MARKET FAILURES AND BARRIERS AFFECTING ENERGY EFFICIENT OPERATIONS IN SHIPPING

By

Nishatabbas Rehmatulla

UCL Energy Institute

Supervised by:

Dr. Tristan Smith

Prof. Paul Wrobel

A dissertation submitted for the degree of Doctor of Philosophy

Declaration

'I, Nishatabbas Rehmatulla confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis'

Signed:

The research presented here was made possible by funding from the 'Low Carbon Shipping – A Systems Approach' project and from Lloyds Register, for which the author wishes to express his sincere appreciation. Low Carbon Shipping is a consortium of five UK universities; University College London, Newcastle University, University of Strathclyde, University of Hull and University of Plymouth and a number of industry partners. The project started in January 2010 and it is majority funded by the Research Council UK energy program programme (£1.7m over 3 years), but also supported financially and in-kind by a number of industry partners including Lloyds Register, Rolls Royce, Shell and BMT.

The following are the publications resulting from the work reported in this thesis:

1. Rehmatulla, N 2011, 'Applying systems thinking approaches for qualitative analysis of GHG emissions regulations in shipping', *First International Conference on Marine & Maritime affairs*, 4 - 5 April 2011, University of Plymouth, Plymouth.

2. Rehmatulla, N 2012, 'Barriers to uptake of energy efficient operational measures: Survey Report', Energy Institute, UCL, http://www.lowcarbonshipping.co.uk/files/ucl_admin/Rehmatulla_2012_Low_Carbon_Shipping_Survey_report.pdf

3. Rehmatulla, N & Smith, T 2012, 'Implementation barriers to Low Carbon Shipping', *Low Carbon Shipping Conference*, 11 - 12 September, University of Newcastle, Newcastle.

4. Rehmatulla, N, Smith, T & Wrobel, P 2013, 'Implementation barriers to Low Carbon Shipping', *Low Carbon Shipping Conference*, 9 - 10 September, UCL, London.

Co-authored publications:

1. Smith, T, Parker, S & Rehmatulla, N 2011, 'On the speed of ships', *Low Carbon Shipping conference*, 22 - 24 June, University of Strathclyde, Glasgow.

2. Agnolucci, P, Smith, T & Rehmatulla, N 2014, 'Energy efficiency and time charter rates: Energy efficiency savings recovered by ship owners in the Panamax market', *Transportation Research Part A: Policy and Practice*, vol 66, pp. 173-184

Abstract

Shipping contributes to around 3% of global CO_2 emissions and this is expected to increase to around 20 – 25% of global CO_2 emissions by 2050 as other sectors under national inventories decarbonise to avoid dangerous climate change. Improving energy efficiency has a key role as one of the strategies to address the challenges of climate change and this research investigates the barriers to energy efficiency in shipping, which is motivated by the increasing attention given to this subject from shipping regulators, both regional (e.g. UK and EU) and international (e.g. UN and IMO). The few studies that analyse the shipping sector for barriers to energy efficiency lack clear barriers taxonomy, are not rigorous methodologically and theoretically and can benefit from empirical examination of barriers in other sectors. The aim of this research therefore is to thoroughly understand the energy efficiency gap in shipping by examining the level of implementation of energy efficient operational measures and the barriers that may be affecting implementation of these measures. To do this, the research establishes a novel framework for empirically analysing the barriers to energy efficiency. The framework utilises agency theory for comparing perceptions of barriers using the survey method to observed level of barriers using the content analysis method and actual operational data. The survey results show that operational energy efficiency measures are not fully implemented and their implementation varies by sector of operation, size of the firm and chartering level of the firm. More specifically, the survey results show that on average more operational measures are being implemented by firms which have a majority of their fleet on time charter in comparison to firms that have a majority of their fleet on voyage charter and that more measures are being implemented by firms in the drybulk sector than in the wetbulk sector. This supports the findings from fixtures analysis that shows the wetbulk sector has the majority of its fleet on voyage charter, and the content analysis findings show that the voyage charter is more prone to the principal agent usage problem, which affects the implementation of operational measures more than technical measures. The survey results also show that the respondents perceive more market failures in comparison to non-market failures as barriers to implementation of operational measures. This perception of barriers differs amongst the implementation of operational measures, with more technical operational measures being affected by informational problems and speed related measures being affected by split incentives. These findings suggest that the principal agent problem can be a plausible explanation for some of the energy efficiency gap in the implementation of operational measures in the shipping charter markets.

Acknowledgements

In the name of God, the most beneficent and the most merciful.

This research has been made possible with the support of numerous people to whom the author wishes express his sincere gratitude. First of all I would like to thank my esteemed supervisors, Dr. Tristan Smith, Prof. Paul Wrobel and Dr. Mark Barrett. Tristan's insightful comments, guidance and encouragement throughout the process have been invaluable. Special thanks Dr. Megan McMichael who had been instrumental in enabling me to understand better about the methods for gathering evidence and designing the survey.

I would like to thank the LCS consortium members for giving constructive feedback in the technical boards and Lloyds Register for making available the funding for this PhD. Thanks also goes to all those who took part in the research.

I am extremely grateful to my wife Sajida for her unflinching support and the extensive help in getting those survey responses, as well as reading the thesis drafts despite being drowned with many commitments, not to mention taking care of our beloved daughter Saniye Zahra (may her departed soul be a source of continuous blessing for us). It would not have been possible without you, dearest Sajida. I am thankful to my uncle and aunty (foster parents) who have always been committed to giving me the best education and discipline and my family members for their support. Sincere thanks to Capt. Habibi, who has been a beacon for this PhD and my career. I would not give justice to this work if I fail to mention the true inspiration derived from Imam Ali (Peace be upon him) and the diverse qualities that emanate from him especially that of seeking knowledge and Imam Muhammad Al-Baqir and Jaffer As-Sadiq for their contributions to science and philosophy. Some of Imam Ali's guiding maxims were:

"The man of knowledge is the one who recognizes that what is known is very little compared to what is not known, and as a result he considers himself ignorant, and accordingly he increases his efforts to know more by going out in search of knowledge"

"There is no knowledge and science like pondering and thought; and there is no prosperity and advancement like knowledge and science"

Table of contents

List of figures

List of tables

1. Introduction

This chapter introduces shipping's current and future greenhouse gas (GHG) emissions. Thereafter, the rationale for investigating barriers to energy efficiency in this research is discussed. Common concepts in energy efficiency economics are introduced with a view to linking general barriers literature to shipping. This is followed by a discussion of energy efficiency in shipping as a strategy towards low carbon shipping and reducing the GHG emissions. The last section of this chapter provides a brief overview of the following chapters in the thesis.

1.1. Shipping greenhouse gas emissions

Reducing global greenhouse gas (GHG) emissions by 50-80% below 1990 levels by 2050 is necessary to stabilise the climate and avoid dangerous climate change impacts (IPCC 2007). To avoid dangerous climate change, all the sectors of the global economy will be required to lower their GHG emissions. The shipping sector, through its exhaust emissions, is a major contributing source of several greenhouse gases and non-greenhouse gases. Of the GHG's, the most important is carbon dioxide (CO_2), because of the quantity that is emitted and the global warming potential. Other GHG emissions include methane (CH_4), Nitrous oxide (N_2O), Hydroflourocarbons (HFC's), Flourocarbons (PFC's) and Sulfur hexafluoride (SF_6). The shipping sector is also a major source of non-greenhouse gas emissions such as Nitrogen Oxides (NO_2), Sulphur Dioxides (SO_2) and particulate matter (PM). The focus of this research is on GHG's and specifically CO_2 emissions.

1.1.1. Baseline GHG emissions

Since there is no real monitoring of CO_2 emissions in the industry, there are two key ways of estimating CO_2 emissions, based on top down fuel sales estimates or bottom up activity based estimates. The top-down approach is where the ship emissions are based on bunker fuel sales allocated to specific ports/regions and countries, whereas the bottom up approach uses an activity based model to estimate fuel consumption consisting of assumptions of operational profiles, trading patterns etc., which are collected from different sources. The carbon emissions of the industry can be expressed as the product of transport demand (measured in tonne miles) and supply side represented by emissions intensity of the transport supply (gCO_2/t.nm i.e. grams of CO_2 emitted per tonne mile). Using the fuel sales method has its limitations with respect to coverage, consistency of reporting and accuracy in various parts of the world, which presents a risk of errors and under-reporting in fuel statistics (Buhaug et al. 2009). Similarly, the limitations of a bottom up approach to estimating fuel consumption are that it relies on various assumptions about the efficiency of different ship types and activity levels of ships. The result is that estimates from both these approaches vary by over 50%, making it difficult to estimate baseline CO_2 emissions for shipping.

The global transport sector emissions represent around 13% of global CO_2 emissions, of which total shipping CO_2 emissions (from international and domestic shipping) accounted for over 3% (1 Giga tonnes) of global CO_2 emissions in 2007 (Buhaug et al. 2009). Various studies suggest that this estimate can be as low as 2% or as high as 4% of global CO_2 emissions. Figure 1.1 depicts the share of GHG emissions from shipping.

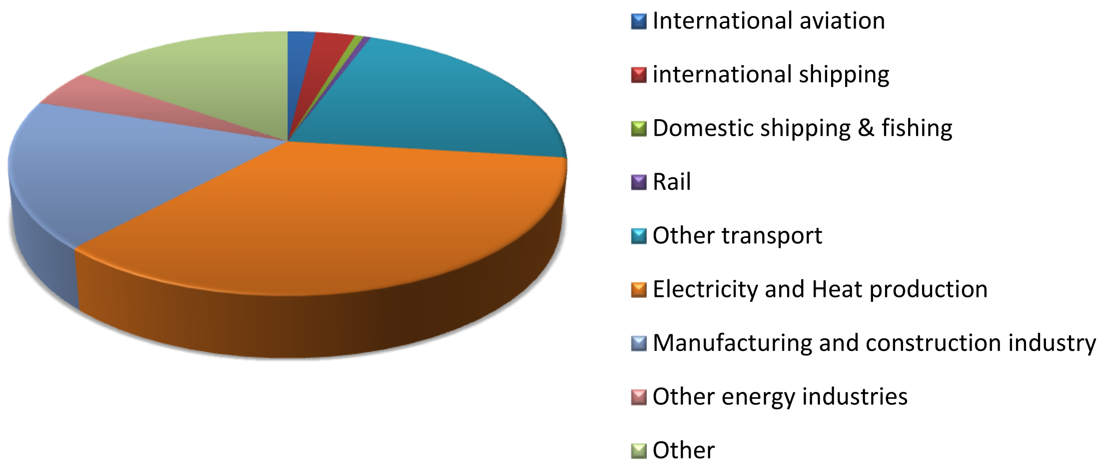


Figure 1.1 Share of international and domestic shipping emissions
Source: Buhaug et al. (2009)

1.1.2. Future GHG emissions

Looking at the historic relationship of global Gross Domestic Product (GDP) and shipping activity, there seems to be a very high correlation between the two (Stopford 2008), thus GDP can be used as an indicator to some extent for estimating demand for future shipping activity, although more recently the trend between the two shows signs of decoupling. At an annual GDP growth rate of around 3-4%, it is estimated that shipping's emissions share will grow by one and half to three times under the business-as-usual scenario (compared to emissions in 2007) by 2050, if the industry is left uncontrolled and in the absence of policies (Buhaug et al. 2009) as shown in Figure 1.2. Moreover, as all other sectors decarbonise, shipping's future CO_2 emissions will represent an even larger share of global CO_2 emissions (Gilbert, Bows & Starkey 2010), estimated to be around 25% of the global CO_2 emissions (CCC 2011).

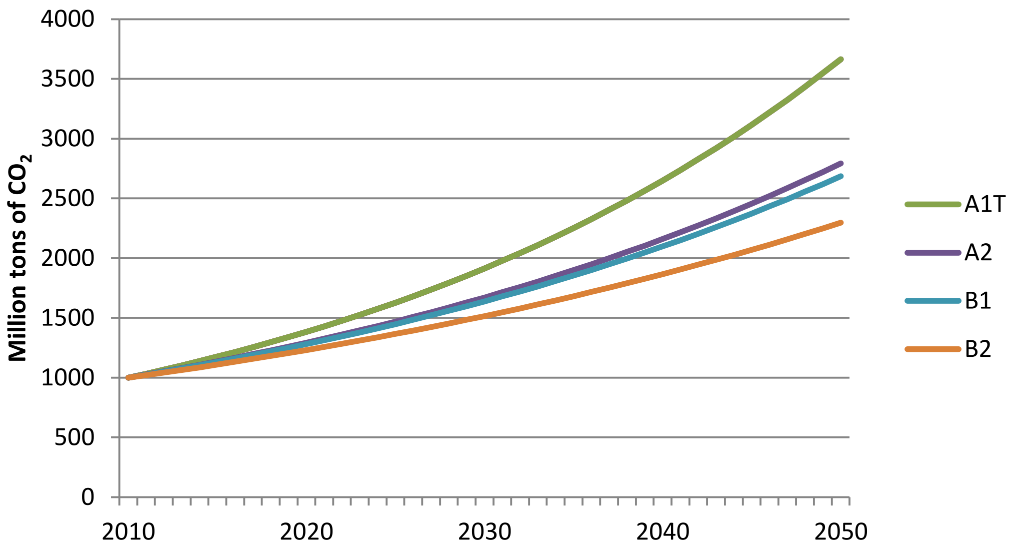


Figure 1.2: International shipping emissions based on IPCC SRES Scenarios
Source: Buhaug et al. (2009)

1.1.3. Regulatory and political context for regulating global CO_2 emissions

Under the Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC), GHG emissions from shipping and aviation have been left to the designated UN agencies, the International Maritime Organisation (IMO) and International Civil Aviation Authority (ICAO), respectively. The IMO under MARPOL Annex VI introduced a mandatory design based energy efficiency standard, called the Energy Efficiency Design Index (EEDI) for all newly built ships built from 2013 onwards. The EEDI (an example of a command and control instrument for environmental regulation) sets mandatory reduction targets, measured in gCO_2/t.nm (as explained earlier in section 1.1.1) when the ship is built, which get tightened every five years up until 2030 and can be said to be driving supply side efficiency. The amendment also introduced the Ship Energy Efficiency Management Plan (SEEMP) which is no more than a requirement to have on-board a vessel a plan to improve operational efficiency.

Negotiations on market based measures (either tax or emissions trading) to curb CO_2 emissions at the IMO level have been hampered due to ineffective ways of reconciling the often conflicting principles of the IMO of 'no more favourable treatment' (NMFT) and UNFCCC 'common but differentiated responsibilities' (CBDR). Non annex I nations argue strongly against a uniform maritime scheme, as it would not fulfil the UNFCCC principle. At the same time, the difficulty in negotiating a global scheme is exacerbated because of the way shipping operations are organised. A ship is a territorial extension of the country whose flag it flies and must be registered to a certain flag (i.e. country) in order to operate and be governed by the rules of that state. However, because the ship is a moveable entity, it is relatively easy to change legal jurisdiction by registering to a flag of choice (often called flag of convenience, that provides benefits such as tax, low compliance to safety and lack of enforcement) resulting in lower costs of operation (as shown below in Figure 1.3). For these reasons attribution of bunker fuels and CO_2 emissions to a specific nation is very problematic (SBSTA 1999; CSC & WWF 2011).

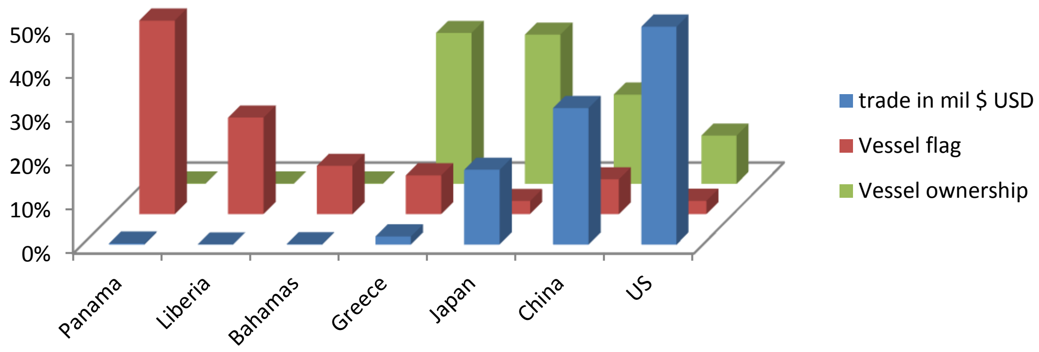


Figure 1.3: Vessel registration, ownership and trade.
Source: McCollum, Gould & Greene (2009)

Due to the stalemate in international agreements that will deal with the rising level of CO_2 emissions from shipping, both the European Union (EU) and UK have considered unilateral action. The EU after deciding not to incorporate shipping emissions into its EU wide emissions trading scheme (EU ETS) is pursuing mandatory monitoring reporting and verification (MRV) of CO_2 emissions from all ships that trade within the EU from 2015. With respect to the UK's position, emissions from aviation and shipping are not currently included in the carbon budgets, however the UK parliament is due to give its decision imminently on whether to include aviation and shipping in its carbon budgets. Part of the reason for non-inclusion is due to various ways of apportioning the share of UK shipping emissions, e.g. based on fuel sales, based on activity, GDP, cargo ownership etc., which result in substantial differences between the apportionment methods (Smith & O'Keefe 2012; Smith, O'Keefe & Haji 2013b).

1.2. Rationale for investigating barriers to energy efficiency

On the supply side i.e. affecting energy intensity (gCO_2/t.nm) there are four options available to reduce emissions from shipping (Buhaug et al. 2009); improving energy efficiency i.e. increasing productivity using the same amount of energy, using renewable energy sources (e.g. solar and wind), using fuels with lower carbon content (e.g. liquid natural gas and biofuels) and using emission reduction technologies (e.g. through chemical conversion, capture and storage). The EU, UK and the

IMO believe there is a need and potential for greater energy efficiency (option one above) to lead the shipping industry towards a low carbon future. The UK government through its Engineering and Physical Sciences Research Council (EPSRC) in 2009 funded the 'Low Carbon Shipping – A Systems Approach' and tasked it to specifically address implementation barriers to low carbon shipping. Previously the UK government, through the Department for Transport (DfT) and Committee on Climate Change (CCC) tasked AEA (Hobson et al. 2007; Kollamthodi et al. 2008) to investigate key barriers to uptake of low carbon technologies. The reasons for the interest in barriers to energy efficiency are that it enables policy makers to develop policies which would overcome such barriers and secondly barriers may directly be affecting a policy's effectiveness.

At the EU level, after having conducted several impact studies for unilateral action on shipping market based measures (Faber et al. 2009; Kollamthodi et al. 2013); the EU also recently completed its assessment of market barriers to cost-effective measures (Maddox Consulting 2012). It is important to note that the focus was, unlike UK government, on negative or low marginal abatement cost opportunities (i.e. fuel savings would exceed the cost of implementing the measures) which include technical and operational measures. The EU and IMO impact studies as well as others (Wang et al. 2010; DNV 2009) identified several measures that could be implemented at current fuel prices (at around $650 per MT). The IMO in its second GHG study identified design and operational measures that could result in between 25-75% in CO_2 savings per tonne mile. The study clearly states that a "considerable proportion of the abatement potential appears to be cost-effective at present. However non-financial barriers (costs, lack of incentives and other barriers) may currently limit the adoption of measures" (Buhaug et al. 2009, p11). Lack of incentives is suggested to be an important barrier and is also found in the terms of references (criteria for evaluation) of the IMO market based measures (MBM) expert group feasibility study (IMO 2010a), which sought to evaluate several MBM's with respect to them incentivising the right stakeholder in the shipping system. Therefore the analysis of barriers to energy efficiency (which can also be seen as opportunities for CO_2 reduction) are important for the ongoing debate of MBM's at IMO level. Criteria three (IMO 2010b) for MBM is that "the proposed MBM's potential to provide incentives to technological change and innovation – and the accommodation of current emission reduction and energy efficiency technologies". An understanding of incentivisation of stakeholders is important in order to understand why cost-effective energy efficiency measures are not being implemented. The United Nations Environment Program (UNEP 2006; UNEP 2011) also considers addressing barriers to energy efficiency to be fundamental in closing the future emissions gap.

Lately, there has also been increased interest from non-governmental organisations (NGO's) in shipping's CO_2 abatement potential. The Carbon War Room with other industry partners have joined efforts to improve uptake of cost-effective measures by targeting the lack of information and financial or capital barriers. Meanwhile, the World Wildlife Fund (WWF) and Forum for the Future launched the Sustainable Shipping Initiative (SSI) and believe that the financing of energy efficient ships needs to overcome the split incentives that separate key decisions from their financial, environmental and social consequences (FFF 2011). Research outputs (directly and indirectly) from this study have helped both these initiatives.

Having recognized the role and potential of shipping from a climate perspective and having identified the need to investigate barriers to energy efficiency in shipping, this research aims to ascertain the implementation of energy efficiency measures and to improve the understanding of the lack of uptake of energy efficiency measures in shipping through multidisciplinary research methods. Section 2.5.2 delves further into the details of the aims of this research.

1.3. Common concepts from barriers to energy efficiency literature

The above sections highlighted the need for energy efficiency as a strategy in tackling rising CO_2 emissions and avoiding dangerous climate change. Despite the substantial abatement potential at negative costs, several studies across different sectors have empirically shown that cost-effective energy efficiency measures are not always implemented, see for example (Velthuijsen 1993; Gillissen & Opschoor 1994; Harris 2000; Sorrell et al. 2000; Sorrell et al. 2004; de Groot, Verhoef & Nijkamp 2001; UNEP 2006; Zilahy 2004; Rohdin, Thollander & Solding 2007; Sardianou 2008; Thollander & Ottosson 2008; Schleich & Grubber 2008; Schleich 2009; Hasanbeigi, Menke & du Pont 2009; Trianni et al. 2012; Shi et al. 2008).

The barriers debate has gained momentum since the 1980's with the first bibliographical account of barriers by York et al. (1978) followed by empirical research by Blumstein et al. (1980) which is then followed by a host of literature e.g. (Fisher & Rothkopf 1989; Hirst & Brown 1990; Howarth & Andersson 1993; Howarth, Haddad & Paton 2000; Howarth & Winslow 1994; Brown 2001; Sorrell et al. 2000; Sorrell et al. 2004; Golove & Eto 1996; Thollander, Palm & Rohdin 2010). A barrier may be defined as a postulated mechanism that inhibits investment in technologies that are both energy efficient and economically efficient (Sorrell et al. 2000). An energy efficient measure is a measure by which the same amount of productivity is achieved by using less energy, whereas a cost-effective (economically efficient) measure is a measure whereby the costs of implementing a measure are outweighed by future returns of the measure. Therefore an energy efficient cost-effective measure could be defined as one that produces the same output with less energy and the savings in energy enable it to pay for itself (i.e. results in net profit, positive net present value). This is an important clarification in the barriers debate (Golove & Eto 1996). According to Sweeney (1993) energy efficiency investments should only be promoted if they improve economic efficiency or increase net social welfare as shown in Table 1.1.

	Decreases energy intensity	**Increases energy intensity**
Increases economic efficiency	Energy efficiency	Energy enhanced progress
Decreases economic efficiency	Not promoted	Rejected as undesirable

Table 1.1: Energy efficiency versus economic efficiency
Source: Golove and Eto (1996)

1.3.1. The energy efficiency gap

The term 'energy efficiency gap' refers to the difference between the actual lower levels of implementation of energy efficiency measures and the higher level that would appear to be cost-beneficial or cost-effective from the consumers or firms point of view based on techno-economic analysis (definition derived by combining Brown (2001) and Golove and Eto (1996)). Therefore there are two issues to consider, firstly obtaining actual levels of implementation, and second is the estimation of level of uptake based on the techno-economic analysis. Some of the energy efficiency gap can be explained by rational behaviour to market barriers that may not be captured by the techno-economic analysis. If these can be accurately modelled then the remaining energy efficiency gap can be explained by market failures, as shown in Table 1.2 and Figure 1.4.

	Explains energy efficiency gap	**Doesn't explain energy efficiency gap**
Barriers that are market failures	• Public good attributes of information • Positive externalities of technology adoption • Asymmetric information leading to problems of adverse selection, moral hazard and split incentives	• Distortions in energy pricing • Environmental externalities
Barriers that are not market failures	• Hidden costs • Reduced product performance • Option value of delaying investment	

Table 1.2: Barriers and orthodox economic theory that explain the energy efficiency gap
Source: Sorrell et al. (2004)

Whilst the above provides a useful starting point and a framework to investigate barriers, Sorrell et al. (2004) suggest introducing transaction costs and more realistic representation of the decision making process to explain the energy efficiency gap.

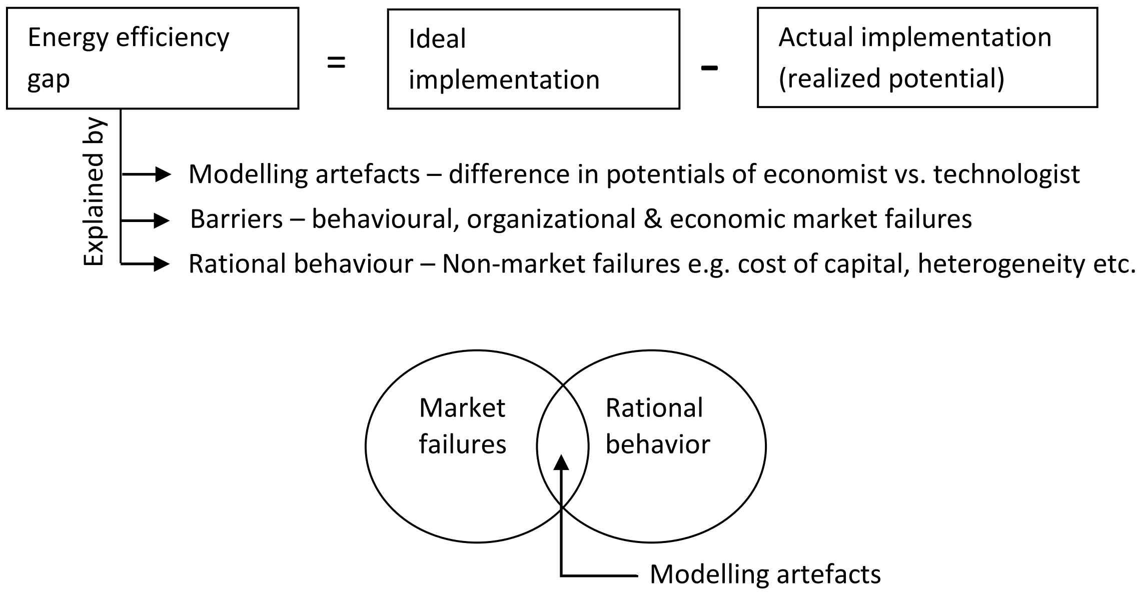


Figure 1.4: Explaining the energy efficiency gap

The scope and focus of this research is less on market barriers and more on market failures that can explain the energy efficiency gap. According to Brown (2001) market barriers are obstacles that are not based on market failures but nonetheless contribute to the slow diffusion and adoption of energy efficient measures. They can therefore be called non-market failures, which are defined as "where the organisation is behaving rationally given the risk adjusted rate of return on an investment in the existing context of energy, capital and unavoidable 'hidden' costs" (Sorrell et al. 2004, p.33). These are real features of the decision making environment, albeit ones which are difficult to incorporate in engineering-economic modelling (Sorrell et al. 2000). A market failure occurs when the requirements for efficient or optimal allocation of resources through well-functioning markets are violated, which leads to incomplete markets, imperfect competition, imperfect and asymmetric information (Sorrell et al. 2000). The latter two are more important and relevant in the context of explaining the energy efficiency gap (Sorrell et al. 2004). In other words market failures occur when there are flaws in the way a market operates (Brown 2001). The important distinction between general market barriers (or non-market failures) and market failures is to do with the legitimacy of policy intervention to rectify market failures (Sorrell et al. 2004; Thollander and Palm 2013).

It should be noted however, that the above classification of barriers is not entirely accurate (Thollander and Ottosson 2008). According to Weber (1997) barriers are "unobservable" and it is "empirically impossible" to find the true reason for lack of action (Weber 1997, p. 834). Moreover, Blumstein (1980) suggests that the causes of barriers are often interlinked and follow a causal chain, citing an example of commercial building operators initially lacking information on conservation measures and about their site energy use, which is further exacerbated by misplaced incentives. Nonetheless, Sorrell et al. (2000 and 2004) provide a useful framework for investigating barriers to energy efficiency by categorising them as organisational, behavioural and economic as shown in Figure 1.5.

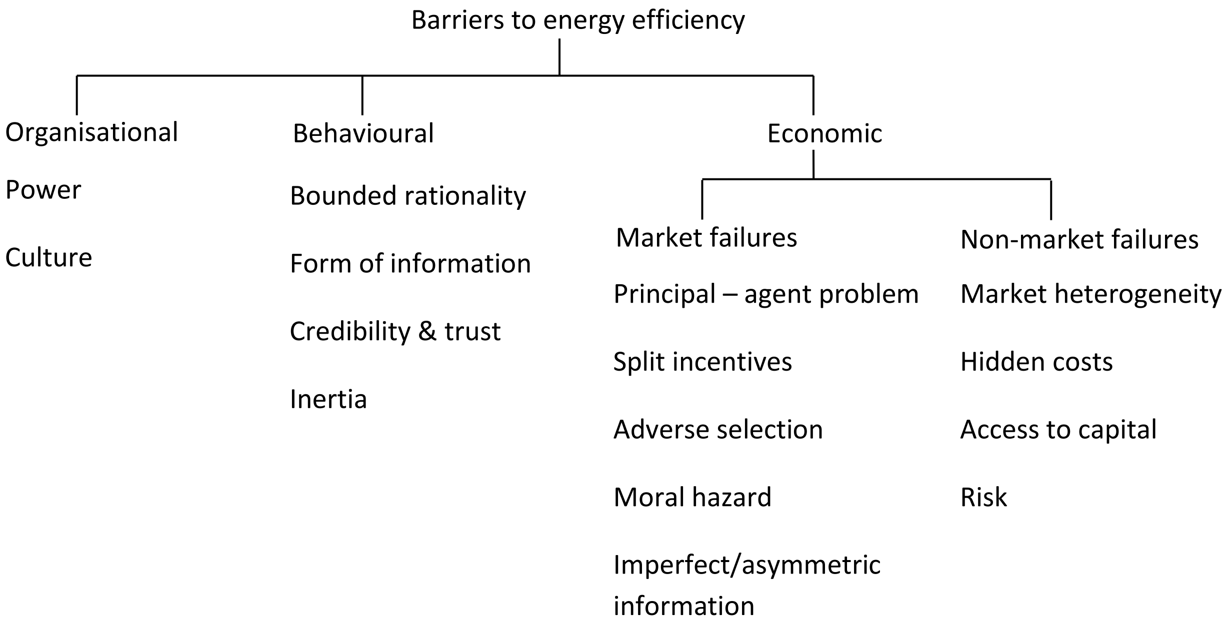


Figure 1.5: Classification of barriers to energy efficiency

1.3.2. Analysis of shipping abatement potential

A common method of calculating the techno-economic potential of CO_2 reducing measures and the order in which they may be adopted is through marginal abatement cost curves (MACC). A MACC presents measures to reduce CO_2 emissions in the order of their cost-effectiveness, which is calculated using the net present value (NPV) cost per tonne of the carbon reduction measure against the amount of carbon saved. A negative marginal abatement cost means that a measure can be implemented at a net profit to the individual/firm, i.e. to reduce one tonne of CO_2 the firm/individual pays zero costs. MACC's are increasingly being used as a tool in the decision making of climate policies. According to Gunningham, Grabosky and Sinclair (1998) several instruments are available to internalise the cost of environmental externalities such as air pollution. The way these correspond to the measures shown on MACC's has been discussed by Kesicki (2010) as shown in

Figure 1.6. MACC's have been produced for several sectors and most feature measures that can be implemented at negative costs.

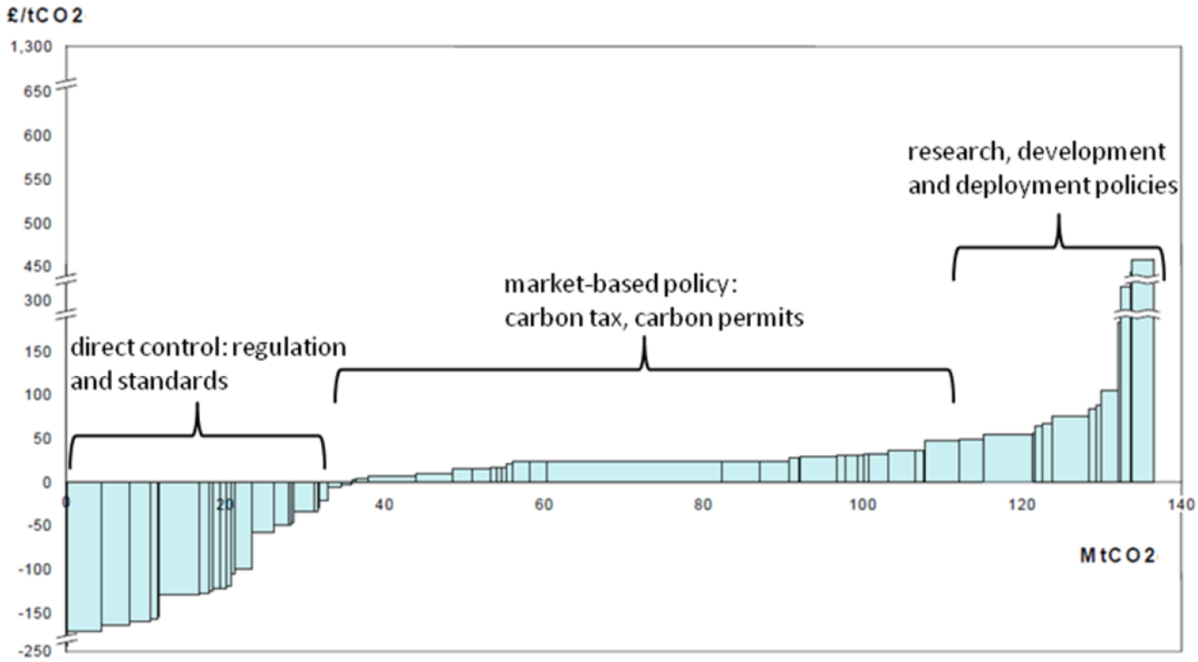


Figure 1.6: Marginal abatement cost curves with relevant instruments
Source: Kesicki (2010)

1.4. Energy efficiency measures in shipping

Shipping as a freight transport mode is considered to be the most energy efficient, with the lowest CO_2 emissions per unit of transport work (cargo carried over distance, t.nm), compared to air, road and rail (Buhaug et al. 2009). The emissions intensity has improved significantly over the 20th century, but remained stagnant over the last decade (Buhaug et al. 2009). If a ship is able to improve its energy efficiency it will result in lower fuel bills and direct CO_2 emission reductions, resulting in a win-win situation. It is suggested that fuel costs in shipping generally account for between 50-70% of a ships operating costs, which is set to increase as Heavy Fuel Oil (HFO) costs increase, so there is an even greater incentive towards energy efficiency in shipping. More than fifty measures (Buhaug et al. 2009; Wang et al. 2010) have been identified that could result in efficiency gains and they are generally grouped as technical measures (some applicable to new ships and some to existing ships) and operational measures. These measures along with their abatement potentials have also been presented in several shipping specific MACC's (Buhaug et al. 2009, Faber et al. 2009; DNV 2009; Eide et al. 2009; Wang et al. 2010). Once again these shipping specific MACC's show that several measures especially operational measures can be implemented at negative costs as shown in Figure 1.7.

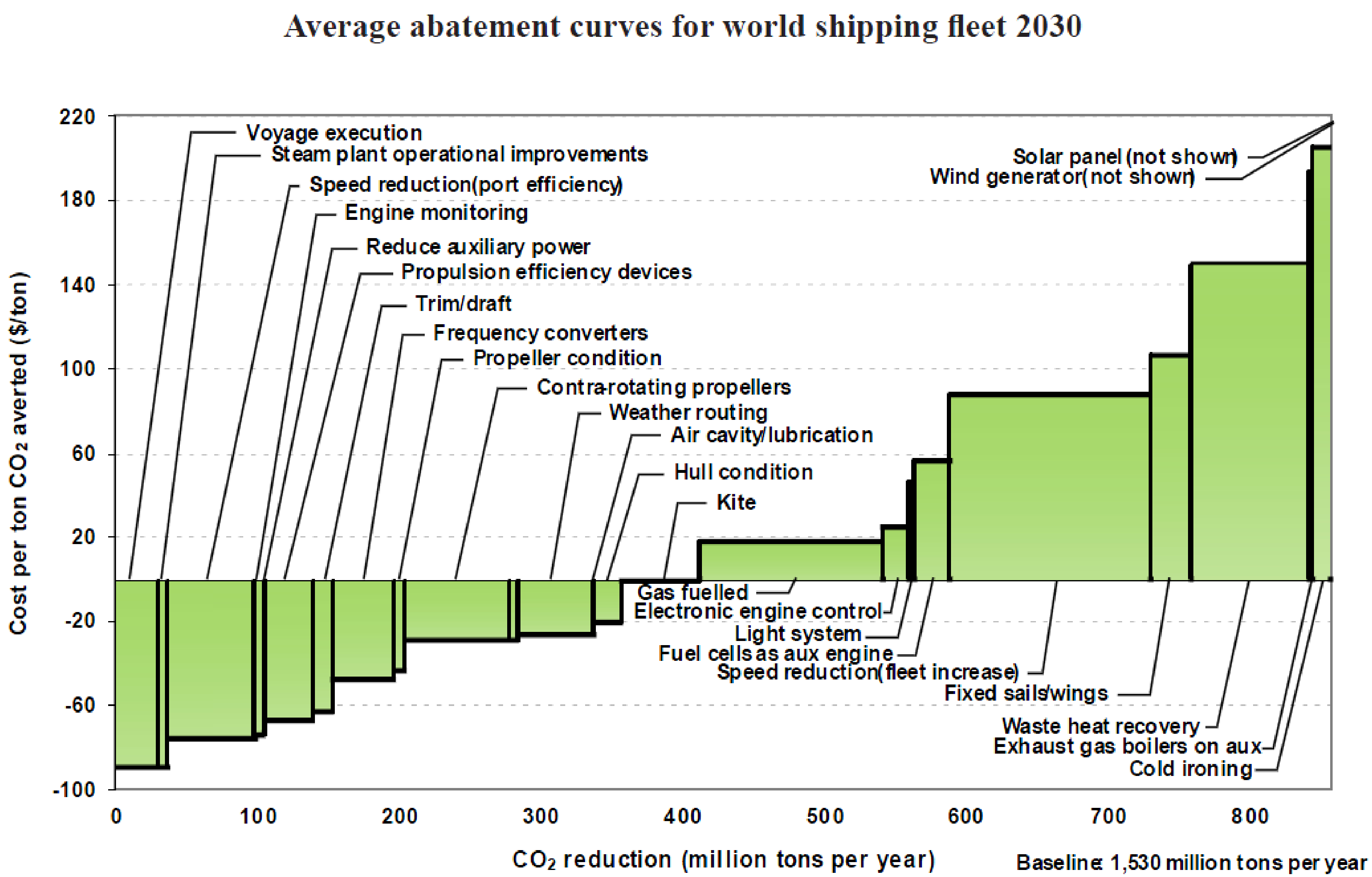


Figure 1.7: MACC for shipping for the year 2030
Source: DNV (2009)

Note that EEDI (which is an example of command and control instrument) is employed to drive uptake of technical measures that are mainly at positive cost, which is in contrast to what is proposed by Kesicki (2010) as shown in Figure 1.6. It is clear from the figure above that several operational measures (shown in blue in Figure 1.8) that can be implemented at negative costs are being neglected perhaps due to institutional barriers (Wang et al. 2010). It is suggested that one of the reasons for not pursuing policies to do with operations is because of the contractual arrangements that have traditionally existed in shipping. For example in the case of speed reduction, the IMO considers it to be one of the best practice measures that should be incorporated in the SEEMP but also recognises that under many charterparties (contracts) the speed of the vessel is determined by the charterer and not the operator (IMO 2009), thus the optimum operational speed may rarely be achieved due to the contractual arrangements that exist within the industry. On the other hand where fuel bill and speed are controlled by the shipowner-operator, and when there are high demurrage rates (cost payable by charterer for additional time a ship spends at ports) there are "incentives for the shipowner to sail at high speed to arrive as early as possible. The net result may be low flexibility for efficient operation and, in the worst cases, incentives for inefficient operation" (Buhaug et al. 2009, p64).

There are two basic forms of contracts (charterparties) for carriage of goods with which the shipowner-operators and charterers contract, namely the voyage charter and time charter. There are other types of contracts but they are not contracts for carriage of goods, for example the bareboat charter is a lease of the vessel to the charterer. Other hybrid forms of charters also exist but they can be reclassified as either voyage or time charter due to the similarities in the cost allocation, examples of these are trip charters which fall into time charter category despite the contract being for a single voyage and Contracts of Affreightment (COA) which fall into the voyage charter category despite the time element (Wilson 2010). The voyage and time charters are of different lengths ranging from days to years, which allocate or divide the responsibility for capital and running costs (including fuel costs) between a shipowner-operator and charterer as shown in Table 1.3. The result of this divided responsibility for costs is that both parties would have diverging or conflicting interests to minimise their share of costs according to the charter arrangements used and that shipowners may not always be in a position to recoup the investment in energy efficiency (Faber et al. 2009).

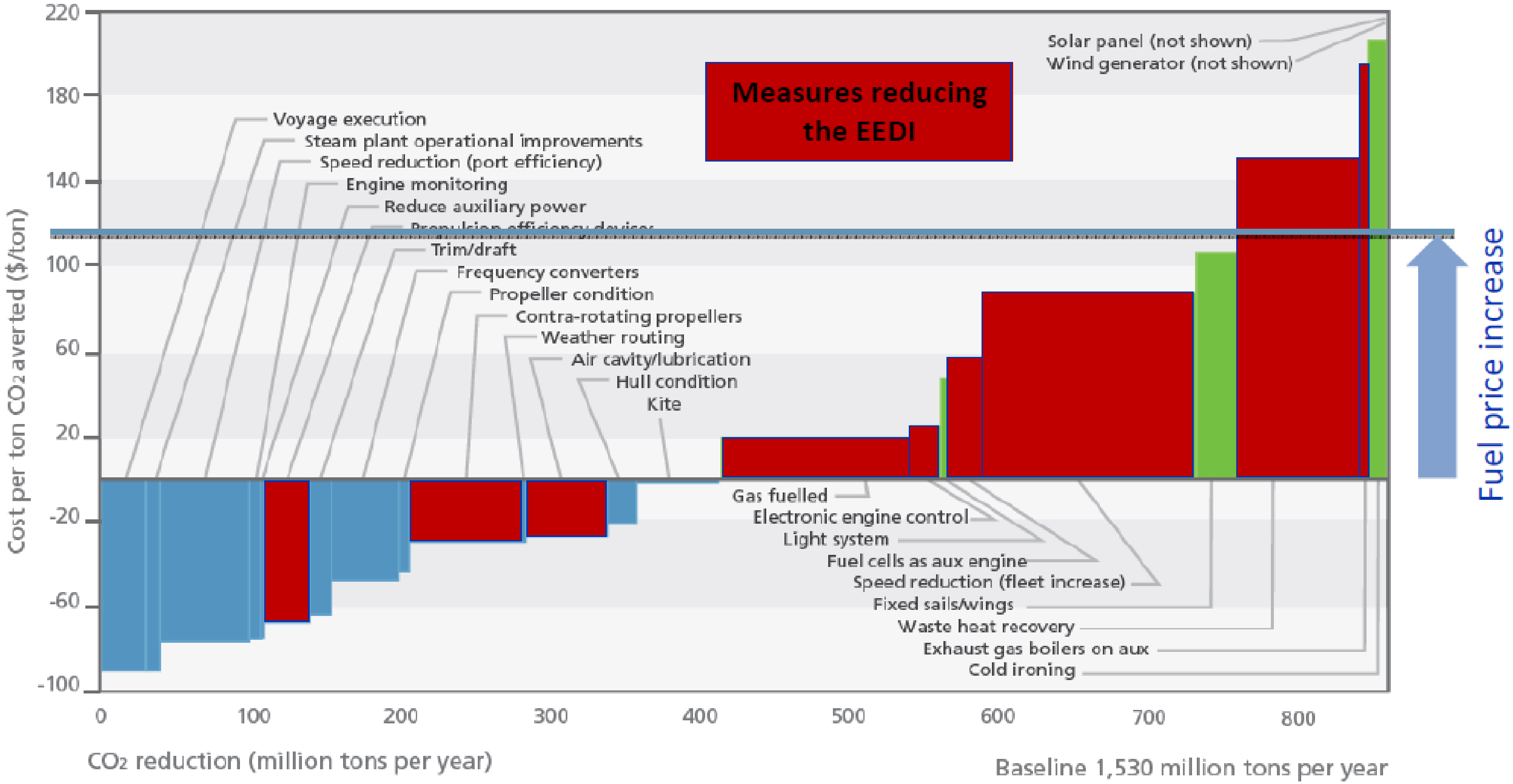


Figure 1.8: Measures targeted by the EEDI
Source: Longva (2011)

Cost element	**Voyage charter** $/tonne	**Time charter** $/day
Cargo Handling	**Charterer**	
Voyage Expenses		
Operating expense	Owner	
Capital costs		

Table 1.3: Cost allocation in the different types of charter

It is important to note that there isn't a clear classification/taxonomy of measures. Operational measures can be more technical (referred to as techno-operational measures such as trim/draft optimisation, autopilot adjustment), some operational measures are more related to maintenance measures (such as hull and propeller polishing) and some can be voyage related (such as speed reduction). For the barriers discussion it is first essential to identify the measures which show sizeable fuel saving potential and are shown to be cost-effective. Below is a brief description of most of the operational measures and their fuel saving potential as estimated from various industry based literature. Note that fuel savings would vary considerably across different ship types and operational assumptions. Also much of the saving potential given by Buhaug et al. (2009) and Wang et al. (2010) is derived from Wärtsilä (2008) (Large engine manufacturer and technical service provider) product catalogue, which could bring into question the figures. Lockley et al. (2011) is an industry guide on energy efficiency technology and energy service providers that assesses fuel savings claims through verification from shipowner-operators. DNV (2010) is a classification society's (similar to auditing company) account of fuel savings potential for energy efficiency measures based on expertise in the sector.

