
Challenging work that gives me a personal sense of accomplishment					
Opportunity for high earnings					
Cooperative colleagues					
Good training opportunities to improve skills					
Good benefits/perks over and above my salary					
Recognition when I do a good job					
Good working conditions					
Good working relationship with my onboard/onshore team					

2. Do you think individuals should be rewarded over and above their salary for good performance in their jobs?

Strongly agree
Agree
Neither agree or disagree
Disagree
Strongly disagree

3. How much would the following performance rewards motivate you to improve your performance? 1 = Not at all, 2 = Somewhat, 3 = neutral, 4 = Moderately, 5 = Very much

	Not at all	**Somewhat**	**Neutral**	**Moderately**	**Very Much**
Monetary bonus over salary (annual or specific)					
Access to upskilling/training programs					
Increased WiFi top-up/internet allowance onboard					
Welfare onboard					
Extra holidays					
Business or first class flights					
Recognition (acknowledgment via awards, certificate)					
Vouchers					
Contributions to a charity by employer on your behalf					

4. Are there any types of rewards that would not motivate you to improve your performance?
5. What types of performance rewards does your company provide (across all types of roles)? Please tick as many as applicable

Monetary bonus over salary (annual or specific)
None of the above/not aware of any
Recognition (acknowledgment via awards, certificate)
Welfare onboard
Access to upskilling/training programs
Increased WiFi top-up/more internet allowance (onboard)
Extra holidays
Business or first-class flights
Contributions to a charity by employer on your behalf
Vouchers
Other

6. Which of the following performance rewards are you currently offered at work for YOUR role? Please tick as many as applicable.

Monetary bonus over salary (annual or specific)
Business or first class flights
Increased WiFi top-up/more internet allowance (onboard)
Contributions to a charity by employer on your behalf
Extra holidays
Welfare onboard
Recognition (acknowledgment via awards, certificate)
Vouchers
Access to upskilling/training programs
None of the above

7. Which of the following measures or behaviours are you rewarded for (over and above your salary/remuneration)? Please tick as many as applicable

Safety record
None of the above
Fuel efficiency
Other
Timely arrival

8. How would you prefer rewards to be attributed? Please tick as many as applicable

On an individual/personal basis
Based on a specific vessel's performance over a given period
Based on overall crew/team performance during a voyage
Other

9. In your opinion, if there are rewards for improving fuel efficiency, how should the rewards be distributed?

The captain should retain all of the reward
The reward should be equally shared amongst the captain and the crew
The captain should get a majority of the reward but the crew should receive a share as well

Demographic questions

10. Please describe your role in the company

Captain
Chief engineer
Chief officer
Crew member
Other

11. How long have you been employed by your company?

Under 1 year
1–3 years
3–5 years
5–10 years
over 10 years

12. Which of the following shipping sectors or ship types does your employment belong to generally? Please tick as many as applicable

Wetbulk/tanker
Other
Container
Drybulk
Ferry/cruise

Appendix B. Thematic Analysis—Operational Efficiency

Table A1. Speed.

Second-Order Code Words	First-Order Code Words	Thematic Analysis
Stakeholders	Charterparty Ship owner Captain Chief Engineer	Certain speeds may be required by the terms of the charterparty. Even if there is room to improve energy efficiency using speed, charter terms, particularly in spot charters, may prevent increases in efficiency. Where there is room to manoeuvre around speed on board, this autonomy is assigned to the captain.
Technical efficiency	Fuel Consumption Ballast	Fuel consumption is measured and monitored by the engine room, and speed may be adjusted based on feedback. In the absence of cargo, slow steaming and ballast are much easier.
Autonomy	Justification Clause Parameters	Any deviations in speed must be justified to the charterer. The possibility of slow steaming is limited by laycan.
Economy	Cheaper Economic Price Profitability	Although slow steaming may reduce bunker prices, speed is still largely determined by market conditions. Technology such as scrubbers which are fitted on ships may reduce bunker prices anyway, reducing the priority of saving fuel through slow steaming.

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Table A1. *Cont.*

Second-Order Code Words	First-Order Code Words	Thematic Analysis
Market	Port Traffic	Congestion/port traffic may affect laytime and speed. This is addressed by using a 24 h arrival window during which better visibility can be afforded than shorter arrival windows such as 3 or 4 h.
Temporal	ETA Duration Laycan	The laycan and charterer directly affect the laytime, and NOR speed is adjusted to meet the predetermined conditions without arriving too early or exceeding laytime, which increases demurrage costs.
Charter	Spot Cargo	Speed is determined primarily by the presence of cargo on board. If there is cargo on board, this means that the ship is bound to a charterer and therefore a predetermined voyage plan and ETA.

