WMU J Marit Affairs
https://doi.org/10.1007/s13437-018-0138-3

ARTICLE

Barriers for adoption of energy efficiency operational measures in shipping industry

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Received: 9 November 2016 / Accepted: 7 March 2018
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Abstract According to the Third Greenhouse Gas (GHG) Study 2014 of International Maritime Organization (IMO), the total emission in 2012 are estimated to be 949 million tonnes which is 2.7% of global CO_2 emission by total shipping and expected to increase from 2012 levels by 50–250% by 2050. Significant changes are needed to all industry by implementation of energy efficiency design and operational measures to meet existing and future global emission reduction targets. Although the fuel cost-reducing effects of some energy efficiency measures and new technologies are well established and matured, shipping companies appear reluctant to adopt them. Besides, it is observed that the stakeholders are directly or indirectly involved for implementation of energy efficiency measures in shipping industry. Therefore, the objective for this study was to identify the barriers to energy efficiency operational measures by a qualitative survey among various stakeholders from all corners of shipping industry. It has been found in the research that the barriers for implementation of all cost-free operational measures are almost the same such as lack of information of the measure, lack of awareness and competence of ship crews and operation difficulties which are in nature of information and technical barriers. But financial issue and owner's interest are the key barriers for some other operational measures which are related to costing and need investment for implementation.

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Published online: 19 April 2018

Keywords Energy efficiency · Energy efficiency barrier · GHG · EEDI · SEEMP · Stakeholders

1 Introduction

Over 90% of world trade is carried by international shipping. Around 68,723 merchant ships are trading for transporting cargo worldwide (BIMCO & ICS, Manpower Report 2015). Everyday each of these ships burns million tonnes of fossil fuels to produce the power for propulsion and daily operation. Burning of a large amount of fossil fuels in large marine diesel engines produces carbon dioxide (CO_2), carbon monoxide (CO), nitrogen monoxide (NO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), etc. which cause air pollution, global warming and other environmental damages (Adamkiewicz and Kołwzan 2007). The CO_2 is one of the greenhouse gases (GHGs) and the main factors of global warming, climate change and sea acidification. Rise in temperature of the earth has resulted in melting of polar ice caps, flooding of low lying areas and rise in sea levels (Ramanathanand Feng 2009). Therefore, the global warming and climate change have become a serious issue of today's world.

The United Nations Conference on Environment and Development (UNCED) was held at Rio de Janeiro in 1992 for global warming and climate change issue (UNCED 1992). Alternative energy sources to replace the use of fossil fuels were one of the agendas in relation to global climate change. This initiative was followed by an effort to make an international agreement, called Kyoto Protocol, within the United Nations Framework Convention on Climate Change (UNFCCC), setting internationally binding emission reduction targets (Nations, United. 1998). The Kyoto Protocol has mandated the International Maritime Organization (IMO) to take jurisdiction over shipping-related greenhouse gas emissions. IMO has initiated certain regulatory measures to enhance energy efficiency of new and existing ships for reduction of CO_2 from international shipping (IMO 2009a, d).

Amendments were made to the MARPOL Convention in Annex VI, regulations for the prevention of air pollution from ships (IMO 2011). The amendments include the new Chapter 4 for introduction of the Energy Efficiency Design Index (EEDI), ensuring carbon emission constraints within the design of new builds and the presence of a Ship Energy Efficiency Management Plan (SEEMP) on board all new and existing vessels. These regulations came into force from 1 January 2013 (IMO 2011) to address reduction of CO_2 emission from international shipping. According to Bazari and Longva (2011), emissions from shipping will continue to rise despite the policy measures introduced through the EEDI and the Ship Energy Efficiency Management Plan (SEEMP) and that further measures are needed if the shipping industry is to contribute to the efforts of counteracting climate change.

Further studies have indicated that more efforts are required to reduce CO_2 emission from shipping. According to IMO Third GHG Study 2014, CO_2 emissions from international shipping accounted for approximately 796 million tonnes which is 2.2% of total anthropogenic (caused by human activity) CO_2 emissions in 2012. If no regulatory measures were developed, the CO_2 emissions were projected to grow between 200% and 300% by 2050, despite significant market-driven efficiency improvements (Smith et al. 2015).

2 Energy efficiency concept and measures

Both innovative technologies and operational measures in energy efficiency will continue to provide a wide range of options and solutions for different stakeholders to implement energy efficiency regulations in their organisations. But it has been observed that the energy efficiency concept is not so clear to the stakeholders of the shipping industry. To grow the interest and awareness on energy efficiency, the concept should be communicated to all stakeholders of shipping industry. Energy efficiency is defined by Johnson and Anderson (2011) as decreasing energy use which opposed to energy cost while maintaining or increasing the level of service provided. 'Efficiency' is thus contrasted with 'conservation', which implies only a reduction in energy use. Energy efficiency is not equivalent to economic efficiency, as it comes with a cost.

By improving the energy efficiency on board a ship, the same works can be done with less energy consumption. Improvement in energy efficiency can be achieved through adoption of measures during ship design and construction stages, i.e. EEDI, and during the operation of ships at sea, i.e. SEEMP. In this research paper, we have discussed the SEEMP measures, their implementation and barriers for adoption in shipping companies of South and South East Asian developing countries.

The purpose of the SEEMP is to establish a mechanism for a company and/or a ship to improve the energy efficiency of a ship's operation. The SEEMP provides a possible approach for improving ship and fleet energy efficiency over time and some options to be considered for optimising the performance of the ship. By MARPOL Annex VI Chapter 4 regulations, all ships must have a SEEMP on board before the issuance of the first International Energy Efficiency Certificate (IEEC).

The SEEMP operational measure includes trim optimisation, weather routing and slow steaming. Trim optimisation is about finding the right trim which gives minimal resistance for the loading condition and service speed (Reichel et al. 2014). Weather routing is to find the most optimal route by taking environmental conditions into account, which consumes the least fuel (Dewit 1990; Lin et al. 2013). The improved voyage planning and weather routing, autopilot adjustment and trim optimisation technical operational measures have been shown to be matured (Maddox Consulting 2012), but there is no reliable information on cost and savings (Rehmatulla and Smith 2015). Increase in fuel price and more stringent environmental regulations have led to slow steaming as a normal practice in order to adapt to new market conditions, which is showed in the research of Cariou (2011), where he points out that the concept of slow steaming has reduced fuel consumption with approximate 11% in major container trades worldwide during 2008–2010. Lindstad et al. (2011) demonstrated that 18% reduction in CO_2 emissions could be achieved by reduction of speed alone, at a negative net cost for society.

Armstrong (2013) reported up to a 4% gain in propeller efficiency with the installation of a Propeller Boss Cap Fin (PBCF). He also reported 1% fuel saving from trim optimisation and 2.5 MT/day fuel saving from cargo heating optimisation. Armstrong (2013) also found 2.5 MT/day of fleet average fuel saving from a full cleaning of a hull after dry-docking. Another researcher De Kat et al. (2010) reported that 1–3 g/kW h was saved after installing injection timing auto tuning for the main propulsion diesel engine. In the same research, he also identified a 70–80 kW savings by performing maintenance and optimisation of the ventilation system. Despite the fact

that cost reduction associated with some measures and new technologies are well established, shipping companies are reluctant to adopt them. This reluctance to adopt economically beneficial energy efficiency measures is often referred to as barriers to energy efficiency (Sorrell et al. 2000) or the energy efficiency gap (Johnson 2011).