1) *Weather routing:* Weather routing is a measure whereby a vessel's master is given information on prevailing weather conditions towards the destination, which should result in reduction of travel time or avoiding rough weather conditions, both leading to lower fuel consumption. There are weather routing services available that help to optimize the route a ship takes, given the corresponding weather conditions. A significant portion of the world's fleet already employs this measure (Faber, Behrends & Nelissen 2011), but for different reasons: some companies use it for safety purposes (passage planning), some charterers use it to monitor ship performance and guarantees by owners (speed and fuel consumption) but few use it for the purpose of saving fuel. The fuel saving potential from this measure is unassessed (Faber et al. 2009), however fuel

savings reported from Fathom (2011), DNV (2010), Wang et al. (2010), Buhaug et al. (2009) are around 0.1 - 4%.

2) *Autopilot upgrade/adjustment*: The ships autopilot is used to maintain a steady course. “Adjusting the autopilot for the route and the operation area prevents unnecessary use of the rudder for keeping the ship on course” (Wang et al. 2010). The fuel saving potential from this measure as reported from Fathom (2011), DNV (2010), Wang et al. (2010), Buhaug et al. (2009) are around 1.5%.

3) *General speed reduction:* Speed reduction is a measure whereby ships reduce their power requirement and hence their fuel consumption. Speed reduction in the industry has a range of interpretations which differ according to the stakeholders, most commonly this measure is known as slow steaming, optimal steaming and speed optimisation. There are different levels of speed reduction leading to a range of potential savings, which will be attractive for different stakeholders over time. As a rule of thumb, power requirement is related to ship speed by a third power function. This means that a 10% reduction in speed results in an approximate 27% reduction in power requirements.

4) *Fuel consumption monitoring:* Several forms of monitoring exist from the most basic tank soundings to accurate fuel flow meters providing real time monitoring of energy consumption. Fuel saving potential of this measure is unassessed.

5) *Trim/draft optimisation*: A vessel’s hull is designed and optimized for the fully loaded condition, therefore the trim that is optimal for a vessel under the different conditions would vary. 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. There are also other ship specific and voyage related factors that also contribute towards optimal trim. In order to compute the effect of these variables, software packages/decision support systems can analyse and facilitate counter measures. Fuel savings are gained by a reduction of extra ballast water. The fuel saving potential for this measure varies considerably across the sources but is in the range of 3%-10%.

6) *Speed reduction due to port efficiency – Just In Time arrivals:* Current contracting process through the use of standard voyage charterparty clauses stipulates that vessels proceed at utmost despatch towards a port, regardless of the prevailing conditions at that port. Therefore conditions that affect the berthing of the vessel such as temporary congestion or lack of cargo space (quay side, oil tank space, etc.) are simply ignored in the current system. It therefore

becomes wasteful for a vessel to steam at full speed only to then wait at anchor for a berth or storage space to become available. Industry initiatives such as the Virtual Arrival (OCIMF & INTERTANKO 2010) therefore shifts the port waiting time into extra sailing time, resulting in fuel cost savings from speed reduction. This measure is reliant on port infrastructure because ports need to be able to secure a vessel's place in a queue without it actually being there and since most ports operate a first come first serve (FCFS) queuing system, the measure's potential has been limited. Fuel saving potential from this should be similar to general speed reduction, but Wang et al. (2010) quote savings of 10% and Buhaug et al. (2009) quote savings of 1%.

7) *Raising crew awareness & energy efficiency training:* Improving energy awareness of crew through training and correct incentives can lead to energy demand reduction on-board ships. There is good scope for reducing CO_2 emissions by making changes to on-board crewing processes, such as through creation of incentive structures, focussed guidelines, etc. Several shipping firms have already begun incentivising crews by paying bonuses based on fuel savings (Sustainable Shipping News 2012a). The fuel saving potential is unknown.

8) *Efficient voyage execution – Voyage planning & DWT utilisation:* For various reasons (such as contractual and tramp operations) ships often do operate without fully making use of their cargo loading capacity. In principle fuel consumption would increase for that voyage but, it should result in lower fuel consumption per cargo/mass transported. The abatement potential for this measure is unknown.

9) *Optimisation of ballast voyages – speed reduction:* Generally there are some routes and ship types that perform round trips between two ports, with one laden leg and one ballast return leg. On some routes and ship types the ratio of ballast voyages is lower. Where there is a high ratio of ballast voyages reducing speed in the ballast voyages when not bound by charterparty speed limits, can result in similar savings as general speed reduction.

10) *Hull and propeller maintenance:* Maintaining the hull surface and propeller surface of a vessel reduces the frictional drag that is caused by biofouling (accumulation of organic materials). There are two types of intervention; based on regular intervals over a period of time or through monitoring (mainly for propeller maintenance). The fuel savings potential of this measure is high considered to be between 2% - 10% based on Buhaug et al. (2009) and Wang et al. (2010).

1.4.1. Speed reduction measures

General speed reduction is considered to have the highest impact on energy efficiency (Faber et al., 2009), therefore this section will deliberate briefly on the measure and the following chapters will add details. Based on the rule of thumb, a 10% reduction in speed results in nearly 30% reduction of power requirements. However this rule ignores that a slower ship would require more time to complete the same amount of transport work. According to Wang et al. (2010) a ship sailing 10% slower would use approximately 11% more time. Taking this into account, a new rule of thumb can be stated that "per tonne mile, there is a quadratic relation between speed and fuel consumption, so that a 10% decrease in speed would result in 19% reduction in power" (Wang et al. 2010, p45). The effect of this is illustrated in Figure 1.9 for three different ship types. There are different levels of speed reductions leading to a range of potential savings, which will be attractive for different stakeholders over time as shown in Figure 1.10.

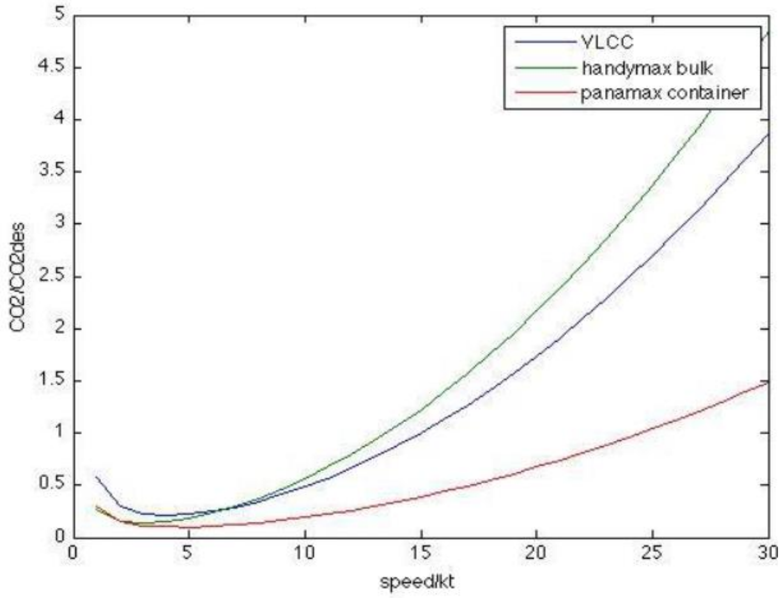


Figure 1.9: Relationship between speed and CO_2 for various ship types
Source: Smith, Parker and Rehmatulla (2011)

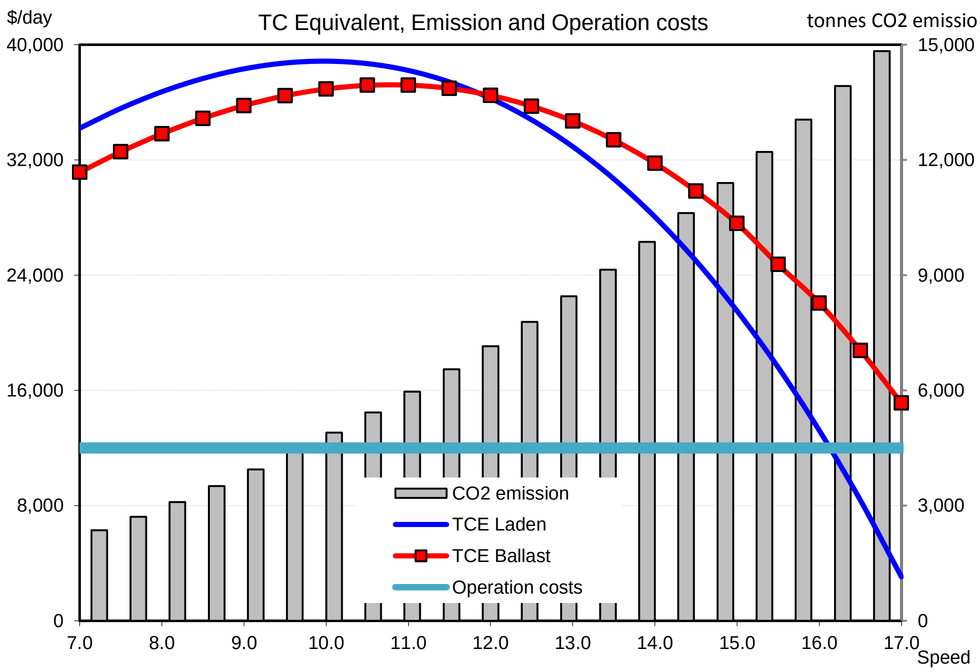


Figure 1.10: Interaction between speed and profit function
Source: INTERTANKO (2012)

1.5. Thesis structure

The thesis follows the chapter outline below;

- *Chapter 2 – Barriers to energy efficiency:* This chapter provides a review of literature on agency theory in general and in the context of energy efficiency. Empirical research on barriers to energy efficiency in general and in shipping is investigated. The chapter concludes with gaps in literature, formulation of research questions and hypothesis.
- *Chapter 3 – Approaches to gathering evidence*: This chapter provides a discussion and evaluation of the research strategy, research design, research methods and data collection mode choices for this research.
- *Chapter 4* – This chapter delves further into the details of the design and implementation of the data collection methods that have been selected to answer the research questions.
- *Chapter 5 – Decomposing the structure of shipping:* This chapter uses the principal agent theory in the context of energy efficiency and applies it to the shipping sector using secondary data.
- *Chapter 6 –Survey results and preliminary analysis:* This chapter presents the findings of the self-administered online questionnaire on implementation of energy efficient operational measures and factors affecting their implementation. The chapter is mainly focussed on the univariate analysis of the survey data.

- *Chapter 7 – Further analysis of survey data:* This chapter examines the survey data using a specific approach to analysis, using the bivariate elaboration model to investigate key relationships between variables of interest.
- *Chapter 8 – Charterparty content analysis:* This chapter combines the content analysis method and the general principal agent theory framework to examine the contracts between the principal and the agent in the shipping industry.
- *Chapter 9 – Discussion:* This chapter triangulates the findings from the various strands of research to explain implementation of energy efficient operational measures and barriers to their uptake. The chapter attempts to answer the research questions and hypothesis by connecting the findings together and analysing them in the context of literature and theory.

2. Barriers to energy efficiency

This chapter provides a review of the literature on agency theory in general and in the context of energy efficiency. Empirical research on barriers to energy efficiency in general and in shipping is investigated and the chapter concludes with gaps in literature, formulation of research questions and hypothesis.

2.1. Role of agency theory in understanding barriers to energy efficiency

Generally and more commonly barriers to energy efficiency are discussed in the context of economic theories. There are several theories within orthodox or neo-classical economics and other extensions of these that can be used to understand and explain barriers to energy efficiency. These theories have existed since the beginning of this century, whilst the barriers to energy efficiency discussion began in the early 80's. It is important to discuss neo-classical economics as much of agency theory is nested on it, and the tenets of the theory itself have been extracted for discussion of barriers to energy efficiency.

2.1.1. Orthodox economics and agency theory

Orthodox or neo-classical economic theory is characterised by the use of mathematical models, calculus, an emphasis on formal modelling and focus on relative prices (Sorrell et al. 2004). The core assumptions of this theory are that (adapted from Sorrell et al. 2004):

- It is based on individuals or unitary actors/agents
- Allocation of resources to attain equilibrium
- Utility and profit maximising behaviour
- Stable and constant preferences
- Ability to solve complex problems instantly at no cost.

The above assumptions will become important in the discussion to barriers to energy efficiency, where for example actors are assumed to be boundedly rational, costs and marginal costs of obtaining information and transactions impede savings etc. Under the neo-classical economic theory, the allocation of resources should lead to Pareto efficiency, where no one can be made better off without making someone else worse off. Market failures under the orthodox perspective occur when the conditions required for Pareto efficiency are violated and result in (Sorrell et al. 2004):

- Incomplete property rights
- Positive and negative externalities

- Imperfect competition
- Asymmetric information

Once again the above conditions for market failures under orthodox perspective are highlighted here in order to understand the barriers to energy efficiency, which are broadly categorised as market barriers (non-market failures) and market failures (Brown. 2001).

Within the context of barriers to energy efficiency, agency theory has been utilised to explain some of the market failures (Levinson & Neimann 2003; Murtishaw & Sathaye 2006; Prindle et al. 2006; IEA 2007; Graus & Worrel 2008; Gillingham, Harding & Rapson 2011; Vernon & Meier 2012). The tenets of agency theory lie under the orthodox economics perspective; hence it was important to understand the assumptions of orthodox perspective earlier, which permeate some of the assumptions of agency theory. The theory is directed at the ubiquitous agency relationship, in which one party (the principal) delegates work to another (the agent), who performs that work (Ross 1986, cited by Eisenhardt 1989) or when one individual depends on the action of another (Pratt & Zeckhauser 1985). According to leading authors on this subject, Jensen & Meckling (1976) describe the agency relationship as:

"Agency relationship is a contract under which one or more persons (the principal) engage another person (the agent) to perform some service on their behalf, which involves delegating some decision making authority to the agent" Jensen and Meckling (1976, p. 308)

From the perspective of the stakeholders involved in shipping, the shipowner and the charterer can be seen as being in an agency relationship, where the principal, the charterer hires the shipowner as an agent to provide service of carrying goods from A to B. This agency relationship is expanded upon in chapter five of this thesis, where the different types of contracts are analysed. Agency theory has expanded the literature that originally discussed only the risk sharing between parties (e.g. Arrow 1971). The theory aims to resolve two key agency problems that occur as a result of this relationship:

- Problem 1: The desires or the goals of the principal and agent conflict (split incentives problem)
- Problems 2: It is difficult or expensive to verify the agent's actions (informational problem)

The unit of analysis is the contract that governs the relationship between the parties, with the objective of the most efficient contract given the above problems. This research attempts to understand both the above problems and the unit of analysis (i.e. contracts) from barriers to energy efficiency perspective. It therefore becomes important to review the theory and its assumptions in its general form first, followed by its application to the barriers discussion. The below assumptions of agency theory are further discussed in chapter five and eight in the context of specific contractual barriers in shipping.

2.1.1.1. Overview and assumptions of the general form of agency theory

Key idea	Principal agent relationships should reflect efficient organisation of information and risk bearing costs
Unit of analysis	Contract between principal and agent
Human assumptions	Self interest, bounded rationality, risk aversion
Organisational assumptions	Partial goal conflict among participants, efficiency as the effectiveness criterion, Information asymmetry between principal agent
Information assumption	Information as a purchasable commodity
Contracting problem	Moral hazard, adverse selection, risk sharing
Source of problem	Contract is inadequate
Implications of inefficient contract	Adverse selection, moral hazard, split incentives

Table 2.1: Overview and assumptions of agency theory
Adapted from Eisenhardt (1989) and Sharma (1997)

2.1.1.2. Positivist and principal agent research for examining contracts

Agency theory has been applied in several fields from political science to marketing and organisational behaviour (Eisenhardt 1989) and has developed along two lines of enquiry by researchers: positivist type research and principal agent type research (Jensen 1983; cited by Eisenhardt 1989), which share a common unit of analysis (the contract) and assumption outlined earlier, however the research differs in three key areas; mathematical rigour, dependent variables and style (Eisenhardt 1989). This section addresses which type of enquiry will be followed within this research and how it is appropriate in answering the research questions that follow. Positivist type researchers have focussed on identifying situations of agency problems, leading to agency costs (e.g. costs of monitoring, costs of incentivising for alignment of goals) and then describing the solutions that limit agency problems, in a less mathematically rigorous way. Much of this type of research has focussed almost exclusively (Eisenhardt 1989) on the principal agent relationship between owners and managers of large public corporations (organisational behaviour/economics), (see for example Ahimud & Lev 1981; Walking & Long 1984; Wolfson 1985; Argawal & Mandelker 1987). On the other hand principal agent type researchers apply the assumptions rigorously, followed by logical deduction and mathematical proof. The result of the different types is that under the positivist type research some contract alternatives or propositions can be identified, whereas the principal agent type research indicates which contract is most efficient or optimal under varying levels of outcome uncertainty, risk aversion levels, information etc., resulting in many more alternatives or propositions. This research presented here is primarily focussed on the positivist type research, thus is an extension of owner-manager (organisational) relationships applied to shipowner-charterer relationships (chapters five, six and seven) but also draws upon some of the propositions of the principal agent type research (chapter eight) with the aim that a combination of the two will improve understanding of the relevant barriers and required type of contracts.

2.1.1.3. Examples of applications of agency theory

Agency theory has been used and applied extensively by both positivist and principal agent type researchers. Most frequently the theory has been applied in the organisational context e.g. compensation, acquisitions, managerial relationships, ownership and financing, etc. in large organisations, of which some examples are outlined below.

Ahimud and Lev (1981) sampled 500 firms to test managerial attitudes to mergers as a strategy of risk diversification and found that conglomerate mergers occur in strong managerial control as opposed to firms with strong owner control, thus supporting agency theory. Walking and Long (1984) come to the same conclusion when testing the managerial welfare hypothesis in the context of resisting takeover bids in a sample of 95 cash tender offers. Their results provide "substantial evidence that the decision to contest a tender offer is conditioned on personal wealth changes" (Walking and Long 1984, p. 67). These were examples of positivist type research. Eisenhardt (1988) is an example of principal agent type research, where she compared use of salary (behaviour based) and commission (outcome based) compensation predicted by job programmability, span of control and outcome uncertainty (key assumptions of agency theory) and found that agency theory provided a good indication (80% correctly identified) of compensation policies actually used. Other examples that empirically examined agency theory are Walker & Weber (1984) on vertical integration, Eccles (1985) on transfer pricing, Cotter & Zenner (1994) on tender offers, Baker, Jensen & Murphy (1988) on executive compensation, etc. Apart from the numerous applications of agency theory in the organisational context, the theory has been applied in positivist type research in different contexts, where assumptions of neo-classical economics may not hold (e.g. profit maximising, self-interested) such as politics and policies (Neil & Morris 2012; Lane 2005), human justice systems (Songer, Segal & Cameron 1994), etc. Section 2.3 of this chapter discusses the application of agency theory in the context of barriers to energy efficiency; however the taxonomy followed is slightly modified to what has been discussed so far. Positivist type research is referred to as qualitative research and quantification of principal agent problem is seen as an extension of positivist type research. There is very little known application of principal agent type research to barriers to energy efficiency.

2.1.1.4. Supposed shortcomings of agency theory

Agency theory has been criticised for being too narrow and having very few testable propositions, resulting in assumptions that make it unrealistic (Perrow 1986) and focussing only on very few dependent variables (e.g. stock price, mergers etc.) (Hirsch & Friedman 1986). Agency theory only presents a partial view of the world and ignores much of the complexity that can be found in organisations and other theories (Eisenhardt 1989). Sorrell et al. (2004) suggest that agency theory lacks consistency and is based on complex and highly formalised mathematical models. Since agency theory is rooted in the neo-classical economics perspectives, it becomes very easy to pick and select those assumptions it is based upon and argue against those. However, one should bear in mind that agency theory has been founded on previous theories of opportunism, information and risk within organisations. Therefore the strength of the theory is that it leverages upon these three fundamental concepts, to define a problem structure that is applicable to a wide variety of transactions (Sharma 1997). The theory has spawned a large volume of conceptual work that flesh out its basic assumptions as well as research that has empirically examined its testable implications in a variety of situations (Sharma 1997). Eisenhardt (1989) based on the above criticisms recommends that the application of agency theory should be expanded to richer contexts (e.g. where there may be a continuum of compensation rather than a simple dichotomy of compensation i.e. salary or commission), that multiple theories that are complementary be used and to look beyond economics where there is better payoff (e.g. empirical research). It is hoped that this research will take into account these recommendations by firstly applying it in the shipping sector and agency problems occurring inter-organisations, rather than within organisations (e.g. owner-manager). Secondly combining agency theory with barriers to energy efficiency it is hoped that complementarity will be achieved and finally use empirical research to examine these theories. It is also important to bear in mind where agency theory adds to the general barriers theory and its position and relationship with other theories that also add to the barriers debate as shown in Figure 2.1.

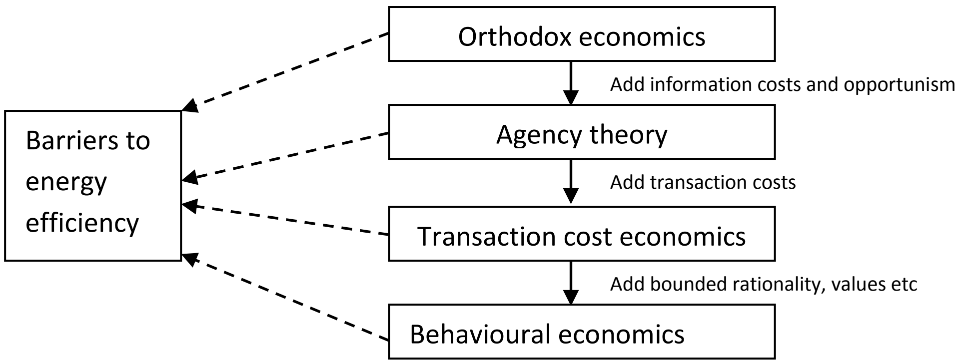


Figure 2.1: Various perspectives in understanding barriers to energy efficiency
Source: Adapted from Sorrell et al. (2004).

2.2. Literature review of studies on market barriers and market failures

2.2.1. Discussion of market barriers and market failures in shipping

As highlighted in chapter one, there exist many opportunities to improve the energy efficiency of new and existing ships through technical and operational measures, some of which at negative costs (i.e. profitable) at current fuel prices. Failure to realise this potential could be attributed to various market barriers and failures, resulting in an energy efficiency gap. Having examined agency theory in detail, this section is a discussion of market barriers and market failures literature combined with agency theory. The result from the referenced analyses in shipping has so far been the identification of substantial unrealised abatement potential using options that often appear to be cost-negative at current fuel prices. Possible explanations for the unrealised abatement potential are that either:

- Models for analysis are inadequate for representing costs/benefits of low carbon and energy efficiency investment or the data used are incorrect; or
- Other implementation barriers (market barriers and failures) exist which are obstructing the shipping industry's implementation of low carbon

Market failures and non-market failures in general were discussed in 1.3.1. This section briefly examines these in context of shipping, beginning with analysis each of the non-market failures followed by the market failures (as presented in Figure 1.5). Non-market failures are obstacles that contribute to the slow diffusion and adoption of energy efficient measures and where the organisation is behaving rationally given their existence. They include heterogeneity, risk, hidden costs and access to capital, which are discussed in turn below in relation to literature in shipping.

Heterogeneity – although a technology may be cost-effective on average for a class of users taken in aggregate, the class (e.g. panamax container ships, specific routes, commodities), itself, consists of a distribution of owners and operators: some could economically purchase additional efficiency, while others will find the new level of efficiency not cost-effective (Sweeney 1993).

Risk - technologies are assumed incorrectly to be mature or a risk is perceived by the firm that performance may be lower than expected, thus risk premiums and depreciation are not adequately included in the model. Early investors may be sceptical about the prospects of a technology and demand a premium on return in order to cover the risks of the investment (Faber et al. 2009). For example, when commissioning newbuilds if depreciation is faster than expected, due to the adoption of technology i.e. diffusion and lower costs due to the learning curve, the solvency of the company may be threatened. So in some cases a shipowner commissioning a new ship would have to compare the risk of having a ship with an innovative design that may depreciate faster than expected with the risk of having a ship with a conventional design but higher operational costs. In such an assessment, the most fuel efficient ship may not always come out best (Faber et al. 2009).

Hidden costs (these are hidden to the analyst but not the investing firm) - the following costs may not have been included:
Life cycle costs - Hidden costs relating to the energy efficient option's life cycle costs including: identification or search costs, project appraisal costs, commissioning costs, disruption or opportunity costs and additional/specific engineering costs.
Transactional costs – Transaction costs and other unobserved cost items may render apparently cost-effective measures costly. Especially smaller ship owners and operators may experience high transaction costs as they cannot spread the costs of for example gathering information over a large number of ships (Faber et al. 2009).
Commissioning or disruption costs - Some measures to reduce emissions require retrofits that can only be installed by temporarily suspending operations. These measures are very costly to implement except at times when production is halted for other reasons, such as major maintenance of installations. There may therefore be a lag between the time when a measure becomes available and its actual implementation. Retrofits to existing ships such as the installation of wind power, waste heat recovery systems etc. can only be done cost-effectively when a ship undergoes a major overhaul during a drydock. This causes a time-lag of several years in the implementation of cost-effective measures.

Access and costs of capital - Restricted access to capital markets is often considered to be an important barrier to investing in energy efficiency. Investments may not be profitable because companies also face a high price for capital. As a result, only investments yielding an expected return that exceeds this (high) hurdle rate will be realised (Schleich & Grubber 2008). Capital rationing is often used within firms as an allocation means for investments (Bhattacharyya 2011), leading to hurdle rates that are much higher than the cost of capital, especially for small projects (Ross 1986). This leads to competition between projects within a company and may lead to low priority given to energy efficiency (Bhattacharyya 2011). If improving energy efficiency comes at the cost of forgoing other more cost-effective opportunities (because of capital or labour constraints or because the projects are mutually exclusive alternatives), it would be rational for the firm to give energy efficiency a low priority (Faber et al. 2009). As an example, a shipowner-operator currently has to decide between investing in a scrubber technology given the regulations around SOx and NOx emissions or improve the energy efficiency of ships given the increasing fuel price.

If the above non-market failures could be accurately represented as modifications in a model and still show existence of apparent cost-negative options that were not being implemented, one could then draw the conclusion that market failures or other types of barriers existed, these are discussed in turn below.

Split incentives - refer to the potential difficulties that arise when two parties engaged in a contract have different goals and different levels of information (IEA 2007). Split incentives occur when the costs and benefits of energy efficiency accrue to different agents (Blumstein et al. 1980; Fisher & Rothkopf 1989; Howarth & Winslow 1994). In shipping, split incentives are likely to occur due to the different types of charter (and the divided responsibility for fuel costs) existing between shipowners and charterers. Ship owners who invest in fuel efficiency improving measures cannot, in general, recoup their investment, unless they operate their own ships or have long term agreements with charterers, because neither charter rates nor second hand prices of ships reflect the economic benefit of its fuel efficiency (Faber et al. 2009). Charter markets not representing fuel efficiency could be due to the variability of actual fuel use, it may be risky for the ship owner to guarantee a low fuel use and hence the fuel efficiency is not reflected in the charter market (Wang et al. 2010). Similarly in time charter contracts speed may be understated and fuel consumption per day may be overstated (Veenstra & Dalen 2011).

Information problems **-** Accurate and reliable information may be difficult to obtain as those who have information have strategic reasons to manipulate it in order to inflate its value. Sellers advertise and promote their goods by providing information about their own goods. “Self-interest is an incentive for the provision of misinformation by sellers and the costs of acquiring additional information may be high enough to inhibit acquisition of sufficient unbiased information to overcome well-distributed misinformation” (Golove & Eto 1996, p. 20). It has been argued that even when information on energy efficiency is signalled through for example labelling, consumers may still be wary because of past experience with advertised misinformation (Stern & Aronson 1984). EEDI and other indicators of fuel efficiency thus may not increase the transparency in the market and owners of efficient ships may not be able to command higher charter rates (Faber et al. 2009). Informational problems don’t necessarily arise due to agent opportunism, it may well be that one party may have relevant information on the costs and benefits of an energy efficiency investment, but may find this difficult to convey to the other party (Jaffe & Stavins 1994, p. 805). In this case if there were no informational problems, the parties would be able to enter into contracts to share the costs and benefits of the investment. However, sometimes this may be outweighed by the transaction costs involved hence investment is likely to be forgone despite potential advantages to both parties (Sorrell et al. 2004). A solution to this would be to standardise energy savings contracts. As shown in Table 1.2 informational problems also have the characteristics of a public good. This means that "to the extent that this information is known by competitors, the risk associated with the subsequent adoption of this same technology may be reduced, yet the value inherent in this reduced risk cannot be captured by its creator" (Golove & Eto 1996, p. 19).

Apart from the economic market failures and non-market failures, Sorrell et al. (2000) suggest other barrier categories such as behavioural and organisational, which could also be plausible explanations of the unrealised potential in shipping. Behavioural barriers stem from the behavioural science field and explain the energy efficiency gap, for example:

Bounded rationality – Orthodox economics as shown in section 2.1.1 assumes that the decision maker will make rational decisions given the available information. Simon (1959) argues that bounded rationality may result in satisfying behaviour using rules of thumb. So, instead of being based on perfect information, decisions are made by rule of thumb (Stern & Aronson 1984). This is connected to the inability to assess life cycle costs of energy purchasing decisions, the same investment appraisals may be utilised throughout all the different types of investment opportunities including, energy efficiency.

Inertia - means that "individuals and organizations are, in part, creatures of habit and established routines, which may make it difficult to create changes to such behaviours and habits" (Thollander, Palm & Rohdin 2010). People generally do not welcome change in their environments and avoid or ignore problems (Stern & Aronson 1984).

Values **–** implementation of energy efficiency measures is influenced by norms and values in a group or society at large. "Values such as helping others, concern for the environment and a moral commitment to use energy more efficiently are influencing individuals and groups of individuals to adopt energy efficiency measures" (Thollander, Palm & Rohdin 2010, p. 55).

Credibility and trust – This is not only related to the information itself but also the provider of information. As with informational problems, it is also the ability of the provider of information to portray and show these qualities, since the adoption is dependent on the receiver's perceived credibility of and trust in the information provider. The trustworthiness of the information provider is of significant importance, Thollander, Palm & Rohdin (2010) cite an example of householders' implementation of measures when information is provided by state versus the same information being supplied by a utility company. The shipping industry is also subject to this issue of trustworthiness of information regarding savings potentials of energy efficiency measures as shown in section 1.4.

Before proceeding to the next section, it is important to clarify the use of some terms that will follow. When agency theory or agency problem is used it will refer to the general economic theory that aims to create most efficient contracts given the assumptions and problems of the agency relationship. When the term principal agent problems is used, it will refer to application of agency theory to the barriers to energy efficiency, which results in several cases suggesting optimal or sub optimal outcomes for investment in energy efficiency.

2.2.2. Empirical research to investigate barriers and drivers to energy efficiency

To date there have been several studies that have empirically (primary data gathered through various research methods) examined barriers to energy efficiency, which can be classified in three types: regional, sectoral and technology specific, see for example (Velthuijsen 1993; Gillissen & Opschoor 1994; Harris 2000; Sorrell et al. 2000; Sorrell et al. 2004; de Groot, Verhoef & Nijkamp 2001; UNEP 2006; Zilahy 2004; Rohdin, Thollander & Solding 2007; Sardianou 2008) (Thollander & Ottosson 2008; Schleich & Grubber 2008; Schleich 2009; Hasanbeigi, Menke & du Pont 2009; Trianni et al. 2012; Shi et al. 2008) etc. Sorrell, Mallet & Nye (2011) cite sixty four such empirical studies. In this section only a handful of these, that are thought to be related to the shipping industry, are reviewed with the following criteria:

- Methodological rigour for empirical research - strategy, design and methods consideration including mixed methods, sampling (frame and types), validity/errors, instrument design, etc.
- Taxonomy of barriers – categorisation, does it follow economic theory?
- Framework on investigating barriers – does it follow a logical framework?

The problem in the earlier barriers literature has been that the term barriers was not being used in a rigorous manner (Sutherland 1991; cited by Sorrell et al. 2004), therefore it is important to classify barriers based on some established theory e.g. market failures economic theory. One of the earliest empirical studies was by Velthuijsen (1993) who used a mixed method approach (interviews and a self-administered questionnaire) to investigate barriers in the following way:

1. Comparing energy efficiency improvement potential of measures (perceived vs. calculated)
2. Actual implementation of energy efficient measures (actual vs. calculated)
3. Identifying the decision process or criteria for implementation
4. Identifying disturbing factors/barriers (based on perception)

5. Determining price elasticities of energy efficiency and its determinants

The above was the first framework or methodology to investigate barriers in a systematic way. The total number of responses for both methods is seventy and the above provides a valuable approach to determining barriers to energy efficiency in a self-administered questionnaire. It is not known where the sample was recruited from (i.e. sampling frame is unknown). The study makes use of the questionnaire method to find the stated and revealed reactions, by combining qualitative questions with quantitative questions (e.g. opinions or perceptions and actual energy use). The purpose of the mixed method approach in the study is for instrument development (Bryman 2006) although not explicitly stated. One of the drawbacks to this study is that it does not use properly defined barriers or categories, perhaps owing to the relatively little literature on this subject. Respondents are given only seven broad categories of barriers for each measure such as 'energy bill is too small thus no priority is accorded to energy efficiency', 'lack of knowledge', 'budgetary constraints', etc. Nonetheless, the results elucidate the energy efficiency gap and indicate quantitatively the level of impact of barriers that contribute to the gap. Gillissen and Opschoor (1994) follow the above phased approach (only phases one to four) in their empirical analysis of the potential influential factors and barriers among 300 Dutch firms through the use of self-administered questionnaires. Once again they also explain implementation by correlation with observed firm specific variables and secondly by analysing the perception of barriers. In the first question regarding implementation they restrict the number of technologies to just six, perhaps due to limitations of the modelling approach that is used to calculate sector specific technology potentials. This suggests that the above phased methodology is helpful in determining the energy efficiency gap, barriers and determinants to energy efficiency, although the categorisation of barriers itself may not be grounded on a theoretical basis. Sorrell, Mallet & Nye (2011) conduct a meta-analysis of all the energy efficiency barrier related studies (empirical and grey literature, academic and non-academic) and conclude that these studies:

"Classified barriers in a variety of overlapping and often inconsistent ways, with most of them conceptualizing barriers from the viewpoint of the industrial firms rather than economic theory. Also, several of the studies are methodologically weak and/or include factors that do not qualify as barriers under our definition" (Sorrell, Mallet & Nye 2011, p. 58).

Various studies have used different classification or taxonomy for various barriers. Table 2.2 below shows just some of these classifications for categorising barriers to energy efficiency.

Classification	Source
• Market failures • Market barriers	Brown (2001)
• Economic: Market failures and non-market failures • Behavioural • Organisational	Sorrell et al. (2004)
• Management knowledge or information • Finance • Policy	UNEP (2006)
• Prices • Financing • Trade and environment • Market structure • Institutional frameworks • Information provision • Social, cultural, behavioural and norms	Sathaye et al. (2001)

Table 2.2: Classification of barriers in literature

Rohdin, Thollander & Solding (2007) draw on the taxonomy of barriers as developed by Sorrell et al. (2000). A mixed method approach is used that utilises focus groups (qualitative strategy) with the high level management of the Swedish foundry industry, to investigate major barriers and drivers to energy efficiency. This is then followed by a self-administered e-mail questionnaire (quantitative strategy) which seeks to assess the perception of barriers and driving forces for implementation of energy efficient measures. The email survey is sent out to fifty nine association members resulting in twenty eight responses, 47% response rate, and a very low response rate for other small companies which are consequently removed from the analysis. This brings into question the validity of the research and whether there is systematic bias in the results but also suggests that targeting large organisations is important because of their share in energy consumption and their having resources to contribute towards research. The study starts with assessing the implementation (phase two) followed by phase three and four (driving forces replace decision criteria phase used by previous studies but is not too dissimilar). Examples of drivers are long term strategy, third party financing, competition etc. Limited access to capital and risk were the highest barriers to energy efficiency perceived by the respondents.

Hasanbeigi, Menke & du Pont (2009) carry out a regional specific study to investigate barriers and drivers in two Thai industrial sectors, combining two research methods, the self-administered postal questionnaire followed by case study interviews, a mixed methods approach with the aim of complementarity and expansion. The sampling methods used in the survey have however brought several concerns over the representativeness of the sample, which could result in coverage and sampling errors. For example postal questionnaire was only sent to textile companies that were members of the Textile Club of Institute of Industrial Energy, resulting in further biases due to their membership of energy related club. The response rate achieved from this sample was around 50%. For the cement industry the postal questionnaire was sent directly to the six cement companies (accounting for the largest share of production capacity), of which only three responded. This method is similar to the probability proportionate to size (PPS) sampling method. The study assumes the energy efficiency gap therefore there are no questions in the questionnaire asking respondents on implementation of measures. The questionnaire is mainly focussed on the barriers and drivers stage (three and four) and policies to overcome those barriers. Ratings on barriers are based on a five-point Likert scale, enabling means of barriers to be calculated for analysis. The Likert scale has repeatedly been used in these studies, suggesting that it is a useful instrument to capture the attitudes and perceptions of respondents on implementation of measures, barriers and drivers to energy efficiency. So far, many studies have used interviews as a research method, but rarely have these been applied to the same type of respondents i.e. the companies who undertake the questionnaire for example, instead interviews seem to be with a wide variety of other stakeholders in the system of the company. This is also the case in Hasanbeigi, Menke & du Pont (2009), where all of the interviews are with governmental departments, federations and consultancies.

Sardinaou (2008) conducted empirical analysis based on face to face interviews using a questionnaire (structured interviews) of fifty out of 779 industrial Greek industrial firms (6.5% response rate) over a one year period. The questionnaire follows the structure that has been used in the aforementioned studies, i.e. contains firm specific questions or variables and perception of barriers, however it does not follow the methodology employed by previously mentioned studies. Moreover the classification or taxonomy of barriers is inconsistent with that which has been developed thus far (e.g. by Sorrell et al. (2000, 2004), Thollander and Palm (2012), etc.) although they broadly fall in those categories e.g. difficulty in keeping proper records of energy consumption and lack of knowhow, would be classified as informational barriers. Nevertheless, this breakdown is perhaps an effort to make the taxonomy of barriers specific to the respondents, however if this was the case, it is envisaged that they would be regrouped for analysis after the survey had taken place. The taxonomy employed thus makes it difficult to interpret some of the results. Generally the results showed significant variation of perception of barriers between sectors and size of the firms. Hidden costs and access to capital were the most cited barriers by the respondents.

Thollander & Ottosson (2008) use the self-administered questionnaire research method to conduct a survey of the Swedish pulp and paper industry. The study received a good response rate of 68% (forty out fifty nine companies responded). There are several factors that contributed to such a high response rate. The study used the taxonomy developed by Sorrell et al. (2000) and their questionnaire was based on a simplified methodology as presented above. For example in order to determine the energy efficiency gap by asking and then comparing energy efficiency potentials of respondents and theoretical, and actual versus theoretical/modelled implementation, they simply ask whether the respondent believes that there exist cost-effective measures within their organisations. There is also evidence that the study has carefully evaluated the research method and executed it with precision. For example, only for the second time in barriers literature references such as Yin (1994) and Bryman (2006) are cited, who are regarded as leading authorities in the social research methods. Another example is a carefully targeted postal mail to the company energy managers, however its unknown as to what exactly was the process that was followed for example for invitation, follow ups etc. Not only did they use Sorrell et al. (2000) barriers taxonomy but also developed on the driving forces taxonomy established by Rohdin et al (2007), that is later also used by Hasanbeigi et al. (2009). It is important to take note of the drivers or opportunities to energy efficiency which have been defined as opposite of barriers, different types of factors that stress investment in technologies that are both energy and cost efficient (Thollander & Ottosson 2008). Table 2.3 identifies the growing literature on drivers to energy efficiency.

Sorrell et al. (2000, 2004) use the structured interviewing method, case studies and postal questionnaire (differed according to sector and country) to investigate four sectors for a host of barriers to energy efficiency. The response rates to postal questionnaire were 31% and 53% in the sectors where this method was used. The barriers taxonomy is derived from different branches of economic theory; orthodox and agency perspectives combined with transaction cost economics and behavioural economics and this is one of the first empirical studies to do this. The methodology varies from sector to sector. For each sector a short list of technologies for energy efficiency is created. Respondents are asked using a rating scale of agreement on the range of efficiency measures with payback of less than four years. Thereafter, respondents are asked to rate (on a numbered scale) the extent to which the energy efficient technologies had been adopted, thus resulting in mean implementation rates, which are converted into percentages. Following this, respondents are asked to rate (on a numbered scale) their perceptions on barriers to energy efficiency in general (not specific to the measure), which have been disaggregated from the main taxonomy, for example indicators for capital barriers were: other priorities for capital investment, adherence to capital budgeting, lack of capital. The perception of barriers is then used to see if there are significant differences among classes of respondents e.g. by size. This research method is then complemented by case study interviews generally of around five to seven companies or institutions for triangulation of results and analysis.

Category	**Driver**
Market related driving forces	• Cost reduction resulting from lower energy use • Rising energy prices • International competition • Third party financing (ESCO's)
Policy related driving forces	• Price on emissions • Obligations • Rebates • Codes and standards • Subsidies
Behavioural & organisational	• Green image • Corporate social responsibility • Personnel • Visions and strategy

Table 2.3: Drivers to energy efficiency
Source: Thollander and Ottosson (2008)

Harris (2000) surveyed 100 Australian firms that participated in the part government funded audit program (Enterprise Energy Audit Program) in order to investigate whether recommendations from the audit had been implemented (i.e. actual levels of uptake), how were decisions made on implementation and why recommendations were ignored or not taken up. The paper explains in detail how the survey questions were developed and how they sought to answer the main questions. The paper demonstrates a well thought sampling strategy (stratified sampling based on industry), design and planning. Implementation rate is based on number of recommendations of the audit (average of around six per firm) and measures actually implemented at the time of survey (average of five per firm), resulting in an implementation rate of 80%. Generally through the survey, scale questions are used to identify justification on implementation, decision rules and perception on barriers. Some of the findings suggest market barriers that explain the energy efficiency gap but do not find market failures as main barriers to implementation. For example, the most widely used decision making rule was the payback period, almost half of the respondents did not implement a measure because of long payback periods. Interestingly the implementation rates did not differ between firms that leased their premises and firms that owned their premises, suggesting that the principal agent problem did not exist in this case, perhaps due to the medium to long length of the leases, which were on average around five years. Secondly, it may be that the survey over represented the firms that own their premises (88% owned all or part of the premises).

An alternative approach to assessing barriers empirically, is to apply econometric analysis to the empirically obtained data, for example Berchling & Smith (1994), Scott (1997), de Groot, Verhoef & Nijkamp (2001), Shcleich and Gruber (2006) etc. The above methodology is also followed by de Groot, Verhoef & Nijkamp (2001) who use a mail questionnaire to obtain 135 responses (4.2% response rate) from various Dutch companies across several sectors. This is then followed by econometric analysis (mainly regressions) used to determine how investment attitude, barriers to investment and responsiveness to policy intervention varied with firm characteristics and sector. Schleich and Gruber (2008) perform econometric analysis on data that is derived from a separate survey of German companies through the use of interviews conducted of nearly 3000 companies across twenty sectors. The interviews loosely followed the above methodology from step two to three. The first set of questions asked which of the energy saving measures (general and sector specific) had been implemented in the organisation. This was then followed by respondents being asked to judge the relevance of potential barriers to energy efficiency in general (rather than technology specific barriers) i.e. perception of barriers. The implementation rate is calculated based on the number of cost-effective measures implemented as a % of total cost-effective measures. It is important to note the different approaches that have been used so far to calculate implementation rates.

2.2.2.1. Conclusions from review of empirical studies literature

The above empirical studies show that a wide variety of social research methods, especially the use of self-administered questionnaires and interviews have been combined and can be helpful in determining the barriers to energy efficiency and perception of barriers to energy efficiency, when conducted with a good phased methodology that governs when the methods are used and how each instrument within the research method is to be deployed. For example, use and position of rating scales and respondent demographics (instruments) etc. within the research method. Moreover, most of the studies reviewed here have used a mixed methods approach (combining qualitative and quantitative methods) for various reasons such as triangulation, complementarity, instrument development etc. (discussed in section 3.2 in the next chapter). Most studies have used the self-administered questionnaire method followed by interview method, with three studies combing these methods, suggesting that these methods are applicable to barriers to energy efficiency research and thus could be potential methods that could be used within this research. Table 2.5 below summarises the methods used by the aforementioned studies.

Study	**Method for calculating implementation rates**
Velthuijsen (1993)	Asking respondents: • Views on own efficiency vs. sector average. • Technologies suggested actually known by the firm, to derive % • Technologies suggested actually implemented by the firm, to derive %
Gillissen and Opschoor (1994)	Asking respondents: • Technologies suggested actually known by the firm, to derive % • Technologies suggested actually implemented by the firm, to derive % • technology is considered profitable, to derive %
Harris et al. (2000)	Asking respondents: • Number of measures implemented from energy audit recommendation
Schleich and Gruber (2008)	Asking respondents: • Technologies suggested actually implemented by the firm, to derive % • Split above into groups of active (greater than or equal to 50%)
Rohdin et al (2007)	Do not calculate implementation rates, only look at whether cost efficient measures existed or not, to derive % and assume energy efficiency gap
Sordinaou (2008)	Do not calculate implementation rates, assume energy efficiency gap
Thollander & Ottosson (2008)	Do not calculate implementation rates, assume energy efficiency gap
Sorrell et al. (2000, 2004)	Asking respondents: • To rate technologies on a rating scale to show level of implementation, to derive mean implementation.

Table 2.4: Methods for calculating implementation rates or energy efficiency gap

It was also observed that response rates to these studies have been generally low even when the studies lasted for nearly a year (e.g. Sardinaou, 2008). The methodological rigour of many of the aforementioned studies simply either lacked reporting or was neglected. As Sorrell et al. (2011) conclude:

"Several of the studies are methodologically weak and/or include factors that do not qualify as barriers under our definition" Sorrell et al. (2011, p.58)

This has made it difficult for some of the studies to make broader generalisations of the population from the sample. It suggests that the research strategy, design, methods and sampling will need to be carefully designed and implemented if a good response rate is to be achieved. This will be discussed in the following chapter and strategies that are used to ensure a good response rates and valid generalizable results.

Depending on the methodology, some of the studies assume that an energy efficiency gap exists and focus their discussion on barriers and drivers to energy efficiency, whereas some studies start from before this, take a step back to calculate the implementation rates of the ideal versus actual, to postulate an energy efficiency gap. Those studies that do use the latter approach have used different ways to calculate implementation rates. However this approach could result in respondent burden, which explains the differences in the level of response rates achieved by the two types. All the above studies acknowledged the fact that the research methods which will be used will enable 'perception' of barriers to be understood, which is then compared with firm specific indicators such as size, energy use, energy investment as a proportion of total investments. Only in some studies do the firm specific indicators actually contribute towards a barrier itself.