Table A2. Just-in-Time Arrival.

Second-Order Code Words	First-Order Code Words	Thematic Analysis
Stakeholders	Charterer Ship owner Ports	Charterer presets arrival windows/laycan. Ship owners may not find JIT acceptable, as it means they could lose out on demurrage.
Technical efficiency	Fuel consumption Speed	Noon reports are prepared for the shore crew for ETA. By the different types of speed predetermined by charterer, such as full speed, eco speed or super eco speed.
Autonomy	Pressure	Ship may receive pressure from receiver with regard to arrival times.
Economy	Incentive Save	100% of the difference between CP and actual speed is passed onto the charterparty. This may create a split incentive for the crew who work to achieve economical speeds but do not reap the benefits. Even if JIT arrival is implemented/achieved, the savings go to the charterer and not the crew/top four.

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Table A2. *Cont.*

Second-Order Code Words	First-Order Code Words	Thematic Analysis
Market	Port congestion Commercial	Commercially, JIT may not currently make sense due to the lack of synchronisation and trust between various stakeholders to facilitate the real-time communication required to coordinate JIT. Port-time efficiency can be particularly low in times of port congestion.
Temporal	Laycan Delivery widow Laytime Port time efficiency NOR Virtual Arrival	There is a delivery window of charterer for collection and delivery of cargo. Speed and consumption are adjusted for laycan. NOR is given to port as a joint decision between charterparty and captain. Virtual arrival is being implemented by some ports (e.g., Australian); however, many ports currently do not offer it.

Table A3. Weather Routing.

Second-Order Code Words	First-Order Code Words	Thematic Analysis
Stakeholders	Charterparty	Charter instructions can include permitted deviations. Route is decided in the first instance by the charterer.
Technical efficiency	Fuel consumption Weather routing services/skysails	Weather routing services will provide feedback on the most economical speed, or the shortest route to take. Routing services will also suggest good routing for reducing consumption.
Autonomy	Justification Autonomy Choice Override Challenged Follow Permitted Deviation Contradiction	Weather routing contradictions with what is happening at sea/what crew is experiencing may lead to valid rejections of suggestions. Bad weather is the main cause of the master overriding weather routing suggestions. It is unclear how much autonomy masters have in overriding weather routing decisions. While some respondents say that there is a choice as long as there is a justification, others say there is little autonomy.
Economy	Cost	Areas of high traffic, e.g., Taiwan straits will be avoided by routing services to manage costs, but not at the cost of safety.

Table A3. *Cont.*

Second-Order Code Words	First-Order Code Words	Thematic Analysis
Voyage	Distance	Weather routing services will also provide the shortest distance from route A to route B.
Miscellaneous	Experience Realistic	While charters suggest that meteorological advice is to be followed, guidance may not always be realistic to what is happening at sea, and some seafarers will choose to follow their experience/what they know to be safe, particularly in areas of high traffic, and this may be at the cost of profitability. Seafarers do not like change.

Table A4. Trim/Draft Optimisation.

Second-Order Code Words	First-Order Code Words	Thematic Analysis
Stakeholders	Charterer Chief Mate	There is a company policy on safety margin. Trim is in the Chief mate's hand with feedback provided via loadicator systems.
Economy	Savings	On one hand, some respondents say that it may be difficult to measure the savings which can be achieved with trim–draft optimisation. On the other hand, others say that weather routing services such as skysails collect data on what trim saves the most money, which is correct.
Monitoring	Skysails Trim tables	Skysails stability software is used to adjust draught and trim, which is daily reported. This is done both in laden and ballast.
Charter	Cargo	Sometimes trim may not be applied due to type of cargo present. Some trim decisions may cool down cargo. Therefore, adjusting trim is more doable in ballast than laden voyages. Trim tables are used to maintain even keel in relation to cargo. Trim by stern is preferred to trim by forward and allows more efficient propeller immersion.

Table A4. *Cont.*

Second-Order Code Words	First-Order Code Words	Thematic Analysis
Sea condition	Trial data Experience	In some cases, trim–draft optimisation is only carried out in trials, and not during the voyage itself. Many respondents claim that trim/draft optimisation is not currently used. While it is acceptable that some vessels may have more advanced systems to optimise trim, manual methods of optimising trim have existed for decades, and are particularly important when manoeuvring shallow waters, not as an efficiency method, but for safety.