3 Implementation of energy efficiency operational measures and associated barriers

Until now, fuel cost is the biggest expenditure for the ship owner to run their shipping business. Therefore, the ship owner is always concern for saving fuel cost from their fleet. They are very interested to introduce the proven technology in their fleet to reduce the fuels. On the other hand, from the media and international political movement, the ship owners are well aware of the global warming and climate change issue. For the operation of their ships in international water and foreign ports, the ship owners are also experienced strict emission control regulations for ships from national and international regulatory bodies (Flag state, IMO, EU, etc.). Normally, the ship owners do not have the technical knowledge always. The technical managers of the company always suggest them regarding the innovation technology for the fuel reduction.

In DNV GL Energy Management Study 2014, the participating shipping companies have selected optimised voyage planning, hull cleaning, propeller polishing, slow steaming and weather routing that are the most popular measures in their SEEMP [Fig. 1]. Figure 2 shows results of a survey of measures taken by 86 shipping companies as reported by DNV GL (2014). Among the popular measures incorporated in the SEEMP are optimised voyage planning, hull cleaning, propeller polishing, slow steaming and weather routing. Some shipping companies have invested for innovative technology retrofits of energy efficiency devices (28%), the propeller (12%) or hull (11%). Some companies have focused in the need for familiarisation with energy management either through awareness of ship crews or incentive activities (41%) or through establishing a dedicated role for energy management (27%). The survey also found that 91% of the companies do the hull cleaning and coating while propeller cleaning (88%), auxiliary engine optimisation (86%), slow steaming/eco speed and retrofitting of energy efficiency devices, each at 83%, also show high implementation rates.

The above results show that shipping companies prioritise operational measures with low investment cost that are normally part of the operational routine anyhow. Unavailability of financial resources, immaturity of the measures and doubts about claimed fuel efficiency may have their impact. The vendors of energy efficiency measures sometimes claimed efficiencies that are unrealistic and do not reflect actual savings. According to Johnson (2015), a ship owner explained in his interview ‘The vendors are always claim in such a way that if we add them all together, we can save more than 100%’.

One of the barriers for adoption of energy efficiency for the shipping company is the management structure. In the most shipping organisation, no one is truly accountable or responsible for energy costs and cost reduction. The main task of ship managers is to ensure safe and profitable operation of ships only; energy efficiency is just an add-on to follow the regulation. Johnson and Anderson (2011) and Jafarzadeh and Utne (2014)

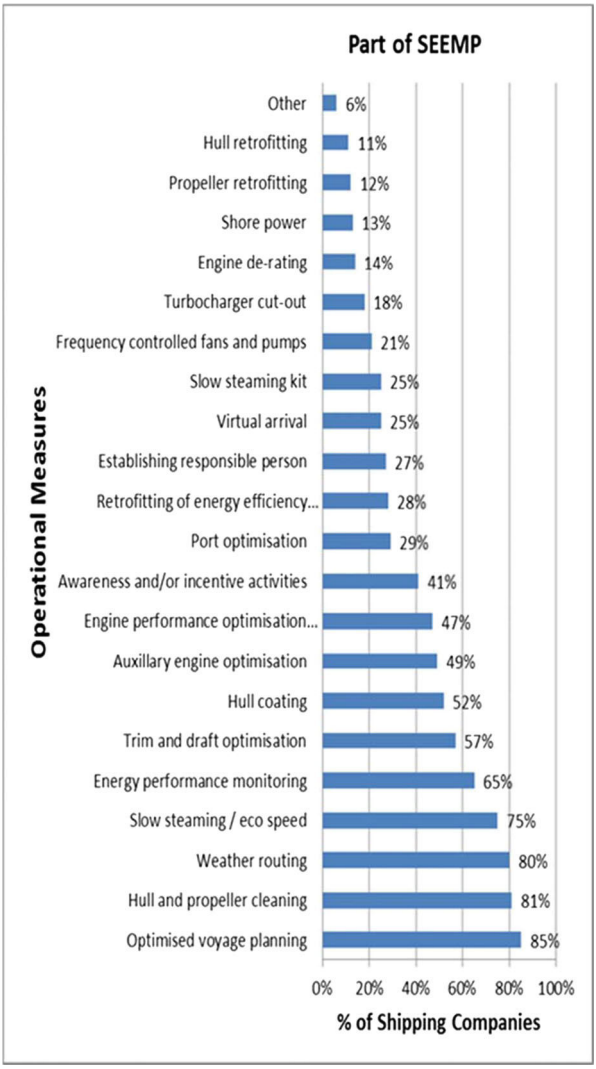


Fig. 1 Operational measures that are part of SEEMP. (Source: DNV GL Energy Management Study 2014)

reported that in a shipping organisation, the ship crew and energy management department are the closest to experiencing and affecting energy use. But they remain far from controlling the resources needed to implement improvement processes. Normally, the ship owners or the ship managers use to deal with the investment. If the energy management department is not enough strong than the other departments in the organisations, energy-efficient measures may not be adopted. So, the lack of power or influence in the organisations is another barrier.

Shipping is a business organisation and consists of number of stakeholders with different responsibilities where the ship owners or the ship managers are the leaders and the ship operators or ship crew are the followers. According to the Max Weber, the organisation is a hierarchy which maintains the relationship between superiors and

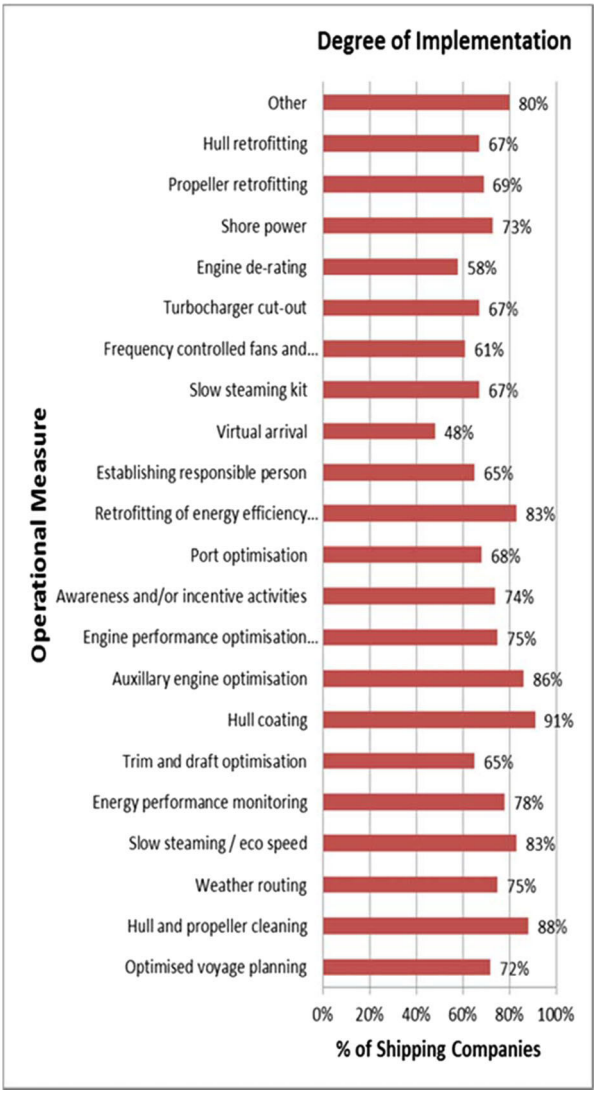


Fig. 2 Operational measures that are implemented. (Source: DNV GL Energy Management Study 2014)

subordinates (Weber 1997). In such hierarchical organisations, decisions to adopt energy efficiency measures are not necessarily made by the ship operators who often reserve the best knowledge about ship operations. On the other hand, ship owners or ship managers without technical background may not have the realisation of benefits for adopting new technology measures. An organisational gap between ship managers and ship operators may cause a hindrance to the process of implementation due to the lack of communication and understanding between them. So, the structural gap in shipping companies is one of the barriers for adoption of energy efficiency measures.