Many of the pre 2000 studies used a taxonomy of barriers that lacked consistency, usually overlapped and were not derived directly from economic theory. Some authors incorporated this in their studies, whereas some simply ignored or argued against such narrow classification, suggesting that actual barriers encountered do not fit neatly into one of the above classifications (Blumstein, 1980; Chai & Yeo 2012). In this research it was felt that economic and theoretical background will enable a better understanding and provide testable hypothesis in order to support or reject the barriers to energy efficiency theory in shipping.

Finally, all of the above studies point toward a wide range of barriers that are inhibiting the uptake of energy efficiency measures, which suggests heterogeneity of the firms and sectors under investigation, implying that the shipping sector would also be susceptible to a wide variety of barriers. Most of the studies (regional and sector specific) above have focussed on the industrial sector, mainly energy intensive production (shipping is not dissimilar to these, in terms of the share of energy costs as total of all the operating costs) and some studies intentionally focussed on non-energy intensive sectors such as commercial (banking etc.) and yet found that barriers to energy efficiency were inhibiting uptake of energy efficiency measures. The above conclusions and lessons are helpful in directing this research, from formulating the research questions to development of empirical research methods. The following section looks at empirical studies on barriers to energy efficiency studies in shipping.

Study	**Interviews**	**Survey**	**Focus groups**	**Mixed methods**	**Econometric analysis**
Velthuijsen (1993)	✓	✓		✓	
Gillissen and Opschoor (1994)		✓			
Harris et al. (2000)		✓			
De Groot et al (2001)					✓
Schleich and Gruber (2008)					✓
Rohdin et al (2007)		✓	✓	✓	
Sordinaou (2008)	✓				
Hassanbeigi et al. (2009)	✓	✓		✓	
Thollander and Ottosson (2008)		✓			
Sorrell et al. (2000, 2004)	✓	✓		✓	
% of studies used	40%	70%	10%	40%	20%

Table 2.5: Methods used by empirical studies

2.2.3. Empirical research to investigate barriers to energy efficiency in shipping

To date there have been relatively fewer empirical studies that have investigated barriers to energy efficiency in shipping. Much of the literature on this subject is grey literature (unpublished and mainly industry reports), thus can hardly be found via conventional channels such as journals. The criteria to assess these studies are same as outlined above. One of the first empirical studies on this subject is by Gordon (2008) an MSc study that uses an online questionnaire to identify barriers to five specific energy efficiency measures (four technical and one operational) and obtains seventy responses (response rate is not mentioned). The barriers are not specific to the measures but rather generic and don't follow any established barriers taxonomy that existed at the time. The survey asks respondents their perception on barriers, potential to save fuel and cost-effectiveness of those measures but does not ask questions on implementation of those measures (similar to Rohdin, Thollander & Solding 2007). Two open ended questions also ask respondents to comment on the biggest barrier and how this could be overcome. To some extent the short survey does follow the framework outlined in the earlier section. However the study is not properly backed with methodological rigour and quality. For example there is no use of a sampling frame, respondents are recruited through affiliations with industry associations, resulting in systematic non-response errors and bias. The survey is targeted towards all those involved in the shipping industry from classification societies and ship builders to owners and charterers, which has meant that the questionnaire would lose its depth over breadth.

Another MSc dissertation by Hill (2010) uses fifteen semi-structured interviews to investigate barriers to uptake of cost negative measures derived from a marginal abatement cost curve (MACC) modelling. The study follows established taxonomy of barriers and at times uses specific barriers to the implementation of measures, which are later classified into the barriers taxonomy. The methodology framework is followed quite well with the exception of calculating actual implementation. The study extends the barriers framework that has been developed thus far, in that it seeks to quantify some barriers, in other words, compares perception of barriers with observed and then follows on to propose policies for removal of those barriers. This is done for the hidden costs barrier (includes additional costs and opportunity costs) for a specific measure. Regarding the methodological quality of the study, one could comment that the respondents are recruited as a purposive sample (to represent a variety of stakeholders) which could perhaps be biased views and therefore questions the validity of the responses as interviews have been shown to have a social desirability bias (Dillman 2007).

There have also been several grey literature studies specific to the shipping industry based on expert views or on less rigorous methods for data collection. These sources include consultancy reports, non-governmental (NGO) reports, International Maritime Organisation (IMO) paper submissions and EU research. See for example Faber et al. (2009), Faber, Behrends & Nelissen (2011), Heisman & Tomkins (2011), Maddox Consulting (2012), Hobson et al. (2007) Kollamthodi et al. (2008), Wang et al. (2010). In this section only two studies are reviewed (based on the aforementioned criteria), as they were specifically commissioned to address the barriers debate. Faber, Behrends & Nelissen (2011) provide a comparative analysis of the marginal abatement cost curves (MACC's) that have been produced so far for the shipping industries (similar approach to Velthuijsen (1993)). The MACC's include the level of uptake or implementation of technologies by assuming adoption behaviour by specifying the criteria for adoption which could be based on cost-effectiveness, highest profits or least cost. This is then followed by semi-structured interviews of two groups of stakeholders: five shipping companies and other stakeholders on the subject of barriers. The interview comprises of two parts, structured questionnaire and another part with open ended questions on barriers. For the structured part, instead of selecting individual measures, individual measures are grouped according technical, alternative fuels and operational measures and implementation rates (as %) are calculated by asking the respondents directly whether they have implemented the specific measure. The questionnaire also asks for expected savings potential which could have been used for gauging differences in calculated and real (similar to Velthuijsen, 1993), but for reasons not mentioned, this is not included in the report. Barriers in general are discussed per measure; however the clear taxonomy of barriers that is suggested within the report is not followed through in the interviews. Moreover the implementation rates (although based on a very small sample) could have been fed in the MACC's to present an alternative or realistic picture of the abatement potential of measures. The empirical analysis is based on only twelve interviews and the actual implementation of measures is answered by only four shipping companies, making the study subject to all four types of errors; coverage, sampling, non-response and measurement error (Groves 1989).

Another report by Maddox Consulting (2012) follows the barriers framework or methodology aforementioned very closely by providing a comprehensive analysis of measures available for reducing CO_2 from shipping at negative cost, with many measures being operational measures. The implementation rates of each of the measures are subjectively determined by a literature review, expert opinions and interviews with stakeholders (such as suppliers of technologies and ship owners and operators 80 altogether including 25 ship owners and operators). At this point they bring in the concept of product life cycle or the 'S' curve (theory of diffusions of innovations, which is also discussed by Jaffe and Stavins (1994)) to determine whether low penetration is due to the measures position in the curve or due to barriers. This is applied to thirteen different measures, with most operational measures (shown to be mature on the S curve) having penetration rates between 50% and 75%, suggesting that there are some barriers to implementation of operational measures. Barriers are then discussed for each measure in good detail, particularly for speed reduction measures, which were shown to have the highest fuel saving potential. However the barriers taxonomy once again does not follow economic theory, except for the barriers classified as market failures (which include split incentives), other barriers could be categorised into the barriers taxonomy presented by Sorrell et al. (2000) such as administrative barrier could be classified as hidden costs, regulatory barrier could be categorised risk barrier. The analysis shows that market failures or split incentives were applicable to all measures. As per the framework on barriers the study looks at policy options to remove or overcome those barriers and also comments on best practice for market barrier removal per measure in other sectors and within shipping. It is not clear from the report how exactly the empirical data was collected, the interview guide/template is not present and sampling of the respondents is absent.

2.2.3.1. Conclusions from review of empirical studies literature in shipping

The above empirical studies show that a variety of social research methods (especially questionnaires and interviews) can be helpful in determining the economics of energy efficiency and perception of barriers to energy efficiency in shipping. However there is a need to adopt the framework that has been developed from the literature in other sectors in order to have a consistent understanding of barriers in shipping. There is also a need for methodological rigour in testing barriers in shipping for example by targeting specific respondents' rather than a broad range of stakeholder. When using interviews as a method to gather primary data it is important to have it structured or semi structured and extra consideration is also required as it can create social desirability bias and interviewer variability. The above empirical studies have not made full use of the mixed methods research as used by empirical studies in other sectors, to overcome the weaknesses of the methods employed or for other purposes such as further development and triangulation.

The response rates to the shipping studies have not been presented perhaps owing to methods employed. The methodological rigour of many of the aforementioned studies simply either lacked reporting or was neglected. This has made it difficult for some of the studies to make broader generalisations of the population from the sample. It suggests that research strategy, design and methods will need to be carefully designed and implemented if a good response rate is to be achieved. This will be discussed in the following chapter and strategies that are used to ensure a good response rates and valid generalizable results. Most of the above studies acknowledged the barriers literature and taxonomy of barriers, but still failed to incorporate it in their studies thus lacked consistency, and developed other categories that cannot be derived directly from or linked to economic theory.

Faber, Behrends & Nelissen (2011) and Maddox Consulting (2012) aimed to obtain the implementation rates of the measures, but both of them differed in the way implementation rates were calculated. Nonetheless, either they have lacked rigour in the way that it has been calculated or sufficient sample size was not obtained. Hill (2010) expanded the framework by comparing or testing perceptions of the barriers with observed or quantification of one of the barriers. All of the above studies show that the number of measures under investigation can be limited to around five to ten to gain sufficient depth on barriers to their implementation.

2.2.4. Non empirical research on barriers to energy efficiency

Koomey & Sanstad (1994) give a modelling framework for ascertaining whether market failures exist or not, and apply this framework to four examples mainly domestic appliances (light bulbs, refrigirators, computers and TV's). Internal rates of return (IRR) for both the energy efficient devices and inefficient devices can be calculated based on purchase prices (initial costs) and operating costs. When the IRR exceeds the social and private discount rate and yet the inefficient device is purchased, then it suggests goods are not being purchased at minimum costs, a necessary condition for efficient allocation of resources, implying the existence of market imperfections. Their framework suggests starting from:

1. Hidden costs (to the analyst) not included in calculations e.g. service levels, tax etc.
2. Incorrect parameter specification in the calculations e.g. running hours
3. Time lags between introduction and adoption e.g. S curve/diffusion of innovation theory
4. Then conclude that market failures are inhibiting uptake.

For all the examples where this was applied, the analysis showed that in all cases there were market failures inhibiting uptake of the technologies.

2.2.5. Non empirical research on barriers to energy efficiency in shipping

One of the first papers to specifically discuss barriers to uptake of low carbon technologies in shipping was Hobson et al. (2007). It classified barriers as technical, economic, social and legislative and discussed each of these for a given set of technologies. This categorisation is disconnected to the general barriers literature and taxonomy. However, a follow on study by Kollamthodi et al. (2008) reviews the barriers literature cited and mentions the principal agent problem, although they conclude that this problem is not significant for capital intensive measures, as owners will be able to increase the charter rates for an improved ship, while users (charterers) are willing to pay the increase if this entails a reduction in fuel costs. This analysis is based on a single conversation with the Norwegian Shipowners Association. They analyse in the same way other barriers such as risks, hidden costs, informational problems for both new and existing ships and technical and operational measures.

Wang et al. (2010) develop marginal abatement cost curves for twenty two technical and operational measures and discuss the implementation barriers for each of the measures, based on the authors' expert opinions. They categorise barriers into technological, institutional and financial. Within the institutional barrier they cite the split incentives barrier, with reference to the barriers literature in other contexts. Wang et al. (2010) challenge Kollamthodi et al.'s (2008) assumption that energy efficient ships can obtain higher charter rates. There is a short discussion of barriers related to speed, length of ownership and cost pass through in shipping.

2.3. Literature review of agency problems in the context of energy efficiency

This section of the chapter examines studies that have specifically focussed on the two agency problems; split incentives and informational problems, that are also categorised as market failures in the barriers literature. These are discussed in the general context and in the context of shipping.

2.3.1. Agency problems in the building and other sectors

2.3.1.1. Qualitative analysis of agency problems (positivist type research)

There are several studies that have focussed on the type of lease and barriers to energy efficiency, however most of them tend to be for private rental in the residential sector. The possibility of split incentives between owners and occupants of residential dwellings was first researched by Blumstein (1980) with case study interviews suggesting a "landlord-tenant" issue. The research first attempts to classify barriers but understandably there was very shallow literature of barriers, so new terms are used. Prior to this study, York et al. (1978) first catalogued around fifty studies that pointed towards the barriers to energy efficiency and barriers to innovation. Blumstein (1980) suggests that the causes of barriers are often interlinked and follow a causal chain, citing an example of commercial building operators initially lacking of information on conservation measures and about their site energy use, which is further exacerbated by misplaced incentives. Blumstein (1980) uses the semi structured interview method to interview twelve stakeholders in the buildings industry, grouped into two. The first group of stakeholders are owners, managers and operators and the second group are those that are indirectly linked to the sector such as brokers and institutional investors. A very good level of detail is provided for each of the interview findings, which mainly suggest existence of split incentives and informational problems.

Meyer (2008) investigates how different types of leases for rental offices in Boston affect the energy efficiency investments of landlords. The research method is semi structured interviews of thirty five office rental stakeholders including; landlords and tenants, real estate brokers, contractors, engineers etc. using purposive sampling strategy. Meyer (2008) also does some analysis (similar to qualitative content analysis) of existing leases used in the Boston area and how each type of lease or lease clauses impact investment in energy efficiency. The key finding is that attitudes of the interviews differed according to leases, which were determined by the market, and at the time of interviewing it was discovered that there was no appetite for renters to pay higher rent for energy efficient space or lack of energy efficiency premium, thus landlords are unable to recoup their investment. More specifically existing recapture clauses, operating expense allocation and payback periods do not justify the investment.

Barriers and principal agent problems in the context of energy efficiency have been also qualitatively discussed in a variety of studies elucidating the potential market failures e.g. Fisher and Rothkopf (1989), Jaffe and Stavins (1994), Brown (2001), Hirst & Brown (1990), Nadel (2002), Carbon Trust (2005), Gillingham, Newell & Palmer (2009) Golove & Eto (1996), Howarth & Anderson (1993), Carbon Trust (2005), Howarth & Winslow (1994), Howarth, Haddad & Paton (2000), Sanstad & Howarth (1994), Thollander, Palm & Rohdin (2010), etc.

2.3.1.2. Quantification of agency problems

Several studies have attempted to quantify or estimate the amount of energy that is affected by the principal agent problem. By doing so they show how much energy efficiency potential is forgone, so that policies can be developed to address them. The forgone energy efficiency potential or extra energy consumption can be said to be analogous to the agency costs encountered in principal agent relationships. Agency costs arise as a result of the two agency problems, so for the first problem of misaligned incentives, the agency costs arise out of the measures that seek to align incentives of the principal and the agent (e.g. stock options to managers), for the informational problems, agency costs are costs of monitoring or obtaining information (e.g. screening) of the agent. These studies are re-examined in detail in chapter five in order to apply the quantification of agency problems in shipping.

Murtishaw and Sathaye (2006) is the first research that attempts the quantification of principal agent problem on US residential energy use. They provide a methodology and a matrix (refer to Table 5.8) allocate households to various principal agent cases, which has been used by all the studies that follow below. The study also draws upon previous work from Sathaye & Murtishaw (2004) quantifying the effects of market failures in domestic appliances market and how these affect take up using a modelling approach. Importantly, in this study, they show that principal agent cases are not static, rather dynamic depending on the appliance or end use (e.g. space heating) being studied. For example a renter is generally said to be the principal and landlord his agent, and appliances where the agent is responsible will typically encounter the efficiency problem, but when appliances where the principal is responsible, such as televisions and set top boxes, there may not be such efficiency problems, thus the principal can be exposed to efficiency problems only in some situations in the residential sector. Another example is of an owner-occupier, thought to be representing a case where no principal agent problem exists, but when the owner-occupier buys an apartment with already fitted appliances (especially new building stock) it would be classified as an efficiency problem, since purchasing decisions on appliance energy efficiency is made by the contractor or builder. Combining the housing survey census data, households are split into the principal agent cases. The number of households affected by principal agent efficiency problem varied for the different energy end use, for example in case of lighting only 5% of households are affected by principal agent efficiency problem, for refrigerators over 30% of households are affected by principal agent efficiency problem, for water heaters 78% of households are affected by principal agent efficiency problem. This finding perhaps suggests that the mobility of energy efficiency measures is an important factor affecting the principal agent problem. Davis (2009) also uses census residential energy consumption survey data to compare energy efficiency of appliances between owner-occupiers and tenants. Controlling for all other factors such as income, building particulars etc. he finds that tenants were "significantly less likely to have energy efficient refrigerators, clothes washers and dishwashers" (Davis 2009, p. 1), confirming findings of Murtishaw and Sathaye (2006) and the efficiency principal agent problem.

Levinson and Niemann (2004) focus on contracts where energy costs are included in monthly rental, a specific case of the principal agent problem, resulting in a 'usage problem' according to Murtishaw and Sathaye (2006). They confirm this 'usage problem' hypothesis using the same data set as above and controlling for all other things, show that tenants living in homes where energy is included in the rent have higher temperatures, between one and three degrees higher during the winter months and when they are absent from their homes. Maruejols & Young (2011) also find that tenant behaviour for households that have energy included in their rent opt for increased thermal comfort and are found to be less sensitive to temperature whether or not someone is at home and severity of the climate when deciding on the temperature. This is an important finding as it suggests that operational efficiency of homes with energy included in rent in the residential sector is lower than non-energy included contracts despite the technical efficiency of the former being higher than the latter.

Prindle et al (2006) and IEA (2007) are both a compilation of several quantification studies, some of which have already been mentioned above. The report brings together several studies from different nations and sectors. Table 2.6 shows the results of the various studies included in the report. It shows there is a wide ranging level of pervasiveness of the principal agent problem by sector and country.

Two studies have attempted to estimate energy end use affected by principal agent problems in the transport sector. Grauss & Worrell (2008) examine the principal agent problem in the Netherlands company lease cars for executives. They show that despite company cars being newer and employing diesel engines, the fuel efficiency is worse than private cars due to them being larger, which is further worsened due to company cars also driving for longer distances compared to private cars. This results in a principal agent problem where both the 'efficiency' and 'usage' problems occur. Vernon & Meier (2012) investigate principal agent problems in the US trucking sector, in which contracts and stakeholders are very similar to shipping contracts and stakeholders. Using Murtishaw and Sathaye (2006) principal agent matrix they estimate that over 90% of the sectors fuel consumption is affected by 'usage' problem because the truck driver does not pay for fuel costs and lacks incentive for fuel saving operation, despite monitoring through miles travelled and fuel used. Only in a few cases the split incentives is addressed by larger firms offering fuel efficiency bonuses. Nearly a quarter of trailers are affected by the 'efficiency' problem because owners of rental trailers do not pay for fuel costs and contracts for rentals do not monetize fuel efficiency of trailers (gained through aerodynamics, energy efficient tyres, etc.). Vernon and Meier (2012) review contracts and do not find any mention of efficiency of trailers and the same is concluded for interviews of stakeholders who were found to have little knowledge or no interest in fuel efficiency of trailers.

End use/sector	Countries examined	Fraction of end use energy affected by all types of principal agent problems
Residential refrigerators	USA	25%
Residential water heating	Norway USA	38% 77%
Residential lighting	USA	2%
Television set top boxes	USA	100%
Company cars	Nethterlands	32%
HVAC	Japan Netherlands Norway	17% 44% 90%
Vending machines	Japan Australia	44% 80%

Table 2.6: End use energy affected by principal agent problems
Source: Meier & Eide (2007)

2.3.2. Agency problems in shipping

To date there haven't been any specific studies to investigate agency problems in the context of energy efficiency. There have however been a handful of studies that explore the general agency problem in a positivist type research, in a non-energy context. Bergantino & Veenstra (2002) investigate specifically the principal agent problems in shipping contracts from an economics perspective. Within the agency theory they focus on the information asymmetry problem and its outcomes adverse selection and moral hazard, thus ignore split incentives branch of the theory. However, the study suggests the heterogeneity of the shipping industry, where practices differ from one sector to another. As an example the use of vetting by oil majors is very different to that used in other sectors. This has large impact on the way information is presented by parties, possibly affecting the barriers to energy efficiency in that sector. Veenstra & Ludema (2006) show from a naval architecture point of view, how design specifications set by shipowners do not actually fully account for the full service life of the ships they order. They show that shipowners only concern themselves with earnings potential which is directly based on cargo carrying capacity, speed & manoeuvrability and versatility. This disconnect eludes to the principal agent problems and lack of priority accorded to energy efficiency.

Other research such as that shown in section 2.2 in shipping has only mentioned the principal agent problem without exploring the subject in greater detail. Both Kollamthodi et al. (2008) and Faber et al. (2009) highlight that the principal agent barrier only affects certain segments of the industry. Kollamthodi et al. (2008) maps out the measures and types of vessel likely to be affected by principal agent problems, however this not based on any empirical data or modelling, and is solely based on subjective opinions of the authors.

Similarly Faber et al. (2009) survey the range of chartering arrangements in shipping, and conclude that either the operator pays for bunkers, or that the price of bunkers is passed on as inclusive in freight rates or additional levies in liner shipping (called Bunker Adjustment Factors). On this basis, they estimate that costs may be passed on for 70-90% of the bunker fuel consumed. Wilson (2010) also estimates that 80% of the fuel in shipping is for the charterers account. These statistics imply a significant 'efficiency' problem since charterers generally do not own their own ships and hire ships, similar to tenants in the building (residential or commercial offices) sector. The problem is that none of the research mentioned here show how these figures have been derived. The key questions then are; how much of the charter market is affected by the principal agent problem? Whether time charter rates reflect or monetize energy efficiency? Do charterers demand energy efficient ships? And as a result do shipowners consider investments in energy efficiency worthwhile i.e. are they able to recoup the investment?

2.4. Summary

The review of literature on barriers to energy efficiency can be categorised into five different topics depending on the focus and sector analysed. This section provides a brief summary using the criteria set out in section 2.2.2 of this chapter; methodological rigour for empirical research, taxonomy of barriers and framework on investigating barriers.

The first set of studies can be categorised as empirical studies that investigated barriers to energy efficiency. Only a handful of studies were reviewed for their methodological rigour and approach towards investigating barriers to energy efficiency (Velthuijsen 1993; Rohdin, Thollander & Solding 2007; Harris 2000; Sardinaou 2008; Thollander & Ottosson 2008; Hasanbeigi et al. 2009). These studies are thought to be most important highly relevant to this research because they have set the foundation on empirical research on barriers to energy efficiency but due to time and resource constraints several other sources were not critically reviewed. These studies generally lacked a good taxonomy on barriers to energy efficiency but followed a good phased approach to investigating the barriers to energy efficiency. Most of the studies did not completely follow the methodology i.e. beginning from analysis of measures to improve energy efficiency and concluding with policies to remove barriers for those specific measures. Most of the studies used the self-administered questionnaire method and interviews (and some combination of these) but did not present the methods in sufficient detail for example the sampling strategy, sampling frames, errors, questionnaire design etc., therefore their methods could not be assessed in detail. Of all, Thollander and Ottosson (2008) is the only study that goes into some detail regarding why the methods were selected, question content, sampling etc. This study is therefore closely followed in this research.

The second set of studies can be categorised as those empirical studies that investigated barriers to energy efficiency in shipping (Gordon 2008; Hill 2010; Faber, Behrends & Nelissen 2011 and Maddox Consulting 2012). Gordon (2008) and Kollamthodi et al. (2008) vaguely followed the taxonomy on barriers to energy efficiency and neither did they follow a good phased approach to investigating the barriers to energy efficiency. Hobson et al. (2007) does not follow the methodology i.e. beginning from analysis of measures to improve energy efficiency and concluding with policies to remove barriers for those specific measures. Hill (2010), Faber, Behrends & Nelissen (2011) and Maddox Consulting (2012) follow the barriers taxonomy and methodology to some extent i.e. some focus on implementation and perception of barriers. The methods selected to do so were also mainly interviews and self-administered questionnaires. The main shortcoming of these studies is that they have very low response rates perhaps due to their failure to address the methods more thoroughly.

The third set of studies focussed on the agency problem and were mainly of qualitative nature and focussed on buildings and other sectors (Blumstein 1980; Sorrell et al. 2000 and 2004; Meyer 2008). Although none of these were exclusively focussed on agency problems in the context of barriers to energy efficiency, they had considerable content which analysed the agency problem. Sorrell et al. (2000 and 2004) thoroughly examined the methods (interviews and self-administered questionnaire) for conducting the research across different industries as well as proposing a well explained taxonomy of barriers. The framework or methodology varied from sector to sector but mainly focussed on implementation level of measures and perception of barriers to energy efficiency. Most of the studies here used interviews followed by self-administered questionnaires. Sorrell et al. (2000 and 2004) are considered to be the only study that meets the review criteria and is therefore thoroughly understood in order to aid this research.

The fourth set of studies focussed on the agency problem and were mainly of quantitative nature investigating agency problems in the building industry and other sectors (Murtishaw and Sathaye 2006; Prindle et al. 2006; IEA 2007; Grauss and Worrell 2008; Vernon and Meier 2012). These studies sought to quantify or estimate the level of principal agent problem in a wide range of sectors. Murtishaw and Sathaye (2006) develop a framework to categorise principal agent problems in the context of energy efficiency in residential sector which is consequently followed by all other literature in other industries.

Finally, the fifth set of studies focussed on the agency problem but mainly from a qualitative perspective in shipping (Bergantino and Veenstra 2002; Veenstra and Ludema 2006; Kollamthodi et al. 2008; Wang et al. 2010). The former two do not apply the agency theory in the context of energy efficiency and the latter two only briefly mention principal agent problem as a barrier category and subjectively show which energy efficiency measures it may affect. These are mainly based on subjective analysis of the barriers with some anecdotal evidence.

2.4.1. Gaps in the literature

From the foregoing analysis, it can be seen that previous studies that used good theoretical framework on barriers, mainly looked at firms (mainly manufacturing) in different sectors e.g. Velthuijsen (1993), Sourdinaou (2008), Sorrell et al (2000) and have ignored transportation companies and shipping companies. The empirical studies that did look at shipping companies e.g. Gordon (2008) and Faber, Behrends & Nelissen (2011) did not base their analysis on any established barriers framework or theories. Most studies that used social research methods such as interviews and surveys were not methodologically rigorous, therefore they did not really go further to explain the lack of uptake of energy efficiency measures.

None of the shipping barriers literature has tested for the principal agent problem rigorously or exclusively, instead they only mention it as barrier to uptake of energy efficiency measures. Few studies attempted to create a baseline on implementation of energy efficiency measures but these were methodologically weak and did not capture the full extent of the perceived barriers in shipping. Several studies have quantified the principal agent problems for various sectors, but no such quantification of the principal agent problem exists for shipping. Thus the positivist type principal agent research is lacking in shipping industry. There has been very little or unknown application of principal-agent type research in the context of barriers to energy efficiency in general and for shipping.

Barriers to energy efficiency literature in buildings and other sectors looked at the principal agent problems mainly on the way it affects investment in energy efficiency but have not looked at how the principal agent problem affects operations or behaviour, e.g. when a tenant does not pay fuel bill how does their action/behaviour differ? Principal agent problem in shipping is approached mainly from an investment in technology or technical measures perspective by the studies that looked at it, but shipping is unique, in that in time charters there are opportunities for operational measures that may not require such investments and changes to attitudes or contracts can provide opportunities or solutions to the principal agent problem.

Agency theory hasn't been applied in a rigorous manner under the positivist type research in the context of energy efficiency (except for a few studies) and in shipping. It has also not been applied under the principal-agent type research for both barriers to energy efficiency in general and in shipping. Finally, the studies reviewed above were in majority empirical studies that examine only perception of barriers, some statistical studies examine the observed level of principal agent problems and very few studies combined both, perception of barriers and observed barriers.

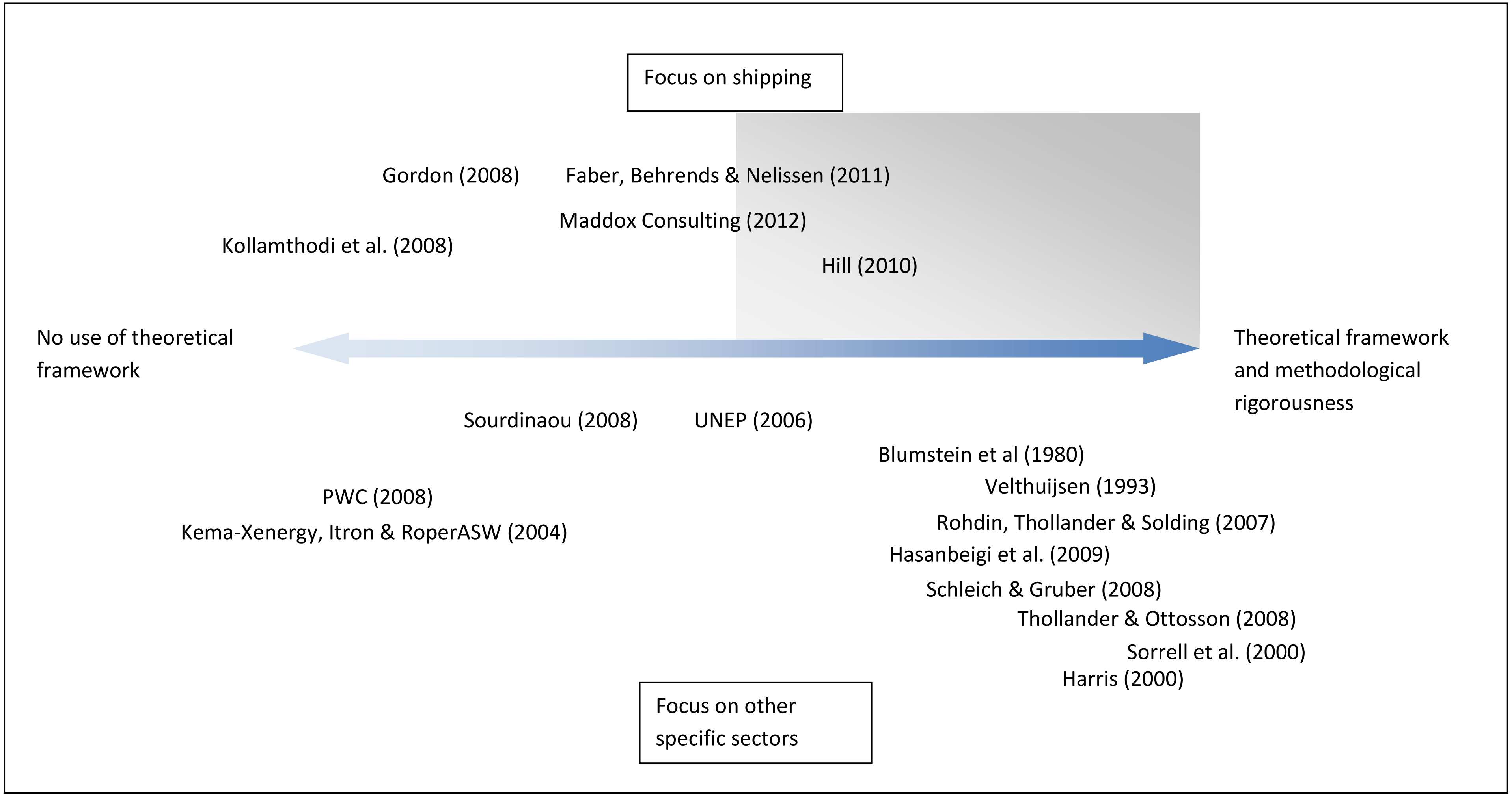


Figure 2.2: Depiction of gaps in literature

2.4.2. Theoretical framework

Agency theory explains a large part of the barriers framework by explaining the market failure barriers, other peripheral theories such as transaction cost theory, behavioural economics branch, contract theory add to the barriers framework but are not in the scope of this research.

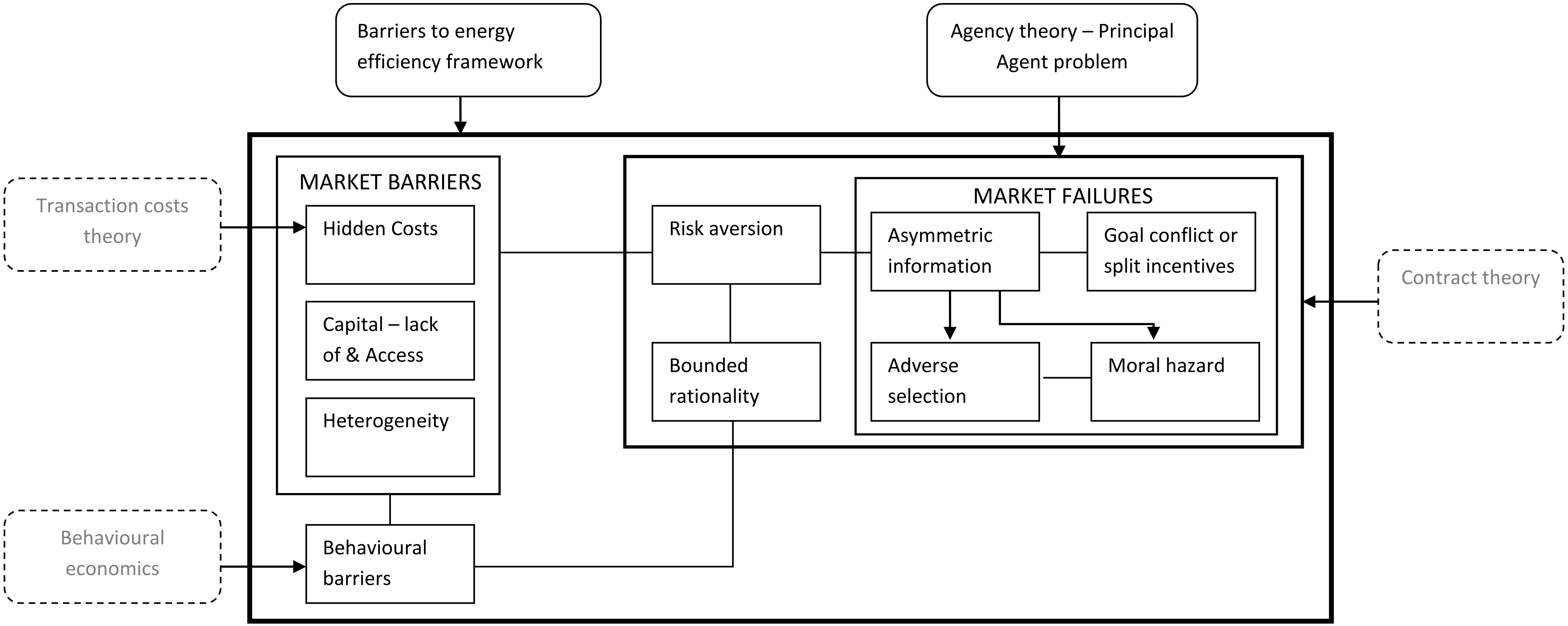


Figure 2.3: Theoretical framework used in this research

2.5. Research questions and hypothesis

2.5.1. Research focus

From the preceding sections of this chapter, it can be concluded that there are several gaps in the shipping literature on the issue of barriers to energy efficiency. Previous studies exploring barriers to energy efficiency did not make use of specific frameworks or theories and the principal-agent problem or split incentives has not been rigorously tested and quantified, despite being reiterated by many. Moreover, much of the research so far is on how barriers to energy efficiency have affected investments in energy efficiency without much attention to how these barriers might affect energy efficient operations.

Therefore the focus of this research is on operational measures for improving energy efficiency in shipping and the market failures (those explained by agency theory) category of barriers, with more attention paid to the speed reduction energy efficiency measure because it has been suggested that it has highest emission reduction potential (of up to 30%) and principal agent problems are thought to inhibit the uptake of this measure.

There are several reasons why operational or voyage related measures have significant potential for reducing CO_2 emissions, which are outlined below;

- Can lead to instant reductions in CO_2 emissions since they are applicable to existing and future fleet.
- Unlike most retrofit measures or technological measures, operational measures can also be implemented by time charterers; therefore there is greater scope for CO_2 reduction.
- Require comparably smaller investment in contrast to other technical and retrofit measures, therefore access to capital market barrier may not be a significant problem.
- Have generally been shown to have a negative CO_2 costs (i.e. resulting also in fuel savings if implemented) by the aforementioned references.
- There also exists significant potential to improve operational efficiency of ships, which has been shown to be wide ranging for different ship types relative to technical efficiency of ships.

Within shipping the main sectors of interest are wet bulk, dry bulk and container because together they represent around 70% of the CO_2 emissions of the industry as illustrated in Figure 2.4. This focus is however not reflective of their relative efficiencies compared to other sectors, which although represent a smaller share of total emissions but perhaps are more inefficient and therefore may have greater potential for energy efficiency. The research is also focussed on the aforementioned sectors because data is generally more accessible for these sectors.

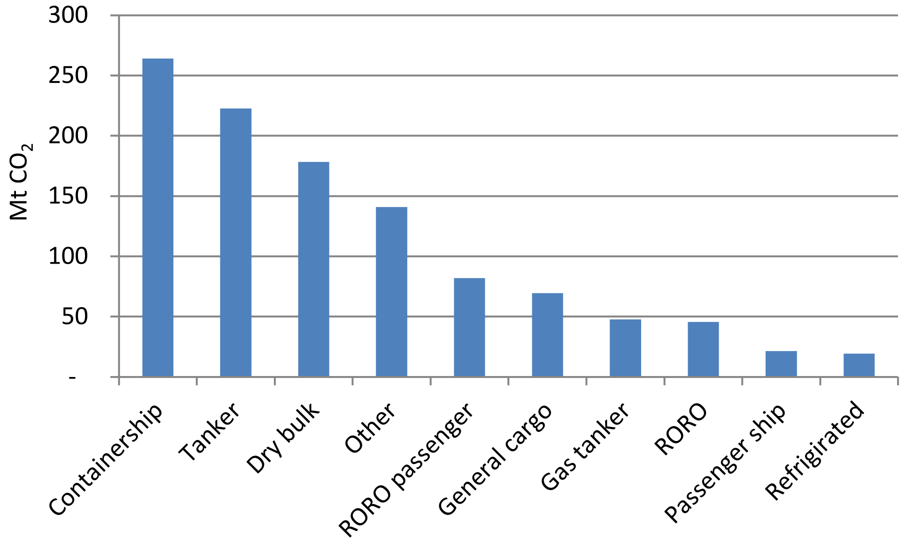


Figure 2.4: CO_2 emissions of the various ship types
Source: IMO (2010c)

2.5.2. Research aims

The literature review showed that there exist many opportunities for shipping companies to improve energy efficiency through cost-effective measures. The aim of this research is to understand what the level of implementation of such measures is and if there is low uptake, why such opportunities are not being taken up or implemented. Specifically, how can agency theory and barriers to energy efficiency explain the lack of uptake. The research aims to investigate the barriers by combining perception of barriers and observed level of barriers to energy efficiency.

2.5.3. Formulation of research questions and hypothesis

The research follows the framework below and steps that have been constructed from relevant literature on barriers to energy efficiency. It proposes different ways to investigate perceived and observed extent of barriers to energy efficiency. Note that some parts of the framework (Figure 2.5) have been greyed out to show that these are not central to the framework but nonetheless will be investigated to some extent. Figure 2.5 depicts the framework, which has the following steps:

Step 1: Understanding what shipowners and charterers think are the most important energy efficient operational measures in shipping.

Step 2: Assessing which of the energy efficient operational measures shipowners and charterers have implemented.

Step 3: Assessing perceptions of barriers to implementation of energy efficient operational measures.

Step 4: Using other methods to assess the observed extent of the identified barriers to implementation of operational energy efficiency measures.

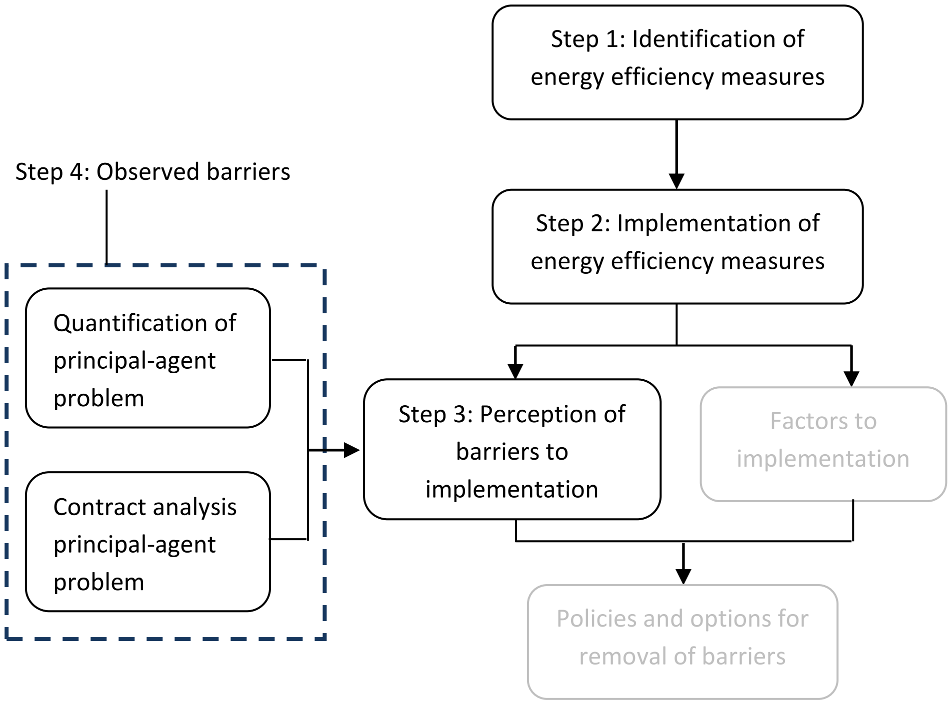


Figure 2.5: Research framework used in this research

Note that some parts of the framework (Figure 2.5) have been greyed out to show that these are not central to the framework but nonetheless will be investigated to some extent.

The following section provides greater detail for identifying the hypothesis and research questions for each step of the framework.

Step 1: Understanding what shipowners and charterers think are the most important energy efficient operational measures in shipping.

Most studies that aimed to investigate perception of barriers to energy efficiency e.g. Velthuijsen (1993), Sorrell et al. (2000), etc. start with the identification of energy efficient technologies and measures, which are derived from various sources e.g. best practice guides, energy audits, literature review etc. from which the technical and economic potentials are obtained. A list of select promising measures is compiled. Operational measures that are available to shipping to improve energy efficiency along with their energy saving potential have been discussed in the previous chapter.

Step 2: Assessing which of the energy efficient operational measures shipowners and charterers have implemented.

The next step is to find the actual uptake or implementation of these measures. Respondents in a survey or an interview are asked which of those measures they have implemented in their organisations and the results are then presented as mean scores for adoption. The results from this method are then compared with ideal or potential levels of uptake estimated using models. Many MACC and models assume a certain level of uptake or implementation but this may not be representative of the real world situation. To some extent, as suggested by Koomey and Sanstad (1994) the models may be susceptible to modelling or parametric specification errors, but even when these have been resolved, there may still be a difference between actual and potential level of uptake. Therefore, the first research question aims to understand more about the actual implementation of operational measures in shipping, which to date has only been investigated by Maddox Consulting (2012) based on expert opinions and interviews with stakeholders from the shipping industry. The general hypothesis is based on the market barriers theory, which suggests that energy efficiency measures may not be fully implemented across the sector because of market barriers and market failures.

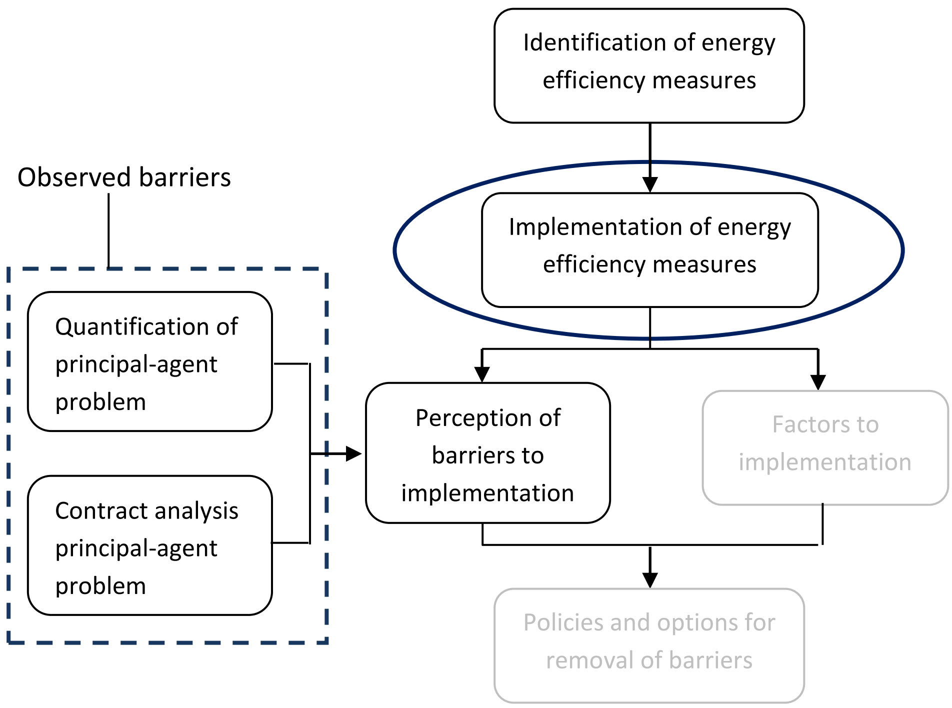


Figure 2.6: Focus of research question one

Research question:

Research question 1 - To what extent are energy efficient operational measures implemented in shipping?

Hypotheses:

Hypothesis 1a – Energy efficient operational measures are not fully implemented.

Hypothesis 1b - Implementation varies across the measures according to size and sector.

Hypothesis 1c - Implementation of energy efficient operational measures is higher for time chartered ships compared to voyage chartered ships.

Step 3: Assessing perceptions of barriers to implementation of energy efficient operational measures.

Once the actual implementation rates for each of the operational measures are ascertained, the literature based framework proposes that some of the gap between ideal or modelled and observed originates from a range of barriers, which limit the adoption of those measures, which is explained by market barriers and market failures, assuming or holding for parametric specifications and costs in the models to be accurate. For the measures that are adopted, there are some references e.g. Rohdin, Thollander & Solding (2007), Thollander & Ottosson (2008) that show that there are also factors that lead to adoption for that energy efficiency measure, however an investigation of these is beyond the scope of this research. This is generally based on perception of barriers, which are then linked to independent variables such as size and sector. The methods (generally surveys) followed by Sorrell et al. (2000), Hasanbeigi et al. (2009), Rohdin, Thollander & Solding (2007), Thollander & Ottosson (2008) are concerned with just the perception of barriers across all measures. So for example the principal-agent barrier indicator in the surveys or interviews would be when a respondent selects 'energy savings cannot be fully recouped'. It is important to note that not all energy efficiency measures in shipping would have the same characteristics; therefore barriers for each measure may differ. Based on this, the following research question is formulated:

Research question:

Research question 2 - What factors are perceived to be the most important in explaining the lack of implementation of energy efficient operational measures?