Table A5. Auxiliary Engine Usage.

Second-Order Code Words	First-Order Code Words	Thematic Analysis
Technical efficiency	Fuel consumption	Sometimes, one engine is kept running while the other are on standby. If the vessel is running on two generators, the crew can intervene. Engine use is guided by consumption for auxiliary engine; range should not be exceeded.
Economy	Energy saving	
Communication	Weekly meetings	Weekly meetings are had. Rounds are done at night.
Sea Condition		Current is taken advantage of.
Charter	Distance	The shortest route is taken
Maintenance		Running only one engine as much as possible reduces the number of hours required to maintain engines.

Appendix C. Thematic Analysis—Incentives

Second-Order Code Words	First-Order Code words	Thematic Analysis
Performance indicators	Fuel consumption KPI Assisting technology Safety	There do not appear to be any rewards for saving on fuel consumption. There is a concern of perverse incentives by incentivising unsafe operation for the sake of cutting down on costs. On the other hand, safety itself already seems to be an incentivised practice through a combination of various key performance indicators (KPIs) including total number of incidents on board.

Second-Order Code Words	First-Order Code words	Thematic Analysis
Monetary	Bonus	Monetary bonuses were a popular incentive type; however, some respondents were aware that increasing monetary benefits may not be the most economical approach to incentives in the long-term.
Amenities	Wi-Fi Food Seasonal provisions	One of the most commonly occurring themes was factors which contributed to crew wellbeing on board on a day-to day basis, such as hot meals, internet allowance, and equipment for entertainment. Respondents also suggested extra dietary provisions based on the holiday season, e.g., Christmas.
Contractual	Closed pool of crew Re-employability Keeping top four together	The human aspect of the environment onboard is significant, with renewed contracts and the concept of re-employment reoccurring as important themes. Respondents were keen on working in the same rotation with the same people for prolonged durations to foster comradery and allow efficient operations within a familiar team. Some thought this was particularly important when the top four were concerned.
Perks and benefits	Business-class flights Holidays	The only specific bonus which was mentioned were business-class flights for captains based on overall performance, and this was already in practice across several different companies.
Interpersonal	Acknowledgment and recognition Pride Competition Comradery	Respondents wanted to be acknowledged and recognised for their efforts, and suggested this could be done through verbal praise, as well as small gifts for the team.
Distribution	Top four Entire crew Team Individual	There is a difference in opinion in who exactly should be incentivised for energy efficiency on board. While some believe that only key individuals such as the master, chief officer and chief need to be incentivised, others believe that the whole crew should receive rewards, i.e., incentivise the team, not the individual.

Appendix D.

Table A6. Listed demographics of interviewees.

Interview No.	Company	Role	Date of Interview	Unique Interview ID
1	Medium-sized tanker operator	Operator	01/12/20	A-OP
2	Medium-sized tanker operator	Captain	16/01/21	B-CAP
3	Medium-sized tanker operator	Chief Engineer	16/01/21	C-ENG
4	Medium-sized tanker operator	Operator	19/01/21	D-OP
5	Medium-sized tanker operator	Technical Manager	19/01/21	E-OTHR
6	Medium-sized tanker operator	Captain	19/01/21	F-CAP
7	Medium-sized tanker operator	Chief Engineer	19/01/21	G-ENG
8	Engine manufacturer	Captain	29/01/21	H-POL
9		Chief Engineer	29/01/21	I-ENG
10	Medium-sized drybulk operator	Chief Engineer	01/02/21	J-ENG
11		Captain	01/02/21	K-CAP
12		Captain	02/02/21	L-CAP
13		Captain	02/02/21	M-CAP
14		Captain	01/02/21	N-CAP
15	Large tanker operator	Operator	04/02/21	O-OP
16	Large tanker operator	Operator	05/02/21	P-OP
17	Management company	MD Shipmanagement Company	06/02/21	Q-POL
18		Chief Engineer	09/02/21	R-ENG
19		Chief Engineer	09/02/21	S-ENG
20	Large tanker charterer	Policy	09/02/21	T-POL
21	Large tanker operator	Captain	10/02/21	U-CAP
22	Large tanker operator	Chief Engineer	10/02/21	V-ENG
23	Large tanker operator	Captain	10/02/21	W-CAP
24	Large tanker operator	Chief Engineer	10/02/21	X-ENG
25	Large drybulk charterer	Operator	25/02/21	Y-OP

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