The decision-makers of the company are usually required to select the best from the available options which might be assessed with regard to some criteria. For example,

for selecting a main engine during ship design, the criteria which can be considered would be multiple criteria in nature in which cost, specific fuel consumption, power and capacity ratio requirement, capability of NOx control and weight are taken into consideration. The workers (ship designer or ship crew) or decision-makers (the ship owners or managers) might have different preferences and perceptions against alternatives and criteria. According to Olcer and Ballini (2015), understanding the importance of criteria might be as important as preferences. The decision-makers might not have a full picture for the assessment of available alternatives. A decision-maker might be biased towards safety rather than energy efficiency when high cost stands with energy efficiency. Under these circumstances, making the right or optimal decisions is not an easy task, which might possibly lead to less optimal decisions in terms of less energy-efficient designs or operations. The optimality of the decisions eminently depends on the quality of the input data in the form of assessments, preferences and perceptions, weighting of the criteria and data type. Therefore, the barriers for adoption of energy efficiency measures can be the lack of knowledge and pertinent training to the decision-makers for assessment of available measures in the market.

According to Jafarzadeh (2014), information barriers, economic barriers, intra-organisational barriers, inter-organisational barriers, technological barriers, policy barriers and geographical barriers are the main barriers for adoption of energy efficiency measures in international shipping. On the other hand, Sorrell et al. (2000), Sudhakar and Painuly (2004), Girard (2010) and Acciaro et al. (2012) highlighted in their research the barriers to energy efficiency in shipping in some categories like safety and reliability of the measures, technical uncertainty of the new technologies, organisational behaviour of the company and market constraints and financial and economic constraints of ship's operation. But according to Mark Jacobson and his colleagues (2015), the main barriers for getting to 100% clean energy are social and political, not technical or economic barriers.

The Institute of Marine Engineering, Science & Technology (IMarEST) in a submission to the 60-s session of IMO's Marine Environment Protection Committee (MEPC) has identified technological and commercial constraints as possible barriers to the uptake of energy efficiency measures, requiring action by all stakeholders to overcome them. Sometimes, these barriers may be real or may be preconceived but the net effect is always to delay implementation. Further, the impact of these barriers may vary from one country to another because of varied levels of economic, social and technological environment.

Forty-six barriers for implementation of energy efficiency measures in shipping industry are listed from 15 different studies, and then they are divided into 7 distinct barrier groups as shown in Table 1. All informative barriers about the operational measures and about the technology manufacturers are grouped in information barriers. All financial matters such as budgeting, financial risk, maintenance or hidden costs and financial benefits are grouped into financial barriers. Companies' organisational problems, cultures, authority and power are grouped into intra-organisational barriers. Technological complexity, incompatibility and immatureness of measures are divided into technological barrier group. All kinds of technical knowledge and training-related barriers are grouped into technical barriers. For implementation of energy efficiency measures for a nation, there can be some policy barriers such as policy formation, implementation, reviewing and amendment. Few geographical situations, e.g. piracy

area, wind or tidal effect and route dependency for feeder service in between two or multiple ports, can be defined as geographical barriers for implementation of energy efficiency measures.

4 Study scope

Shipping is international business, and many stakeholders (ship charterers, flag state and port state administration, dry-dock and ship repairers, class surveyors, bunker suppliers) are directly and indirectly involved. In many cases, they also have good influence for implementation of energy efficiency measures. In previous studies by Johnson and Andersson (2011), Jafarzadeh and Utne (2014), Acciaro et al. (2012), DNV GL Energy Management Study 2014 and Rehmatulla and Smith (2015), surveys and interviews were limited to the shipping companies and ship's oriented stakeholders (e.g. ship owners, ship managers, ship crews). Therefore, in the present study, all types of stakeholders were covered so that the actual barriers for implementation of energy efficiency measures in shipping industry could be identified, and their influences could be quantified.

To get a comprehensive industry overview, stakeholders were selected from 14 ship owning and ship management companies, 5 ship charterers, 2 flag state and 3 port state administrations, 8 class surveyors from four main classification societies, 4 shipyards and dry-docks, 1 bunker supplier, 7 ship crew trainers from five maritime training institutes and 6 experienced ship's masters and 18 chief engineer level seafarers in Bangladesh and Malaysia. This study was carried out by distributing an online survey form among various stakeholders of the shipping industry of Malaysia and Bangladesh. The online survey form was distributed by emails to 118 stakeholders who have important roles for the implementation of energy efficiency measures in shipping industry. In the survey form, some selected energy efficiency operational measures were described briefly so that they can understand well of each measure. Then, they were requested to put tick marks on the boxes of appropriate barriers which are related to implement the measures in their ships.

4.1 Research methodology

To identify key barriers for implementation of energy efficiency, questionnaires were designed and used in a pilot survey among various stakeholders both in Bangladesh and Malaysia. The surveys were carried out at technical seminars arranged jointly by Nautical Institute (NI) and the Institute of Marine Engineering, Science & Technology (IMarEST) of Bangladesh at Bangladesh Marine Academy on 27 December 2015, and Malaysia Joint Branch (MJB) for IMarEST and the Royal Institute of Naval Architects (RINA) in Kuala Lumpur on 24 March 2016. After the technical talk on Ship Energy Efficiency Management, the pilot survey form was distributed to 52 attendees, selected stakeholders of shipping industry of Bangladesh and Malaysia. The pilot survey form listed the most popular operational energy efficiency measures taken from DNV GL (2014) as shown in Fig. 2. Participants of survey were asked to select the operational measures which

Table 1 List of barriers for implementation of energy efficiency measures in shipping industry

Information barriers	Financial barriers	Intra-organisational barriers	Technological barriers	Technical barriers	Policy barriers	Geographical barriers
1. The lack of information	1. Limited access to capital	1. Organisational culture	1. Incompatibility between technologies and ship types	1. Crew's lack of technical knowledge	1. Policy formation barriers	1. Piracy area
2. The overload of information	2. External risk	2. Inertia	2. Immatureness Technical risk	2. Crew's lack of awareness training	2. Policy implementation barriers	2. The route dependency
3. New-building contracts not including information technologies	3. Business risk	3. Bounded rationality	3. Interference with main processes	3. Crew's lack of competence	3. Lack of reviewing and amendment of policy	3. Wind or tidal effect
4. Not using information	4. Hidden costs	4. Lack of power	4. The complexity of measures	4. Managers without technical background	4. Conflicting policy regulations	
5. Not maintaining information	5. Heterogeneity	5. Lack of trust in the organisation	5. Improvement likeliness			
6. The inaccuracy of information	6. Imperfect budgeting	6. Lack of time	6. Incompatibility between technologies and operations			
7. The improper form of information	7. Unrealistic basis for cost-benefit analyses	7. Communication problems				
8. Cultural differences regarding the required information		8. The lack of trust in technologies				
9. Adverse selection		9. Split incentives				
10. Moral hazard and principal-agent relationships		10. The ownership of vessels				

Table 1 (continued)

Information barriers	Financial barriers	Intra-organisational barriers	Technological barriers	Technical barriers	Policy barriers	Geographical barriers
11. The lack of credibility and trust in the source of information		11. Difference in risk perception				
12. Variations in circumstances						

Source: Adapted from the researches of Johnson and Andersson (2011), Jafarzadeh and Utne, 2014), Acciaro et al. (2012), Faber et al. (2011), Jaffe and Stavins (1994), Thollander and Palm (2013), Sorrell et al. (2000), Blumstein (1980), Fleiter et al. (2011), Chai and Yeo (2012), Cagno et al. (2013), Trianni et al. (2013), Faber et al. (2009), Faber and Behrends (2011) and Fleiter et al. 2012a, b)

are part of SEEMP and being used in their shipping companies or their related shipping companies. They were also asked to write about the barriers that they are facing for implementation of those selected operational measures.