Hypothesis:

Hypothesis 2 - Market failures (principal agent problems specifically) are perceived to be more important than non-market failures for lack of implementation of operational measures.

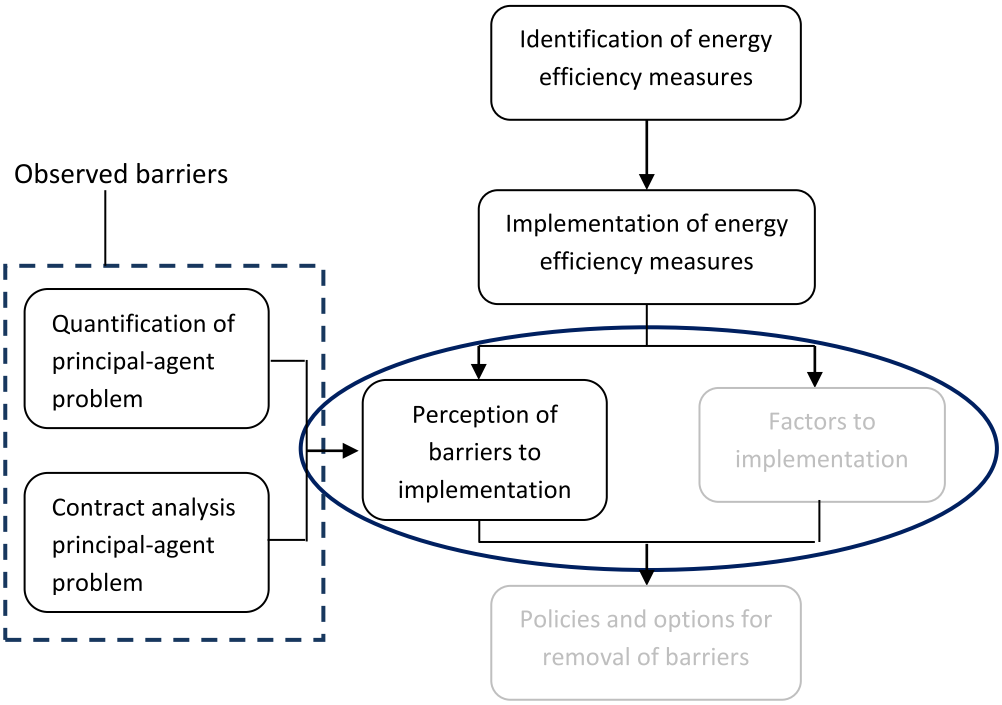


Figure 2.7: Focus of research question two

Step 4: Using other methods to assess the observed extent of the identified barriers to implementation of operational energy efficiency measures.

The barriers framework as proposed by Velthuijsen (1993), Koomey & Sanstad (1994), Jaffe and Stavins (1994), Sorrell et al (2000) combines general economic theory and barriers theory with empirical research where hypothesis and research questions are based on respondent's perception of barriers. In this research, the framework is adapted to focus more on the principal agent problem. In order to validate or cross check the responses on perception of barriers and get a fuller picture of the pervasiveness of the principal agent problem, there is a need to combine several strands of research and triangulate between the methods and data. One method is to quantify or estimate the amount of energy consumption that is affected by the principal agent problem (Prindle et al. 2006; Vernon & Meier 2012), through desk or secondary research. One can also estimate the extent of the principal agent problem by asking the respondent their ownership and leasing in and out structure (called chartering). Harris (2000), Trianni et al. (2012) adopt this approach of perceived barriers and measuring the extent of observed barriers. The unit of analysis within the agency theory is the contract governing the relationship between the principal and the agent and the objective is to determine the most efficient contract taking into account assumptions such as risk, incentives, etc. Sorrell et al. (2004) suggest that split incentives could be addressed by properly designed contracts. Since the focus of this research is the principal agent problem and operational measures, a review of the contracts between the principal and the agent for the most promising operational measures e.g. speed reduction, would also provide some insight into how charterparties (contracts) can affect implementation of certain measures. Therefore the remaining research questions seek to investigate the observed extent of the principal agent problem in shipping and whether there are differences between perceived and observed principal agent barriers?

Research questions:

Research question 3 – What population of ships is affected by the principal agent problem in implementation of energy efficient operational measures?

Research question 4 – How is the energy efficiency in operations affected by the principal agent problem?

Research question 5 – How do the agency problems in contracts affect implementation of energy efficient operational measures?

Hypotheses

Hypothesis 3 – A high proportion of the population is affected by the principal agent problem when implementing energy efficient operational measures.

Hypothesis 4 – Operational energy efficiency of ships is better for time chartered ships compared to voyage chartered ships.

Hypothesis 5 – Agency problems affect the implementation of energy efficient operational measures.

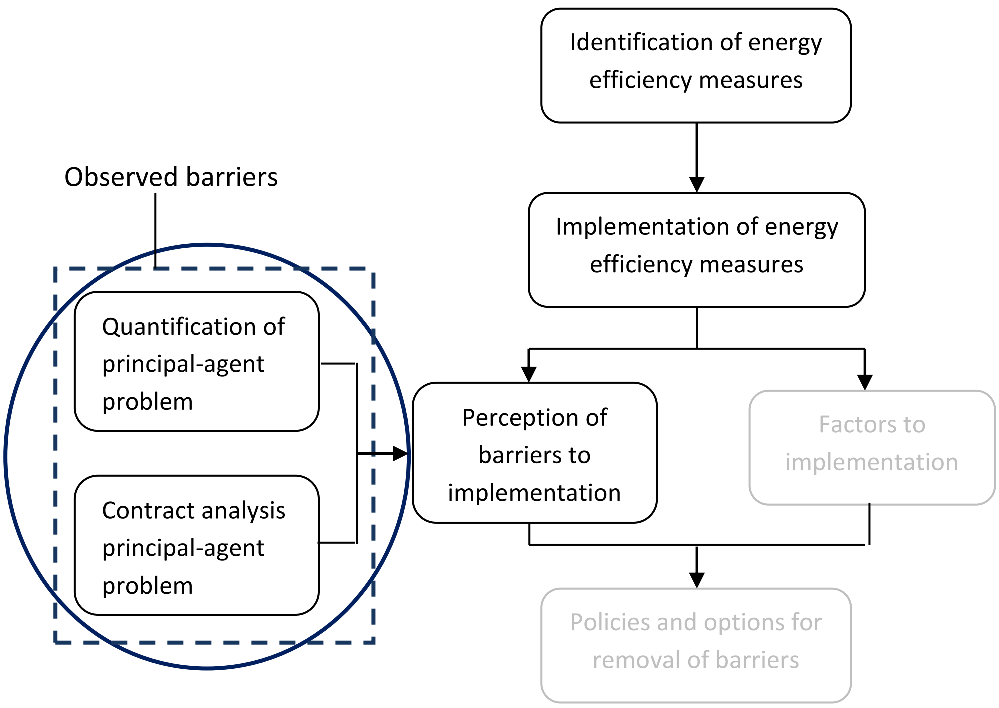


Figure 2.8: Focus of research question three, four and five.

2.5.4. Summary of research questions and hypotheses

Research question	**Hypotheses**
RQ 1 - To what extent are energy efficient operational measures implemented in shipping?	H1a – Energy efficient operational measures are not fully implemented. H1b - Implementation varies across the measures according to size and sector. H1c - Implementation of energy efficient operational measures is higher for time chartered ships compared to voyage chartered ships.
RQ2 - What factors are perceived to be the most important in explaining the lack of implementation of energy efficient operational measures?	H2 - Market failures (principal agent problems specifically) are perceived to be more important than non-market failures for lack of implementation of operational measures.
RQ3 – What population of ships is affected by the principal agent problem in implementation of energy efficient operational measures?	H3 – A high proportion of the population is affected by the principal agent problem when implementing energy efficient operational measures.
RQ4 – How is the energy efficiency in operations affected by the principal agent problem?	H4 – Operational energy efficiency of ships is better for time chartered ships compared to voyage chartered ships.
RQ5 – How do the agency problems in contracts affect implementation of energy efficient operational measures?	H5 – Agency problems affect the implementation of energy efficient operational measures.

Table 2.7: Summary of research questions

2.5.5. Barriers framework and thesis structure

The chapters of this thesis are organised using the research framework constructed earlier and shown in Figure 2.9 below.

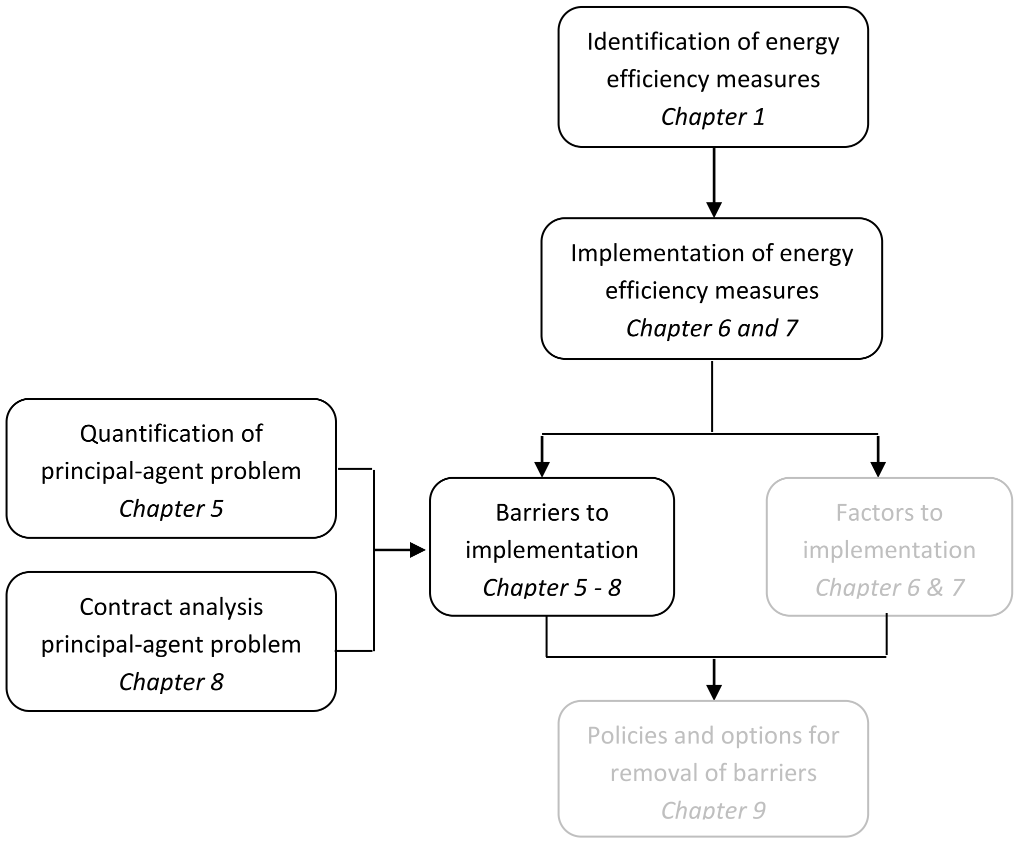


Figure 2.9: Structure of thesis and barriers framework

Note that some parts of the framework (Figure 2.9) have been greyed out to show that those are not central to the framework but will be investigated to some extent in the respective chapters.

3. Approaches and methods for gathering evidence

Having established the theoretical frameworks and research questions, this chapter discusses the structure of the research to answer the research questions. The first section identifies the general approach to theory, followed by a discussion of the research design and research strategy employed laying a foundation for the research methods that follow. The research methods are discussed briefly, with some detail on the method that contributes the most to answering the research questions.

3.1. General theoretical approach

The research questions formulated are a mixture of 'what' and 'why' questions. 'What' is going on is described as descriptive research and 'why' is it going on is described as explanatory research, with the aim of describing and understanding the phenomena (de Vaus 1995). Descriptive research is used in the first set of methods discussed in section 4.4, to describe what is going on in shipping, for example stakeholders and contracts interaction, and explanatory research is used in this research to describe why something is happening for example why do companies forego energy efficient operational measures, why is the level of implementation different, why do barriers exist etc. Much of the research undertaken here is explanatory. Explanatory research involves two related processes, theory construction and theory testing, according to de Vaus (1995). Theory testing starts with a theory, and using this theory a prediction is made how things will be in the 'real' world (de Vaus 1995) and is often called deductive research. Deductive research starts from general to more specific, starting with a theory, hypothesis, observation and ending with confirmation, i.e. theory guides the research (Bryman 2008). Theory construction begins with a set of observations and moves up to develop theories for the observations, of which Grounded theory (Strauss & Corbin 1990) is an example. This is often called inductive research and moves from specific observations to broader generalisations and theories. The process starts with observations, patterns, hypothesis and followed by a theory i.e. theory is an outcome of research (Bryman 2008). The majority of the work in this research is based on theory testing or deductive research, where the two methods are applied to answer research questions one to four, the process for which is outlined below. Another method is used to inductively answer research question five. Stage one has already been discussed in chapter two and the remainder of this chapter will cover stages two, three and four. Stages five and six are covered in chapter six, seven and eight.

There are six stages to theory testing according to de Vaus (1995):

1. Specifying theory to be tested – in a causal or diagrammatic form

2. Deriving a set of conceptual propositions – making a statement which specifies the relationship between two factors, which are still abstract terms (i.e. not directly observable). According to Stinchcombe (1968, cited by de Vaus 1995) the more propositions tested the stronger the test of theory.
3. Restatement of conceptual propositions as testable propositions – the process of deciding how to translate abstract concepts into something more concrete and directly observable (operationalization). Abstract concepts are rigidly defined and replaced with indicators.
4. Collection of relevant data
5. Analysing the data – how much support there is for testable propositions, conceptual propositions and initial theory.
6. Assessing the theory – implications for propositions

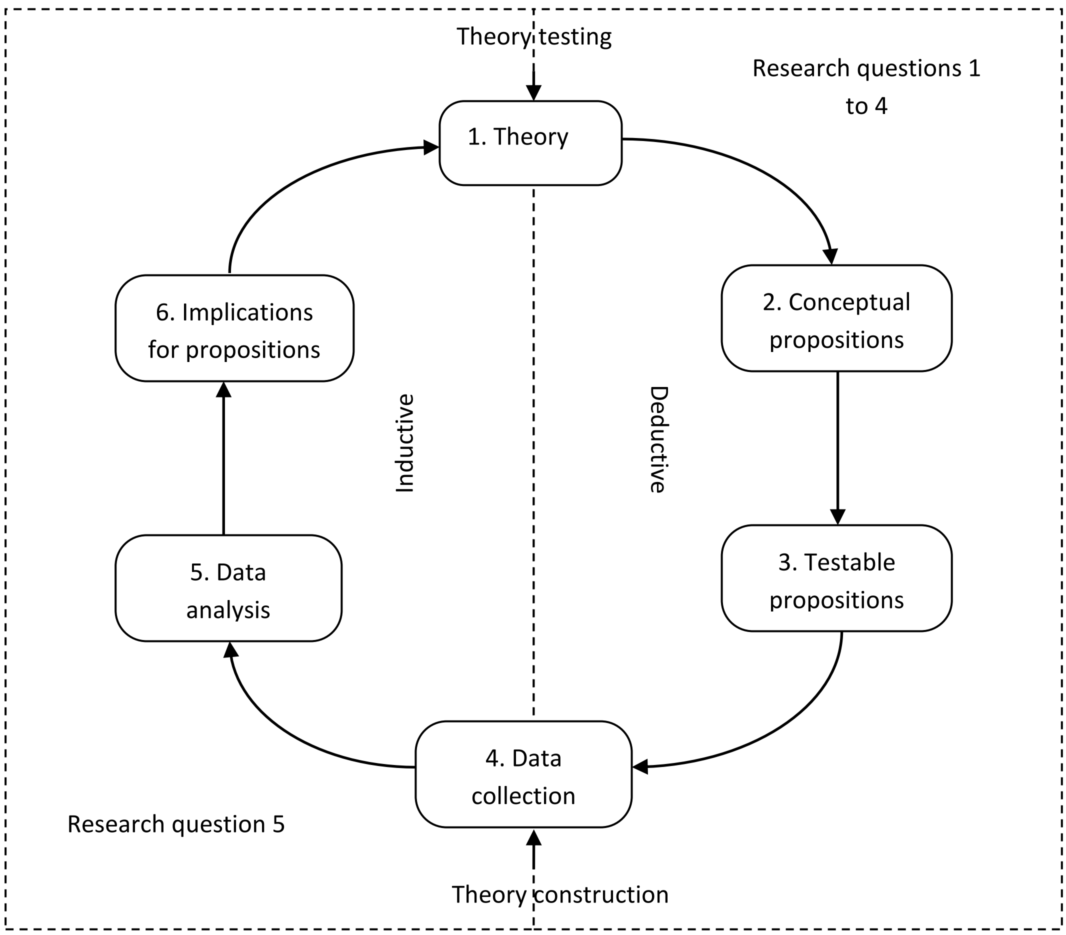


Figure 3.1: Logic of this research process
Source: adapted from de Vaus (1995)

3.2. Research Strategy

According to Bryman (2008) research strategies refer to the choice of quantitative research, qualitative research or a mixture of the two (mixed methods research). Quantitative research emphasises quantification in data collection and analysis, whereas qualitative research emphasises words or observations, and mixed methods employ some combination of the two (Bryman 2008). Generally, a quantitative research strategy is deductive and considered to conform to the theory testing approach, whereas a qualitative research is generally inductive and conform to theory construction approach. Mixed methods research strategy would generally therefore be inductive and deductive, employing theory testing and construction approach. Table A1 in Appendix A shows the differences between quantitative and qualitative research from different research orientations. In order to evaluate the research strategy choices, table A2 in Appendix A briefly presents the strengths and weaknesses of the different strategies and thereafter a discussion of which research choice is most relevant to this research follows.

The choice of research strategy will affect a number of criteria that are used in the evaluation of a study. The criteria for each of the strategies are outlined in the table 3.1, which are also applicable when selecting the appropriate research designs. Table 3.1 is used also as a framework for evaluating and selecting the strategy that is appropriate for this research. The main research questions that guide this study seem to require a combined approach. The first set of research questions are of a quantitative nature and the second set research question is both of quantitative and qualitative nature, thus a mixed methods strategy could be employed. This combining of methods and paradigms is important because the subject of barriers is complex and may require more than one method for the research to be valid, as suggested by Mangan, Lalwani & Gardner (2004) in the context of general logistics or transportation research. This research choice is also increasingly advocated within business and management research (Curran & Blackburn 2001), where quantitative and qualitative methods as well as using primary and secondary data are combined within one single research study (Saunders, Lewis & Thornhill 2007). The following section further elaborates on this strategy and its appropriateness and applicability to this research.

Quantitative	Qualitative
Reliability – consistency of results if repeated	Dependability – parallels reliability in quantitative strategy, i.e. are the findings likely to apply at other times?
Replicability – repeating the exact study	Confirmability – parallels objectivity in quantitative strategy
Validity – integrity of the conclusions, which includes; • measurement validity – whether a measure that is devised of a concept really reflects the concept • internal validity – whether a conclusion that incorporates causality is real • external validity – generalisation beyond the specific sample • Ecological validity – findings applicable in natural social settings	• Credibility – parallels internal validity in quantitative strategy, i.e. how believable are the findings? • Transferability – parallels external validity in quantitative strategy, i.e. do findings apply to others?

Table 3.1: Evaluation criteria for research strategies
Source: Lincoln & Guba (1985, cited by Bryman 2008)

3.2.1. Mixed methods strategy

A combination of research strategies as described above is referred to as multiple method research (Mark & Shotland 1987) multi-strategy research (Bryman 2006) or mixed methods (Greene, Caracelli & Graham 1989; Bryman 2008). Mixed methods have been defined either as “adopting a research strategy employing more than one type of research method” by Brannen (2005) or “those that include at least one quantitative method (designed to collect numbers) and one qualitative method (designed to collect words)” by Greene, Caracelli & Graham (1989). There are several reasons for combining more than one method according to Greene, Caracelli & Graham (1989):

- Triangulation – seeks convergence, corroboration, correspondence of results from the different methods, which increases the validity of constructs and counteracts inherent method bias. There are four types of triangulation according to Easterby-Smith, Thorpe & Lowe (1991; cited by Mangan, Lalwani & Gardner 2004);
    - Data triangulation – data collected at different times and from different sources
    - Investigator triangulation – different investigators independently collect data
    - Methodological triangulation – both quantitative and qualitative methods are employed

    - Theory triangulation – theory from one discipline is applied to another.
- Complementarity – seeks enhancement, elaboration, clarification of results from one method to another, in order to increase interpretability, meaningfulness and validity of constructs.
- Development - the results from one method are used to help develop or inform the other method, where development is broadly construed to include sampling and implementation, as well as measurement decisions, making use of each method's strengths.
- Initiation - the discovery of paradox and contradiction, new perspectives of frameworks, the recasting of questions or results from one method with questions or results from the other method, in order to increase the breadth and depth of inquiry.
- Expansion - extends the breadth and range of enquiry by using different methods for different inquiry components.

Bryman (2006) gives sixteen justifications for combining quantitative and qualitative research strategies in their analysis of 232 articles, which had a rationale of combining them or combined them in practice. The use of both quantitative and qualitative research strategies is consistent with the aims of this research because each method would help answer a different set of questions, provide a level of completeness and explanation to the results obtained from each strategy, thus providing context. The mixed method approach will also help to illustrate, confirm and discover, and enhancement of the findings generated as explained in table A3 in appendix A. Thus the use of both approaches in tandem will add strength to the research which is greater than either qualitative or quantitative research alone (Creswell & Plano Clark 2007). Although mixing qualitative and quantitative strategies have been shown to help researchers think 'creatively and outside the box' (Mason 2006) and as shown above can help to further research in many directions, there have been philosophical issues that were debated during the paradigm wars of the 1980's (Tashakkori & Teddlie 1998; Bazely 2002; Bryman 2008; Mangan, Lalwani & Gardner 2004). It is important to understand the issues surrounding mixed methods because they enable the researcher to evaluate in what way the research strategy is useful i.e. understand the basis for the reasons mentioned in table A3 in Appendix A. Traditionally there has existed the so called qualitative and quantitative divide (Mason 2006; Greene, Caracelli & Graham 1989; Bazeley 2002), which has been discussed since, but perhaps not fully resolved. Three positions on this issue have been outlined by Greene Caracelli & Graham (1989), the purist stance which rejects the mixing of methods, the second position being that qualitative and quantitative methods are logically independent and therefore can be mixed and finally the situationalist which argues the purist approach but also argues that understanding of an enquiry can be significantly enhanced by exploring convergences in the strategies. The combining of quantitative and qualitative method with a view to providing ‘completeness and enhancement’ to the subject of barriers to energy efficiency can be seen to be the situationalist stance, as the aim is to provide a comprehensive account of the enquiry. Bryman (2006) suggests a set of questions, which are each addressed to explain the methodology in this research as shown in table A4 in appendix A.

3.2.2. Summary

Using the framework constructed in chapter two, agency theory and market barriers theories are used to assess implementation of measures and perception of barriers (using one method), observing the extent of the barriers (using another method) and quantifying the extent of barriers (using a third method). The use of these methods provides methodological and data triangulation (Easterby-Smith, Thorpe & Lowe 1991). It is hoped that this triangulation of methods and data will improve overall research validity and accuracy. The quantitative method is used first (sequential mixed method) to deductively test for principal agent problem and market barrier theories in shipping. Then a qualitative method is used to inductively assess and propose a theory on barriers specific to shipping, but more generally adding to the agency theory. This approach fits well with the procedures for mixed methods as defined by Creswell (2009) as shown below in Table 3.2 and Figure 3.2.

Timing	**Priority**	**Mixing the data**
Concurrent	Equal	Integrating – merging quantitative data with qualitative data
Qualitative first	Qualitative	Connecting – data analysis of quantitative with data collection of qualitative
Quantitative first	Quantitative	Embedding – Collecting quantitative form of data supported with qualitative data

Table 3.2: Planning a mixed methods design
Source: Adapted from Creswell (2009)

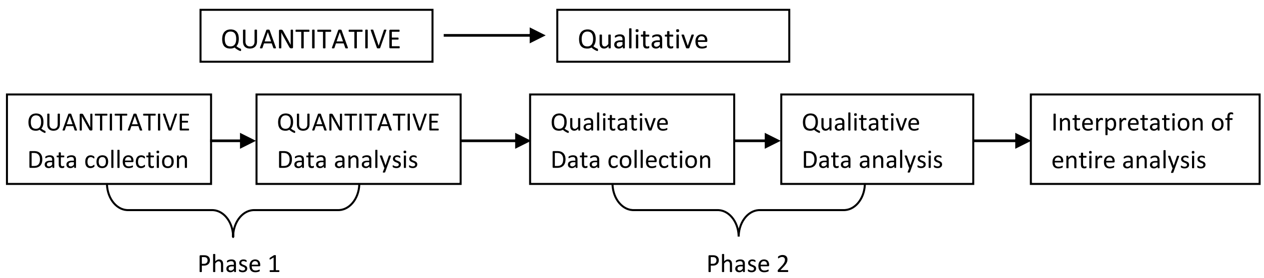


Figure 3.2: Sequential explanatory design
Source: Adapted from Creswell (2009)

3.3. Research Design

According to de Vaus (2001) "The function of a research design is to ensure that the evidence obtained enables us to answer the initial question as unambiguously as possible" (de Vaus 2001, p9). It provides a framework and structure for determining the way data is to be collected, when is it be collected, what data to gather and from whom and how to analyze that data (Bryman 2008). Research designs are important in explanatory research (why something is or isn't happening) because they help in avoiding invalid inferences about causation of variables (de Vaus 2001). Appendix A provides a brief explanation of the four main types of research in table A5 and table A6 briefly presents the strengths and weaknesses of each of the research designs. This is followed by the below evaluation using criteria from Yin (2003), Creswell (2009) and Bryman (2008) to discuss which one is most appropriate for this research.

According to Yin (2003), each of the above designs has advantages and disadvantages depending on:

- Type of research questions
- Control over actual behaviour or events
- Focus on contemporary as opposed to historical phenomena

According to Bryman (2008), the choice of research design reflects importance attached to:

- Expressing causal connection between variables
- Generalising to larger groups of individuals
- Understanding behaviour in its context
- Having a temporal appreciation of social phenomena and their interconnections

Bryman (2008) further outlines other criteria for selection of the research design, which fall under the 'practical considerations'. Practical considerations in selecting the right research design require the researcher to evaluate:

- Nature of topic and people being studied
- Existence of previous research
- Resources such as time and money

For the purposes of this research each of the four research designs is discussed briefly using the aforementioned criteria. Research question one and two require assessment of implementation of energy efficiency operational measures and their perception of barriers in the population of interest. A longitudinal design would be useful for this research question, particularly in understanding the different phases of implementation of operational measures, for example in terms of evolving regulatory environment (mandatory EEDI and SEEMP) or changing attitudes towards speed reduction. A longitudinal research design could also track changes in perception of barriers and observed barriers and contrast these with the findings on implementation of operational measures. An experimental design requires a good level of control and manipulation of the variables (Bryman 2008) and the lack of these means that this research design is not appropriate in answering this research question in the context of business or social research. Similarly a case study design would limit the research on implementation to a small population due to concerns over low external validity or generalizability (Bryman 2008).

Research question five aims to investigate the observed barriers to implementation. Here some of the research designs can be appropriate. A case study design would provide contextual depth on barriers to implementation of operational measures, giving 'complex and fuller explanation' (de Vaus 2006) of the barriers that may be encountered by the case firms. A cross sectional design on the other hand would provide a 'broad' view of these (Gerring 2007) by obtaining a snapshot (Barrington 2012) of the variables of interest (X and Y) included in the study, revealing how those variables are represented in a cross-section of the population, which could either be a subset or the whole population. A longitudinal research design could also track changes in perception of barriers and actual barriers and contrast these with the findings on implementation of operational measures.

From the discussion above and Table 3.3, it can be seen that longitudinal and cross-sectional research designs are appropriate for both sets of research questions. Both of these research designs can be helpful in expressing causal connection between variables if correct procedures are followed resulting in high internal validity (Bryman 2008) and as a result they can be used to make generalisations. To narrow down the research design selection, the last selection criteria on practical considerations are therefore important. This research needs to engage with businesses to determine their adoption of measures and perception of barriers to implementation. This business type research has to minimize respondent burden (Purdon & O'Connor 2008) and therefore be as unobtrusive as possible. A cross-sectional design would require data to be collected at a single point in time, whereas longitudinal data would require data to be collected over multiple time periods, making longitudinal data more obtrusive. Furthermore "because of the time and cost involved, longitudinal research design is relatively little-used in social research" (Bryman 2008, p.49). The shipping industry is often considered to be a conservative industry (Lloyds List 2013) i.e. changes often are as a result of regulation rather than innovation, for example in the case of safety regulations, etc. and especially on the subject of GHG emissions and energy efficiency (e.g. only a handful of companies reporting annual GHG emissions), thus making repeated engagement through longitudinal designs on this subject difficult.

Research design	RQ1 – implementation	RQ2 – Perception of barriers	RQ5 – Observed extent of barriers
Longitudinal	✓	✓	✓
Cross-sectional	✓	✓	✓
Case-study		✓	✓
Experimental			

Table 3.3: Research questions and research design

Bryman (2008) expands the definition of cross-sectional designs to not only include the number of cases (more than one) and time (single point in time) but also adds that it is used to collect a body of quantitative or quantifiable data to detect patterns of association among variables. Using this design information is collected from at least two groups of people at one point in time and this is then compared with the extent to which the two groups differ in the dependent variable (de Vaus 1995). Cross-sectional designs can be helpful when there are constraints of time and resources as they are generally less expensive compared to other research designs (Collis & Hussey 2003). According to Collis & Hussey (2003) cross-sectional designs are a positivistic methodology designed to obtain information on variables in different contexts. This means that they can be used in a deductive approach and for theory testing. It also places it firmly in the quantitative research strategy, however even qualitative research also entails a form of cross-sectional design mainly in the form of interviews (Bryman 2008, Saunders, Lewis & Thornhill 2007). Issues of reliability, replicability and validity of cross-sectional designs will be discussed in later sections after considering the research methods and data collection modes. Based on the evaluation criteria discussion above, the cross-sectional design was deemed most appropriate for answering the different types of research questions in this research.

3.4. Research methods

A research method is a technique or instrument for collecting data (Bryman 2008). There are several research methods that fit into the cross-sectional design and mixed methods strategy. These include: questionnaires, interviews, observation, content analysis and focus groups (Saunders, Lewis & Thornhill 2007). Each of these methods can be applied using the quantitative or qualitative strategy with the exception of focus groups. A very brief description of each research method and its quantitative and qualitative variant is given in appendix A, followed by strengths and weaknesses of each of these methods given in table A7. This is followed by the below evaluation on their applicability and appropriateness to this research using Creswell's (2009) selection criteria.

The choice of research methods will depend on the purpose of the research, research strategy and research design (Creswell 2009). The purpose of the research as outlined in chapter two is to understand why seemingly energy efficient operational measures are not being implemented by firms and to understand the role of barriers that may be inhibiting their implementation, which have been subsequently translated into two types of overarching research questions. The first set of research questions attempt to understand level of implementation of operational measures i.e. what is going on (descriptive research) and perception of barriers. The second set of research question is mainly of an exploratory nature attempting to understand observed barriers i.e. asking why something is going on or not going on, thus using both the inductive theory testing approach. Hence a mixed methods strategy in a cross-sectional design is deemed appropriate to meet the research aims. As described above there are mainly four research methods that can be of quantitative nature and equal number of research methods for qualitative research.

It is thought that a structured interview method would be applicable and appropriate in answering mainly the second set of research questions and possibly to some extent also the first question (as used by Velthuijsen (1993) in assessing the implementation of measures if enough interviews are conducted). However the practicality in terms of the resources (time) was seen as a major setback, as well as issues of representativeness and generalisation to make inferences to the larger populations for the first research question. Similarly, the quantitative content analysis and structured observation methods are thought to be inappropriate to answering the first research question but there is a possibility of using these methods to collect data to answer the second research question. For example the quantitative content analysis of the news or media could reveal the barriers that are being mentioned by the businesses and industry or company policies relating to the implementation of measures. Structured observation would be suitable in a case-study design where for example organisational procedures and processes regarding the implementation of measures could be observed. Both these methods although applicable were deemed not adequate enough to add depth to answering the second research question, and secondly they would require many more resources including permissions and access to organisations. Since the structured interview (which can also be referred to interviewer administered questionnaire) was a very valid method to investigate the research questions but with the main disadvantage of resources, it is thought that self-completion questionnaires would overcome this problem. This is because self-completion questionnaires are cheaper and quicker to administer. This research method can generate enough data to answer the first set of research questions, although employing this method to answer this would also mean that the disadvantages such as response rates and missing data become a problem. It is thought that following the advice of respected authorities on this subject e.g. Dillman (2007) and de Vaus (1995) and carefully designing the instrument and implementing it carefully would enable to some extent to overcome the pitfalls of this method and thus improve the reliability and validity of the method. Furthermore, a carefully devised self-completion questionnaire using or learning from existing empirical barriers research (framework and methodological pitfalls as discussed in chapter three) should be able to also gauge the perception of barriers.

Table 3.4 below shows that no single research method can answer all of the research questions with sufficient detail in a perfectly valid and reliable manner, hence the need to employ mixed methods strategy. To answer the second set of research question, which seeks to discover observed barriers the inductive research process, theory building approach is taken, employing the qualitative research strategy with a cross-sectional design. The semi-structured interview and focus groups research methods would be highly appropriate in this regard, for example to be able to gauge particular problems with charterparties by speaking to the relevant professionals on this subject or to shed light upon the most pertinent barriers perceived. Its major limitation is that it is an obtrusive method (Hussey & Hussey 1997), asking industry participants to partake in an interview and contributing their time is difficult because it presents a greater opportunity cost to the participant's time. Considering the industry characteristics and the business type research, the repeated data input from people using the aforementioned methods would be more difficult. Nevertheless, every effort was made to obtain their views on this research in an informal way, enabling the research to be ecologically valid (Bryman 2008). Examples of engagement with industry stakeholders were through email exchanges with the experts, attending and presenting at seminars and conferences (e.g. as a subject matter expert on shipping in Carbon War Room Creating Climate Wealth symposium, presenting work at Low Carbon Shipping conferences, speaking in industry conferences such as Capital Link Forum and Royal Institute of Naval Architects). Other examples of this regular contact with industry were a DNV (classification society equivalent of an auditor in other industries) organised seminar on energy efficiency measures, where charterparties were discussed at length, attendance at a two day training course on charterparties which provided a network and an opportunity to present the findings thus far and email exchanges with a large shipping law firm and large operators, etc. This active participation and interaction with the industry meant that informal or anecdotal ethnographic observation was always taking place, which provided avenues to mould this piece of qualitative research.

Based on the limitations of the above methods in answering the qualitative research question, the qualitative content analysis (or ethnographic content analysis - ECA) method seems to be relatively convenient way of collecting data for the research question, least obtrusive method that would allow quick and easy access to data i.e. thinking that is going on this subject, with the advantage of a methodology enabling continuous refinement. The qualitative content analysis method can be merged to the results of the self-administered questionnaire to provide completeness to the research findings. Agency theory, which purports the principal agent barrier, focuses on the contract between the parties and is concerned with creating the most 'efficient' contracts that overcome the problems of agency i.e. goal conflict and informational problems between the principal and agent, as well as problems of risk. Agency theory research is based on research methods such as questionnaire (Eisenhardt 1985), and other data analysis such as meta-data analysis (Ahimud and Lev 1981) with some agency theory research focussing on contract itself or contract design (Crocker & Reynolds 1993; Aubert, Patry & Rivard 1997; Molinie & Abran 1999; Stremitzer 2005; Masten & Snyder 1991; etc.). There are a host of charterparties (contracts) used by shipping companies which can be analysed for themes and categories as barriers to operational measures. There may still be a problem of access to these charterparties, which can result in a non-representative sample, but this is rarely a high priority objective of qualitative research (Patton 1990). Furthermore the charterparties may be difficult to interpret but it is anticipated that with sufficient reading of authoritative texts on this subject (such as Wilson 2010; Girvin 2007; Spurin 2004; etc.) the knowledge gap to adequately interpret the clauses will be overcome. This method will be further discussed in section 3.5.6 of this chapter and potential solutions to overcome the problems are addressed. For a summary of the research path or choices made so far refer to summary section 3.6.

Using Creswell's (2009) selection criteria for research methods as discussed above and weighing up the strengths and weaknesses of each method, it is deemed that the methods employed in this research would be a quantitative cross-sectional self-completion questionnaire and qualitative cross-sectional content analysis. Both these research methods fit the research design and strategy well. In fact, of these the ones that fit cross-sectional design particularly well are questionnaires or surveys according to Saunders, Lewis & Thornhill (2007), de Vaus (1995) and Bryman (2006) and are by far the most common method employed in cross-sectional design. A cross-sectional design is also appropriate for the content analysis method because it involves more than one case, takes place in a single point in time and aims to determine patterns of association. For both the aforementioned methods, all three types of research strategies are possible i.e. a qualitative or quantitative survey, qualitative or quantitative content analysis or any combination of the two. The main reason for combining them in a mixed methods approach as outlined in section 4.3.1 was so that the latter method would add depth to the broad findings of the questionnaire (enhancement), it would provide completeness in the subject of inquiry, in terms of assessing the principal-agent theory which is based on contractual relationships and illustrate the implementation of operational measures from a contractual perspective, adding “meat on the bones” (Bryman 2006, p106) in explaining associations gathered in the quantitative questionnaire. Furthermore, the combination of the methods is also thought to be balancing the advantages and disadvantages of the specific methods (i.e. offsetting, Bryman 2006), for example the advantage of content analysis methods over survey method is that it is a non-obtrusive method, where subjects of the study are unaware and unaffected by the research. The self-completion questionnaire is further discussed in section 4.1 and content analysis in section 4.2.

Method	RQ1 – Measures implementation	RQ2 – Perception of barriers	RQ5 – Observed barriers
Structured interview		✓	✓
Quantitative content analysis		✓	
Structured observation		✓	✓
Self- completion questionnaire	✓	✓	
Semi/un structured interview		✓	✓
Qualitative content analysis			✓
Ethnographic observation		✓	✓
Focus groups		✓	✓

Table 3.4: Appropriateness of methods in answering research questions

3.5. Data collection mode

As a research method, the self-completion questionnaire can be applied in several different forms or modes. The most prominent mode being the mail or postal self-administered questionnaire (Bryman 2008), which has been used extensively (in all cases where self-completion questionnaire method was used) in the empirical studies examining barriers to energy efficiency. According to Saunders, Lewis & Thornhill (2007) there are three types (modes) of self-administered questionnaires; internet mediated self-administered questionnaire, postal questionnaire, and deliver and collection questionnaire. The choice of questionnaires will be influenced by research questions and objectives of the research as well as (Saunders, Lewis & Thornhill 2007):

- Characteristics of respondents
- Importance of reaching particular respondents

- Types of question being asked and number of questions
- Sample size required taking into account the likely response rates
- Automation of data entry
- Resources - Financial implication (cost) and time availability.

The above criteria, Bryman's (2008) criteria on practical consideration and a further three criteria derived from comparative literature on self-administered questionnaires (quality, time to completion and representativeness, e.g. Fricker & Schonlau 2002, etc.) are used to evaluate each of the data collection modes. Data collection mode discussion only applies to the quantitative self-completion questionnaire that has been selected as a research method and does not apply to the qualitative content analysis method. The questionnaire would be administered to technical superintendents and operational managers of global shipping companies who are generally responsible for the implementation of operational measures of the fleet under their control. The people in these management roles are generally mobile but can also be located in the global or regional head offices of the companies. They can be said to be highly internet-literate and have good access to the internet. A highly established news agency (Lloyds List) which can be said to have a monopoly in the shipping news market recently claimed that vast majority of its readers now consume their content online and via email services rather than waiting for their newspaper. On average their website receives over 200,000 visits (71,000 unique visits) every month, 90% coming from desktop or laptop devices, with an average duration of over four minutes (Lloyds List 2012). It is thought that an email invitation to a web based survey would reach the intended recipient regardless of where they are located and would ensure that the required respondent answers. Web based surveys in conjunction with emails have a higher degree of control, because most users read and respond to their own mail at their personal computer (Witmer, Colman & Katzman 1999). The first research question is mainly quantitative and therefore much of the questionnaire could use closed ended questions (this is further discussed in instrument design section 4.1.5). Keeping the above mentioned respondent profile and research aims and questions in mind, the following section discusses the relative strengths and weaknesses and response rates of the two main modes of self-administered questionnaires.

From Table 3.5 it can be seen that web based questionnaires have several advantages over postal questionnaires, such as ease of data entry, financial resources, time taken to completion, confidence of the right respondent answering and low level of contamination. Each of these is assessed in detail and in relation to the respondent profile aforementioned.

	Web based	Postal
Population characteristics for which suitable	Computer literate, contactable by email or internet	Literate, contactable by post
Confidence that right person has responded	High if using email	Low
Size of sample	Large, can be geographically dispersed	Large, can be geographically dispersed
Likely response rate	Highly variable, 10% or lower (Wiltmer et al. 1999)	Variable, 30% reasonable, 60% reasonable for TDM
Length of questionnaire	Conflicting advice on typical length but fewer screens better	6 – 8 pages
Suitable types of question	Closed questions, not too complex, can be complicated sequencing if uses IT	Closed questions, not too complex, simple sequencing only
Time taken to completion/collection	2 – 6 weeks dependent on number of follow ups	4 – 8 weeks dependent on number of follow ups
Financial resource implications	Web page design, although automated expert systems reduce this dramatically	Outward and return postage, photocopying, data entry time
Data input	Usually automated	Only closed questions can be read by optical mark readers.

Table 3.5: Main attributes of internet and postal questionnaires
Source: Mostly from Saunders Lewis & Thornhill (2007)

3.5.1. Cost

By definition a web based survey will almost be cheaper than postal surveys (Fricker and Shonlau 2002), but the total costs of the survey need to be considered. Expenses incurred in web based surveys include e.g. additional electronic mailing package costs, development costs if using tailored web page design, monthly fees of online software providers. Typical cost per 10,000 respondents for web survey cost much less than postal surveys (Watt 1999 cited by Yun & Trumbo 2000). Additionally, web based modes save time on data entry but this can be outweighed as the design stage can take longer (Fricker and Shonlau 2002). Cobanoglu, Warde & Moreo (2000) analyse the fixed and variable costs of three modes of questionnaire, postal, fax and web based and conclude that web based surveys were the least costly even when taking into account the high initial fixed costs, postal surveys were the costliest due to the variable costs despite the low initial costs. Their analysis does not take into account the full cost i.e. coding costs, where web based surveys would have fared on top due to automation. Forrest & Schleyer (2000) conduct a similar study to evaluate the total cost-effectiveness of the different modes and conclude web survey to be the cheapest overall based on a certain breakeven point or formula that is suggested. The respondent’s profile mentioned earlier was shown to be geographically dispersed and global, thus a postal survey would entail significant cost in this case.

3.5.2. Time to completion

By definition delivery time of a web based survey is faster than postal, but there is little evidence that this leads to a shorter data collection period (Fricker and Shonlau 2002). Yun and Trumbo (2000) show that electronic surveys (mainly email surveys) provide a faster reaction time than mail surveys, with many responses arriving within two or three days following initial contact before the first completed paper surveys are returned. Cobanoglu, Warde & Moreo (2000) show that the fastest mode of response to their survey was fax with a mean of four days, web mean of six days, postal surveys with a mean of sixteen days.

3.5.3. Representativeness

Coverage error has almost received every mention in the discussion of web based and postal modes (Dillman 2007; Fielding, Lee & Blank (eds.) 2008). However, this is generally a concern for surveys on citizens or non-specialized groups and may not apply to businesses, as all businesses now have internet and email access (Vehovar, Lozar & Batagelj 1999 cited by Fricker & Shonlau 2002) and may not apply to specific sub sets of the population or those that are being studied (Cobanoglu, Warde & Moreo 2000). Fricker and Shonlau (2002) suggest that non response errors occur more in electronic formats email than postal. However, Stanton (1998) and Kwak & Radler (2002) report obtaining less missing data (item non response) from a web based survey perhaps because they can be designed to skip irrelevant questions.

3.5.4. Quality

Yun and Trumbo (2000) suggest that quality of responses to open-ended questions is better for electronic formats, where respondents have been noted to write lengthier and more self-disclosing comments, than on mail survey questionnaires (Bachmann, Elfrink & Vazzana 1996; Loke & Gilbert 1995; Schaefer & Dillman 1998). For example, Schaefer & Dillman (1998) attained a four-fold increase in length of open-ended responses using electronic methods, and Lock and Gilbert's (1995) study showed greater self-disclosure in electronic formats, similar to that achieved by Kwak and Radler (2002). A possible explanation for this is the speed of typing compared to writing by hand

(Bachmann & Elfrink 1996). Stanton (1998) points out that the web based surveys have the advantage of being stricter in how they allow respondents to answer, as opposed to postal or paper based and e-mail surveys where respondents can write or type whatever they want in the marginal space of the paper or in the e-mail reply. In a web based survey this only permitted responses in the designated spaces such as in the open-ended question screen. The only serious disadvantage of using web based mode then is the level of response rates, which necessitates further evaluation of this mode for this research.

3.5.5. Literature review of response rates for web based and mail questionnaires

The only serious disadvantage of using web based mode is the level of response rates, which is generally a third or less of that achieved by postal (Saunders, Lewis & Thornhill 2007; Fricker and Shonlau 2002; Yun and Trumbo 2000). There have been several studies (Fricker & Shonlau 2002; Yun & Trumbo 2000; Cabanoglu, Warde & Moreo 2000; Greenlaw & Brown-Welty 2009; Hadre, Crowson & Xie 2012; Millar & Dillman 2011; Sax, Gilmartin & Bryant 2003; Shih & Fan 2008; etc.) that have compared the survey response rates between different modes especially web based and postal modes. Fricker & Shonlau (2002) show response rates for six web only surveys varied from 8% to 44% across different types of respondents. Where respondents were given a choice between the modes, the postal survey mode had five to ten times greater selection than that of web based. However, there are two instances where response rates of web based exceeded that of mail by a factor of four and it is important to note who the respondents were; dentists and researchers (Fricker & Shonlau 2002), which suggests that respondent profile is a key factor in response rates. Other studies have only focussed on the response rates of web based questionnaires such as Cook, Heath & Thompson 2000; Fan & Yan 2010; Archer 2008; etc. Although web based survey response rates varied widely as shown earlier, in general around a 10% response rate is deemed acceptable (Saunders, Lewis & Thornhill 2007 give an average of 11%). Fielding, Lee & Blank (eds.) (2008) suggest that response rates vary considerably from less than 1% for enterprise surveys, resulting in large non-response error, to almost 100% for specific membership surveys. The difference in response rates could be due to many factors such as survey fatigue (Witte 2009), poor design, very lengthy and inappropriate subjects (Saunders, Lewis & Thornhill 2007). Saunders, Lewis & Thornhill (2007) give a table of factors and its impact on response rates. According to Archer (2007) there are many other questionnaire and process variables that affect the response rates, but the most significant are sending email invitations and allowing longer completion window to respondents.

There are several ways to tackle the low level of response rates in web based surveys. One of the best ways to increase response rates is through the questionnaire design and deployment processes

(Archer 2008). Other methods include sending personalized email notifications, invitations, and follow-up reminders (Dillman 2007). Other factors that increase response rates include; incentives, sponsorship and multi-modal approaches (Dillman 2007), discussed in greater detail in section 4.1.

3.5.5.1. Surveys in shipping

This section briefly reviews surveys of all types and modes conducted in shipping and looks at the quality measured through the response rates achieved by the surveys. Response rates for Faber, Behrends & Nelissen (2011), Gordon (2008) and Hill (2010) have already been discussed in literature review. These coupled with DNV (2012) are most relevant surveys to this research as they are focussed on barriers to implementation of energy efficiency measures. DNV (2012) used the self-administered questionnaires and received twenty four responses to their questionnaire, however the response rates are not known for these and it is not known which type of stakeholders participated in these.

Norton Rose (2009, 2010, 2012, 2013) is an annual survey of three transport sectors including shipping, on issues such as finance, economy and future scenarios. The latest survey used the online questionnaire mode and received 1,100 responses from these sectors, of which nearly half were from shipping, actual response rate is not known. The respondents are recruited from subscriptions to industry magazines (e.g. Marine money) and the firm's own contacts. The survey included all types of stakeholders including shipowner operators, population of interest for this research. Over half of the respondents were from Europe followed by a quarter from Asia Pacific and 15% from North America, which represents the shipping clusters.

NAPA (2012) conducted a survey using the online questionnaire mode to assess the readiness of shipowners, operators and charterers for the Ship Energy Efficiency Management Plan (SEEMP) legislation. The survey received just over fifty responses and the response rate again is not known, as well as the sampling frame and method. The respondents' demographics are similar to that of Norton Rose (2012) but the survey received more Middle Eastern respondents than North American. A quarter of the respondents were from large companies (more than sixty ships), half from medium sized companies (between fifteen and sixty ships) and remainder from small sized companies (less than fifteen ships). The majority (90%) of the respondents were shipowner-operators and management companies. In addition to the above, industry press such as Lloyds List and Sustainable shipping carry out various polls and short surveys using the web based online questionnaires, which have had modest participation from the industry. This brief overview shows that most surveys in shipping can be conducted via online questionnaires. Table 3.6 summarises the strengths and weaknesses of web based and postal mail questionnaires.

	Online	**Postal**
Strengths	• Relatively lower cost for a larger volume of data • Relatively faster response and turnaround times • Relatively more attractive formats and flexible designs focussing on user friendliness • Mixed mode administration • Not geographically limited • Lower item non response • Better response to open ended questions • Automation and accuracy of data entry and analysis • Easier to monitor responses and completion	• Relatively higher response rates requiring relatively smaller sample • Easier to incentivise using prepaid tokens • Postal addresses provide more reliable sampling frame and enable variety of sampling methods • Can be relatively longer in number of questions
Weaknesses	• Lower response rates requiring a relatively larger sample • Restricted to online populations • Difficult to portray confidentiality and anonymity • Cost of programming or fees for web survey software • Concerns over some sampling methods used to recruit participants resulting in sampling and non-response bias • Need to be shorter up to fifteen questions to avoid dropouts • Susceptible to technical problems • Relatively difficult to incentivise	• Limited to geographical coverage • Relatively more expensive and slower to administer • Requires additional time to input data or responses • Data entry accuracy is lower • Difficult to monitor progress of respondents

Table 3.6: Strengths and weaknesses of self-administered questionnaire modes
Source: Bryman (2008), ESRC NCRM (2013)

The evaluation of both the data collection modes using the criteria outlined above supports the use of a web based data collection mode for this research. Most important factors for this choice are the respondent profile (which has an implication on representativeness and bias), global nature of the industry (which has a cost implication) and time to completion. This choice of a web based data collection mode will have to address the issue of low response rates. In the next chapter the details of the design of the web based mode and other factors relating to the self-completion questionnaire (e.g. internet sampling strategies) are addressed in order to overcome the problem of low response rates.

3.5.6. Content analysis forms

Content analysis is defined as the "analysis of the manifest and latent content of a body of communicated material through classification, tabulation and evaluation of its key symbols and themes in order to ascertain its meaning and probable effect" (Krippendorf 2004, p. 17). It is an "empirically grounded method, exploratory in process and predictive or inferential in intent" (Krippendorff 2004, p.17). "Content analysis is a research technique for making replicable and valid inferences from texts (or other meaningful matter) to the context of their use" (Krippendorff 2004, p.18). Thus it concerns itself with replication of results and what can be legitimately inferred from available texts. Schreier (2012) describes qualitative content analysis as a "method for systematically describing the meaning of qualitative material. It is done by classifying material as instances of the categories of a coding frame" (Schreier 2012, p.1). Bryman (2008) sets out the key evaluation criteria for qualitative content analysis as discussed in section 4.2. In content analysis the source for categories and a coding scheme can be the data itself, previous related studies, and theories (Zhang & Wildemuth 2006). The key difference between quantitative and qualitative content analysis is the way categories are constructed. In quantitative content analysis categories are generated from sources other than the data to be analysed where as in qualitative content analysis the categories are constructed at least in part inductively (Forman & Damschroder 2007). An example of the use of quantitative content analysis in shipping is Karamperidis, Jackson & Mangan (2013). Since there are no previous studies that have done a thematic content analysis of charterparties in shipping it is advisable to use inductive content analysis. "The use of inductive content analysis is recommended when there are no previous studies dealing with the phenomenon or when knowledge is fragmented" (Elo & Kyngas 2008). Inductive research moves from specific observations to broader generalisations and theories (Spens & Kovacs 2006). Inductive research in qualitative content analysis is applied mainly through inductive category development process (Mayring 2000), which begins with research questions, broad or abstract categories, revision of categories and analysis.

There are several forms of qualitative content analysis, discourse analysis, social constructivist analysis, rhetorical analysis, ethnographic content analysis and conversation analysis (Krippendorf 2004, see table A8). From these the most relevant form of content analysis for this research is thought to be qualitative content analysis in the form of ethnographic content analysis (ECA). The reasons for this are that it is thought that through the reflexive and re-iterative reading of the charterparties emergent categories that would allow for answering research questions would be constructed. The emphasis of ECA on gaining familiarity with the content tackles the researcher's lack of content knowledge of charterparties. Furthermore, the use of ethnographic content analysis would remove the problems associated with structured protocols such as definitive categories, sampling methods etc. In section 4.2, the application of this method in this research is revisited. Table A9 in appendix A briefly summarises and contrasts the ECA method that is used in this research to quantitative content analysis.

3.6. Summary

So far the chapter has explored various theoretical approaches which underpin the research choices, research designs, research methods and the data collection mode of the research methods. Key to the choices of the aforementioned are the research questions that are developed in the preceding chapter. The questions could be answered through the combination of primary and secondary research. For primary research questions the mixed methods approach is deemed most appropriate, using the cross-sectional research design and employing the self-administered questionnaire and content analysis method. The justification and evaluation of each of these are provided in the relevant sections above and Figure 3.3 and Figure 3.4 present a pictorial format of the research choices. Figure 3.5 and 3.6 show how these research choices fit with the research framework developed earlier.

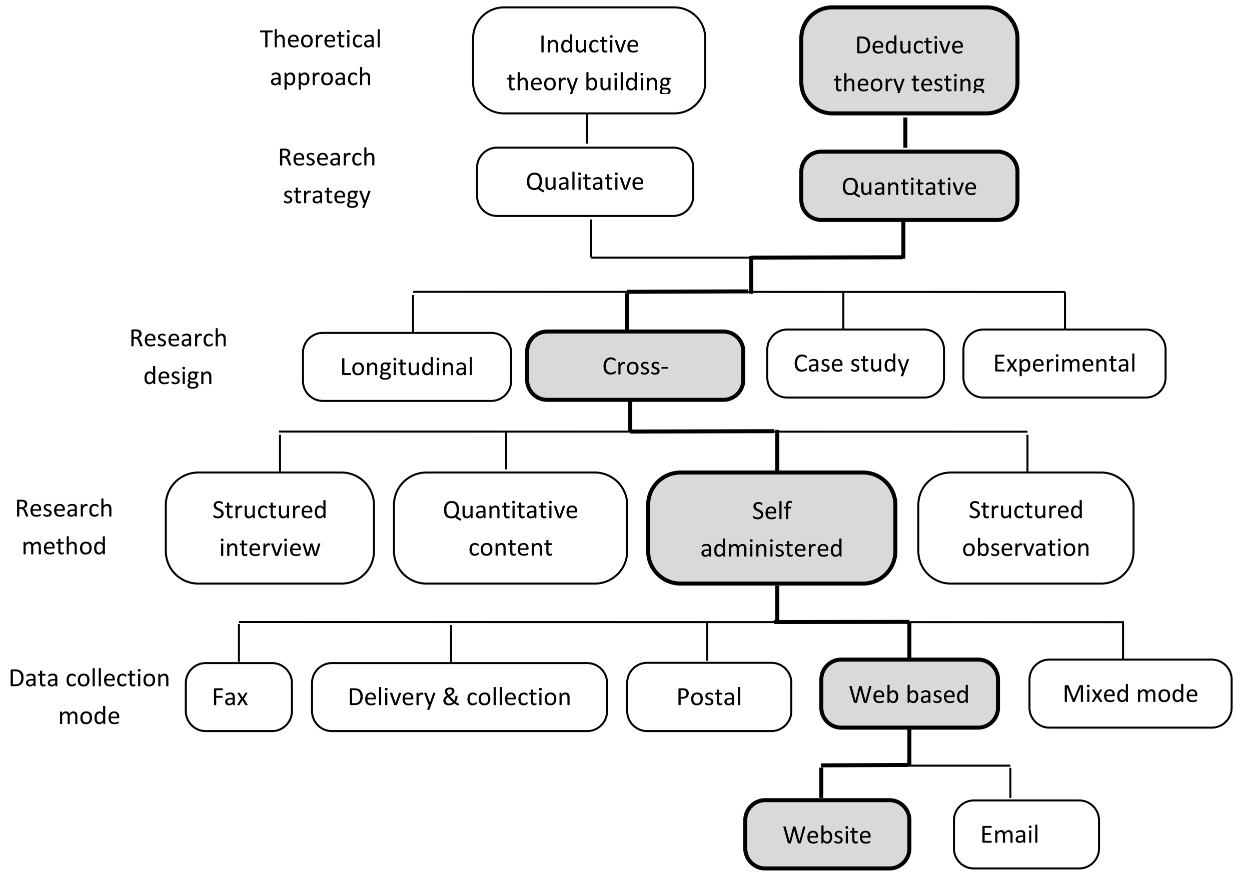


Figure 3.3: Research path and choices to answering research questions one and two

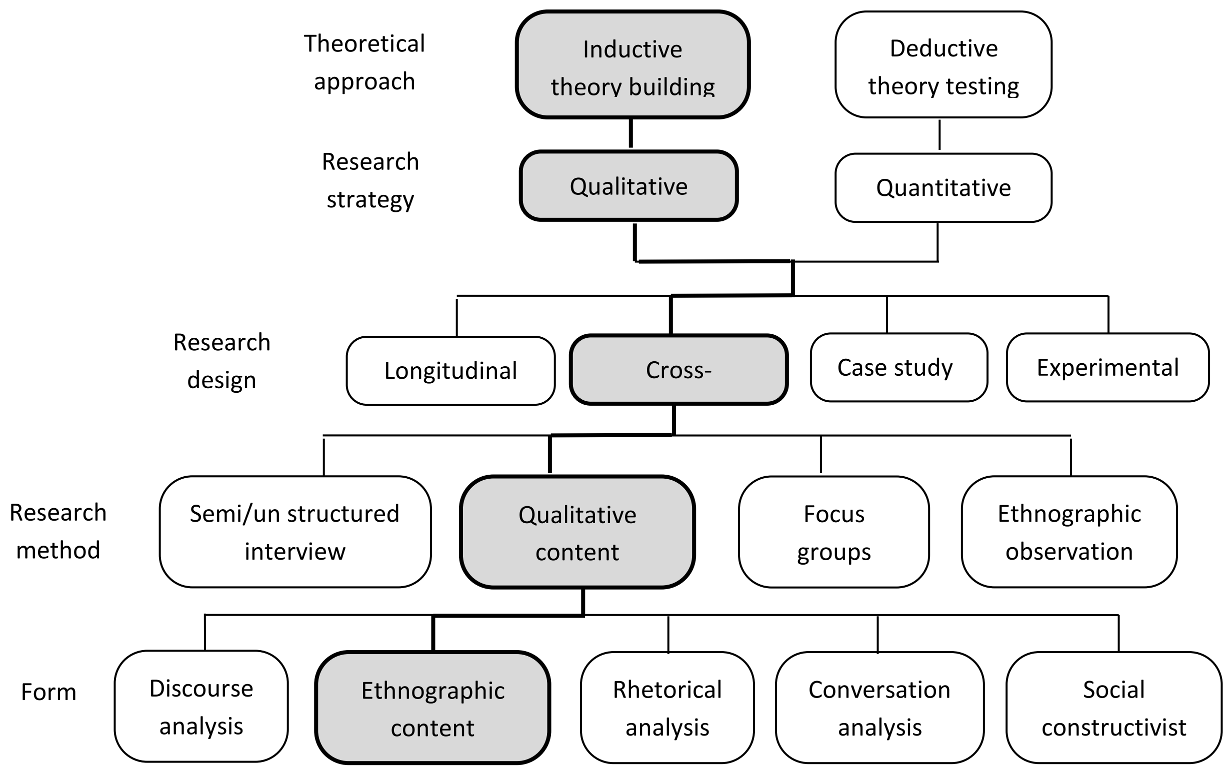


Figure 3.4: Research path to answering research question five

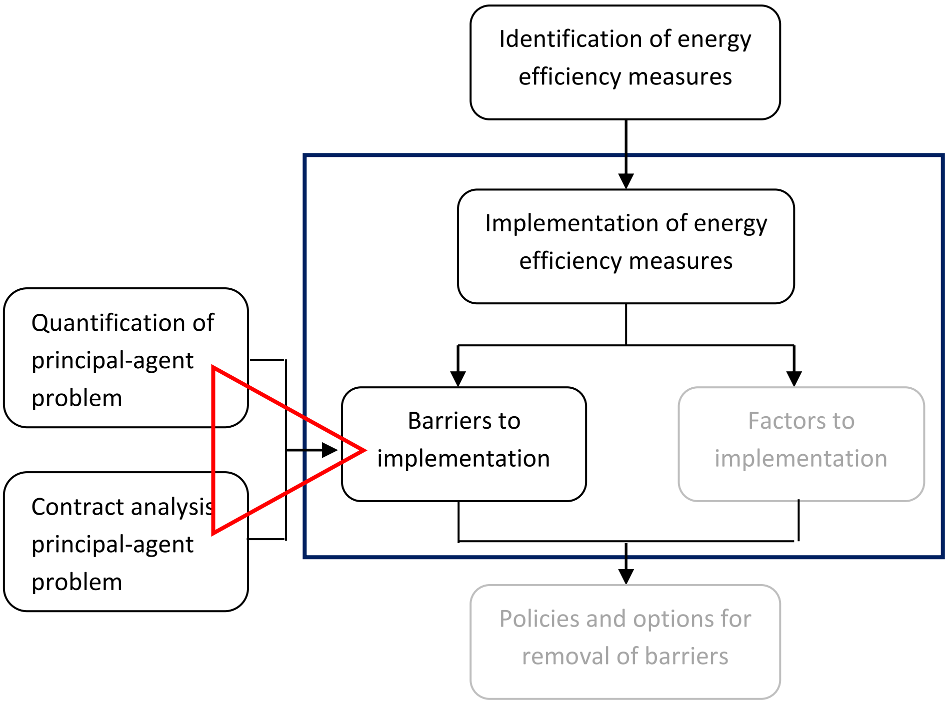


Figure 3.5: Self completion questionnaire method used within the barriers framework

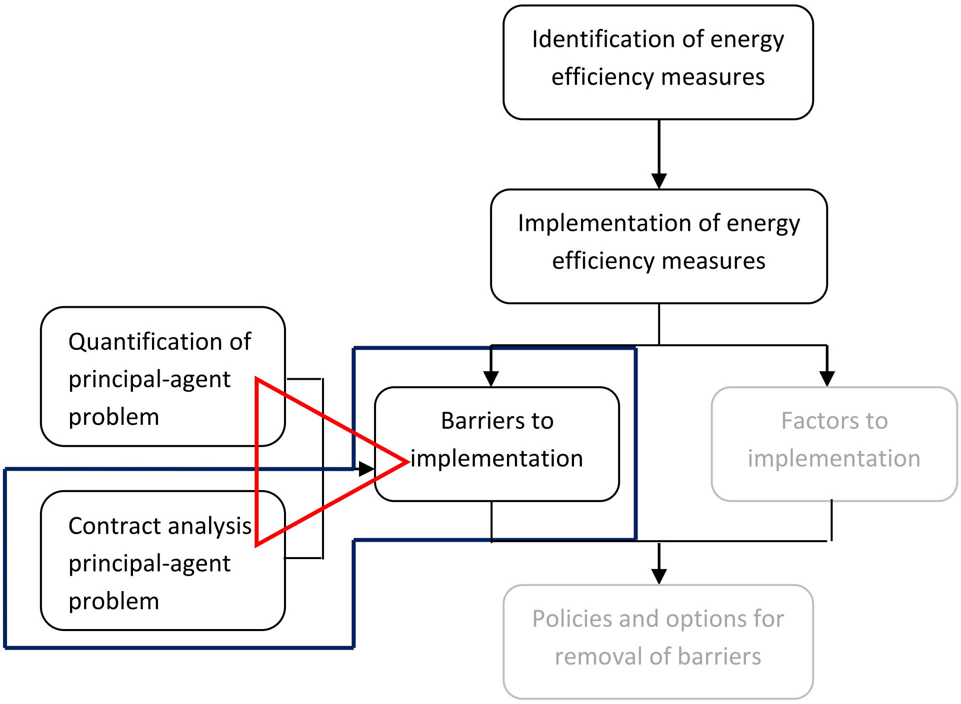


Figure 3.6: Content analysis method used within the barriers framework

4. Design and implementation of research methods

This chapter delves further into the details of the design and implementation of the data collection methods that have been selected above to answer the research questions. The chapter begins with describing the quantitative self-completion questionnaire method, followed by describing the qualitative content analysis method, thereafter describing the secondary data gathering analysis which is used as a parallel strategy to test the findings of the primary research methods.

4.1. Self-completion questionnaire: Instrument design and implementation

This section describes the process used in this research for creating, designing and implementing the self-completion questionnaire. This starts with a review of the aims and objectives of the survey, followed by discussion of the data collection mode, sampling of the participants, Tailored Design Method (TDM) that is used to maximise response rates, pretesting, design of questions and indicators and issues of concern. This is an important area for discussion because previous empirical studies on barriers to energy efficiency both in general and in the shipping literature have hardly been able to generalize beyond the sampling population as most lacked serious methodological rigour (e.g. Hasanbeigi, Menke & du Pont 2009; Sardinanou 2008; Kollamthodi et al. 2008)In order to address the issue, the Tailored Design Method (TDM) (Dillman 2009) is used. TDM has a set of several guidelines that if followed should yield in high response rates. There are various guidelines in TDM but two sets of guidelines are most relevant to this research; guidelines on web survey implementation and guidelines on web survey design, as outlined in appendix A. Some of these guidelines were handled by the web survey software, such as assigning respondent ID, providing a survey link, monitoring progress and completion rates. The remainder of the guidelines such as emails frequency, timing, and incentives are discussed in the following sections.

4.1.1. Survey aims and objectives

It is essential that the survey aims and objectives are kept in mind when implementing and designing the web survey. The purpose of the survey is to assess the level of uptake of energy efficiency operational measures within the shipping industry and to understand the perception of barriers to their implementation. Therefore, the survey should be able to provide an indication of what energy efficient measures are implemented in each of the shipping sectors and shed light on why some are not undertaken or seem unattractive for investment, thus enabling to answer research questions one and two.

4.1.2. Data collection mode

The data collection mode has been discussed in section 3.5. It was concluded that a web based cross-sectional quantitative self-completion questionnaire would be best suited for answering the research questions. There is a very good set of literature (Fielding, Lee & Blank (eds.) 2008; Dillman 2007; Witte 2009; etc.) that has been used throughout this research for ensuring that correct procedures are followed. Furthermore the extensive online training package by Economic and Social Research Council (ESRC) for internet research methods was also used (www.restore.ac.uk/orm) in conjunction with the WebSM portal (www.websm.org). There are several off-the-shelf 'point and click' questionnaire design software available on the internet, which are best suited for university students (Fielding, Lee & Blank (eds.) 2008). WebSM portal lists more than 350 online software available, by type of source (open or closed), pricing structures, etc. (Kaczmirek 2008). After a thorough investigation of the available software, the best software that met the needs of this research was Qualtrics (www.qualtrics.com) as it allowed many very advanced features (such as skip logic, display logic, JavaScript, branching, user interface enhancement in the design), as well as complex online analysis tools and good export functionality (for further analysis of data in SPSS), to be incorporated into the survey at no additional costs, thereby reducing the initial costs of the survey, which has been one of the major criticisms of the web based survey mode.

Since the survey is a web based questionnaire the sample could be recruited by one of the online sample recruitment methods (discussed in the following section). According to DIllman (2007), there are four ways to mix modes in order to improve response rates:

1. Use one mode to contact respondents and to encourage response by a different mode.
2. Use a second mode to collect responses from the same respondents for specific questions
3. Use alternative modes for different respondents in the same period
4. Use a different mode to survey the same respondents in a later data collection period.

The main motivation for the above is to increase response rates, reduce coverage error and non-response rates. The primary limitation to combining different modes is measurement error or biases (Dillman 2007). Within this research only the first two approaches are used in order to reduce measurement error and different answers, with the expectation that participants will need to be reminded to take part in the web based survey and the second approach in order to remove item non-response. Fricker (2008) shows that response rates increased by 8% up to 35%, when more than one mode was used for follow up and administration of the survey. The modes used in this research were email and telephone, over the three to five contact points with the respondents, which followed the TDM guidelines. Note that only the follow up mode was changed from email to telephone rather than administration of the questionnaire from web to telephone. The contact points are discussed in detail in section 4.1.3.3. A spreadsheet was used to track the contacts points and persons (from pre-notification to thanking respondents who completed the survey), listing completions which are then matched to the sampling frame, which is discussed below.

4.1.3. Sampling

A good sampling method is required to get a representative view of the cross-section of the population studied. "To be representative the sample should be a small scale replica of the population in all essential respects" (Orr 1995, p. 293). A sample is selected based upon the population, sampling frame and sample size required to make generalisations (de Vaus 1995). A population consists of all units to which one desires to generalise the result of the survey (Dillman 2009). The population for the survey would be all the shipowners, ship operators, ship owner-operators, charterers, management companies, as well as shipping divisions of cargo owning companies, i.e. any entity that is involved in the direct operation of the ship. The population does not include other stakeholders such as shippers, ports, etc. involved in the shipping supply chain. Each shipping company is considered as the unit of analysis as it would be implementing the operational measures, consequently only one person employed by the company is considered to be the decision maker or responsible for those measures i.e. operations manager or technical superintendent acting as a proxy for that company. This means that in very large companies, where it is likely that several operations managers would be employed, the results may not be representative of the whole company, although it is thought that these large firms would have unified policies on implementation of measures. In these situations every effort is made to contact the most senior personnel regarding the operational measures.

4.1.3.1. Sampling frame

A sampling frame is the "complete list of all the cases in the population from which a sample is drawn" (Saunders, Lewis & Thornhill 2007, p.610), although it is very rare to have a sampling frame which is truly complete (Bryman 2008; Saunders, Lewis & Thornhill 2007). There are many sampling frames (or online databases) that represent to a good degree the population of interest, of which the major ones are Clarksons Ship Information Network (SIN), IHS Fairplay Sea-web (previously known as World Shipping Directory), World Shipping Register and Infomarine. Clarksons SIN has the most up to date information and it is believed that this is the most comprehensive list of the target population. Access was granted through a user license already available under the LCS project. However, upon comparison with other online databases such as World Shipping Register slight under-coverage of companies was noted, suggesting a non-coverage error/frame coverage bias, for which every effort was made to merge the frames to cover as accurately as possible the target population. Thus a completely new frame had to be constructed for the purposes of this research. The Clarksons SIN covered all the entities of the population shipowners, ship owner-operators, charterers, management companies and shipping divisions, however it most accurately reflected the first three types of respondents. For these categories certain useful information was held in an online database, which had to be manually entered onto a spreadsheet on a company by company basis, starting with companies with the highest number of ships in the fleet to the lowest. The sampling frame initially consisted of the following fields; company name, headquarter address, main telephone contact number and fax, company email (missing on average 10% for large and medium, 25% for small), size by number of ships, size by total DWT and region.

The above fields formed the basis of the first version of the sampling frame, gathered from Clarksons SIN, which is then updated with companies from other databases. Where there were missing cells or fields the company's website was used to find the relevant details, as well as specific departments and personnel in the operations department. Companies were only included in the sampling frame if they belonged to one or more of the sectors of interest i.e. companies that actively traded in the wetbulk, drybulk and container. Actively traded in sector is defined when more than 90% of the company's fleet is engaged in the any one of the sectors. Companies actively engaged in all the above sectors were categorised as operating in mixed sectors.

According to Stopford (2008) in 2007 there were over 5,500 shipping companies, owning nearly 40,000 ships, with an average of seven ships per company. 33% of the fleet (by number ships) was owned by only 112 companies with fifty ships and above (large companies). Another 33% of ships were owned by 716 companies operating ten to forty nine ships (medium sized companies) and the remainder third owned by 4700 companies owning between one and ten ships (small companies). The sampling frame based on the above taxonomy is then stratified according to sector and size. Regarding the size of companies there was a significantly large tail of small companies with less than five ships in their fleet (see Figure 4.1). Focussing only on the large and medium sized companies would result in nearly 70% of ships being covered. In business surveys it is quite common to have cut off samples because according to Eurostat (2008):

"Small sub-populations may sometimes be quite impossible to reach although they are known,.....Cut-off samples are applied in business surveys where the smallest units do not contribute too much to the parameter of interest. However, since one part of the target population is deliberately excluded there is a chance to obtain bias in estimation" (Eurostat 2008, p.11).

There were more than 7500 companies that were listed on the online database, but a large majority of these were single ship companies, which are created to protect the beneficial owner (Stopford 2008). It was therefore decided that a cut off of less than five ship companies would be appropriate, which would also be reflected under probability proportionate to size method, a common sampling method for sampling enterprises and organisations or business surveys, where a few large organisations dominate (Purdon and O'Connor 2008). This therefore does not reflect some very small companies i.e. less than five ships in their fleet, meaning that the results are not applicable to this group. As suggested above, the construction of the sampling frame required merging the databases, filtering companies and entering the required fields, which was a resource intensive task and therefore the cut off was an acceptable trade-off between time and resources expended versus creating a more reflective sampling frame containing almost 6000 very small companies. This characteristic will directly impact the sample size and required response rate and is further discussed in section 4.1.3.4. Most of the empirical studies on barriers to energy efficiency used sampling frames, generally membership frames e.g. Gordon (2008), Hasanbeigi, Menke & du Pont (2009) that would result in non-coverage errors and bias to a select group. The end result of the refinement of the sampling frame for this research resulted in the figures shown in table 4.3 to 4.5. The sampling frame was also divided according to four geographic regions in order to time the contact points both emails and telephone calls, according to TDM guidelines "carefully and strategically time all contacts with the population in mind" (Dillman 2009, p. 298). The majority of the companies are headquartered in European Union region and the Far East, altogether representing nearly 90% of the census population as shown in Figure 4.2 and Table 4.1.

	EU	**West**	**Asia SC**	**Far East**	**Total**
Wetbulk Large	9 (2%)	6 (1%)	2 (0%)	10 (2%)	27 (5%)
Wetbulk Medium	88 (15%)	6 (1%)	14 (2%)	33 (6%)	141 (24%)
Drybulk Large	4 (1%)	3 (1%)	1 (0%)	10 (2%)	18 (3%)
Drybulk Medium	75 (13%)	11 (2%)	6 (1%)	49 (8%)	141 (24%)
Container Large	13 (2%)	0 (0%)	0 (0%)	11 (2%)	24 (4%)
Container Medium	37 (6%)	4 (1%)	2 (0%)	14 (2%)	57 (10%)
Mixed Large	23 (4%)	1 (0%)	4 (1%)	21 (4%)	49 (8%)
Mixed Medium	80 (13%)	1 (0%)	8 (1%)	54 (9%)	143 (24%)
	329 (55%)	32 (5%)	37 (6%)	202 (34%)	600 (100%)

Table 4.1: Population divided according to major geographic regions for large and medium firms

4.1.3.2. Sampling method

Sampling methods for internet based surveys differ from the traditional sampling methods which have been mentioned above. According to Couper (2000) and Fricker (2008) the similarity only lies in the probability (probability based or non-probability based). Table 4.2 shows the different methods in these and highlights the main sampling method used in this research. This research makes use of list based sampling, which is a similar method to traditional sampling, where only contact information is required and is applicable to large homogenous groups e.g. universities, large corporations etc. (Fricker 2008). Just after the survey was fully designed and set up via a link to the survey website, an opportunity to place the survey as a rotating banner on www.shippingefficiency.org, a website that is used by the population of interest for ascertaining energy efficiency of ships. This is equivalent of a non-probability based sampling, the self-selection web based sampling method. This method is used by Berson & Berson (2005) who placed their survey link in the relevant website and managed to obtain over 10,000 responses. This type of sampling is a convenience sample as it is based on respondents self-selection, and therefore may not be generalizable to a larger population (Fricker 2008). Thus this method has its major disadvantage of not allowing for generalisation. The survey for this shipping survey was hosted by the website for a period of two months (November to December 2011) in parallel to the list based sampling method and consequently yielded only three partially completed responses from this sampling method, which excluded in the analysis that follows in chapter six and seven. As a result the list based sampling frame was the best choice and efforts were concentrated on improving the sampling frame and contacting the respondents via email and telephone using this sampling method.

	Traditional	**Web based**
Probability based	• Simple random sampling • Stratified random sampling • Cluster sampling • Systematic sampling	• *List based sampling frame* • Non list-based random sampling • Intercept (pop-up) survey • Pre-recruited panel
Non probability based	• Quota sampling • Snowball sampling • Judgement sampling	• Unrestricted self-selected • Harvested email lists • Opt in panels

Table 4.2: Traditional and web based sampling methods
Source: Fricker (2008) and Bryman (2008)

Because the concern of this research is to be able to make broader generalisations about the implementation and perception of barriers in the shipping industry and its sub sectors, there is a need to recruit a representative sample and avoid sampling error. Sampling error is defined as error stemming from the fact that only subset of the entire population is surveyed. There are standards to determine the sample size in relation to accuracy that aim to reduce sampling error. As shown earlier in section 3.5 a significant disadvantage of web surveys is the very low level of response rates relative to other modes. For this reason and also to remove item non-response "when response to a single question is missing" (Groves et al. 2004, p. 187) it was decided that as many responses should be collected, thus the complete list based sampling frame (of large and medium sized firms) was contacted to take part in the survey. This is not unusual as Dillman (2000) indicates:

"As population sizes drop lower, a greater and greater proportion of the population needs to be surveyed in order to achieve a given level of precision... this question is especially critical for self-administered surveys, in which the marginal costs of contacting additional people is usually less than for interviews"

Therefore for the large organisations (around 120 companies) and medium sized companies (around 480 companies) the census approach was taken i.e. all the companies with more than ten ships were included in the sample, called a census tracts approach. A similar method is followed by (McMichael 2011) in obtaining as many responses from the self-administered postal questionnaire. For the remaining 1000 small firms a simple random sampling was used as shown in Figure 4.1. Furthermore, the approach taken in this study makes use of auxiliary information (background information on variables) in this case the size variable, as derived from the sampling frame. There are several advantages of using this approach in business surveys according to Purdon and O'Connor (2008):

"Using other sampling methods would generate very few cases from the top of the size distribution, which will often rule out separate sub-group analysis of the largest businesses. Given the impact the largest businesses have on the economy, not being able to test whether their behaviour is different to that of other companies can undermine the value of a survey" (Purdon and O'Connor, 2008, p. 14)

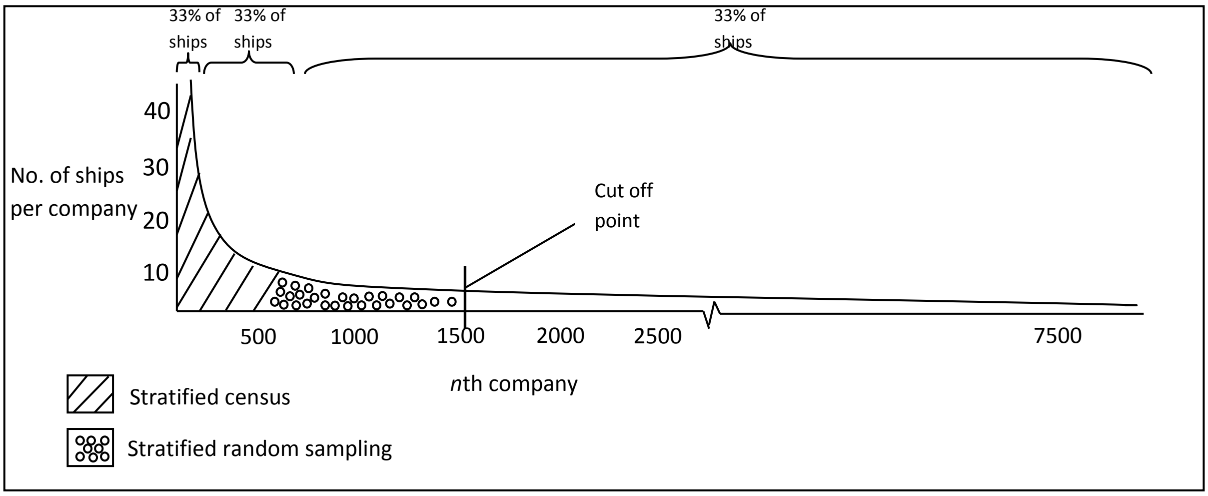


Figure 4.1: Sampling method, frame population by size in this research

The stratification is based on the number of ships within a company's fleet, however equally the total DWT (deadweight) could also be used as determinant of company size. The method used here could be said to be biased against larger ship sizes and favouring small ships, for example a company with five Very large Crude Carriers (VLCC), with total cargo carrying capacity (deadweight tonnes, DWT) of 1 million, would be classed as a small company, whereas a company with twenty small tankers, with a total DWT capacity of 200,000 DWT, would be classified as a medium sized company. This quandary is generally also faced by other business surveys where different measures for size can be used such as number of employees, turnover, etc. Categorising by number of ships also meant that the stratification was subject to change during the six month survey period because a company acquired or sold ships, thus its position in the sampling frame could possibly change.

4.1.3.3. Contact points

The first contact point was a pre-notification email to each company's general email (All large and medium companies i.e. 600 companies) and sample of small companies (400 companies out of 1000 companies). The second contact point was a phone call to each of the large and medium size companies and a random sample of the small companies. Every effort was made to reach to the operations/technical department (for example by researching online the company's departments and personnel). There were very few refusals at this stage, however the main problem encountered here was firstly getting through the company's general telephone switchboard or reception and secondly getting to speak with the operations manager or technical superintendent. In some instances a departmental email would be provided with the name of the relevant person only. After the second contact, a total of 313 individual names, telephone numbers and email addresses were compiled for the large and medium sized firms, to which personalised emails were sent from the university email. This can be said to be the first email contact for many respondents. A follow up reminder email was then sent to this new personalized mailing list after two weeks to those who had not yet completed the survey. After one to two weeks from the reminder email, another telephone call was made to speak to those who had still not completed the survey. This was followed by a final reminder email to complete the survey, which was attached with draft report of the results that had been obtained so far, in order to create reciprocative response i.e. using norm of reciprocity (Gouldner 1960).

4.1.3.4. Response rates required and achieved

As a result of this mixed mode approach, exactly 150 surveys were completed or mostly completed by the large and medium firms resulting in a response rate of 48% (note this is based on the sampling frame tracking and does not match to all the results obtained directly from the respondents, which further increases the response rate). In order to reduce item non response, when there were some questions with missing responses, especially the chartering ratios, a telephone call or an email was sent to those who had left their contact details. In order to be representative and to make generalisations i.e. reach statistically overall significant results with a confidence level of 90% or 95% and margin of error interval of +/-15% or +/-20% each stratum required a certain number of responses as shown in Table 4.3. Values are also included for large and medium sized companies where the whole sampling frame was used. Each stratum is considered as a sub-population. The confidence level portrays the degree of certainty that the population mean will fall within the margin of error or standard error (de Vaus 1995). Margin of error is the range within which the true mean can lie (de Vaus 1995). Table 4.4 and Table 4.5 show the number of responses required if the population is not stratified by size and sector. From Table 4.4 it can be seen that the actual results achieved in each stratum only allow for generalizations to be made for wetbulk and drybulk medium firms with confidence level of 90% and margin of error of 20%. Despite this, it is thought that the responses achieved in other stratums would also be beneficial because of scarcity of information on this subject area. Moreover, if the stratification is ignored i.e. if the industry is treated as homogeneous then the results allow for even greater accuracy with 95% confidence level and 12.5% margin of error.

Sector	**Size**	**Population**	**+/- 15% error (90% CL)**	**+/- 20% error (90% CL)**	**+/- 15% error (95% CL)**	**+/- 20% error (95% CL)**	**Actual results achieved**
Wetbulk	Large	27	15	11	17	13	9
	Medium	141	25	16	33	21	17
Drybulk	Large	18	12	9	13	11	3
	Medium	141	25	16	33	21	17
Container	Large	24	14	11	16	13	1
	Medium	57	20	14	25	18	4
Mixed	Large	49	19	13	24	17	
	Medium	143	25	16	34	21	
All	Small	≈ 1000	30	17	41	24	20

Table 4.3: Required sample sizes and actual responses achieved*

* The actual results may be higher than what is shown for each stratum because not all respondents completed demographic questions.

Sector	Population	+/- 15% error (90% CL)	+/- 20% error (90% CL)	+/- 15% error (95% CL)	+/- 20% error (95% CL)	Actual results achieved
Wetbulk	168	26	16	35	22	26
Drybulk	159	26	16	34	21	20
Container	81	23	15	29	19	5

Table 4.4: Required sample sizes and actual responses achieved when stratified by sector only*

Sector	Size	Population	+/- 15% error (90% CL)	+/- 20% error (90% CL)	+/- 15% error (95% CL)	+/- 20% error (95% CL)	Actual results achieved
Wetbulk, Drybulk & Container	Large & medium	408	29	17	39	23	51

Table 4.5: Required sample sizes and actual responses achieved when no stratification*

* The actual results may be higher than what is shown for each stratum because not all respondents completed demographic questions.

The above values are calculated taking into account how much sampling error can be tolerated within a given confidence interval, the level of confidence required, how varied the population is with respect to the characteristics of interest and size of the population (each stratum in this case which is a finite population), following the formula given below:

$$SI = \frac{Z^2 \times P \times (1-P)}{C^2}$$

Where:
Z = Z value (e.g. 1.96 for 95% confidence level)
P = Degree of variation in respondents, generally 0.5 if not known
C = Confidence interval or margin of error
Correction for Finite Population:

$$SF = \frac{SI}{1+\frac{SI-1}{P}}$$

Where:
SI = Calculated sample size assuming infinite population
P = Population size

In conclusion, it can be said that the final sampling frame was a good representation of the actual population and therefore was used to stratify the population by size and sector. For large and medium wetbulk, drybulk and container strata, the sub populations were small and therefore the census tracts approach was employed. For small firms, which could not be stratified by sectors, the simple random sampling method was used. Where the census approach was applied, the TDM guidelines for implementation were followed (e.g. using mixed mode contact methods, personalisation, carefully drafted emails etc.). This generated a sampling frame with 313 respondent names and emails of operations managers and technical superintendents yielding 150 responses, a response rate of 48%. In addition the random sampling of the remainder 1000 small companies resulted in additional twenty responses, thus in total 170 responses were received from all sectors and sizes.

4.1.4. Incentives

Incentives are a common and effective means for increasing response rates in traditional surveys (Fricker 2008). Pre-paid monetary incentives have been found to have a high impact on the response rates (e.g. Church 1993; Petrolia & Bhattacharjee 2009; Brennan 1992; etc). However, most findings are based on postal questionnaires and “it is questionable whether findings from offline studies can be generalised to the online realm” (Goritz 2006, p. 59). This could be due to the different environments and types of monetary gifts that can be given. A brief review of literature on incentives in survey is provided in appendix A.

As it was decided to also use a list based sampling method to recruit respondents many of the drawbacks of incentives can be limited (e.g. item non response in intercept sampling methods). Furthermore it is thought that the population of interest would be interested in responding to this survey as it is relevant (issue salience), which has also been shown to be a key determinant for response rates by Dillman (2009), Cobanoglu & Cobanoglu (2003) and Ray, Griggs & Tabor (2001). According to meta-analysis by Ray, Griggs & Tabor (2001) in 57% of web based surveys, respondents were promised summary survey results as an incentive to participate. Since the survey is topical and relevant it is believed that the respondents would benefit from knowing the outcome of the survey, hence it was decided to use the survey results as an incentive and token of appreciation for the participants. It should be remembered that incentives may only partially affect response rates in web surveys (Dillman 2000). In order to improve response rates and to alleviate the dangers of data validity inherent in the use of monetary incentives various different techniques are used in this research, as outlined below:

- Use of Tailored Design Method – personalisation, pre-notification, deadlines, reminders, mixed mode follow ups.
- Sampling method – use of dynamic sampling frame
- Use of incentives – non monetary, survey results report
- Design of questionnaire – visual appearance, content, type of questions and length of survey (determined through pilot research and pre-testing and well evaluated web survey software) (discussed in next section)

The following section looks at the design of the questionnaire and mainly focuses on the content, type of questions and pre-testing of the survey as well as operationalizing and creating indicators for measurement.

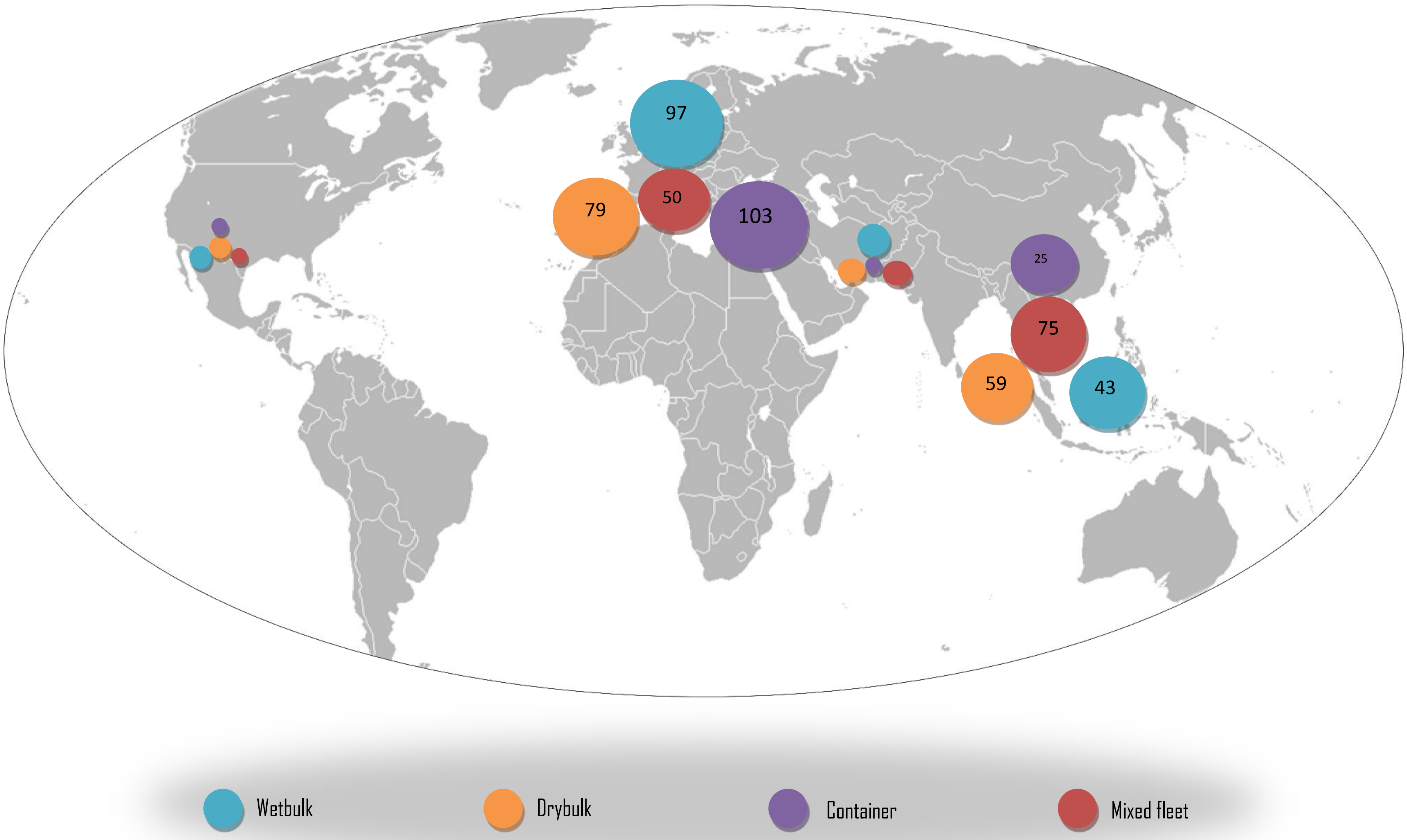


Figure 4.2: Global maritime clusters

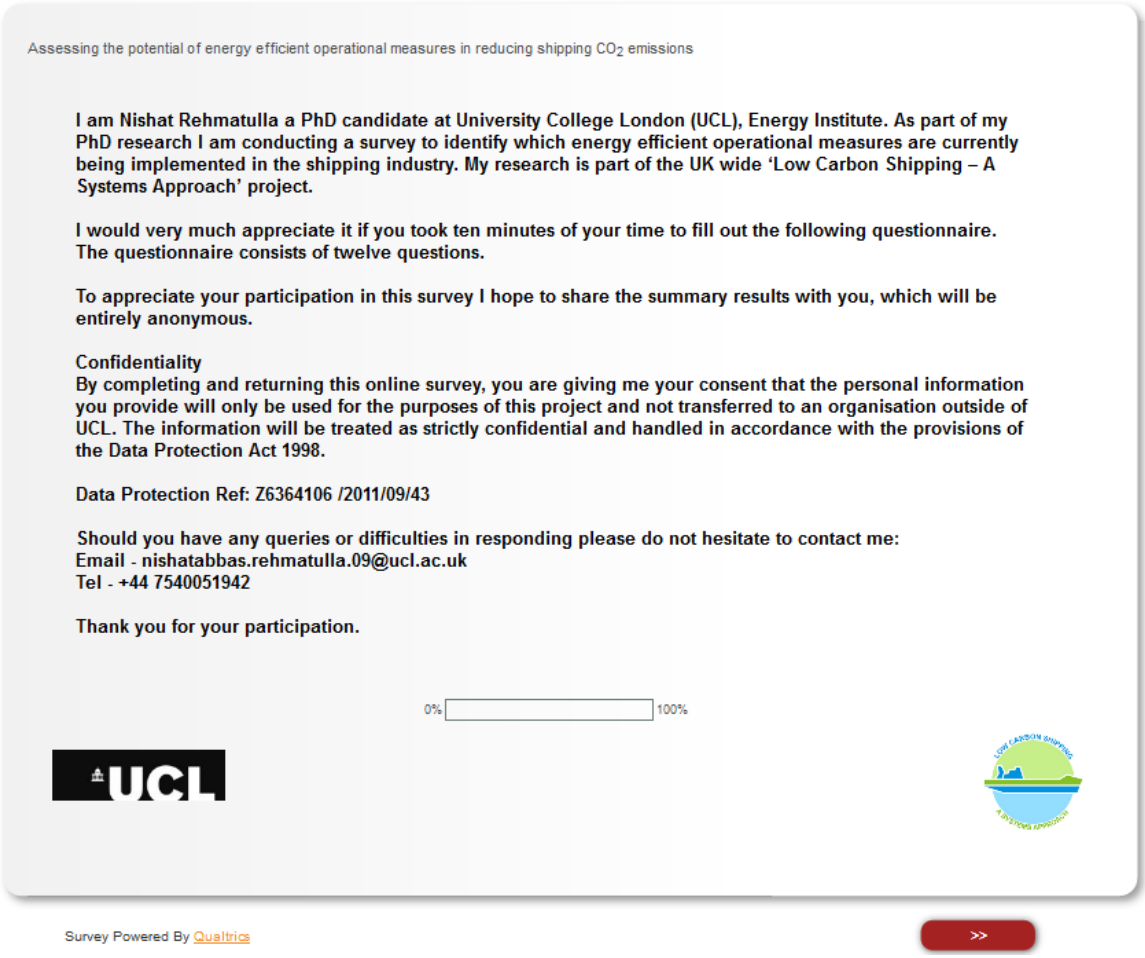
4.1.5. Questionnaire design

As mentioned in the previous sections, the design of the questionnaire is a key element in increasing response rates. A good level of research has been done on the specifics of designing web surveys (e.g. screen layout, font size, page length, etc) to increase response rates (e.g. Dillman 2000, 2007 and 2009; Healey, Macpherson & Kuijten 2005, Schleyer & Forrest 2000; etc). The web survey that is developed in this research largely follows the guidelines from Dillman (2009) Tailored Design Methods (TDM) and Best & Krueger (2008). TDM consists of sixteen specific guidelines for designing web questionnaire, centred around on visual stimulus, as outlined in appendix A. The TDM approach guidelines were also used in the sampling method and implementation stage. Most of these guidelines are supported by empirical evidence (e.g. Smyth et al. 2009; Couper, Traugott & Lamias 2001; etc.), therefore are adhered to within this research. The following section provides discussion on how these were incorporated in the questionnaire design.