The results of the pilot survey identified 16 most potential barriers: lack of information about the measure, financial (budgeting and costing issue), financial (maintenance or other hidden cost), intra-organisational difficulties in company, installation difficulties, lack of awareness and knowledge of ship crews, operational difficulties, technical risk and safety issue, lack of credibility and immaturity of measure, unrealistic cost-benefit issue, conflict with charter party requirements, policy formation and implementation barrier, owner's lack of interest, crew's lack of competence, incompatibility between technologies and ship type and route dependency of the ship.

From the pilot survey, the most used ten (10) operational measures in SEEMP such as improved voyage planning and weather routing, just in time/virtual arrival, speed optimisation/slow steaming, trim optimisation, ballast water optimisation, hull cleaning and coating, propeller cleaning and polishing, main propulsion performance monitoring systems, ship's power use optimisation, and crew awareness and training on energy efficiency are selected for the qualitative survey. Besides, few more operational measures such as using of de-rated main engine, proper cargo handling with regard to energy savings, ship and voyage performance analysers, adaptive autopilot/optimum use of rudder, use of propeller boss cap fins/Mewis Duct propeller, Bulbous Bow re-shaped and improved fuel management are also selected as per IMO Publication 'Study on the optimization of Energy Consumption as Part of Implementation of a Ship Energy Efficiency Management Plan - SEEMP, (2016)' for this survey, which have been implemented by most of the shipping companies around the world (IMO 2016). In the online survey form, the stakeholders were requested to select one or more appropriate barriers by putting tick marks in the boxes for implementation of each energy efficiency operational measures for ships.

5 Study Results

5.1 Quantify the influence of stakeholders for implementation of energy efficiency operational measures

We have collected data from 81 respondents of different stakeholders of shipping industry in Bangladesh and Malaysia. Among them, 7 are ship owners and ship managers, 18 are technical managers, 18 are engine crews (chief engineers), 16 deck crews (masters), 7 are crew trainers, 8 are class surveyors, 5 are flag state and port state control, 6 are ship repairers, 5 are ship charterers and 1 bunker supplier. Percentages of respondent stakeholders are presented in Fig. 3. By a Google online survey form, the stakeholders were asked about their influence for implementation of energy efficiency operational measures by using the Likert scale. We have used *Very Low to Very High* scale by selecting the ascending number *1 to 5*. Findings from the Likert scale data are presented Table 2.

Table 2 Stakeholder's influence on implementation of energy efficiency operational measures

Energy efficiency operational measures	Stakeholders' influence on implementation of energy efficiency measures																			
	Ship owners and managers		Deck crews		Engine crews		Technical managers		Flag state and port state control		Class surveyor		Ship charterers		Shipyard and repairers		Crew trainers		Bunker suppliers	
	Mean	VD	Mean	VD	Mean	VD	Mean	VD	Mean	VD	Mean	VD	Mean	VD	Mean	VD	Mean	VD	Mean	VD
Improved voyage planning and weather routing	4.3	VH	4.8	VH	3.2	M	3.7	H	3.0	M	3.0	M	4.2	H	2.5	L	2.1	L	1.0	VL
Just in time (virtual arrival)	4.1	H	4.7	VH	3.3	M	3.0	M	3.4	M	2.4	L	4.2	H	2.2	L	2.1	L	1.0	VL
Speed optimisation/slow steaming	4.4	VH	4.5	VH	3.7	H	3.3	M	3.6	H	2.9	M	4.2	H	2.7	M	2.4	L	1.0	VL
Trim optimisation	3.7	H	4.2	H	3.3	M	3.1	M	3.6	H	2.6	M	3.4	M	2.5	L	2.3	L	1.0	VL
Ballast optimisation	3.4	M	4.3	VH	3.0	M	3.2	M	3.6	H	2.8	M	3.6	H	2.5	L	2.3	L	1.0	VL
Hull cleaning and coating	4.4	VH	3.7	H	3.8	H	3.7	H	3.4	M	3.5	H	3.6	H	2.7	M	2.4	L	1.0	VL
Propeller polishing	4.3	VH	3.5	H	3.8	H	3.7	H	3.4	M	3.5	H	3.4	M	2.7	M	2.6	L	1.0	VL
Main propulsion performance monitoring systems	3.9	H	3.8	H	4.2	H	4.2	H	3.0	M	3.1	M	3.0	M	2.7	M	2.4	L	4.0	H
Ship's power use optimisation	3.7	H	4.2	H	4.1	H	3.9	H	3.0	M	3.6	H	3.6	H	2.7	M	2.6	L	1.0	VL
Crew awareness and training on energy efficiency	3.5	H	4.2	H	4.1	H	3.9	H	4.0	H	3.6	H	2.8	M	2.2	L	3.7	H	1.0	VL
Legends																				
Rating scales	Verbal description (VD)																			
1.0–1.8	Very low [VL]																			
1.9–2.6	Low [L]																			
2.7–3.4	Medium [M]																			
3.5–4.2	High [H]																			
4.3–5.0	Very high [VH]																			

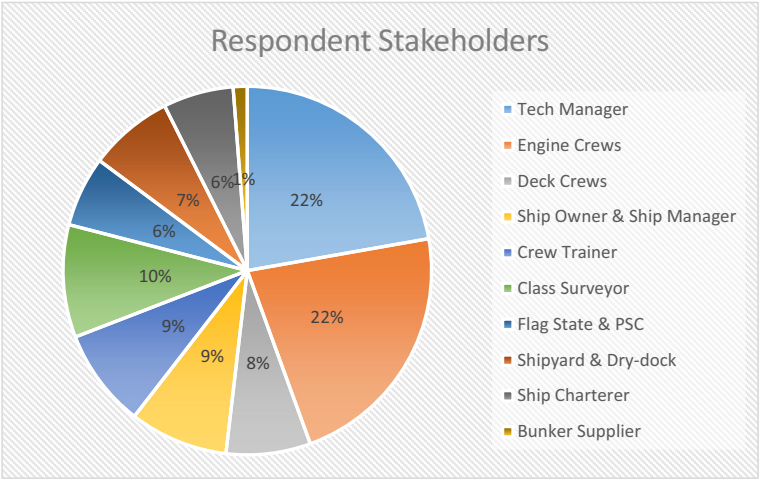


Fig. 3 Percentage of respondent stakeholders

5.2 Identifying the barriers for adoption of energy efficiency operational measures

In the online survey form, the stakeholders selected multiple appropriate barriers by putting tick marks on the barriers' boxes. They were given the freedom to select one or multiples or write some other barriers which are not in the survey