4.1.5.1. General questionnaire design

The questionnaire consisted of twenty questions, which appeared one page at a time as shown in Figure 4.3 (refer to appendix A for the full survey). The question format varied according to the need, but consistency in similar type of questions was maintained. Throughout the survey various tools have been used to make the survey as easy and quick as possible. This is done through the vendors advanced features such as skip logic (skips the questions not relevant to the respondent based on their previous selection), display logic (displays the respondent's previous choices in the following questions). The first page is carefully designed so as not to discourage roll off or drop out by being welcoming to the respondent, describing the research and making it belong to an individual or student so that there is some degree of sympathy and a need to contribute to the greater good of society. The project is described in a couple of sentences and is followed by very brief instructions on completing the survey and the incentive is mentioned. Confidentiality is stressed by mentioning and providing the UK Data Protection reference number. This is followed by contact details and appreciation in advance.

Each page has the survey title included at the top of the page and the bottom of the page displays the logo of the project and university, this consistency enables the respondent to stay focussed in the survey (Dillman 2009). A very soft tone of background colour was selected, so that the completion status, next/back buttons and questions can be contrasted. Use of point of completion (POC) indicators gives a sense of completion to the respondent (Dillman et al. 1998), although Best and Krueger (2008) suggest that it may increase download times and decrease completion rates, just as Crawford, Couper & Lamias (2001) discourage its use in open-ended web surveys. Since each question is placed on a different page, it was decided that the POC would be important as it would enable the respondent to gain a sense of completion and remaining survey length. Questions were placed on different screens because Dillman (2009) suggests that a scroll down web questionnaire can have higher item non response. This also enabled use of skips logic and display logic to take the respondent to different pages according to the answers on previous questions. Displaying questions one page at a time also allows for keeping incomplete responses that may not yet be completed (Best and Krueger 2008).


Assessing the potential of energy efficient operational measures in reducing shipping CO_2 emissions

I am Nishat Rehmatulla a PhD candidate at University College London (UCL), Energy Institute. As part of my PhD research I am conducting a survey to identify which energy efficient operational measures are currently being implemented in the shipping industry. My research is part of the UK wide 'Low Carbon Shipping – A Systems Approach' project.

I would very much appreciate it if you took ten minutes of your time to fill out the following questionnaire. The questionnaire consists of twelve questions.

To appreciate your participation in this survey I hope to share the summary results with you, which will be entirely anonymous.

Confidentiality
By completing and returning this online survey, you are giving me your consent that the personal information you provide will only be used for the purposes of this project and not transferred to an organisation outside of UCL. The information will be treated as strictly confidential and handled in accordance with the provisions of the Data Protection Act 1998.

Data Protection Ref: Z6364106 /2011/09/43

Should you have any queries or difficulties in responding please do not hesitate to contact me:
Email - nishatabbas.rehmatulla.09@ucl.ac.uk
Tel - +44 7540051942

Thank you for your participation.

0% 100%

UCL

Survey Powered By Qualtrics

>>

Figure 4.3: Screenshot of the first page of the survey

The survey was tested for visual display across the most common browsers which include Mozilla Firefox, Internet Explorer, Google Chrome and Safari. Different font sizes and settings were experimented and in conclusion it was decided to keep the Arial font as it is one of the most widely used font on the internet (Best and Krueger 2008) and allows for backward compatibility on different operating systems. Questions were in bold and answer choices in normal format, important key words and instructions within each of the question were displayed in full capital letters. Error messages were made specific to the errors in questions. The survey consisted of a maximum of twenty one questions (fourteen related to the subject and seven respondent profiling questions), depending on the respondents choices, and a minimum of two compulsory questions. Each question was displayed in a separate page of the browser following the guideline ‘avoiding placing questions side by side’, similar to Scyleyer and Forrest (2000). Only question one and two of the survey were made compulsory as it would be these that would determine the follow up questions on implementation and perception of barriers to implementation of energy efficiency measures, in line with TDM guidelines “Do not require responses to questions unless absolutely necessary”. The survey length was given significant consideration as it is a key element in determining retention and response rates. As a result many other peripheral and non-critical questions had to be deleted in order to make the completion time around ten minutes as promised to the respondent in the beginning of the survey. This corresponds to the ideal time a respondent would spend on a web survey (Sleep & Puleston 2008).

The quick completion time and minimum respondent burden were accomplished through the use of multiple check boxes, radio buttons in a list format and semi-closed ended questions. Drop down menus and other sophisticated formats available from the vendor were not used because of the respondents’ lack of experience with those. The use of ‘all of the above’ was avoided in line with TDM guidelines. The web survey could be paused by the respondent and would remain open for two weeks allowing them to complete at a later time and date, in line with TDM guideline. Similarly, if the survey is closed half way and consequently the link is opened again as a result of a follow up, the respondent would start the survey from where they left. This has its benefits and drawbacks with the obvious benefit being that it would reduce completion time and encourage the respondent to complete the survey and the drawback being that the respondent may have forgotten the objectives of the survey and their answers to previous questions.

4.1.5.2. Pretesting and piloting

Dillman (2009) provides four guidelines on pretesting questionnaires, these are:

1. Obtain feedback on the draft questionnaire from a number of people, each of whom has a specialized knowledge of some aspect of questionnaire quality.
2. Conduct cognitive interviews of the complete questionnaire in order to identify wording, question order, visual design and navigation problems
3. When stakes are high, consider doing experimental evaluations of questionnaire components
4. Conduct a small pilot study with a subsample of the population in order to evaluate the questionnaire and implementation procedures.

The questionnaire was sent to nine colleagues at the institute who responded to the questionnaire and gave constructive feedback through the questions that were appended to the end of survey (refer to appendix A for details on pretesting). The pretesting stage benefited from expert advice from three researchers who have extensive experience of questionnaires and social research methods, with nearly twenty hours contact with one researcher whose PhD thesis used the self-completion questionnaire in a similar context (implementation of energy efficiency measures in households). This was particularly useful for two reasons, testing the format of questions, e.g. moving from scalar to tick box questions and secondly providing clear instructions for each question e.g. capitalizing fonts, using bold fonts etc.

The pretesting showed that the mean length of the survey was twenty three minutes, which was deemed to be high compared to that advocated in literature, thus further revisions to question formats and order were made. The initial request email sent out to the pilot panel was personalised to each respondent and the response rate was just over 90% with (ten out of eleven colleagues answering the questionnaire). Following the fourth guideline, the amended survey was piloted with a small subsample of the respondents within the shipping industry. The survey request was sent out to six industry respondents and resulted in 100% response rate. The mean completion time was fourteen minutes which was deemed acceptable. The mean completion time for the final survey was just over sixteen minutes, with almost 25% of the surveys being completed before ten minutes and under half of the respondents completing between ten minutes and half an hour. Some surveys took much longer to complete and it is believed that the respondent may have left survey window open, whilst doing other things.

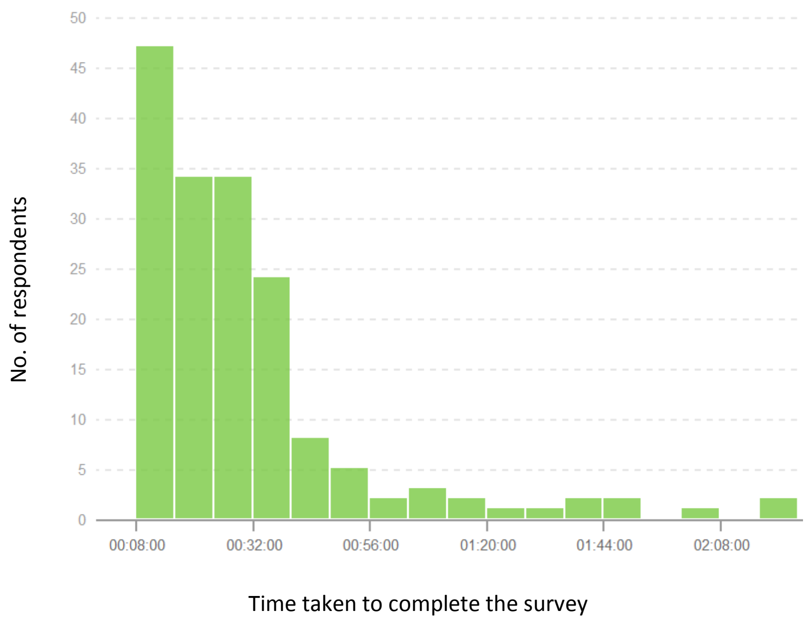


Figure 4.4: Final survey completion times

4.1.5.3. Operationalization and indicators of hypothesis

Bryman (2008), de Vaus (1995) and Saunders, Lewis & Thornhill (2007) give clear instructions and practical examples on wording questions in a self-completion questionnaire, which have been adhered to in this research. In order to obtain high internal validity and reduce measurement error, the questionnaire should be able to reflect what is being measured, which is rooted in the research question and hypothesis, as shown in Table 2.7.

According to de Vaus (1995) there are four aspects the questionnaire could be used to measure:

- Measures of the dependent variable – what the research is trying to explain, in this case implementation of measures and perception of barriers to energy efficiency.
- Measures of the independent variable – causal variables, in this case chartering ratio.
- Measures of test variables – clarifying the link between independent and dependent variable similar to the background measures as below;
- Background measures – characteristics such as age, sex, religion, in this case sector, company type etc.

The variables of interest in this research are briefly discussed below.

4.1.5.3.1. Measures of the dependent variable

There are two measures of the dependent variables; implementation of measures and perception of barriers. The first survey question asks respondents to select the measures they believe have the highest fuel saving potential. This is similar to the approach taken by Velthuijsen (1993) where respondents are asked to provide what they believe to be the fuel saving potential of the measures, in percentages, this format is also known as the continuous interval variable measurement which is defined as “one in which the categories have a natural ranking and it is possible to quantify precisely the difference between categories” de Vaus (1995, p.130). According to Dillman (2009) this should be avoided especially in the beginning of the survey as it results in high respondent burden. Therefore, the first question of this survey asked respondents to select choices with highest potential. This format is also known as the categorical nominal variable which is defined as “one where we can distinguish between categories of a variable but cannot rank the categories in any order” de Vaus (1995). This is then followed by the second question in the survey asking respondents whether they have implemented those measures, using the nominal variable to measure implementation. Previous surveys on barriers to energy efficiency also start with a similar approach (e.g. Sorrell et al. 2000). Some studies limit the number of measures that a respondent selects (e.g. Velthuijsen 1993; Harris 2000) and the reason for doing so is to gain in-depth analysis of the perception of barriers, and similar style is used in this research. In the second question the measures that appear on the left hand side (as rows) of the grid have been 'followed through' to this question, using the display logic feature of the web survey vendor. The question in the survey is constructed as a categorical variable rather than an ordinal variable, which is defined as one where there it is meaningful to rank the categories, however it isn't possible to quantify precisely how much difference there is between categories (de Vaus 1995.) The ordinal variable format has been used in previous studies on barriers, for example Sorrell et al. (2000) and Schleich and Gruber (2008). This survey made use of the categorical nominal instead of the usual ordinal level measurement for measuring implementation because it reduces respondent burden, secondly, according to TDM guidelines, the first questions need to be easily comprehended to have retention of the respondent and finally use of ordinal scales is disputable as the distance from one position to another may or may not be the same (Field 2009). Using categorical nominal variables to measure implementation of measures will result in frequencies rather than a mean score (de Vaus 1995) and inferences to the larger population can be made from both of these level of measurements. The first two survey questions directly address the first hypothesis and will help to answer the first research question.

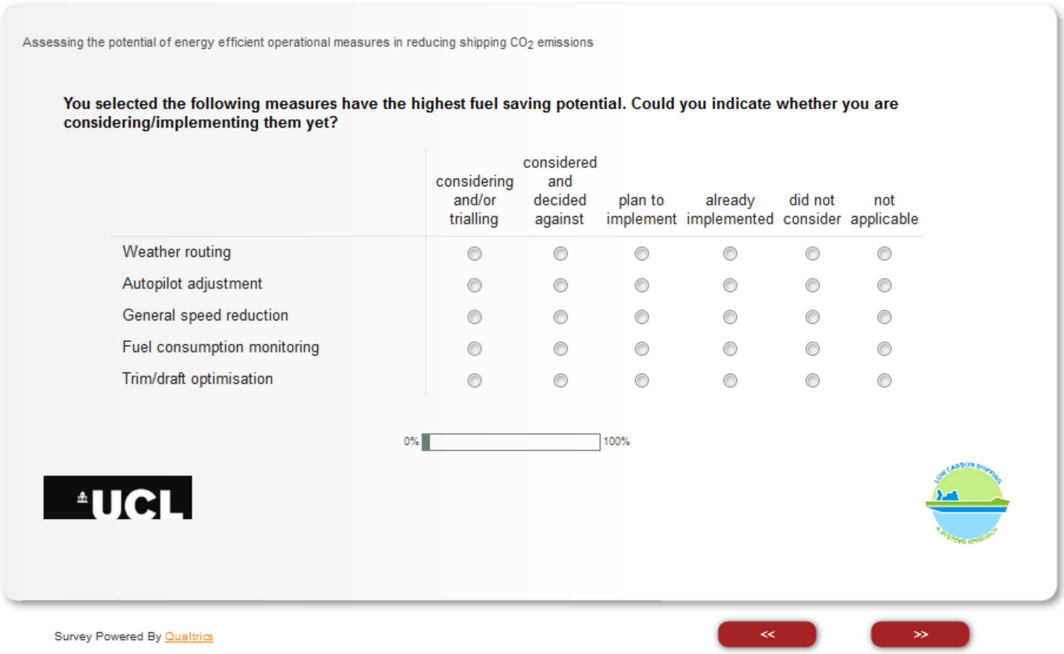
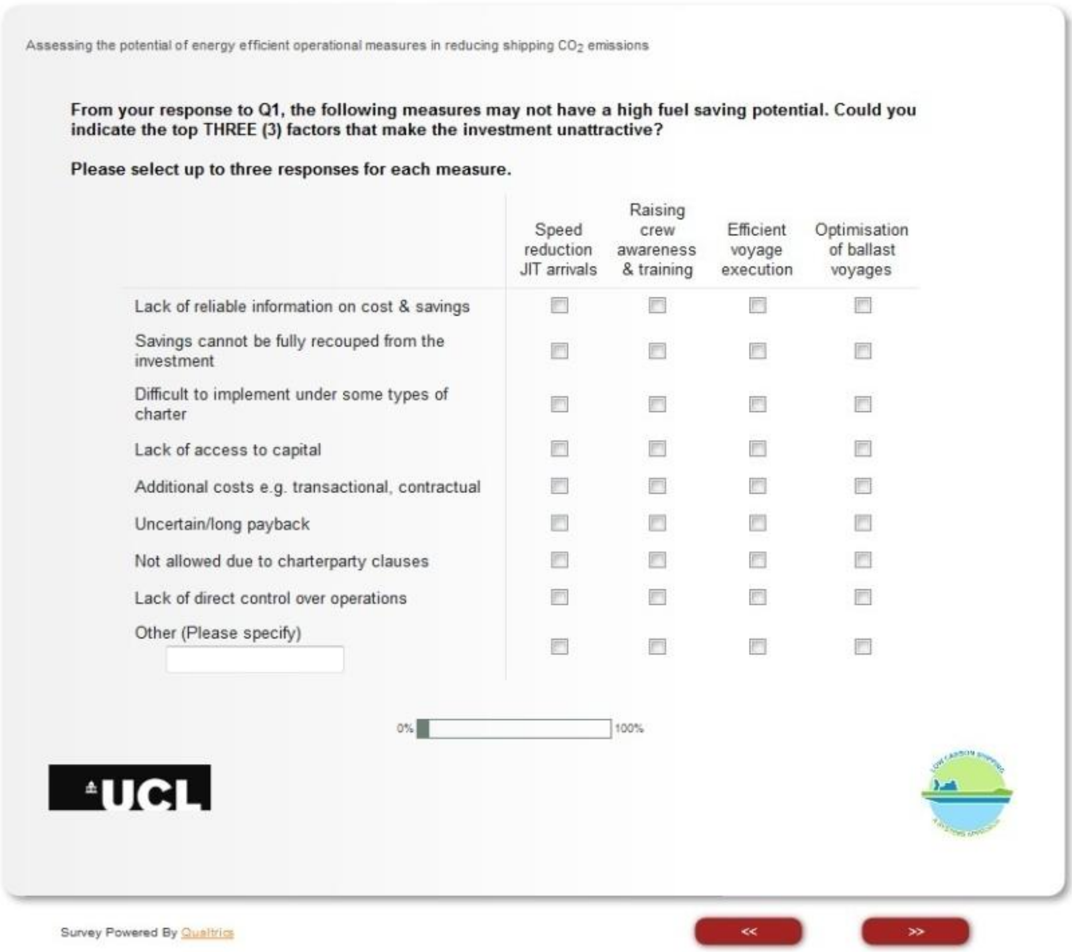


Figure 4.5: Question two, implementation of measures

The second measure of the dependent variable is through perception of respondents to barriers to energy efficiency. Once respondents have completed the implementation of measures question, they are asked what made them believe that a measure did not have high fuel saving potential in the first question, as shown in Figure 4.6. This survey question is a matrix or grid style question which was designed to get many answers per question despite the risk of overburdening the respondents and potentially resulting in dropouts according to Sleep and Puleston (2008). The measures appear on the top as columns and barriers as rows (opposite of that in second question) and this is contradictory to the guidelines of TDM, which emphasises consistency among all the survey questions. However it was decided to follow this style because the questions would not fit the entire screen, meaning the respondent would be required to scroll across and vertically, contravening another TDM guideline. This survey question addresses the second hypothesis.


Assessing the potential of energy efficient operational measures in reducing shipping CO_2 emissions

From your response to Q1, the following measures may not have a high fuel saving potential. Could you indicate the top THREE (3) factors that make the investment unattractive?

Please select up to three responses for each measure.

	Speed reduction JIT arrivals	Raising crew awareness & training	Efficient voyage execution	Optimisation of ballast voyages
Lack of reliable information on cost & savings	☐	☐	☐	☐
Savings cannot be fully recouped from the investment	☐	☐	☐	☐
Difficult to implement under some types of charter	☐	☐	☐	☐
Lack of access to capital	☐	☐	☐	☐
Additional costs e.g. transactional, contractual	☐	☐	☐	☐
Uncertain/long payback	☐	☐	☐	☐
Not allowed due to charterparty clauses	☐	☐	☐	☐
Lack of direct control over operations	☐	☐	☐	☐
Other (Please specify)	☐	☐	☐	☐

0% 100%

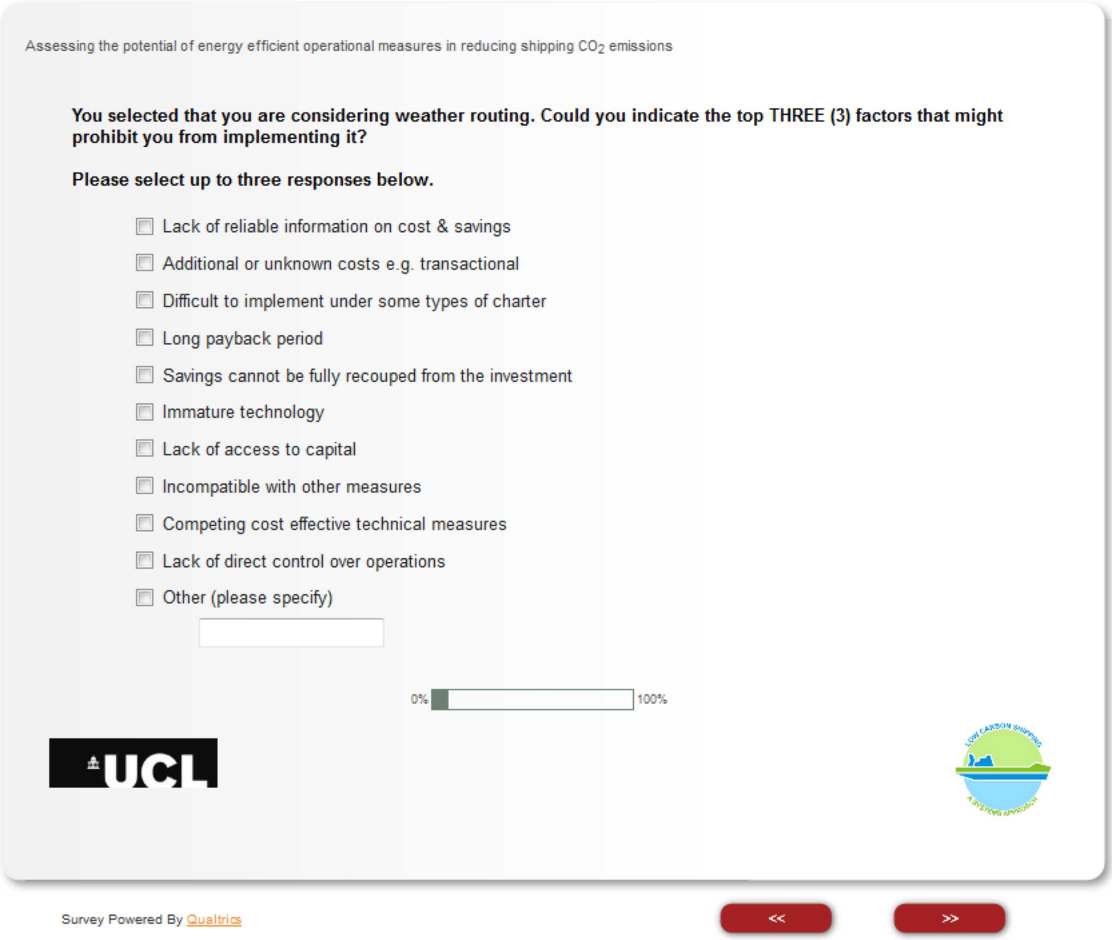
UCL

Survey Powered By Qualtrics

<< >>

Figure 4.6: Reasons for measures believed not having a high fuel saving potential

Following the matrix style question on barriers to energy efficiency measures that have been deemed not having a high fuel saving potential, the respondent is asked questions based on the implementation level of the measures that had been listed in question one and two. Use of display logic in the software allows the questions to be specifically written according to the respondent's selection. For example, if the respondent selected weather routing measure in question one and selected 'considering or trialling' this measure in question two (implementation), the question perception of barriers question would automatically include these in the wording of the question and display the appropriate answer categories (tick box options) pertaining specifically to that measures barriers. Similarly, if the respondent selects weather routing as a measure with highest fuel saving and selects already implemented in question two (implementation) the perception of barriers question would be worded with appropriate answer categories (tick box options) pertaining to drivers leading to implementation. This set of survey questions address the second research question.


Assessing the potential of energy efficient operational measures in reducing shipping CO_2 emissions

You selected that you are considering weather routing. Could you indicate the top THREE (3) factors that might prohibit you from implementing it?

Please select up to three responses below.

- [ ] Lack of reliable information on cost & savings
- [ ] Additional or unknown costs e.g. transactional
- [ ] Difficult to implement under some types of charter
- [ ] Long payback period
- [ ] Savings cannot be fully recouped from the investment
- [ ] Immature technology
- [ ] Lack of access to capital
- [ ] Incompatible with other measures
- [ ] Competing cost effective technical measures
- [ ] Lack of direct control over operations
- [ ] Other (please specify)

0% 100%

UCL

Survey Powered By Qualtrics

<< >>

Figure 4.7: Follow on question from question two

4.1.5.3.2. Measures of the independent variable

An indicator for the principal agent problem in the context of barriers to energy efficiency and implementation of measures in shipping could be the chartering level of the shipping company. In order to estimate a company's fleet that may be affected by this, one can ask what proportion of ships are owned or chartered in various forms to meet the demand that the company faces. This can be a mixture of ships fully owned by the company, bareboat chartered in, time chartered in or occasionally voyage chartered in. This is then compared to how the company utilises this mix to satisfy the demand through chartering out in the form of voyage charters (including contract of affreightments) and time charters mainly. This chartering level or ratio was measured in two questions split between chartering-in and chartering-out, as an interval variable, where the respondent would estimate the percentages. This survey question addresses the first and second research questions.

For the principal agent problem, it is important to categorise the population into maximum of four different groups. For example, Murtishaw and Sathaye (2006) categorises households into three; owner-occupied, rented with utility included, rented without utility included. In order to assess the level and group according to the principal agent problem, the chartering level of the firm was used. According to de Vaus (1995) when there is no agreed way of measuring a concept (which is the case presented above) then it may be helpful in developing indicators for a range of definitions of the concept and it may require a number of questions to capture the scope of the concept. The principal agent problem was also captured through perception of respondents when asking about barriers to implementation of specific measures i.e. a categorical level variable for each of the measures. The specific assumptions of case two and four of the principal agent problem are related to two shipping charters; the voyage and time charter, as mentioned in chapter one. It is likely that shipping companies will employ their fleet on a mix of these. It was decided that 50% and above of any charter would represent that the fleet is mostly employed in that type of charter. Chapter five further discusses the principal agent problem in shipping and chapter six considers the grouping in detail.

4.1.5.3.3. Background measures

The main background variables which are also the test variables (i.e. that need to be controlled for in bivariate elaboration analysis) are sector, size and company type. The sector variable allows to see if there are differences in between sectors (through measures like the Chi squared test), measured as nominal variable and resulting in frequencies. Company type variable allows for checking if there are differences between the different types of shipping companies, measured as nominal variable. Company size measured as nominal variable in three different estimators of size; by number of ships, by annual fuel use, by number of employees. Chapter six discusses each of these and the choice made in greater detail.

In summary the questionnaire design closely followed most of the guidelines set out by Dillman (2009). After feedback from pretesting and piloting in particular, the question formats were changed from scalar choices to list based choices in order to reduce respondent burden, improve item response and avoid dropouts. Thus, most questions made use of tick boxes which meant that data would be measured at the lowest measurement level, i.e. at the categorical nominal level.

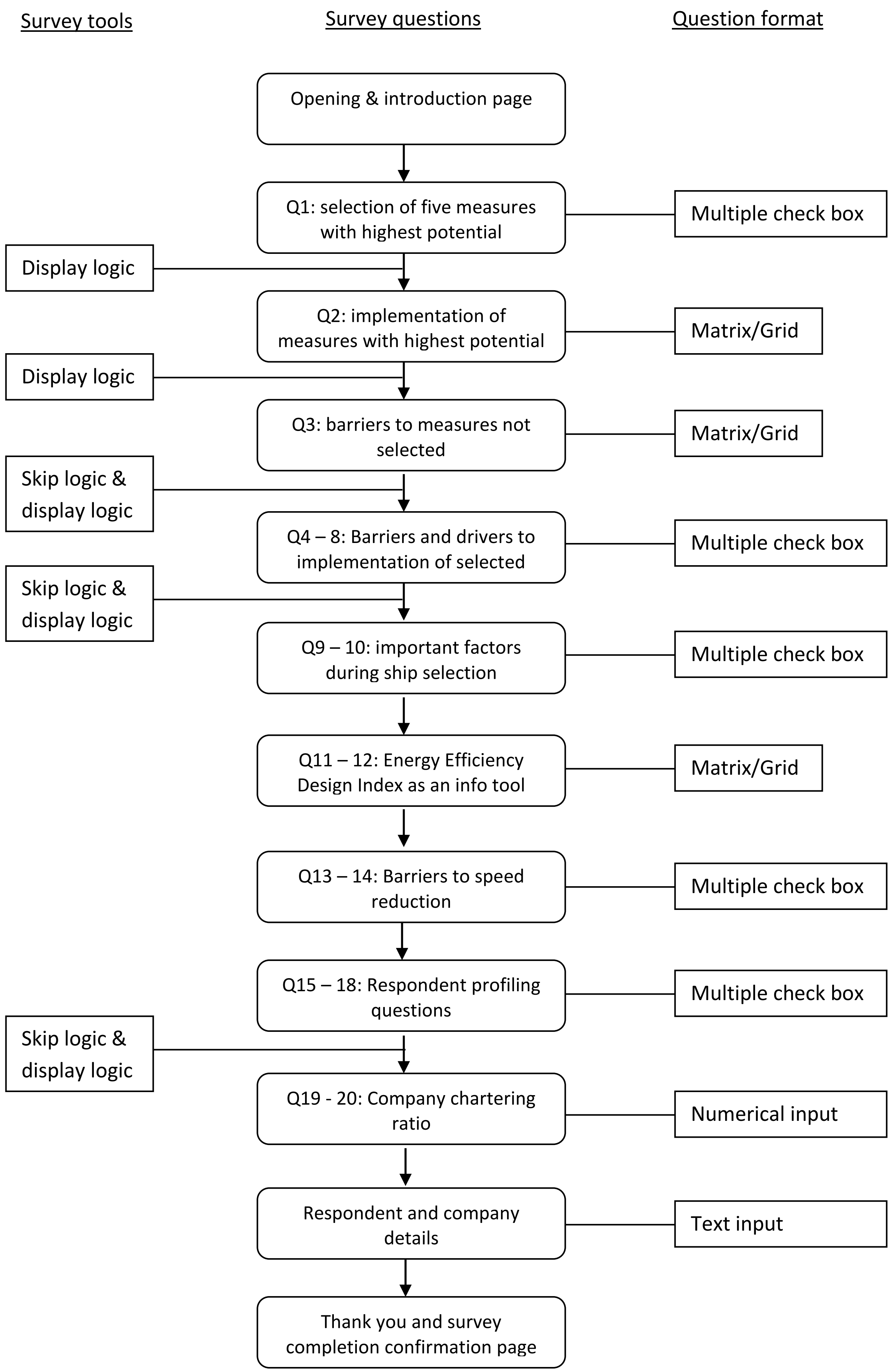


Figure 4.8: Flow chart of survey questions, software tools and question formats used

4.1.6. Issues of concern

One of the important causes for concern in quantitative methods such as the self-administered questionnaire is the issue of reliability, replicability and validity (Bryman 2008). Reliability is concerned with issues of consistency of measures, whereas validity refers to whether an indicator that is used to gauge a concept really measures that concept. The aforementioned issues coupled with the sampling and non-sampling error are referred to as Total Sampling Error (Groves, 2004). Errors can be categorised as sampling errors and non-sampling errors as shown below in Table 4.6.

Sampling error	Sampling error	Surveying only some, not all of the population
Non-Sampling error	Coverage error	Not an equal or known chance of selection in a sample
	Measurement error	Bad instrument design, poor question wording
	Non-response error	Respondents being different from non-respondents

Table 4.6: Different sources of error
Source: Fielding (2008), Bryman (2008) and Dillman (2009)

The most important criterion in evaluation of quantitative research is validity (Bryman 2008). The survey question that is most susceptible to the issue of validity is the chartering ratio question at the end of the survey. The chartering ratio is used as an indicator or a measure of the principal agent problem or concept. There is no previous research in shipping that suggests that this is the correct or stable indicator of the concept, however research from other transport sectors and building sectors have used similar indicators to measure principal agent problem. Secondly, during the piloting stage to test the validity of the measure the survey was sent to two different individuals of the same firm (large container line), to test the consistency of answers to this question. The answers to the chartering ratio question differed marginally. The results were then compared with the respondent's actual answers and showed that there was no difference, suggesting the stability of the indicator.

Another issue of concern is the internal validity of cross-sectional designs, employed in this research. Internal validity is concerned with the question of whether a conclusion that incorporates a causal relationship between two or more variables is true (Bryman 2008). This issue is dealt with bivariate elaboration analysis that is used to control for other intervening variables in the relationships of interest within the research e.g. to see the relationship of chartering group with implementation of a measure, when the sector variable is controlled. However because of the small number of responses it is not possible to control for more than one variable in the relationship. On the subject of external validity, which is concerned with the issue of whether results of a study can be generalized beyond the sample (Bryman 2008), this research can be to some extent be said to representative because of the census approach applied to the strata that had small populations and achieving a good response rate for these. This research is also one of the first to have investigated this subject in a systematic and scientific way in the industry, therefore it provides baselines for a number of areas such as actual implementation of measures.

Cross sectional designs are distinct from other designs in that they aim to collect data at a single point in time from a single subject. In the actual implementation of surveys (questionnaires and interviews) the time lag between initial contact and final response can often get quite drawn out between respondents (Saunders, Lewis & Thornhill 2007) for example Sardinaou (2008) conducted a cross-sectional survey of industrial companies and barriers to energy efficiency in Greece over a period of one year. In this research the survey data collection period spanned over six months. The long data collection period of this research may affect the comparability of results of those who answered initially to those who responded in the last contact points. This is because the industry is facing increasing pressure through regulations such as the EEDI and SEEMP as well as economic pressure through rising fuel prices, which may affect the level of uptake of operational measures and the perception of barriers to operational measures.

With regards to coverage there was some bias towards companies headquartered in the European Union region mainly as a result of the language barrier with Far East and Asian headquartered companies. To some extent this reflects the population of the industry, where EU headquartered companies represent 55% of the population and the respondent profiles achieved by other surveys conducted in shipping.

4.1.7. Ethics

Ethical issues arise in various stages in social research (Bryman 2008) and are closely interrelated with the type of research methods (Eynon, Fry & Schroeder 2008). All primary social research will involve contact with people and therefore ethical considerations become a topic of concern. Diener & Crandall (1978) break down these considerations into four main areas for traditional social research methods:

- Lack of informed consent
- Harm to participants
- Invasion of privacy
- Deception

The above are covered by the principles in the UK Data Protection Act (1998). Each of the above is addressed during the design and implementation of the survey and is evidenced through registration with UCL Data Protection Officer and obtaining a Data Protection number. The first point of informed consent was the telephone conversation with the respondent and also clearly highlighted in the first (welcome page) of the survey. Internet related social research, which differs from traditional settings, adds novel ethical dilemmas for internet researchers (Eynon, Fry & Schroeder 2008), however the extent to which new rules are required is debatable (Walther 2002; Ess and AOIR 2002) with little common agreement (Cavanagh 1999). To date there are no specific ethical guidelines for internet based research; hence the above ethics are used as a starting point, and as shall be seen below attempt to create separate guidelines has resulted in fairly similar issues of concern. The ethical concerns posed by Ess and AOIR (2002) for internet based research are in the form of questions as follows:

1. What is the venue for the research? What are the privacy expectations established by the venue?
2. Who are the subjects or participants?
3. How will informed consent be obtained?
4. How far do legal requirements or ethical guidelines of the country implicated in the research apply?
5. How to monitor participants?
6. How will anonymity, reputation and trust be maintained?
7. How will deception be avoided?
8. Does the benefit of the research outweigh the potential harm to the participants?

4.2. Content analysis of charterparties

Qualitative content analysis is used with the objective of providing complementary and corroborative analysis to the quantitative results from the survey method. The use of inductive content analysis is recommended when there are no previous studies dealing with the phenomenon or when knowledge is fragmented (Elo & Kyngas 2008).

4.2.1. Aims and objectives

The aim of this method is to provide completeness and comprehensiveness to the findings generated by the quantitative survey method. A qualitative analysis of charterparties will also give a detailed context of the barriers that may be hindering the uptake of operational measures. This method will also enable in directly answering the fifth research question and confirming or rejecting the hypothesis that there may be barriers inherent in the charterparty that affect the implementation of operational measures.

4.2.2. Content analysis design

Zhang and Wildemuth (2006), Krippendorf (2004) and (GAO 1989, 1996) show practical steps in conducting qualitative content analysis with the use of several examples. The process they advocate is more inclined towards making the method more quantitative, however the examples and references to qualitative analysis are very helpful. Various forms of content analysis were discussed in section 3.5.6. There are also several different (and sometimes overlapping) ways for conducting content analysis which were reviewed for suitability ranging from ethnographic content analysis (Altheide 1987), inductive and deductive content analysis (Mayring 2000), problem driven analysis (Krippendorff 2004) and directed content analysis (Hseih & Shannon 2005). The following steps as suggested by Altheide (2004; cited by Bryman 2008) are used in this research:

1. Generate research questions
2. Become familiar with the context within which the documents were/are generated
3. Become familiar with a small number of documents (six to ten)
4. Generate some categories that will guide the collection of data and draft a schedule for collecting the data in terms of the generated categories
5. Test the schedule by using it for collecting data from a number of documents
6. Revise the schedule and select further cases to sharpen it up.

This study also uses salient aspects of each of the types of content analysis as they are not too dissimilar to each other and integrates them mainly for categories and coding development. So for example the deductive category determination was applied to use agency theory propositions and inductive category determination was applied to make it specific to shipping contracts, making the content analysis research a directed content analysis as well as conventional content analysis, according to Hseih and Shannon (2005).

Categories can be therefore derived from previous research, data or theories (Zhang & Wildemuth 2005; Krippendorff 2004) and researchers interest (Hseih and Shannon 2005). Since category development is key to the success or failure of content analysis method (Berelson 1952), it will be discussed in detail in chapter eight. As seen above there are many different typologies of content analysis. For this research agency theory is used as a starting point to derive the coding agenda, but since this theory has not been applied to the barriers to energy efficiency literature, the content analysis then moves more towards directed and summative research. This is applied in the form of ethnographic content analysis, as discussed in section 3.5.6, and the steps suggested above.

Categories can be therefore derived from previous research, data or theories (Zhang & Wildemuth 2005; Krippendorff 2004) and researchers interest (Hseih and Shannon 2005). Since category development is key to the success or failure of content analysis method (Berelson 1952), it will be discussed in detail in chapter eight. As seen above there are many different typologies of content analysis. For this research agency theory is used as a starting point to derive the coding agenda, but since this theory has not been applied to the barriers to energy efficiency literature, the content analysis then moves more towards directed and summative research. This is applied in the form of ethnographic content analysis, as discussed in section 3.5.6, and the steps suggested above.

Type of content analysis	**Study starts with**	**Timing of defining codes or keywords**	**Source of codes or keywords**
Conventional	Observation	Codes are defined during data analysis	Codes are derived from data
Directed	Theory	Codes defined before and during data analysis	Codes are derived from theory or relevant research findings
Summative	Keywords	Keywords are identified before and during data analysis	Keywords are derived from interest of researchers or review of literature

Table 4.7: Major coding differences among three approaches to content analysis
Source: Hseih and Shannon (2005)

4.2.3. Unit of analysis

The unit of analysis or coding unit according to Krippendorf (2004) is the basic unit of text to be classified during content analysis (Zhang & Wildemuth 2006). According to Berg (2001) in content analysis there can be seven types of units of analysis; words, themes, characters, paragraphs, items, concepts, semantics. The theme is a more useful unit to count because it provides context and in its simplest form is a string of words or a sentence with a subject and predicate (Berg, 2001). For this research the units of analysis are specific clauses or sub-clauses dealing with a particular energy efficiency measure.

Contextual units are “units of textual matter that set limits on the information to be considered in the description of recording units” Krippendorff (2004, p.101). According to Schreier (2012) it is useful to focus only on selected aspects of the material. For this research the charterparty content analysis focuses only on the aspects that would affect the operational energy efficiency related to the ship and its stakeholders. Therefore other clauses not related to the subject are ignored. The contextual units are clauses that address operations and measures; other clauses related to war risks, general average, etc. do not fall within the research scope. The table below shows the clauses or sections of the voyage and time charterparty which will be investigated.

Voyage charterparty components		**Time Charterparty components**	
Preamble	✓	Part A - details	✓
Owners responsibility	✓	Preamble	✓
Deviation	✓	Period & delivery	✗
Freight	✗	Cancelling	✗
Loading/discharging	✓	Trade	✗
Laytime	✓	Owners obligations	✓
Demurrage	✓	Charterer obligations	✓
Laydays and cancelling	✓	Bunkers	✗
Lien	✗	Hire payments	✗
Bills of lading	✗	Redelivery	✗
General average	✗	Cargo	✓
Brokerage	✗	Master & crew	✓
Strikes	✗	Direction & logs	✓
War risks	✗	Offhire	✓
Ice	✗	Maintenance	✓
Clause paramount	✗	Advances	✗
Both to blame	✗	Port exclusions	✗
Law and arbitration	✗	Loss of vessel	✗
Rider clauses	✗	Lien	✗
		Subletting	✗
		Rider clauses	✗
		Technical forms	✓

Table 4.8: Contextual units of investigation for content analysis

4.2.4. Sampling

In order to limit the research to a manageable body of texts and to collect data by means of sampling that minimise bias, a relevance sampling strategy is used. Relevance sampling is when all the units that contribute to answering a research question are selected (Krippendorff 2004). The resulting units of texts are not meant to be representative of a population of text; rather they are the population of relevant texts (Krippendorff 2004). This sampling method is typical of qualitative research as it helps to enhance the understanding of the information-rich case (Sandelowski 2000; Patton 1990). This sampling strategy is particularly relevant to content analysis because it limits the texts to the most relevant records based on the analyst's knowledge of the population. The knowledge of the important charterparties and salient points were derived from attendance at a two day intensive course on charterparties (Chartering in Practice: A commercial guide to charterparties in operation). A charterparty is a contract which is negotiated in a free market and the shipowner and charterer are able to negotiate their own terms (Wilson 2010) making the contract highly variable or deal specific. In practice however, the contracting parties will invariably select a standard form charterparty as the basis of their agreement, which will be modified in some way (Wilson 2010; Faber et al. 2012).

In order to further identify the most important standard form charterparties an email was sent to twenty survey respondents who were selected based on the primary sector of their company. The survey contained a detailed list of standard form charterparties for that sector and the respondents were asked to select and comment on the most commonly used charterparties. This brief investigation confirmed that there are about fifteen to twenty most often used standard form voyage and time charterparties. These 'off-the-shelf' charterparties are generally preferred by brokers and shipping practitioners to creating a totally new document for an individual charter as they produce uniformity in the application of the law and its interpretation (Wilson 2010). Moreover, the use of standard form charterparties is usually made compulsory by the protection and indemnity (P&I) clubs to restrict the chance of disagreements resulting from different interpretations of unclear clauses. Another advantage of standard form charterparties is that they are of considerable advantage in international trade where parties may be domiciled in different countries and their negotiations hampered by language problems (Wilson 2010).

These off-the-shelf standard form charterparties are usually modified in two ways, by use of rider clauses agreed between the parties and generally be appended to the standard clauses and amending the actual clauses. The result of these modifications is that sometimes the final agreement bears little resemblance to the original standard form (Wilson 2010). The focus of this analysis is only on the standard form charterparties since only off the shelf charterparties are being looked at, with a view that these are not modified in any way, for ease of comparison.

Based on this brief research, literature on most often used charterparties from UNCTAD (1990) and Baltic and International Maritime Council's (BIMCO) charterparty editor (IDEA), the most relevant charterparties to analyse were selected and are presented below in Table 4.9. It should be noted that there are a large number of standard charterparty forms, especially with respect to voyage charter parties of which more than fifty have been approved by BIMCO covering various trades (UNCTAD 1990). Within the tanker voyage charterparties there are also standard charterparties that reflect the particular characteristics of the trade as well as partly reflecting the relatively stronger bargaining power of tanker charterers (UNCTAD 1990; Wilson 2010).