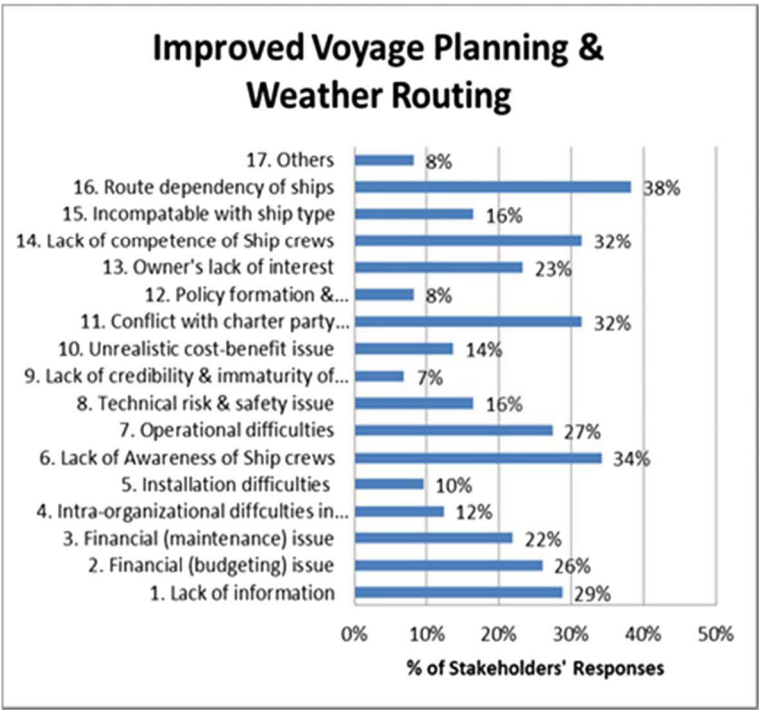


Fig. 4 Improved voyage planning and weather routing

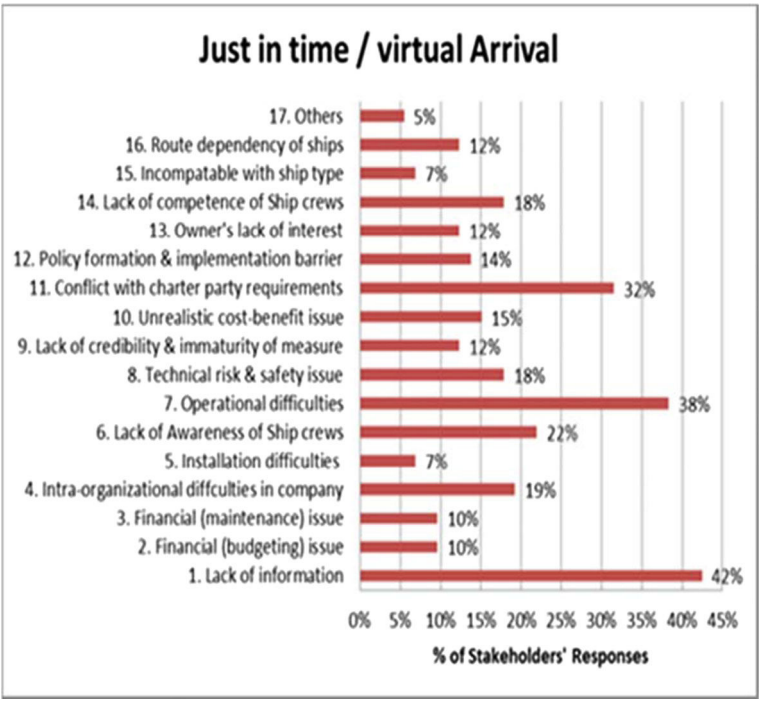


Fig. 5 Just in time/virtual arrival

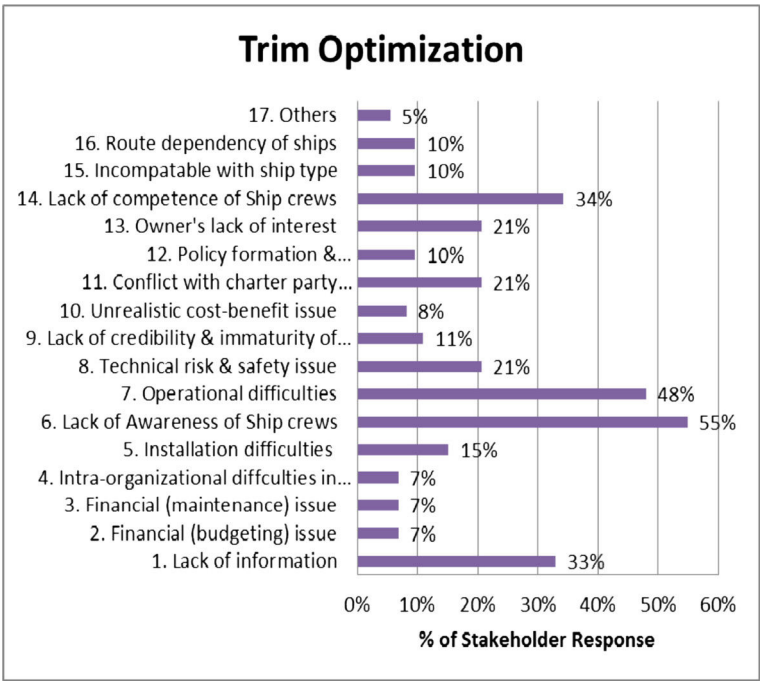


Fig. 6 Trim optimisation

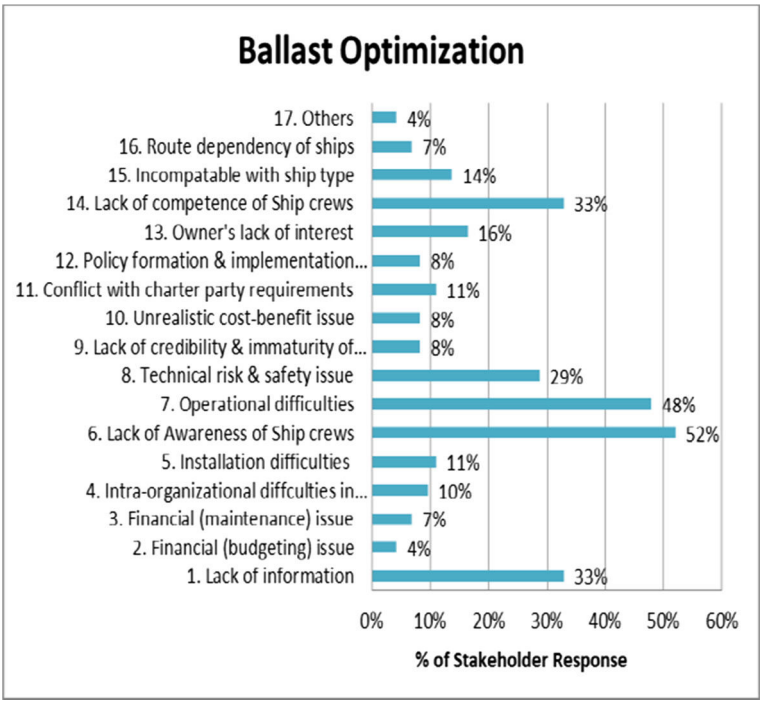


Fig. 7 Ballast optimisation

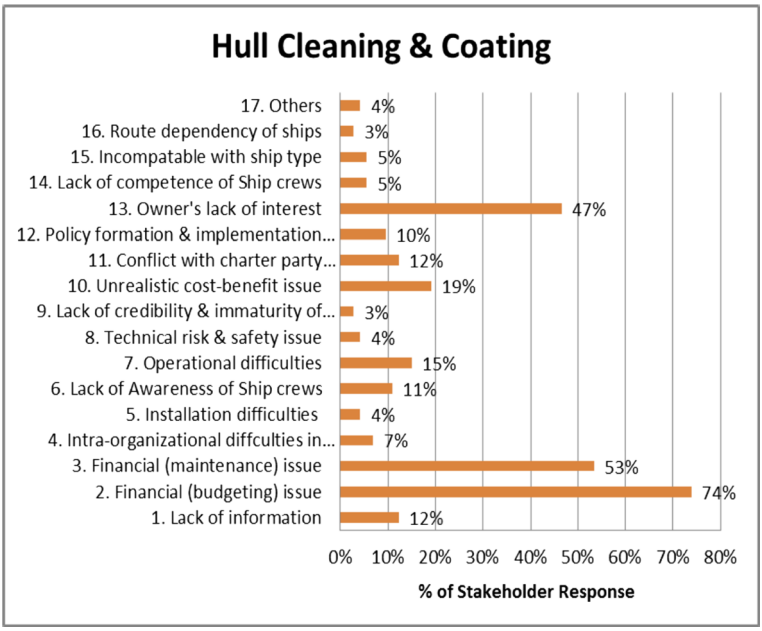


Fig. 8 Hull cleaning and coating

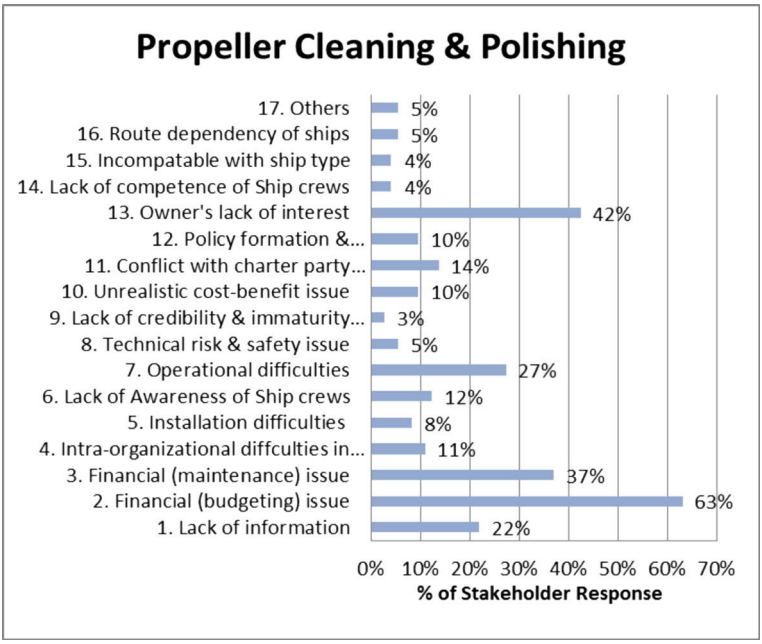


Fig. 9 Propeller cleaning and polishing

form by putting tick mark on others. Responses were received from 81 participants and their response data were analysed and presented in Figs. 4, 5, 6, 7, 8, 9,