Sector	***Voyage charterparties***	***Time charterparties***
Wetbulk	BIMCHEMVOY INTERTANKVOY ASBATANKVOY BEEPEEVOY 4 SHELLVOY 6	INTERTANKTIME BIMCHEMTIME BPTIME 3 SHELLTIME
Drybulk	COALOREVOY OREVOY NIPPONORE POLCOLVOY SYNACOMEX BHPBVOY03 NIPPONCOAL NUBALTWOOD RIO DOCE ORE AMWELSH GRAINCON	BHPBTIME03 BALTIME GENTIME NYPE 46 NYPE 93 ASBATIME BOXTIME
General	GENCON *SCANCON* *NUVOY*	

Table 4.9: Charterparties analysed

4.2.5. Issues of reliability and validity

In section 3.2, the criteria to evaluate quantitative and qualitative research were outlined. Issues of reliability and validity mainly apply to the quantitative research, whereas issues of credibility, transferability, dependability and conformability apply to qualitative research (Lincoln & Guba 1985). Each of these are discussed below.

4.2.5.1. Credibility

This criterion parallels internal validity i.e. how trustworthy are the findings? (Bryman 2008). In this study carefully designed coding agenda and data analysis procedures ensured the credibility of the research results from this method. The survey method solicited respondents own accounts of the relevance judgements they made on charterparties. Lincoln and Guba (1985) recommend triangulation to improve credibility. The results of the charterparty content analysis are corroborated with survey results especially for the speed reduction measures. Lincoln and Guba (1985) also suggest that to improve credibility, research findings should be submitted to members in order confirm findings, a process called member or respondent validation (Bryman 2008). Every effort was made to communicate the findings with members with relevant expertise. Example of this was contacting survey respondents to confirm most often used standard form charterparties. Similarly the research findings were also published in conferences mainly consisting of industry members (e.g. presentation at Royal Institute of Naval Architects and Low Carbon Shipping Conferences). Attempt was made to contact four experts (mainly lawyers) involved in shipping and a professor who is thought to be working on the same subject, one of the experts responded with constructive feedback on the findings but unfortunately no feedback was received from the remaining experts. The key findings are currently being reviewed by another expert in the field of maritime law.

4.2.5.2. Transferability

This criterion parallels external validity i.e. do the findings apply to other contexts? The transferability of the research is made possible by the detailed documentation of the coding agenda used to categorise various clauses affecting implementation of measures. However, one needs to bear in mind that qualitative research entails intensive study of a small sample i.e. depth is emphasized over breadth, therefore the findings will be contextually unique. Qualitative research should produce ‘thick descriptions’ (Bryman 2008) i.e. rich accounts of details, which provides others to make judgements about the transferability (Lincoln and Guba 1985) of the findings.

4.2.5.3. Dependability

This criterion parallels reliability i.e. are the findings consistent? According to Bryman (2008) dependability of research is when the research process can be accessed by peers (as auditors) through complete records of problem formulation, selection, fieldwork notes, data analysis decisions etc. In this research, most of the above have been documented in the thesis and a separate spreadsheet file is also available as well as hard copies of the initial (step one) charterparties investigated. Because the research was conducted by a single analyst, the issue of inter-coder reliability in content analysis is of little concern.

4.2.5.4. Confirmability

This criterion parallels objectivity i.e. is there investigator bias? Objectivity in this research is evidenced by use of existing theory to guide the content analysis design and coding agenda. However using theory also has some inherent limitations in that the researcher approaches the data with an informed but nonetheless with a strong bias and within qualitative research it is extremely difficult to have complete objectivity (Bryman 2008).

4.3. Secondary desk research

Much of this chapter focuses on answering the explanatory research questions, which primarily seek to answer why shipping firms may implement or not implement energy efficient operational measures and whether there are barriers inhibiting the uptake of operational measures. In order to complement the empirical primary research and to triangulate between methods (use of online survey method and content analysis method), there is a need to first have a good description of the problem, i.e. through descriptive questions that aim to address what is actually going on in shipping rather than ask 'why', through secondary desk research. A good description is important, as it forms the basis of sound theory and provides stimulus a for explanatory research (de Vaus 1995).

4.3.1. Aims and objectives

The aim of this task is to detail the stakeholders involved in the shipping system, the contracts with which they interact, conceptualise the principal agent problem, to be able to quantify the level of principal agent problem in shipping and assess the level of impact on energy efficiency. This will reflect to some extent the positivist type principal agent research as explained in section 2.1.1.2. Furthermore, it will help in the development of the survey (for example through the development of good indicators for the survey method, population of interest etc.) and enable comparison with perceived barriers after the survey has been conducted.

4.3.2. Data collection methods

A significant amount of data that is collected here is based on desk research (secondary research) which is analysed to provide a conceptualised form of the principal agent problem within the shipping industry.

1. Stakeholders and contracts in the shipping system - data and information is derived from various sources such as journals, specific databases, specific content related to the industry (e.g. charter parties) and maritime textbooks. Systems thinking methods such as the stakeholder mapping tool are used to depict the stakeholders within the shipping system and sub systems (sectors). Stakeholder mapping tool are used again to depict the stakeholders within the different types of contracts and business arrangements (types of companies) within the shipping system and sub systems (sectors).
2. The data collected above will provide a better understanding of the principal agent problem, that to date has not been well defined within the industry. Several studies have mentioned its existence but none have holistically understood and applied the concept, with no attempt made to methodically quantify the amount of fuel that may exposed to such a problem. This section uses the previous analysis to define and conceptualise the principal agent problem in greater detail.
3. Quantification or estimation of the principal agent problem – data is obtained from the Clarkson's Shipping Information Network (SIN) for fixtures on the various contracts of carriage for the different sectors that are obtained from the above analysis. The Murtishaw and Sathaye (2006), Prindle et al. (2006), IEA (2007) and Vernon and Meier (2012) approach to quantification of the principal agent problem in the context of energy efficiency is applied.

4.3.3. Issues of concern

One of the main causes for concern is the database that is used to quantify the level of principal agent problem in shipping. The Clarkson's SIN is not representative of all the fixtures that are taking place in the industry and its sectors, but cover only some part of those fixtures that have been mainly brokered by Clarksons brokers or for which information by the relevant parties to a fixture has been sent to Clarksons. The limited dataset would result in a bias and may perhaps only be a reflection of certain regions or specific types and size of companies, which could affect the generalizability of the research findings from the secondary data analysis.

5. Decomposing the structure of the shipping industry

This chapter delves further into the principal agent problem and its use in explaining barriers to energy efficiency. Of the several barriers (market failures and non-failures) discussed in chapter two, the information asymmetry and split incentives are rooted in agency theory. In order to guide the primary research methods (use of online survey method and charterparty content analysis), this chapter attempts to define and describe the problem in greater detail for shipping, as this was shown to be lacking in previous literature that examined barriers to energy efficiency in shipping. This chapter follows part of the methodology set out by Prindle et al. (2006), Murtishaw and Sathaye (2006), IEA (2007), and Vernon and Meier (2012). This is done by following three of the four steps to identify the pervasiveness of the principal agent problem. Step one is identifying and selecting situations where principal agent problems may exist, which requires an analysis of the stakeholders and contracts used in shipping. Step two attempts to estimate the population of end users affected by principal agent problem and step three attempts to estimate the energy consumption affected by the principal agent problem. This type of research can be said to be positivist type research as it aims to 'identify situations' in which principals and agents are likely to have conflicting goals (Eisenhardt 1989). This chapter deals with the quantification of principal agent components of the research framework as proposed in chapter two, highlighted in Figure 5.1.

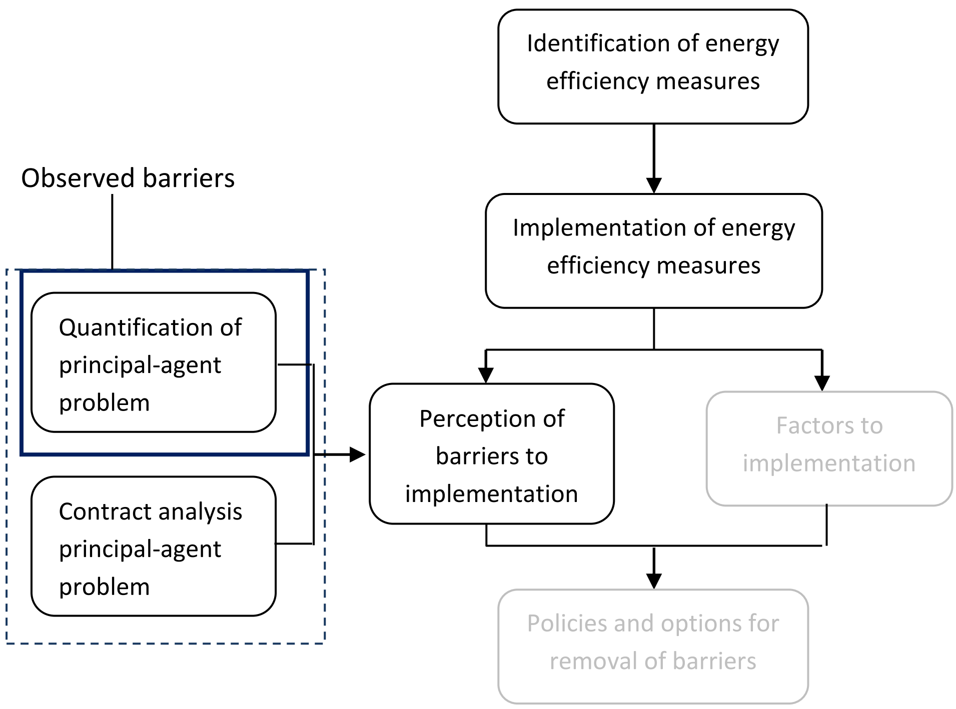


Figure 5.1: Focus of this chapter in the context of the framework

5.1. Introduction to the structure of shipping

In order to evaluate principal agent problems in the shipping industry, according to Vernon & Meier (2012) methodology, it is first necessary to identify the participating firms and understand the basic types of contracts through which they interact. Thereafter, it is necessary to identify which entity makes capital or equipment purchasing decisions and fuel consumption costs. Systems thinking methods such as the stakeholder mapping tool are used in this research to depict the stakeholders within the shipping system and sub systems (sectors). Stakeholder mapping tools are used again to depict the stakeholders within the different types of contracts and business arrangements (types of companies) within the shipping system and sub systems (sectors). The stakeholder map for shipping is represented in Figure 5.2.

In the shipping industry there are various stakeholders that enable it to function and deliver the ocean transportation service, however a few stakeholders have the largest impact on the way that it operates. The industry aims to provide transportation service to firms that desire to ship goods from one location to another, in a broader international sales context these are called the shippers of goods. Within the context of shipping, these shippers are also called charterers of ships, when they hire or rent part or full ship to transport goods. The former is mainly applicable to container shipping and the latter is applicable to bulk shipping such as wet and dry bulk commodities. These shippers and charterers contract with mainly shipowner-operators that provide the ship and the services to transport the goods under various types of arrangements. It should be noted that shipowner-operators could be common carriers (in container or liner shipping), tramp shipowner-operators (bulk shipping), management companies (who assume the responsibility of operating the ships from shipowners). In some instances the charterer may wish to do the transportation using an in-house shipping service, which owns and operates ships solely for the purpose of carrying cargo for the charterer (the parent company), in which case these shipping companies are referred to as shipping divisions of cargo owning company (shipping divisions in short). These key companies and stakeholders are defined in Table 5.1. Figure 5.3: International sale and role of shipping shows a typical international sale, which involves shipping as part of the contract.

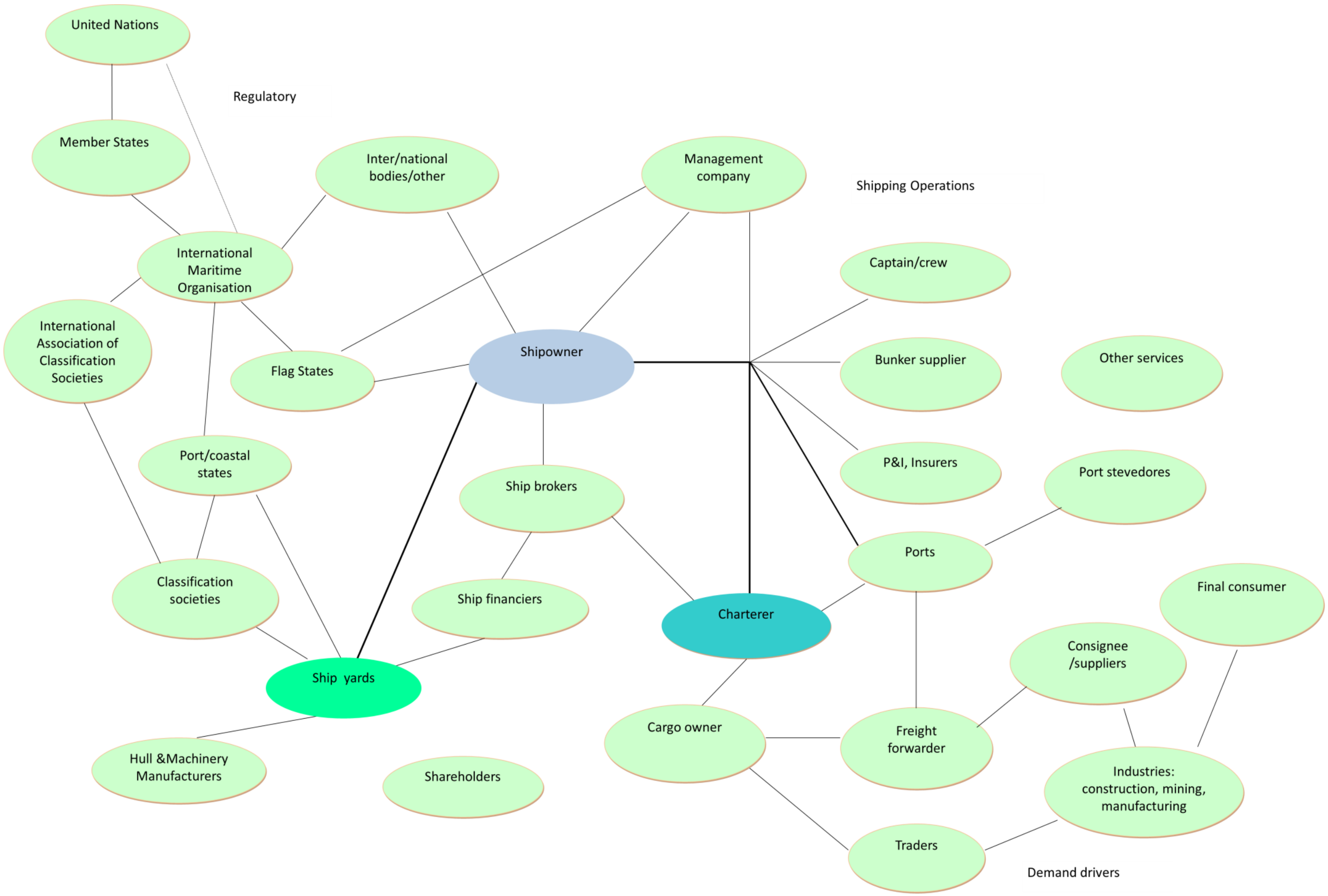


Figure 5.2: Stakeholders in the general shipping system

Type of company in operations	Description
Shipowner-operator	Own (or bareboat charter) the ship and operate the ship in voyage and time charter markets
Common carrier	Containership operator who may own or hire ships on bareboat or time charter
Management company	Manage day to day running (or full operation) of ships on behalf of shipowners
Shipping division	Department or separate legal entity of a major cargo owning company created with the sole purpose of carrying parent companies cargo

Table 5.1: Types of ship operating firms

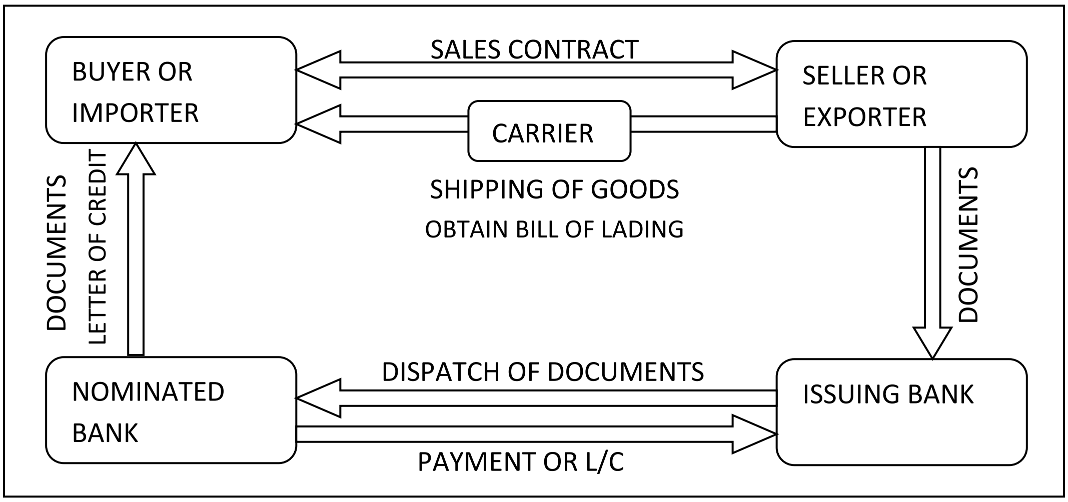


Figure 5.3: International sale and role of shipping
Source: Shaddick (2012)

Shippers and charterers enter into a contract with the shipping company/operator (as mentioned in Table 5.1) through various types of chartering arrangements to obtain shipping services. These arrangements are voyage charter and time charter which have been briefly explained in chapter two. In the following sections each of these are examined in greater detail.

5.2. Analysis of the different types of contracts

There are essentially only two basic forms of charter for carriage of goods with which the shipowner-operators and charterers or shippers (referred to as charterers only from here onwards) contract, voyage (or voyage) charter and time charter (Wilson 2010). In a voyage charter, a charterer contracts a shipowner for the carriage of a specific amount of cargo, from a load port to discharge port, which is comparative to hiring a taxi. In the voyage charter, the capital expenditure, operational control and fuel cost is borne by the shipowner-operator. The shipowner-operator's earnings are based on the amount of cargo transported (hence $/tonne) and the average length of a voyage varies from days to months for round trip voyages. This is also called the 'freight contract' in which the shipper buys transport for a fixed price per tonne of cargo (Stopford 2008).

	Responsible entity for cost elements	
	Shipowner-operator	**Voyage charterer**
Operating costs	• Voyage costs – fuel, port dues, canal dues • Despatch (cost of early relief from the contract) • Operating costs – crewing, repair, dry-docking, maintenance, surveys, insurance	• Cargo handling • Freight • Demurrage (cost of delays)
Capital costs	• Debt repayment • Interest • Retrofit	• None

Table 5.2: Costs allocation under voyage charters

In a time charter, a charterer contracts with a shipowner-operator for the use of a crewed vessel for a certain period of time, which may be for a single trip (trip charter) or certain length of time (period charter). This contract is similar to hiring a car from a rental company (but with the difference that the driver is also included in the hire). A time charterer gains the operational control of the ships carrying its cargo, while leaving the ownership and management of the ship for the shipowner. As shown in Table 5.3 under a time charter, the ships capital expenditure and some operational control is done by the shipowner (e.g. providing crew and master) but the fuel cost is paid by the charterer in addition to the charter day rate.

A bareboat charter involves the use of a vessel in which the capital expenditure is accrued by the bareboat owner and all other costs are borne by the bareboat charterer, which is similar to a long lease in the property market as shown in Table 5.4. The bareboat charter is however not technically a carriage of goods contract rather it is a lease of the vessel to the charterer (Wilson 2010). Unlike in commercial property, the hire charge for the boat is on a per day basis rather than an upfront lump sum. The bareboat charterer obtains possession and full control of the vessel along with the legal and financial responsibility for it.

	Responsible entity for cost elements	
	Ship owner	**Time charterer**
Operating costs	• Operating costs – crewing, repair, dry-docking, maintenance, surveys, insurance	• Cargo handling • *Voyage costs* – fuel, port dues, canal dues • Freight
Capital costs	• Debt repayment • Interest • Retrofit	• None

Table 5.3: Costs allocation under time charters

	Responsible entity for cost elements	
	Ship owner	**Bareboat charterer**
Operating costs	• None	• Cargo handling • Voyage costs – Fuel, port dues, canal dues • Operating costs – crewing, repair, dry-docking, maintenance, surveys, insurance • Freight
Capital costs	• Debt repayment • Interest • Retrofit	• None

Table 5.4: Cost allocation in bareboat charter

The above types of charter are the main ways of earning revenue for a shipowner. However, other hybrid forms of charters also exist, such as trip charters, which fall into time charter category despite the contract being for a single voyage, Contracts of Affreightment (COA), which fall into the voyage charter category despite being for a specified period of time (Wilson 2010). In a COA the shipowner is free to choose whichever of the above contracted ships to meet this requirement, but generally this contract has the same profile as a voyage charter (Stopford 2008) and the actual vessels used are normally chartered under individual voyage charters. In summary, the different types of charters are as a result of varying degree of responsibility over operating and capital costs of running a ship as summarised in Table 5.6. These charters are also of different lengths ranging from days to decades as shown in Table 5.5. The result of the varying degree over capital and operational costs and the duration of control is that both entities have conflicting interests (split incentives principal agent problem) to minimise their share of costs according to the charter arrangements used.

Type	**Voyage charter**	**Time charter**	**Bareboat charter**
Average length	Single voyage, Up to 1 month	1 – 12 months, up to 5 years	7 – 10 years, up to 20 years

Table 5.5: Different types of charters and charter length
Sources: Stopford (2008) and Clarksons SIN

	Voyage charter	**Time charter**	**Bareboat charter**
Cargo Handling			
Load port			
Discharge port			
		Charterer	
Voyage Expenses			
Fuel			
Port dues			
Canal dues			
Operating expense			
Crewing			
Maintenance			
Repairs			
Surveys			
Insurance			
management			
	Owner		
Capital costs			
Interest			
Dividends			
Debt repayment			

Table 5.6: Cost allocation in the different types of charter

5.3. Principal agent problem in general

Chapter two investigated the literature on the various barriers to energy efficiency. Much of this literature such as Blumstein (1980), Fisher and Rothkopf (1989), Jaffe and Stavins (1994), Sorrell et al. (2000 and 2004), etc. has focussed on understanding the market barriers to explain under-investments in energy efficiency and identifying the specific barriers responsible for the under investment or lack of uptake. The principal agent problem (rooting from agency theory) has been classified as a market failure in the literature by Brown (2001), Jaffe and Stavins (1994), etc. and is the focus of this section. Under orthodox economics a market failure occurs when the conditions required for Pareto efficiency are violated, resulting in incomplete property rights, positive and negative externalities, imperfect competition and asymmetric information. According to Sorrell et al. (2000) market failures are market barriers that require policy intervention or in other words existence of market failures is a prerequisite for market intervention (Brown 2001). The principal agent problem arises from an agency relationship, which was described in section 2.1.1. The principal agent problem as a barrier in energy efficiency arises in:

"transactions when the entity responsible for making investment decisions is not the party responsible for paying future costs of operation caused by that investment" (Vernon & Meier 2012, p 267).

It has long been recognised that principal agent problems are pervasive in the buildings sector, both residential and commercial rental markets (for which it has been referred to as the landlord-tenant problem) by Blumstein (1980), Jaffe & Stavins (1994), Lovins (1992), Fisher and Rothkopf (1989), IEA (2007) etc. Apart from the rental markets (or operations), it is thought to be impeding energy efficiency at design and construction as well. For example in construction of buildings, builders do not optimise for energy efficiency in order to hold construction costs down (e.g. developers choosing to install electric space heating, even though for tenants this is more expensive than gas) and because their productivity is measured in different scales (Lovins 1992 and IEA 2007). In the rental market, landlords will generally not purchase efficient devices for rental properties since the tenants pay the cost of operating the devices (Jaffe and Stavins 1994; Murtishaw and Sathaye 2006; Maruejols & Young 2011) thus the tenant pays energy costs that are largely determined by the infrastructure present in the building, which is subject to landlord's decision. Similarly, landlords may not maintain the devices well when tenants pay the operating costs (Murtishaw and Sathaye 2006). Generally, the landlord has no incentive to make energy efficient investment as only the tenant directly benefits from these reduced costs, which insulates the landlord from energy price signals.

In some cases where markets are efficient this may not hold, as a landlord who has invested in energy efficiency of his building should be compensated with higher rent. Thus, the principal agent problem is a function of several different conditions such as the number of contracting entities, length of contracts, apportionment of costs and the level of information. The above however are only related to one type of contract that is prevalent in the rental markets (this classical landlord-tenant relationship is depicted Figure 5.4), where the tenant (the principal) pays rent to the landlord (agent) in exchange for the use of the building and additionally pays energy costs. According to Prindle et al. (2006), Meier and Eide (2007) and IEA (2007) up to four different relationships are possible depending between the contract between the parties as shown below in Table 5.7.

According to the above sources, different questions have been put forward to determine whether the end use is affected by principal agent problem. According to Murtishaw and Sathaye (2006) the following three questions must be answered:

- Who uses the device?
- Who selects the device?
- Who pays the energy cost?

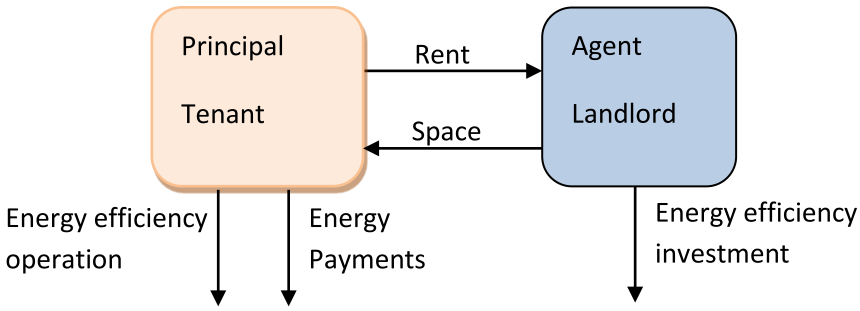


Figure 5.4: Classical tenant-landlord problem

If the answer to any of the above questions is; not the same person, then one any one type of the principal agent problem could exist. For example, a tenant living in a rented apartment buys a television, he or she would use the device, select the device and pay for its energy (Box one in Table 5.7), therefore no principal agent problem is envisaged here (at least in the purchasing market, the problem may exist further up the chain e.g. with manufacturers). For the same tenant, the replacement of refrigerator could pose a different type of principal agent problem, since the appliance is used by the tenant and energy is paid for by the tenant but the selection and purchase is by the landlord, thus efficiency principal agent problem (Box two in Table 5.7) can exist here.

	Can chose technology	**Cannot chose technology**
Direct energy payment	1) No problem	2) Efficiency problem
Indirect energy payment	3) Usage and efficiency problem	4) Usage problem

Table 5.7: Classification of principal agent situations according to Murtishaw and Sathaye (2006)

The questions are extended by IEA (2007) and Meier and Eide (2007), to include the following:

- Who selects the energy using technology?
- Who purchases the energy using technology?
- Who pays the energy bill?
- Who owns the energy using technology?
- Who controls operation of the energy-using technology?

The two by two matrix to conceptualise the principal agent problem in energy end use, which classifies the energy end use by the ability to choose the device and responsibility for paying the energy costs differs slightly between the sources. By categorising who is responsible for energy costs and energy purchases (as shown in Table 5.7 and Table 5.8), the principal agent problem can arise from two kinds of split incentives, one concerning usage (demand for energy services) and other concerning the technical efficiency of the end use device (Murtishaw and Sathaye 2006).

	End user can chose technology	**End user cannot chose technology**
End user pays energy bill	No principal agent problem. Case 1	Efficiency problem. Case 2
End user does not pay energy bill	Usage and efficiency problem. Case 3	Usage problem. Case 4

Table 5.8: Transactions from an end user perspective

In case one, the end user (e.g. dwelling occupant) selects the energy-using technology (e.g. refrigerator, etc.), selects its energy efficiency and pays for its energy consumption, thus the end user will be incentivised to make a reasonable investment in energy efficiency (although this may be affected by other barriers that may be present). In this case there it can be said that no principal agent problem exists because the principal and agent are the same entity (IEA 2007) or the principal makes the energy efficiency investment and pays the energy cost. In the context of energy efficiency this is the ideal situation because there are no diverging interests between principal and agent, information is costless, easily transferred, and all costs and benefits of energy efficiency investment are internalised (Vernon and Meier 2012). This situation is illustrated in Figure 5.5.

In case two, the end user cannot choose the energy using technology or make an energy efficiency investment, instead the agent selects the energy-using technology and makes the energy efficiency investment, but the end user i.e. the principal pays for the energy use. A principal agent problem can be said to exist here and is defined as an "efficiency problem", which refers to the forgone energy efficiency investment, referred to in the earlier example of the classical tenant-landlord problem. In this case, the market also fails to provide adequate information on energy efficiency to the principal (IEA 2007) resulting in adverse selection by the principal (due to agent's pre contractual opportunism) or the inability of the agent to recoup the investment in energy efficiency. Other examples of this situation are in the car rentals business, sale and purchase of capital equipment and appliances.

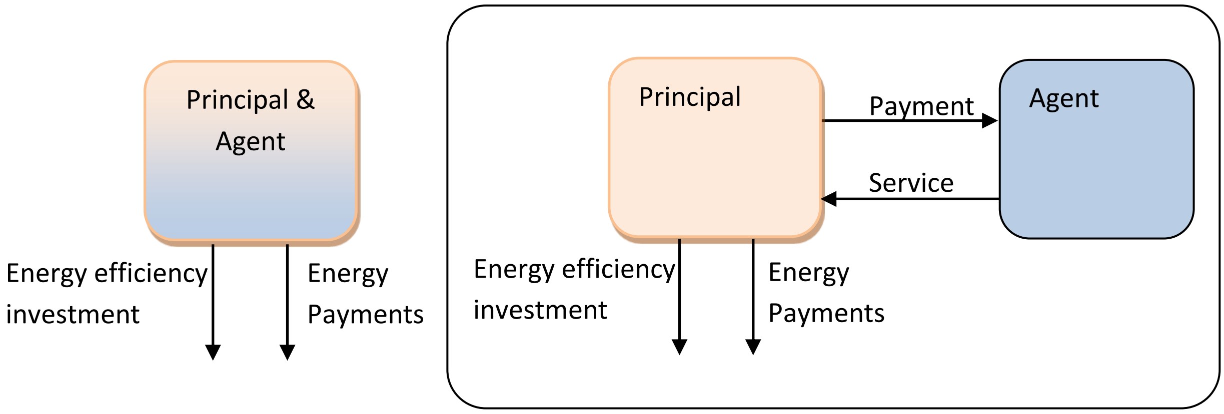


Figure 5.5: Case one adapted from Vernon and Meier (2012) and IEA (2007)

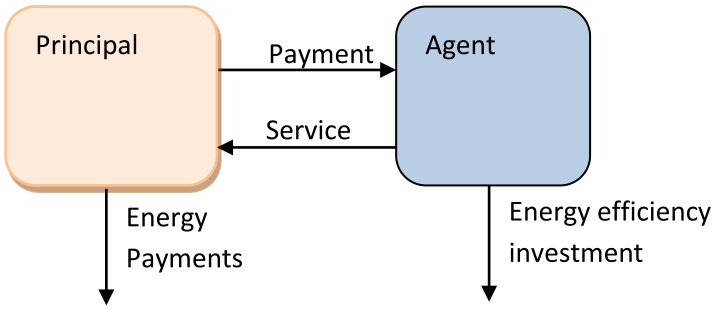


Figure 5.6: Case two, efficiency problem in principal agent problems

In case four, the end user is neither able to select the energy-using technology or make the energy efficiency investment nor pays the energy cost, as shown in Figure 5.7. This is classed as "usage" problem because the end user faces no economic constraint on usage, i.e. the end user consumes more energy than is reasonable (Meier and Aide 2007). Examples of this situation are where energy cost or utilities are included in the overall rental charge, hotel rooms, etc. The principal pays only indirectly for energy use as part of the payment for use of the product or service (IEA 2007). In this case, the agent may try to over-invest in efficiency in order to minimise the consequences of unconstrained usage problem.

In case three, the end user selects the technology and makes the energy efficiency investment but does not pay the energy costs, as shown in Figure 5.8 which is a complete reversal of case two, where the end user pays the energy cost but cannot choose the technology. Case three, is a combination of the usage problem as shown in case four and efficiency problem as shown in case two. This situation may seem unlikely but it actually exists. Examples of this case are company cars, where in some companies the employees are permitted to select their cars and the company pays for fuel consumed on both company and personal trips, and when costs of utilities are included in condominium fees charged to the owner-occupiers of condominiums. It is however unclear as to who is the agent and who is the principal in this case. IEA (2007) and Vernon and Meier (2012) consider the principal as making efficiency investments and agent paying for energy costs, whereas Grauss and Worrell (2008) consider the principal (company owning lease cars) as paying for fuel costs and agent (employees) making car selections i.e. making the energy efficiency investment and operating them, which results in the same situations as case two above, as shown in Figure 5.9. Grauss and Worrell (2008) find that company cars are less efficient despite being newer and using more efficient engines types (efficiency problem) and drive for longer distances (usage problem), resulting in up to 7% increase in fuel use in all passenger cars in Netherlands.

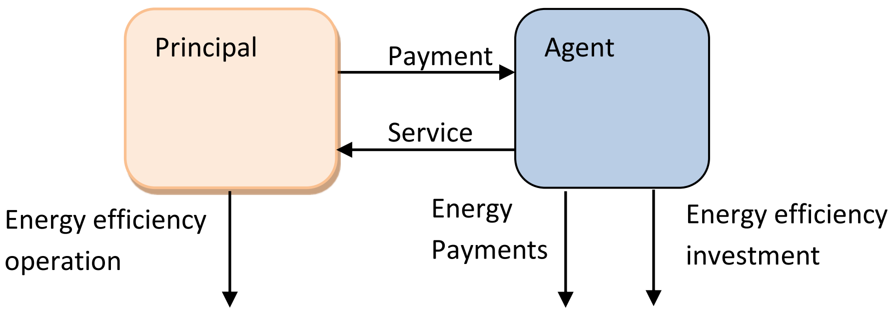


Figure 5.7: Case four, usage problem in principal agent problems

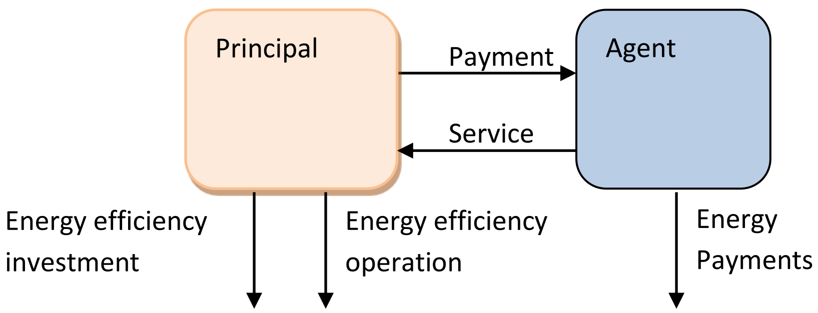


Figure 5.8: Case three, Efficiency and usage problem according to IEA (2007)

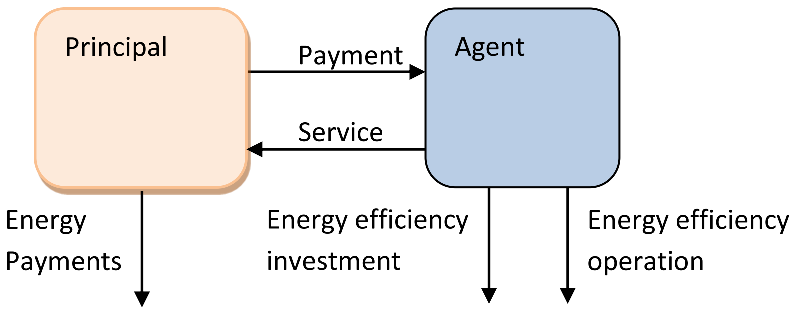


Figure 5.9: Case three, Efficiency and usage problem according to Grauss and Worrell (2008)

To summarise the above classification and to make it easier to understand, the following matrix has been developed.

	Principal selects technology, agent cannot select technology	**Agent selects technology, principal cannot select technology**
Principal pays energy bill (Direct energy payment), agent does not pay energy bill	No principal agent problem. Case 1	Efficiency problem can exist Case 2
Agent pays energy bill, principal does not pay energy bill (indirect energy payment)	Usage and efficiency problem can exist Case 3	Usage problem can exist Case 4

Table 5.9: Adapted classification of principal agent problems

The following section of the chapter uses the above classifications and analysis from chapter two to define and conceptualise the principal agent problem in shipping.

5.4. Step one: Identifying situations where principal agent problem may exist in shipping

Section 5.2 briefly described the contracts through which the charterer i.e. the entity desiring the shipping service contracts with various types of shipping companies or operators. As with other studies and contexts (Vernon and Meier 2012; IEA 2007; etc.) this is the person who 'hires' an agent for a service, thus in this case the charterer is identified as the principal (this follows the classification in the tenant-landlord problem as well). The shipping companies or owner-operators (from here on referred to as shipowner-operator) are identified as agents to the charterer since they are contracted by the charterer. This characterisation is similar to Veenstra and Dalen (2011).

The end user perspective as shown in the earlier sections in shipping is somewhat different because operations of ships could be carried out by another entity that does not own the ship and neither pays for the fuel e.g. management companies or operators. Moreover, even when the charterer pays for the fuel e.g. in case two, the end user is actually the shipowner-operator's agents e.g. the crew and master. Because this research goes further than just looking at technology selection i.e. mainly concerned with principal agent problem in operations, section 5.4.3 adds another dimension to the above matrix, the ability to select energy efficient operations e.g. weather routing, speed reduction etc.

In case one, where the principal and the agent are the same entity or all costs are internalised then the principal agent problem may not exist. The same entity selects the energy efficiency of its purchases and pays for its energy consumption, thus it will be incentivised to make a reasonable investment in energy efficiency. An example of this in the residential sector is an owner-occupier, and within shipping, a shipping division that owns and operates its own ships (including crewing and all other management) and carries its own cargoes, examples of which are major commodities traders (or cargo owners) such as BP, Rio Tinto, Cargill who satisfy much of their transport demand through their owned and operated ships. Case one could also be said to reflect the bareboat charter, where the bareboat charterers, can be in control of the energy efficiency investment either at the design stage or during operation. In the design stage, where the vessel is merely an asset to another financial institution (beneficial owner or registered owner, see below), the bareboat charterer could govern the design of the vessel. In this case, it is not a true lease contract according to IEA (2007) and can be considered analogous to the owner-occupier. During the operations the bareboat charterer can also make changes to the vessel so long as there is consent of owners (either the financial institution or a professional ship owning company), according to clause nine of the Barecon 89 charterparty (BIMCO 1989). Since the length of charter or ownership is sufficiently long, most energy efficiency investments could theoretically payback within this period. However, initial estimates by (Stott 2013) show that on average only under 10% of operating owners keep the ship for its full working life (of around 25 years), the remainder of the owners keep the asset for an average of around eight years, with the mode value of five years, which could have determining effect on the investment attitude towards energy efficiency of ships. It is important to note the two types of shipowners;

- Beneficial owner: is the ultimate controlling owner who benefits from any profits the ship makes (Stopford 2008). According to the Harmonised Vessel Particulars Questionnaire (HVPQ) this is the registered owner, which could be a one ship company (protecting other assets of the beneficial owner) or a holding company (shares in each one ship company) incorporated in a favourable tax jurisdiction.

- Disponent owner – is the bareboat charterer who has the full operational control of the ship for a long period of time and can sometimes have a say in the design of the ship.

Although this case is an ideal situation, there may still exist principal agent problems internally which would affect the energy efficiency investment and operations. According to Decanio (1993) this can happen because the firm is a collection of individuals brought together under a set of complex contracts (where the principal is the firm, employees are agents), which would affect the behaviour of those agents (with divergent goals) e.g. short-sightedness of management, overly stringent investment criteria due to managerial job rotation and performance related pay.

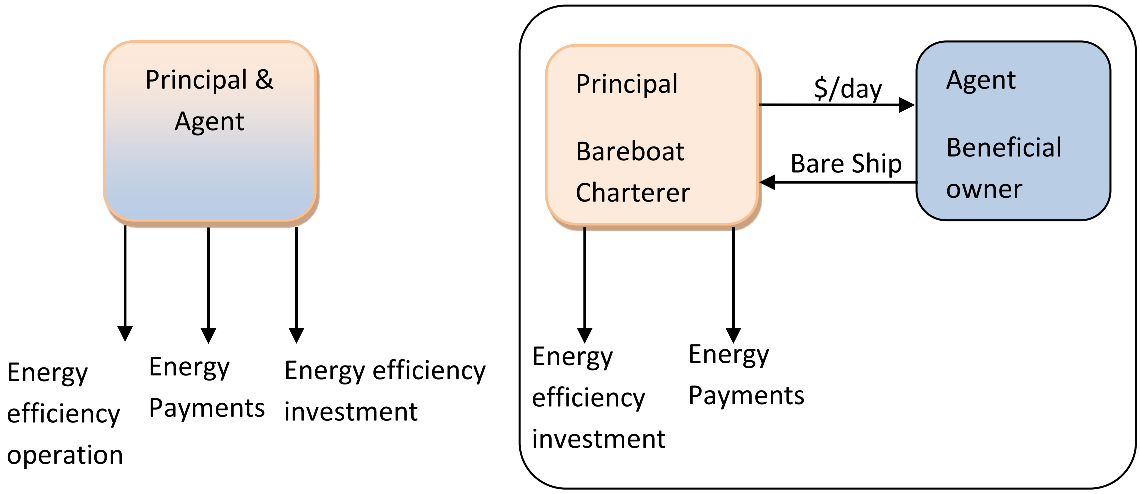


Figure 5.10: Case one in shipping

	Principal	**Agent**
Wetbulk	BP Oil International	BP Shipping
Drybulk	Cargill	Cargill Shipping division
Container	N/A	N/A

Table 5.10: Example of case one principal agent problem in shipping carriage of goods contracts

In case two, the charterer cannot select the technology but pays for the fuel as a result of the investment decision made by the shipowner-operator. This could result in a split incentive efficiency problem, where the principal would prefer to have an efficient technology or ship that results in lower fuel costs, but their agent the shipowner-operator is not incentivised because they are concerned with initial costs (capital) and not the energy costs. In most cases the contracts between the entities in this case are signed after construction (and many years after), therefore the principal has little influence over the design (IEA 2007), however a few examples have begun to appear in shipping where the charterer influences the design of ships through retrofits and subsequently pays either a lower time charter rate or benefits from lower fuel consumption. The incentives could be realigned if the investment by the agent in energy efficiency could be directly reflected through a higher charter rate charged by the agent to the principal who would save on the fuel costs. According to Jaffe and Stavins (1994) adoption will only occur if the adopter can recover the investment from the party that enjoys the energy savings. The extent to which the fuel cost savings are passed back to the owner-operator through a higher charter rate i.e. the ability to recoup the investment, has not been investigated thoroughly in shipping. There is difference of opinion in the grey literature regarding this subject and this has been detailed in a paper submitted to Transportation Research Part A, Policy and Practice by Agnolucci, Smith & Rehmatulla (2014) who show that up to 50% of the investment can be recouped in the drybulk panamax sector. The inability to recoup the investment could in part be due to informational problems or information asymmetry meaning that a charterer is not fully able to assess the actual (technical and operational) efficiency of the ship and thus not willing to pay a higher rate to reflect this prior to signing the contract. This could be because the shipowner-operator is either not able to portray the energy efficiency of the ship (i.e. has difficulty in communicating information) to be able to reflect the charter rate, or in other cases is the result of agent opportunism (Williamson 1979) thus the market does not allow for a sufficient return on energy efficient vessels. Thirdly, despite paying for the fuel, the charterer is still not in 'full' control of its use because the operation of the ship is left to the shipowner-operator, the charterer can only direct the master with respect to cargo (Stopford 2008).

According to agency theory the second problem (first being split incentives) of informational problem arises here because it is either difficult or costly to perfectly monitor the agent's behaviour, leading to a moral hazard. Moral hazard refers to situations where actions of one party are unobservable to another party after the contract has been signed (post contractual opportunism) (Sorrell et al. 2004). To that extent, charterers would incur the cost of using weather routing companies to monitor the performance of the ship (speed and consumption under various weather conditions). However, even with perfect information the incapacity of the principal to control the actions of the agent may still produce a principal agent problem (Murtishaw and Sathaye 2006). In shipping this would be the ability to lodge a concrete claim against the shipowner for breach of contract, called the speed consumption claim. Even when this happens the principal is only able to monitor a very limited amount of information relating to the energy efficiency of the ship. Fourthly, the short term nature of the contract in various sectors (typically three to six months, see

Figure 5.24) is a relatively short period for a charterer to make an investment in energy efficiency technologies, as most of these would be expected to payback between two to ten years. This case is applicable to all three major sectors of interest; wetbulk, drybulk and container sector, which have varying amount of ships on this type of charter.

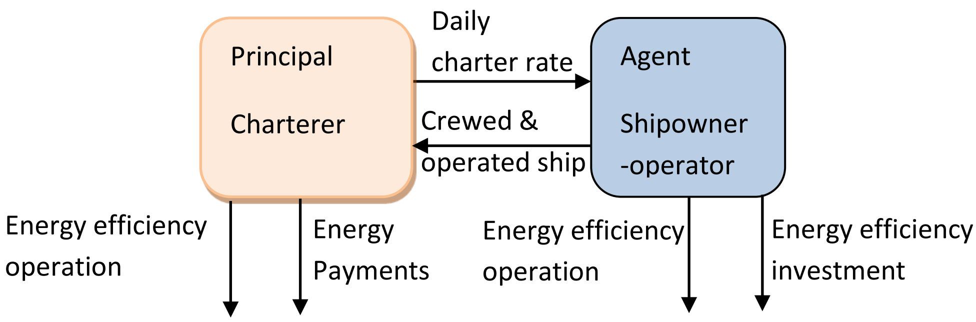


Figure 5.11: Case two, efficiency problem in principal agent problems

	Principal	**Agent**
Wetbulk	Petrobras	Frontline 2012 tankers
Drybulk	Rio Tinto	Gearbulk
Container	Maersk Line	Seaspan Corporation

Table 5.11: Example of case two principal agent problem in carriage of goods contracts

In case four, the charterer is neither able to select the energy-using technology or make the energy efficiency investment nor pays the energy cost (at least not directly), which is representative of the voyage charter. Generally in other contexts this case could result in a principal agent usage problem because the end user faces no economic constraint on usage, i.e. the end user consumes more energy than is reasonable, thus the agent over invests in efficiency. In shipping however, the charterer is not the end user as implied by this case, as the operation of the ship is still carried out by the agent, so in the literal sense the usage problem may not apply.