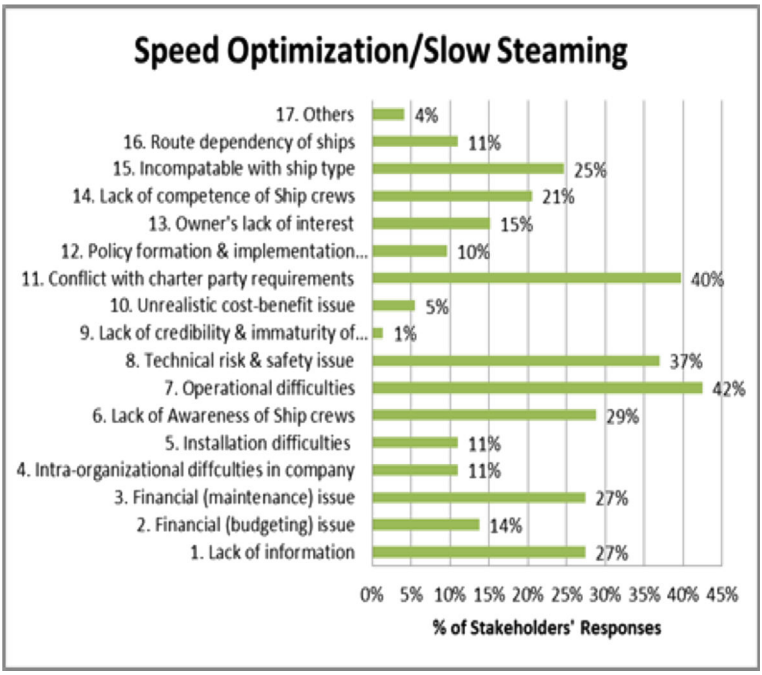


Fig. 10 Speed optimisation/slow steaming

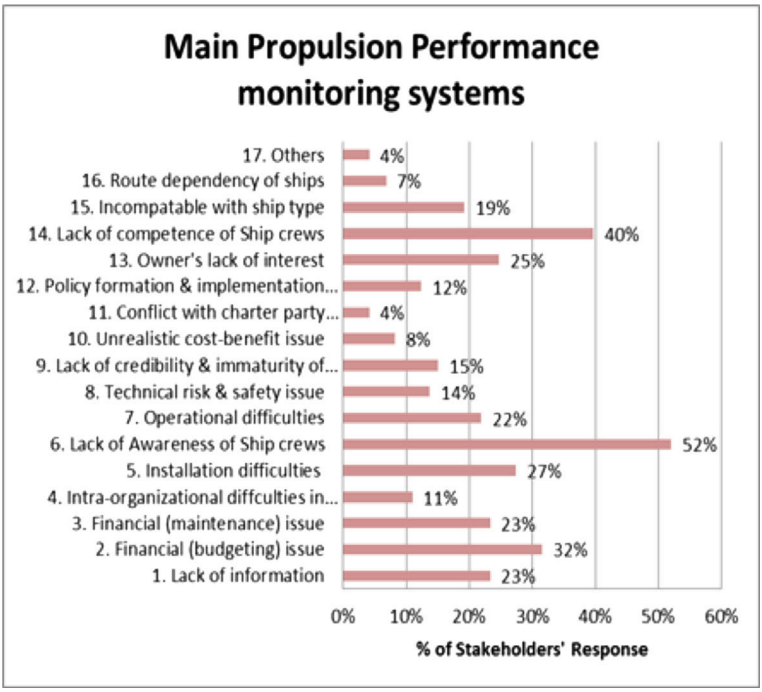


Fig. 11 Main propulsion performance monitoring system

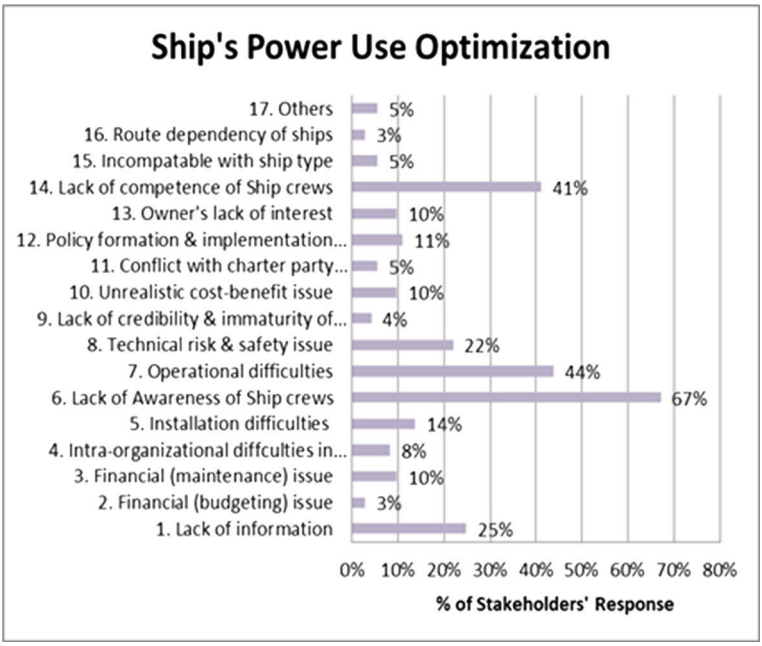


Fig. 12 Ship power use optimisation

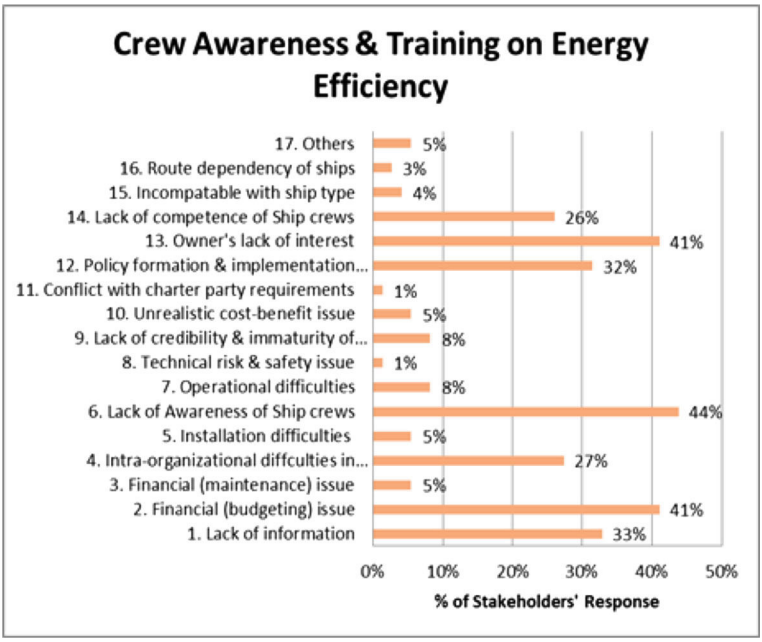


Fig. 13 Crew awareness and training on energy efficiency

10, 11, 12, and 13 for ten most used operational energy efficiency measures from SEEMP (as described in research methodology) and identified barriers for implementation of these measures by the percentage (%) of responses of various stakeholders of maritime sector in Bangladesh and Malaysia (Fig. 3).

The following information can be derived from the summary of responses as presented in Figs. 4, 5, 6, 7, 8, 9, 10, 11, 12, and 13:

1. Improved voyage planning and weather routing

From Table 2, we can generate Table 3 and find that the stakeholders ship owners & ship managers, deck crews have very high and technical managers and ship charterers have high influence on implementation of improve voyage planning and weather routing energy efficiency measure.

The optimum route and improved efficiency can be achieved through careful planning and execution of voyages, and significant savings can be achieved. The survey indicates that *lack of information*, *operational difficulties*, *conflict*

Table 3 Stakeholders' influence on implementation of improved voyage planning and weather routing

Stakeholders' Influence on Implementation of Energy Efficiency Measures									
Ship Owners & Managers	Deck Crews	Engine Crews	Technical Managers	Flag State & Port State Control	Class Surveyors	Ship Charterers	Shipyard & Repairers	Crew Trainers	Bunker Suppliers
Very High	Very High	Medium	High	Medium	Medium	High	Low	Low	Very Low

Table 4 Stakeholders' influence on just in time/virtual arrival measure

Stakeholders' Influence on Implementation of Energy Efficiency Measures									
Ship Owners & Managers	Deck Crews	Engine Crews	Technical Managers	Flag State & Port State Control	Class Surveyors	Ship Charterers	Shipyard & Repairers	Crew Trainers	Bunker Suppliers
High	Very High	Medium	Medium	Medium	Low	High	Low	Low	Very Low

with charter party requirement and lack of awareness of ship crews are hindering the effective implementation of this measure (Fig. 4). As this measure is a technical operational measure, no financial barrier is associated for this measure.

5.2.1 Just in time/virtual arrival:

From Table 2, we can create Table 4 and find that the deck crews have *very high* and ship owners & ship managers and ship charterers have *high* influence on implementation of Just in time/virtual arrival energy efficiency measure.

Early communication with the next port should be an aim in order to give maximum notice of berth availability and facilitate the use of optimum speed where port operational procedures support this approach. This is a complex operational barrier which involves many stakeholders. Figure 5 indicates that *lack of information*, *operational difficulties*, *conflict with charter party requirements and lack of awareness of ship crews* are the main barriers for implementation of this measure.

5.2.2 Trim optimisation

From Table 2, we can get Table 5 and find that the deck crews, the ship owners & ship managers and flag state and port state administration have *high* influence on implementation of trim optimisation energy efficiency measure.

Loaded or unloaded, trim has a significant influence on the resistance of the ship through the water and optimising trim can deliver significant fuel savings. Design or safety factors may preclude full use of the trim optimisation. It is identified by the survey that *lack of awareness of ship crews*, *operation difficulties*, *lack of competence of ship crews and lack of information* are the main barriers for implementation of this measure (Fig. 6). Since this is an operational and technical type measure, major barriers are the ship technical operation and the ship crew related.

Table 5 Stakeholders' influence on trim optimisation measure

Stakeholders' Influence on Implementation of Energy Efficiency Measures									
Ship Owners & Managers	Deck Crews	Engine Crews	Technical Managers	Flag State & Port State Control	Class Surveyors	Ship Charterers	Shipyard & Repairers	Crew Trainers	Bunker Suppliers
High	High	Medium	Medium	High	Medium	Medium	Low	Low	Very Low

Table 6 Stakeholders' influence on ballast optimisation measure

Stakeholders' Influence on Implementation of Energy Efficiency Measures									
Ship Owners & Managers	Deck Crews	Engine Crews	Technical Managers	Flag State & Port State Control	Class Surveyors	Ship Charterers	Shipyard & Repairers	Crew Trainers	Bunker Suppliers
Medium	Very High	Medium	Medium	High	Medium	High	Low	Low	Very Low

5.2.3 Ballast optimisation

From Table 2, we can generate Table 6 and find that the deck crews have *very high* influence and flag state & port state administration and ship charterers have *high* influence on implementation of Ballast Optimisation energy efficiency measure.

Ballast conditions have a significant impact on steering conditions and autopilot settings, and it needs to be noted that less ballast water does not necessarily mean the highest efficiency. Moreover, more ballast water needs more time and energy for treatment. The respondents cited *lack of awareness of ship crews*, *operation difficulties*, *lack of information and lack of competence of ship crews* as the major barriers for implementation of this measure (Fig. 7).

5.2.4 Hull cleaning and coating

From Table 2, we can generate Table 7 and find that the ship owners & ship managers have *very high* influence and deck crews, engine crews, technical managers, flag state & port state administration, class surveyors and ship charterers have *high* influence on implementation of hull cleaning and coating energy efficiency operational measure for existing ships.

Hull resistance can be optimised by new technology-coating systems, possibly in combination with cleaning intervals. The smoother the hull, the better the fuel efficiency. Figure 8 shows that *financial (budgeting) issue*, *financial (maintenance) issue and owner's lack of interest* are major barriers for implementation of this measure. As this measure is relating to costing, financial issue and owner's interest are the key barriers for this SEEMP measure.

5.2.5 Propeller cleaning and polishing

From Table 2, we can create Table 8 and find that the ship owners & ship managers have *very high* influence and deck crews, engine crews, technical

Table 7 Stakeholders' influence on hull cleaning and coating measure

Stakeholders' Influence on Implementation of Energy Efficiency Measures									
Ship Owners & Managers	Deck Crews	Engine Crews	Technical Managers	Flag State & Port State Control	Class Surveyors	Ship Charterers	Shipyard & Repairers	Crew Trainers	Bunker Suppliers
Very High	High	High	High	Medium	High	High	Medium	Low	Very Low

Table 8 Stakeholders' influence on propeller cleaning and polishing measure

Stakeholders' Influence on Implementation of Energy Efficiency Measures									
Ship Owners & Managers	Deck Crews	Engine Crews	Technical Managers	Flag State & Port State Control	Class Surveyors	Ship Charterers	Shipyard & Repairers	Crew Trainers	Bunker Suppliers
Very High	High	High	High	Medium	High	Medium	Medium	Low	Very Low

managers, class surveyors have *high* influence on implementation of Propeller Cleaning and Polishing energy efficiency operational measure for existing ships.

Propeller cleaning and polishing or even appropriate coating may significantly increase fuel efficiency. Figure 9 indicates that *financial (budgeting) issue*, *owner's lack of interest*, *financial (maintenance) issue and operational difficulties* are the main barriers for implementation of this operational measure. As this measure is also relating to costing, financial issue and owner's interest are the key barriers for this SEEMP measure too.

5.2.6 Speed optimisation/slow steaming

From Table 2, we can generate Table 9 and find that the ship owners & ship managers and deck crews have *very high* influence whereas engine crews, flag state & port state administration and ship charterers have *high* influence on implementation of Speed Optimisation / Slow Steaming energy efficiency operational measure for existing ships.

Speed optimisation can produce significant fuel savings. However, optimum speed means the speed at which the fuel used per tonne-mile is at a minimum level for that voyage. Possible adverse consequences of slow speed operation may include increased vibration and problems with soot deposits in combustion chambers and exhaust systems and thus shortened maintenance duration and increase maintenance cost. Figure 10 shows o*perational difficulties*, *conflict with charter party requirements and technical risk and safety issue* are the major barriers for implementation of this measure.

5.2.7 Main propulsion performance monitoring systems

From Table 2, we can create Table 10 and find that the ship owners & ship managers, deck crews, engine crews, technical managers and bunker suppliers have *high* influence on implementation of main propulsion performance monitoring system SEEMP measure for existing ships.

Table 9 Stakeholders' influence on speed optimisation/slow steaming measure

Stakeholders' Influence on Implementation of Energy Efficiency Measures									
Ship Owners & Managers	Deck Crews	Engine Crews	Technical Managers	Flag State & Port State Control	Class Surveyors	Ship Charterers	Shipyard & Repairers	Crew Trainers	Bunker Suppliers
Very High	Very High	High	Medium	High	Medium	High	Medium	Low	Very Low

Table 10 Stakeholders' influence on main propulsion performance monitoring systems

Stakeholders' Influence on Implementation of Energy Efficiency Measures									
Ship Owners & Managers	Deck Crews	Engine Crews	Technical Managers	Flag State & Port State Control	Class Surveyors	Ship Charterers	Shipyard & Repairers	Crew Trainers	Bunker Suppliers
High	High	High	High	Medium	Medium	Medium	Medium	Low	High

In particular, the new breed of electronic controlled engines can provide efficiency gains. However, specific training for relevant staff may need to be considered to maximise the benefits. Figure 11 indicates, l*ack of awareness and lack of competence of ship crews*, *financial (budgeting) issue and installation difficulties* are the main barriers for this measure.

5.2.8 Ship's power use optimisation

From Table 2, we can get Table 11 and find that the ship owners & ship managers, deck crews, engine crews, technical managers, class surveyor and ship charters have *high* influences on implementation of Ship's Power Use Optimisation energy efficiency operational measure for existing ships.

On board ships, power management can result in significant fuel oil savings. By practicing good power management and pre-planning of power uses, optimisation of diesel generator load by running of minimum number of generators in safe load condition can be achieved on board ships. From the stakeholder responses, Fig. 12 shows that *lack of awareness of ship crews*, *operation difficulties* and *lack of competence of ship crews* are the major barriers for implementation of this SEEMP measure.

5.2.9 Crew awareness and training on energy efficiency

From Table 2, we can generate Table 12 and find that the ship owners & ship managers, deck crews, engine crews, technical managers, class surveyors and flag state & port state administrator and crew trainers have *high* influences on implementation of Crew Awareness and Training on this SEEMP measure for existing ships.

Crew awareness may be increased through the use of appropriate energy saving checklists, developed based on best practices identified after numerous energy audits. An incentive or bonus scheme can be introduced on fuel savings. Figure 13 presents that *lack of awareness of ship crews*, *owner's lack of interest*, *financial (budgeting) issue*, *lack of information and policy formation* and *implementation barriers* are the main barriers for implementation of this SEEMP measure.

Table 11 Stakeholders' influences on ship's power use optimisation measure

Stakeholders' Influence on Implementation of Energy Efficiency Measures									
Ship Owners & Managers	Deck Crews	Engine Crews	Technical Managers	Flag State & Port State Control	Class Surveyors	Ship Charterers	Shipyard & Repairers	Crew Trainers	Bunker Suppliers
High	High	High	High	Medium	High	High	Medium	Low	Very Low

Table 12 Stakeholders' influences on crew awareness and training on energy efficiency measure

Stakeholders' Influence on Implementation of Energy Efficiency Measures									
Ship Owners & Managers	Deck Crews	Engine Crews	Technical Managers	Flag State & Port State Control	Class Surveyors	Ship Charterers	Shipyard & Repairers	Crew Trainers	Bunker Suppliers
High	High	High	High	High	High	Medium	Low	High	Very Low

6 Conclusion

This study has identified the barriers for adoption of some popular energy efficiency operational measures in shipping industry based on responses from various stakeholders of South Asian developing countries. In this study, it was found that four main barriers which impede the adoption of all cost-free operational measures *are lack of information of the measure*, *lack of awareness*, *lack of competence of ship crews and operation difficulties*. These four common barriers can be eliminated by training of the ship crews and office personnel who are directly involved with ship's operation. On the other hand, *financial issue and ship owner's interest* hinder the implementation of the operational measures which involve costs such as hull cleaning and coating, propeller cleaning and polishing and main propulsion performance monitoring systems. Therefore, green policy of the country for easy sourcing of financial support from governments, shipyards, banks and easy and long-term payment scheme to technology manufacturers can be helpful for the ship owners & ship managers to eliminate these barriers.

Malaysia is one of the Lead Pilot Countries (LPCs) of GloMEEP (Global maritime energy efficiency partnerships), a GEF-UNDP-IMO project. The GloMEEP components aim to enhance awareness of stakeholders, maritime sector energy efficiency capacity building, knowledge creation and dissemination, legal, policy and institutional reforms for the implementation and enforcement of IMO's energy efficiency regulations, as well as promote the uptake of ship operational and design energy efficiency measures in the lead pilot countries. Therefore, the recent GloMEEP and IMO regional Maritime Technology Cooperation Centre (MTCC) of Asia have to give more focus to maritime sector energy efficiency capacity building, raising awareness as well as knowledge creation and dissemination among all stakeholders. This will help Asian developing countries to effectively implement and enforce of IMO's energy efficiency regulations to contribute to significant reduction of GHG emissions from international shipping.

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