In the voyage charter the price charged by the shipowner-operator (agent) to the charterer (principal) is called the freight rate. The freight rate for drybulk sector is quoted in $/tonne basis, for wetbulk sector quoted in Worldscale (route cost index) basis and for container sector quoted in $/TEU or FEU (Twenty foot equivalent, Forty foot equivalent), which cover all the transport or voyage related costs including fuel costs for that voyage. Thus, the principal would be indirectly paying for fuel costs as mentioned earlier, which is analogous to the residential sector where utility bills are included in the rent. When fuel costs increase the shipowner-operator must either increase the freight rates or increase the fuel efficiency to maintain a constant profit margin (Vernon and Meier 2012), although the immediate and short-term response may be to pass on the fuel costs in the form of fuel surcharges (Vernon and Meier 2012; Faber et al. 2009), which is dependent on the elasticity of the freight rate to bunker price. This elasticity has been shown to be ranging widely across the shipping markets (Vivid Economics 2010; Chowdhury & Dinwoodie 2011). In the case, when the energy cost is passed through from the agent to the charterer the situation resembles case two. Thus, this case could then be similar to case two, and at times the lines between case two and four can be blurry (Murtishaw and Sathaye 2006). In fact IEA (2007) in two instances simplifies case two and four to be the same “To simplify calculations, this study assumed that all offices pay their own energy bill in the end, therefore only case one and two are applicable” IEA (2007, p79 and p88). Nevertheless the split between case two and four is important in shipping and in the context of investment in operational energy efficiency measures, which will be discussed in section 5.5.

The pervasiveness of fuel cost pass through in the shipping industry may discourage the shipowner-operator to invest in energy efficiency. There are many examples of cost pass through in shipping, especially those related to fuel (surcharges). There are many other common and uncommon surcharges that exist in shipping, such as peak season surcharge by container lines, low sulphur fuel surcharge etc. Bunker adjustment factors (BAF) are prevalent in the container sector, with almost all companies charging shippers for any fluctuations in bunker prices. They have also been introduced by some drybulk shipowner-operators and roll-on/roll-off operators. More recently this concept of surcharges (as a separate item on freight) was also being proposed by Maersk tankers, because the Worldscale index does not accurately account for the current fuel price. The following quotes demonstrate this:

“We’re making sure that our higher oil costs are being covered by the bunker fuel charges that we add to the freight rates. As long as we’re covered via the [bunker] surcharge, we won’t slow down any further.” Maersk Line's Chief Executive Officer (CEO) Eivind Kolding (Sustainable Shipping News 2011b).

"We will have this done in one way or another. To start with we can make our customers aware of how much bunker makes up of the bills we send them. Because of the way billing takes place in the tanker industry (Worldscale rates), we do not get compensated at all for the increase in bunker costs that has taken place" Maersk Tankers Chief Executive Hanne Sorensen (Sustainable Shipping News 2012b).

According to Faber et al. (2010) the cost pass through depends on market circumstances, thus in a market where demand for shipping is higher than supply of ships, the costs are borne by the shipowner-operator because prices are not cost related and based on marginal benefits, whereas when demand for shipping is lower than supply of ships, the costs will be passed on to the charterer and ultimately the consumer because prices are based on marginal costs. Although this may not hold when a round voyage/trip (e.g. in the liner trade) is considered consisting of both the above markets, thus in this case the shipowner-operator would pass the costs even when demand for shipping is higher than supply (least price sensitive market), in order to cover the costs of the return journey (Faber et al. 2010).

To some extent the usage problem (by the charterer) is illustrated by the way the speed is stipulated in the voyage charter. Generally the speed (which is one of the most important variables in energy efficient operation and has the highest energy saving potential) is not the energy efficient speed because the charterer does not pay the freight rate in direct relation to speed and there is often no negotiation of varying level of freight rates dependent on speed. This subject is further discussed in chapter eight. Generally, in other contexts or sectors this case results in over investment in energy efficiency, which suggests that in the absence of cost pass through of energy costs there is sufficient incentive for the shipowner-operator to invest in energy efficiency in order to maintain a profit margin or to compete on cheaper freight rate.

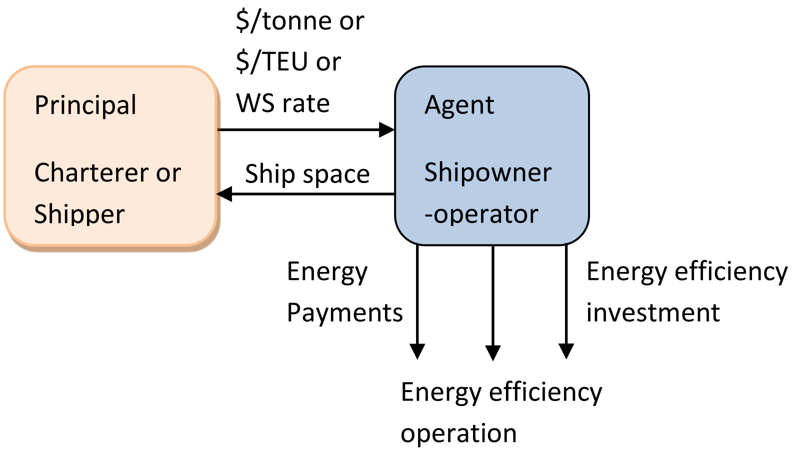


Figure 5.12: Case four in shipping

	Principal	Agent
Wetbulk	ExxonMobil	Tsakos Energy Navigation (TEN)
Drybulk	BHP Billiton	Star Bulk carriers
Container	B&Q	Maersk

Table 5.12: Example of case four principal agent problem in shipping

In case three, the end user selects the technology and makes the energy efficiency investment but does not pay the energy costs. Since this case is very rare (IEA 2007) most studies have found it difficult to identify situations where this would exist. Murtishaw and Sathaye (2006) only find a small number of instances (almost negligible) in the residential sector, for example in the case of condominiums where the cost of fuel in non-residential parts of the buildings is included in the condominium fee. This case does not exist in shipping.

	Charterer selects technology, Shipowner-operator cannot select technology	**Shipowner-operator selects technology, Charterer cannot select technology**
Charterer pays energy bill (Direct energy payment), Shipowner-operator does not pay energy bill	No principal agent problem. Case 1 Charterers shipping division	Efficiency problem can exist Case 2 Time charter
Shipowner-operator pays energy bill, Charterer does not pay energy bill (indirect energy payment)	Usage and efficiency problem can exist. Case 3 None	Usage problem can exist Case 4 Voyage charter

Table 5.13: Allocation of cases in shipping to the principal agent matrix

5.4.1. Multiple principal agent relationships

The above cases highlight the principal agent problem between two stakeholders, the shipowner operator and the charterer or shipper. In many cases the applications of agency theory is limited to the analysis of a single, well defined one principal and one agent (Neill and Morris 2009). In reality there are many situations with several principals and agents, with the same entity being a principal in one case, but at the same time being an agent for another principal (Levine & Florence 1990; Breaux et al. 2002). This chain of relationships between principals and agents can lead to conflicting goals even in cases where the principal and agent have convergent goals (e.g. in case one). According to Neill and Morris (2009):

"As the chain of principal agent relationships expands, it becomes less likely that the "interests of the original principal and the final agent coincide" (Breaux *et al*. 2002, 94). This chain of relationships exacerbates the problem of asymmetric information, as the initial principal is even less likely to know what its "contractor's contractors" are doing" Neill and Morris (2009, p633)

Figure 5.13 shows several cases of principal agent relationships (synonymous to the aforementioned four cases) but also shows that the same entity may have a different role in its relationship with other stakeholders in the same contractual context. Figure 5.14 is adapted to show the stakeholders in shipping specifically involved in carriage of goods contracts for voyage and time charters in various sectors. It shows a typical principal agent relationship chain in an oil sale or other drybulk commodity sale, which is followed by an explanation of the chain and an example.

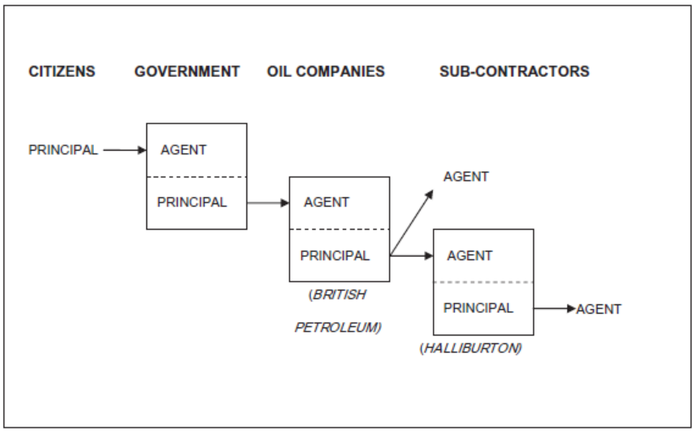


Figure 5.13: Complex principal agent problems in Deepwater Horizon
Source: Neill and Morris (2009)

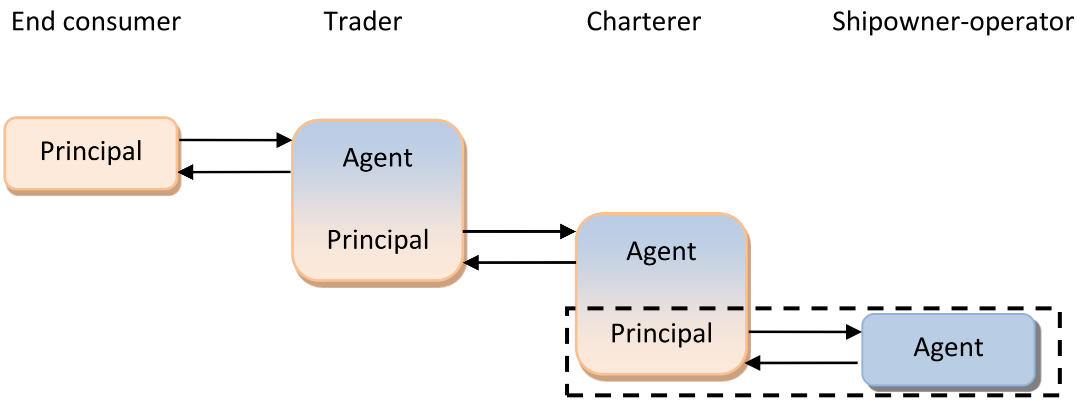


Figure 5.14: Principal agent relationship chain in the wetbulk and drybulk shipping sector

As can be seen the charterer who had been portrayed as the principal in all of the above cases (Figure 5.10 and Figure 5.12) is now shown to be the agent for the trader. This is typical of a CIF (Cost, Insurance & Freight) sale, where the charterer (seller of the commodity) would include these costs and thus would arrange the shipping of the goods as well. In an FOB (Free On Board) sale the trader (buyer of the commodity and seller to the end consumer) would arrange for shipping, thus bypassing or assuming the role of the charterer. In both cases the contract with the shipowner-operator would be a voyage charter (case four), i.e. for a specific cargo requiring transport from A to B. Table 5.14 gives an example of this. In a time charter, the charterer would give the buyer the option to have the cargo delivered i.e. CIF (Cost, Insurance & Freight) sale, but this time would have some operational control of the shipping activity as long term charterer of the ship through either a time charter with the shipowner-operator or bareboat charter with the owner.

	End consumer	Trader	Charterer	Shipowner-operator
Drybulk	Bao Steel Chinese Steelmill	Trafigura	Rio Tinto	Gearbulk shipping
Wetbulk	Reliance Indian refinery	Vitol	Shell	Teekay tankers

Table 5.14: Example of multiple principal agent relationships

In some cases where the principals or agents are small in size or geographically dispersed, there would be intermediaries that would connect the principal and the agent, such as brokers (cargo brokers and shipping brokers). Other examples of intermediaries between charterer and shipowner-operator (case two and four) are shipping pools. Section 5.4 and the four cases only describe only the one principal and one agent relationship as shown by the dashed outline in Table 5.14. The above principal agent relationships are only in the context of carriage of goods, and there are many several dimensions or contexts other than these, for example a shipowner-operator (as a principal) would hire the crew (as agents), or shipowner (as a principal) would hire a management company (as an agent) to operate the ships, the management company (as a principal) would hire technical operators (as agents) and manning agents (as agents) as shown in Figure 5.15, relationships between other stakeholders (e.g. ports, classification societies etc. as shown in Figure 5.2).

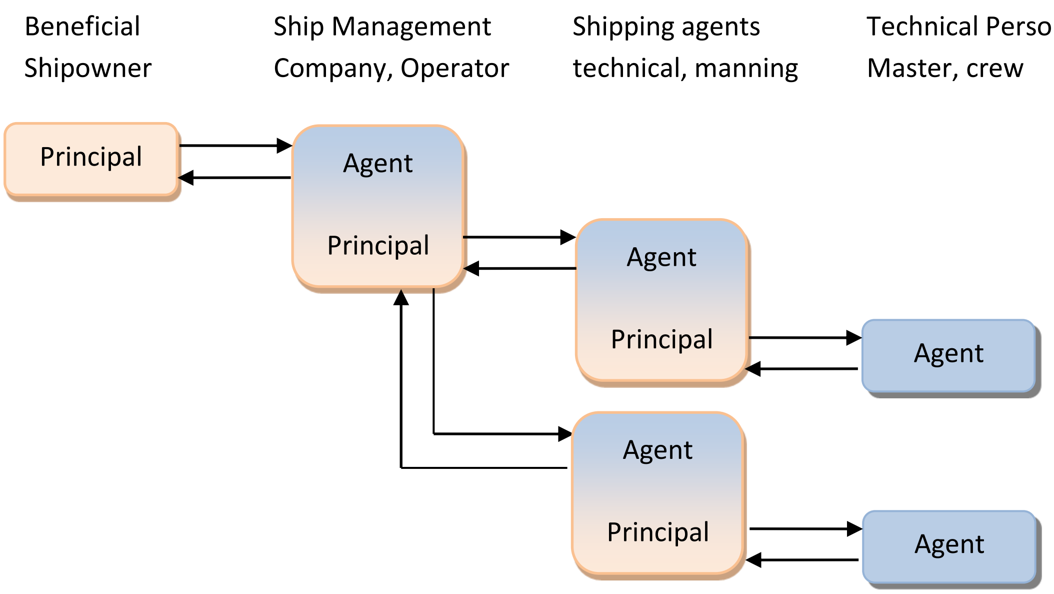


Figure 5.15: Principal agent relationship chain in other contexts

When the chain of principal agent relationships extends, and other than interests of the original principal and the final agent not coinciding (goal conflict or split incentives), other agency related barriers such as asymmetric information and monitoring and other barriers become more pervasive. Combining the above analysis of multiple principal agent relationships with previously mentioned one principal one agent cases (case one to four), should lead to a more realistic and accurate picture of the principal agent problems and its classification as well as other barriers that may be impending as a result of those relationships. The following section shows the various stakeholders arrangement in the voyage and time charter (case two and four) and shipping division and bareboat charter (case one) for bulk and container shipping sectors.

5.4.2. Arrangements of stakeholders and barriers in the voyage and time charter

Case two and four, mentioned above were shown to be prone to the principal agent efficiency and usage problem. Case two which represents the time charter has been extended from the initial one principal (time charterer) and one agent (shipowner-operator) to include principals and agents before and after. As can be seen in Figure 5.16 to Figure 5.19, investment in energy efficiency is farther out from where it was originally, the commercial operator is only responsible for maintaining the daily operations of the ship, with the energy efficiency investment responsibility carried out by the registered or beneficial owner. Operators can be analogous to management companies who have contracts that get renewed or expire typically every two years, which could further decrease the time horizon of ownership at that level. The situation of management companies is comparable to managers of publicly listed companies, discussed in section 5.4, where performance is assessed on a shorter timeframe compared to the timeframe that the energy efficiency measure will take to pay off. The Management company or operator is generally not allowed to make capital changes to vessels although it can make some operational changes to save fuel. All costs are passed from the operator or management company to either charterers or owners, hence the operator or management company may have no direct interest in energy efficiency. Unless the shipowner expects and rewards the operator to improve energy efficiency, split incentives will exist between the owner and operator.

Under a voyage charter, in between the trader, charterer and operator, fuel costs are included on a dollar per-tonne basis, so the charterer cannot see the fuel costs of the voyage (lack of transparency) nor offered different rates for different efficiency levels e.g. at different speeds. Furthermore, the full efficiency of a vessel is generally not portrayed by the broker to the voyage charterer due to general lack of information and or information asymmetry. Maddox Consulting (2012) report that there is a general lack of fuel consumption data (most direct metric for energy use). Their discussions with numerous ship operators, charterers and brokers cite the lack of reliable, accurate, and publicly available information on the fuel consumption of individual ships. For example, the IHS Fairplay Sea-Web which was used to calculate reference EEDI baselines has the fuel consumption data for only on average 25% for tankers, dry bulkers, and container ships listed in the database. On the subject of information asymmetry in the chartering operations, Maddox Consulting (2012) say the following:

"A few brokers and charterers maintain "proprietary" databases on vessels available for charter, which include fuel consumption figures for individual vessels. Based on discussions with industry participants, it appears that these data are either expensive to obtain or are not available to third parties" Maddox Consulting (2012, p65)

In summary from the above sections, the principal agent problems and barriers in case two and four in shipping can be summarised generally as follows:

Problems	**Explanation**	**Mainly affecting**
Split responsibility for capital and operational costs	The entity investing in technical energy efficiency is different from the one bearing the cost of the energy efficiency.	Time charter (case two)
Short term ownership periods compared to life of ships	Owner-operators own ships on average for around eight years, each ship has around three owners with the first owner retaining the vessel for approximately fifteen years.	Voyage charter (case one) Time charter (case two)
Cost pass through and cost elasticity in different markets	Freight rates quoted to the charterer in most markets include cost of fuel along with other costs, which are not discernable.	Voyage charter (case one)
Information asymmetry or lack of information on energy efficiency of ships	Full energy efficiency of a vessel is generally not portrayed by broker to the voyage charterer due to general lack of information and or information asymmetry. Operational energy efficiency data is also seldom recorded and portrayed. Lack of information is also due to lack of accurate measurement.	Voyage charter (case one) Time charter (case two)
Cost of monitoring and claiming	Charterer can only effectively challenge or verify shipowners fuel consumption guarantee through third party weather routing companies. Charterer also has to consider the cost of litigation in the event of underperformance or over consumption.	Time charter (case two)
Charterers lack of full or direct control	Although in commercial control of the ship, the charterer does not employ the crew on-board ships	Time charter (case two)

over operations		
Charter rates not reflecting energy efficiency proportionally	The savings in fuel costs made by the charterer as a result of an energy efficient ship are not fully passed back to the shipowner in the form of proportionally higher charter rates.	Time charter (case two)
Fixed schedules and inventory costs resulting in usage problems	Charterers stipulate that the ship should proceed at utmost despatch under the voyage charter and inventory costs sometimes outweigh the fuel savings from slower speed. Under the time charter, the charterer would have other contractual obligations (e.g. buyer) thus bill of ladings stipulate full speed and also have to consider their inventory costs across the supply chain.	Voyage charter (case one) Time charter (case two)
Short term duration of time charters	Over 90% of time charters are for less than two years, therefore it does not permit charterers from getting payback from the investment in technical and some operational efficiency measures.	Time charter (case two)

Table 5.15: Summary of key problems in the contracts for carriage of goods

Technical or capital intensive measures can therefore be challenging to implement. Operational energy efficiency measures can be implemented but in a limited number of situations. In case two the time charterer can implement a limited number of measures and in case four in very few situations can the charterer determine the speed at which the ship will travel. The next section explores the principal agent problem and operational measures in shipping in comparison to other literature looking at operational or behavioural aspects of the principal agent problem.

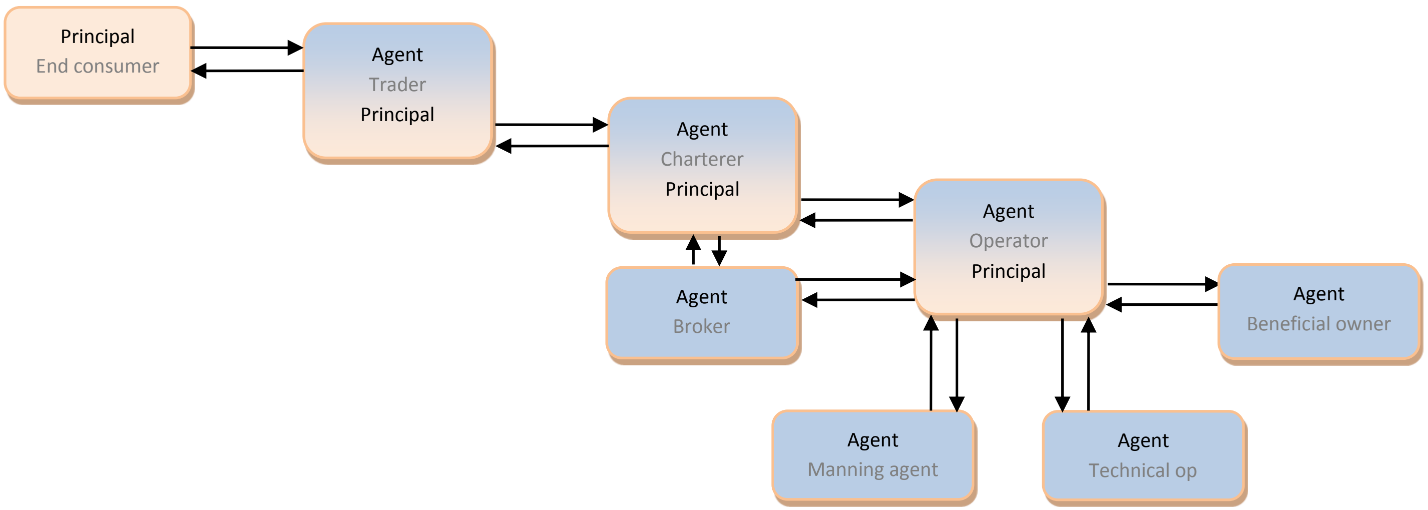


Figure 5.16: Extension of case two and four in bulk shipping (voyage and time charter)

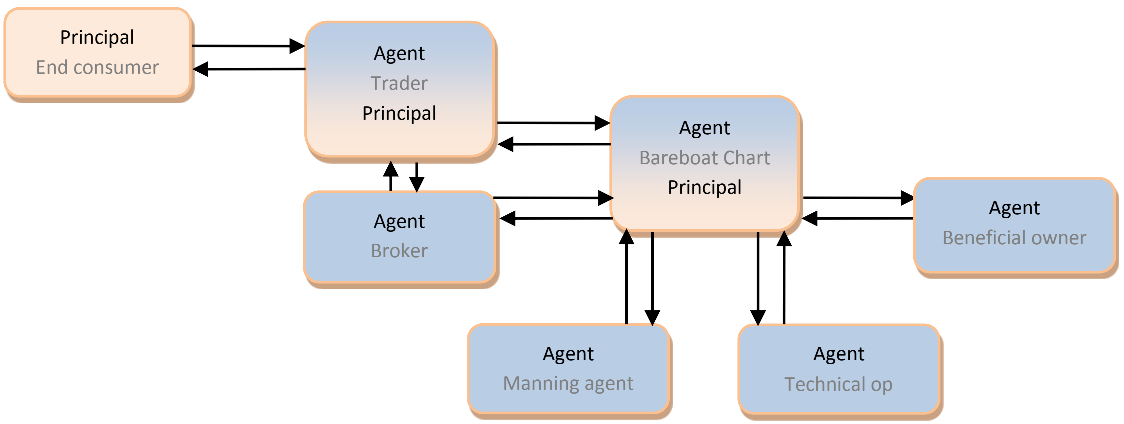


Figure 5.17: Extension of case one in bulk shipping (shipping division or bareboat charter)

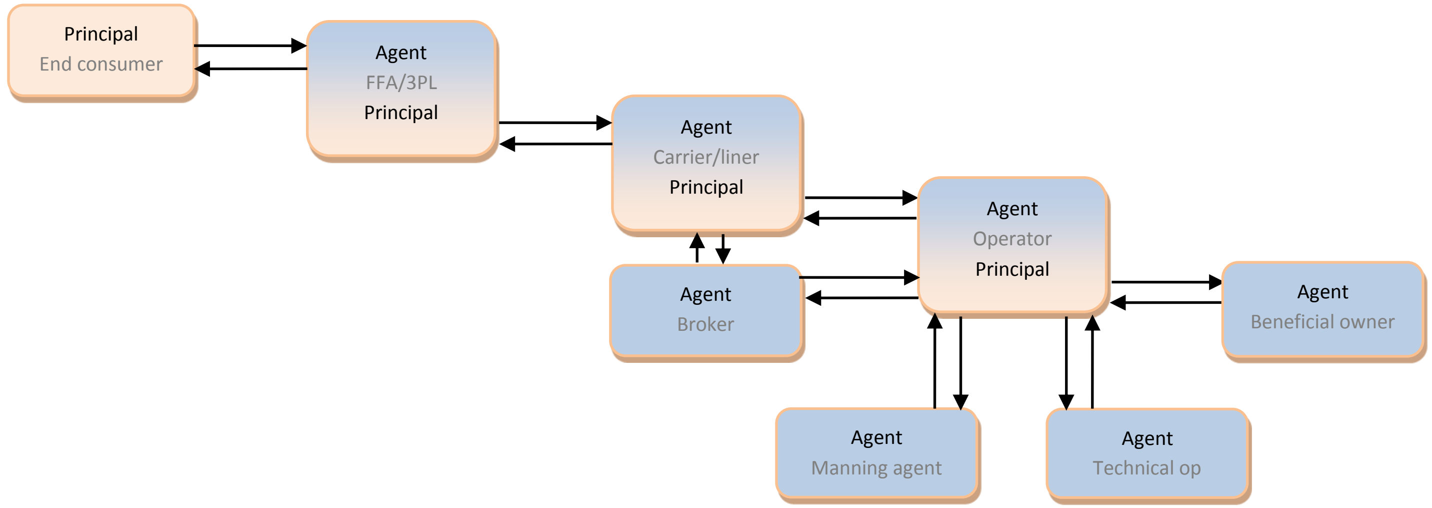


Figure 5.18: Extension of case two and four in container shipping (time charter)

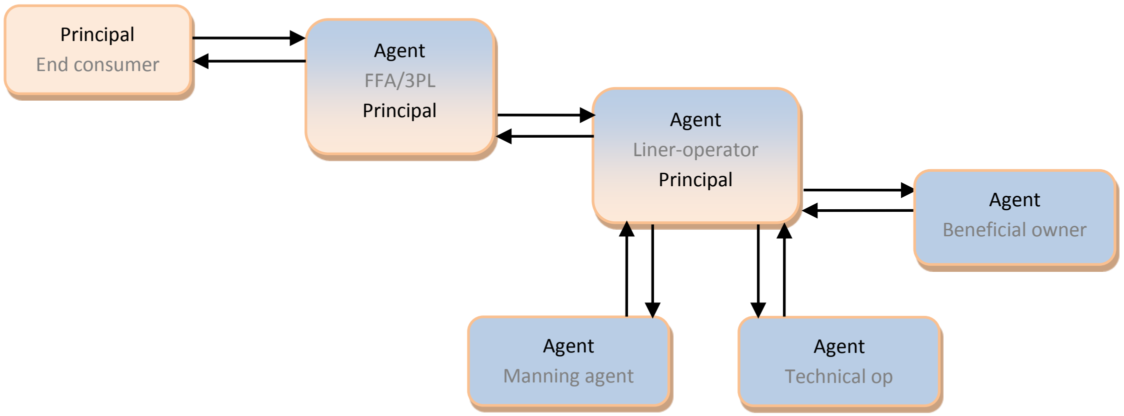


Figure 5.19: Extension of case one in container shipping (carrier-operated or bareboat charter)

5.4.3. Principal agent classification and *operational* measures in shipping

Much of the literature on the classification principal agent has focussed on the problems of implementing technical measures in various cases. It is however possible for end users or principals to influence part of the energy use by changing their behaviour. Taking the example of the principal in case two, who cannot implement the technical measures as the agent is responsible for these, can to some extent modify his/her behaviour to control the energy payments. So a tenant in case two, could change his/her pattern of use of space heating, cooking, etc even though he or she is not in control of selecting their design based efficiency. Prindle et al. (2006), Murtishaw and Sathaye (2006), IEA (2007), Grauss and Worrell (2008), Vernon and Meier (2012) acknowledge that operational measures also need to be considered and classified as above, however none has applied this in their estimation of the principal agent problems. Furthermore for case two IEA (2007) show that it can be further split into two groups, one group not being able to choose the technology and another group able to choose some technology. This is important for the analysis of the shipping cases as it suggests that charterers (principals) in case two can to some extent choose the efficiency measures which will affect the energy costs that they pay.

Murtishaw and Sathaye (2006) show that it is possible to create separate principal agent classification matrices for different energy efficiency measures for the same users, for example refrigirators, water heater, space heating and lighting. As an example a tenant cannot choose his or her own water heater (case two) but can choose his or her own television (case one). Moreover they show that not all rental households fall strictly in case two and four, as has been generally assumed in IEA (2007), and neither do all occupant owned households strictly fall in case one. For example some rental households with no refrigerators included can fall in case one and conversely newly built occupant-owned households can fall in case two. The result of this is that principal agent problems can be quite pervasive in some measures, whereas completely non-existent in other measures, for example, Murtishaw and Sathaye (2006) find that for water heaters 21% of units are allocated in case one and 68% of units allocated in case two and for lighting 95% of units are allocated in case one.

Thus it is important to examine the principal agent problems in shipping on a measure by measure basis, rather than assuming that a type of charter is representative of a principal agent case. As discussed in chapter one, operational measures are relatively cheaper to implement and mostly require a change in behaviour or contracts for implementation. For example a weather routing service subscription could cost between $1,000 to £20,000, depending of level of complexity (DNV 2010) and can be applied to the whole fleet. 'Just In Time' arrival would require a change in contractual terms or charterparty clauses. Under a time charter, charterers would generally have these options available to them, therefore as a principal paying the energy bill, they can select the operational measure, resulting in less of principal agent problem i.e. shifting from case two to case one, for example in applying the weather routing measure, Just In Time arrival (see appendix B). However, strictly speaking the charterers are still not in direct control of the vessel since they are using their agent's subcontracted agents (shipowner-operators crew and master). Therefore, in some operational measures such as autopilot adjustment, trim/draft optimisation, the principal agent problem could still exist. Under a voyage charter the charterer has no option of selecting the operational measures; only in a limited number of situations (in the case of oil major charterparties) can a charterer select the speed (as an operational measure) of the ship. When the above mentioned shift occurs, the principal agent problem of efficiency may be reduced from its original level but the situation is still surrounded by other barriers such as short time horizon, operational measures efficiency etc.

	Charterer can select operational measure	**Charterer cannot select operational measure**
Charterer pays energy bill (Direct energy payment),	No principal agent problem. Case 1 Time charter	Efficiency problem. Case 2 Some trip (time) charters
Charterer does not pay energy bill (indirect energy payment)	Usage and efficiency problem. Case 3 NA	Usage problem. Case 4 Voyage charter

Table 5.16: Operational measures and principal agent problems

In conclusion it can be seen that for some operational measures the time charter can be classed as case one where there is no principal agent problem. In this case the implementation of operational measures should hypothetically be at its highest, but if it is not, could it be said that there are other barriers that are inhibiting the uptake of operational measures in time charters? Similarly, could the barriers also explain the lack of implementation of operational measures under voyage charters? The following chapter aims to answer these questions through the use of a survey method.

5.5. Step two: Estimating population affected by principal agent problem

Section 5.4 described the first step of the principal agent methodology as suggested by Murtishaw and Sathaye (2006), Prindle et al (2006) and IEA (2007). The second step involves estimating the population falling into each of the cases in the above matrices (Table 5.13 and Table 5.16). Step one discussed in depth the various situations in which principal agent problems may exist in shipping.

However, estimating the population for each of the cases in matrices is a challenging task, not least because the data is extremely difficult to obtain. As IEA (2007) suggests:

"Estimating the population of end users falling into each category is a challenging task because statistics for energy consumption and stock (that is, the number of products) rarely correspond to the categories. This fraction of the population must be estimated indirectly through combinations of other sources" IEA (2007, p45)

Thus in this step it is decided that a simplified approach would be taken, to gain a first order estimate of the population that would potentially be affected by the principal agent problem. This simplified approach has been taken in various case studies within Prindle et al. (2006) and IEA (2007). For example, in the case of commercial offices in Japan, Netherlands and Norway IEA (2007) used a fairly generic classification of the principal agent problems and assumptions to estimate the population affected.

Most of the classifications or allocations into cases are based on assumptions or data derived from external sources such as national surveys or other studies. In the former case, the Norwegian case study uses two approaches to identify total office space, expert judgement and employment statistics. The most relevant IEA (2007) case study to this research is commercial office space in Netherlands. The relevance is mainly because it is focussed on businesses (which could be said to have a profit maximising or cost minimising objectives rather than individuals in residential sector who could be said to be utility maximising) and secondly it attempts to classify energy efficiency investment decisions into three cases instead of the dichotomous classification that other case studies use. The results are presented in Table 5.17, which suggest that when decisions can be made by renters of office space, they fall into case one. Murtishaw and Sathaye (2006) have been able to disaggregate the classification of cases for separate end use devices, such as water heaters and lighting due to the good quality data from the American Housing survey and Residential Energy Consumption survey, as a result they are able to distinguish between twelve different types of households that can be allocated to each of the four cases.

Each of the above studies estimates the number of units affected in each case, which could be households, offices etc., represented as a percentage of the total population of the units. In some cases this is extended to some other parameter such as floor area, rentable square foot, miles travelled etc. In shipping this could therefore mean number of ships (as units) or an extension of it being the total DWT or tonne miles. However, the important parameter is the unit because the principal agent problem is fairly dependent on each unit falling into a case rather than the size of the unit falling into a case. To illustrate this, take an example of a VLCC on time charter and a handysize tanker on voyage charter. Suppose the VLCC falls in case two and the handysize falls in case four. According to the first parameter i.e. units in this case ships, they would both be the same i.e. one unit, however when considering DWT case two would be larger than case four. The ability to extend to the second parameter will depend on the data availability or can be made using assumptions based on the profile of ships in each sector. It is first important to identify in which case a unit falls and then estimating using the secondary parameter.

	End user can choose technology	**End user cannot choose technology**
End user pays the energy bill	Case 1: No PA problem 60% of all offices (26m rentable square foot, RSF), of which: -Owned: 17.3m RSF -Rented: 8.7m RSF	Case 2: Efficiency problem 40% of all offices (17.2m RSF) -Rented: 17.2 RSF *22.5% not allowed to choose any measures* *77.5% allowed to choose some*
End user does not pay the energy bill	Case 3: Usage and efficiency problem 0%	Case 4: Usage problem 0%

Table 5.17: Principal agent problems in commercial leasing in Netherlands
Source: IEA (2007)

It is also important to note that the allocation into cases describes a given set of ships at one point in time. For other studies such as those relating to the residential sector, commercial offices sector the units don't change very frequently i.e. households or offices generally remain constant in their use but may change over a longer period of time. In shipping this may not be the case, as most ships would move from voyage to time and vice versa and this is highly dependent on the market conditions and a company's target ratio or risk bearing level as shown in Figure 5.20. As a result shipping companies have a range of options to charter-in and charter-out their fleet as shown in Figure 5.21. The following are examples of when chartering levels have changed over time (from Stopford 2008):

- Most LNG projects were set up using vessels owned or leased by the project, but this has changed as the projects expired and LNG ships were beginning to enter the voyage charter market.
- Until 1990's almost all containerships were owned by liner companies, but this changed dramatically as the top thirty liner companies increasingly time chartered-in ships, which is up to 50% of the container fleet.

- In the early 70's around 80% of tanker fleet (in total DWT capacity) was on time charter to oil companies. By 1990 the position had reversed and only around 20% were on time charter.

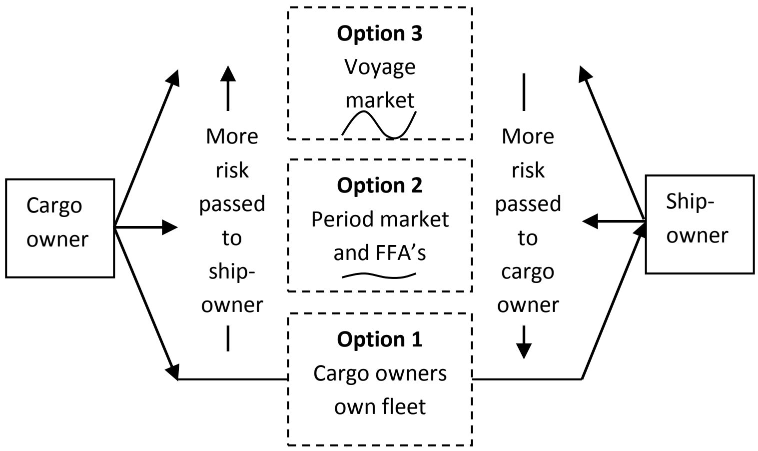


Figure 5.20: Risk management options in bulk shipping
Source: Stopford (2008)

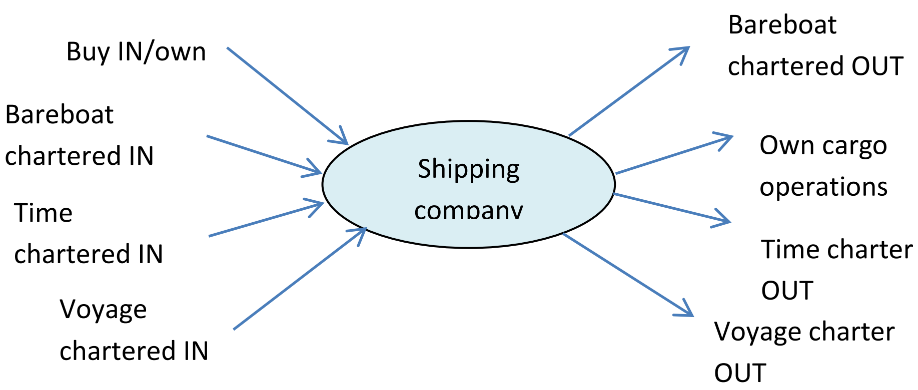


Figure 5.21: Chartering options of a shipping firm

Stopford (2008) refers to the varying levels of chartering as a shipping risk management strategy for the cargo owners i.e. the principal. There are different strategies employed by the principals in relation to risk and the quote below describes the risk management options in bulk shipping.

"If cargo owners feel very confident about their future cargo flows and want to control the shipping, they may decide on option one, which involves buying and operating their own ships (i.e. case one or bareboat charter). In doing this they cut the shipowner out of the equation (though they may use a shipping company to manage the vessels) and take all the shipping risk themselves. If all cargo owners do this then the voyage market (i.e. case four) disappears and the role of independent shipowner shrinks. However, if they are reasonably certain about future cargo volumes, but feel independent shipowners can do the job cheaper, they may prefer option two (i.e. case two), which involves taking long-term charters from independent owners and paying a daily rate, regardless of whether the ship is needed. Finally cargo owners can pass all the shipping risk to the shipowner by using the voyage market, option three (i.e. case four)" (Stopford 2008, p103).

The following sections outline the method for estimating the units falling into each case, following the simplified approach. In Table 5.18, the first allocation of cases, the time charter was allocated to case two (efficiency problem) and the voyage charter was allocated to case four (usage problem). These were in the later sections (departing from the traditional one principal one agent model and focussing on operational measures) shown to be more complex problems than this initial recursion.

	Charterer selects technology, Shipowner-operator cannot select technology	**Charterer cannot select technology, Shipowner-operator selects technology**
Charterer pays energy bill (Direct energy payment), Shipowner-operator does not pay energy bill	No principal agent problem. Case 1 Charterers shipping division Bareboat charter	Efficiency problem can exist Case 2 Time charter
Shipowner-operator pays energy bill, Charterer does not pay energy bill (indirect energy payment)	Usage and efficiency problem can exist Case 3 None	Usage problem can exist Case 4 Voyage charter

Table 5.18: First allocation of principal agent problems in shipping

The above section shows that the number of ships falling in each case would vary according to the market circumstances and the risk appetite of cargo owners (principals). As a result of the global financial crisis, the shipping industry has also been affected through significant over supply in the market (due to over ordering in the peak years and low demand). This market condition directly affects the risk outlook of the industry and the principals (i.e. charterers) would delay from investing in their own fleets (Stopford 2008). This in turn affects any quantification of the number of units falling into each of the cases in the principal agent matrix. Therefore it is important to note that the following analysis is just a snapshot/cross-sectional analysis of the fleet for the specific time period under investigation.

5.5.1. Method for estimating principal agent problems in shipping

In order to estimate the number of units falling in each of the cases, data is obtained from the Clarkson's Shipping Information Network (SIN) for fixtures on voyage charter and time charter for the wetbulk and drybulk sectors. Limitations of using Clarksons SIN fixtures were mentioned in chapter four section 4.3.3 but the major limitations are geographical under-reporting and size related under-reporting, which was confirmed by the then Head of Clarksons Research Services, Dr. Stopford (Personal communication, 29th January 2012) that there is indeed under representation of fixtures from Asia but for most large ships in Asia there is good level of reporting. Secondly, there is also ship size related under reporting i.e. the database has missing data on fixtures on very small tankers which number over 4000. Appendix B shows the number of fixtures (charters) in each of the sectors broken down by the ship size category for the year 2011. The number of fixtures in the voyage charter is very high compared to those on time charter. However, using just the number of fixtures is biased heavily towards voyage charters because of their shorter lengths, thus a single ship could be fixed as many as fifteen to twenty times in a single year.

In the container sector all the fixtures reported in Clarksons SIN only relate to time charters because of the structure of the sector. A containership is always chartered by several (hundreds) of shippers who buy slots or capacity in the ship or route (i.e. a containership is never on a voyage fixture to a single shipper) making it very difficult to estimate the number of shippers who would fall in the voyage charterer column. For the purposes of classifying the case of principal agent problem for the container sector, it is therefore assumed that the shippers contract with the liner operators (who could be shipowners, bareboat charterers and time charterers of the container ships). Therefore the above reported time charter fixtures are second level contracts in a multiple principal agent chain, as shown in section 5.4.1. As mentioned earlier, for this section a simplified approach is followed, that looks only at one level of contracts, contracts of carriage of goods, as summarised in Table 5.19.

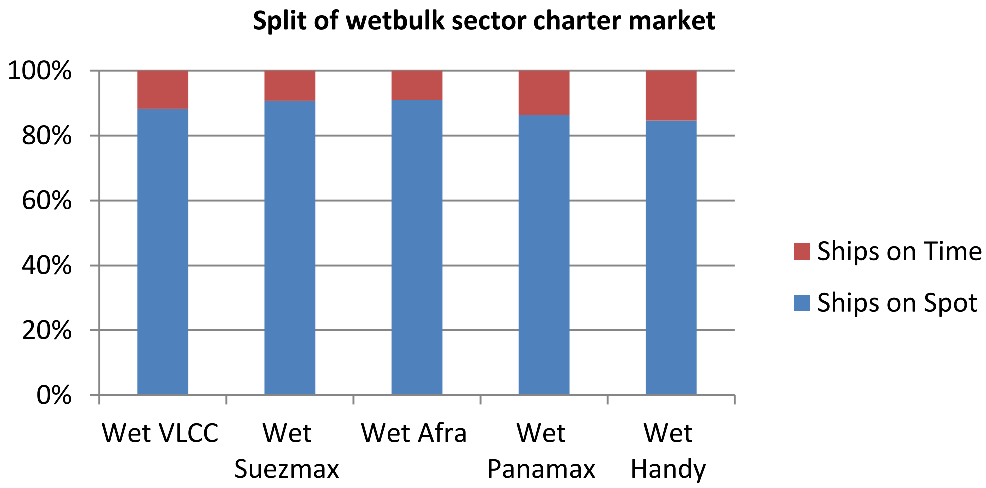
	Voyage charter	**Time charter**
Wetbulk & Drybulk	Charterer (principal) with shipowner-operator (agent)	Charterer (principal) with shipowner-operator (agent)
Container	Shipper (principal) with liner operator (agent)	N.A

Table 5.19: Principal agent problems in contracts of carriage of goods in different sectors

In order to remove the bias of short term fixtures in voyage charter, the number of units i.e. ships falling in each of the cells is required. The result of the number of ships in 2011 falling into each category is shown in table B5 in appendix B. Table B5 limits the ships that are chartered multiple times in a year to only a single ship (or single count of units). As mentioned in the beginning of this section, other studies (e.g. Murtishaw and Sathaye 2006) have purely focussed on the number of units (e.g. dwellings and offices) falling in each category, without adjusting for the length of time of the lease. This is partly due to the units being in a fairly constant state for at least one year (most residential rental contracts are for six months to one year minimum, with office leases having longer minimum periods). As shown earlier, in shipping this may not be the case because ships constantly change the charter market they operate in. Table B5 would therefore be an inaccurate representation, as ships which may be chartered only once on voyage charter will still show as single count for the whole of that year, whereas in reality the ship could have just been on voyage charter for only one month in that year. Similarly, a ship chartered-in on time charter for six months will show as a single count for the whole of the year. Furthermore ships time chartered in previous years for a longer period of time spanning over to or beyond 2011 would not have been captured. In order to represent the time a ship has spent in a particular charter market, further adjustments using several assumptions were required. The process and assumptions are detailed in appendix B.

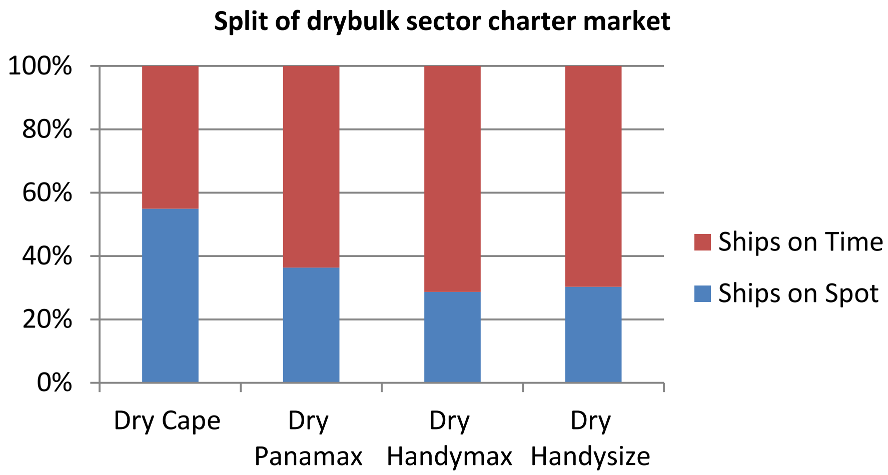
5.5.2. Results

Table B6 in appendix B shows the estimated number of ships adjusted for time in each of the sectors broken down by the ship size category for the year 2011. Figure 5.22 and Figure 5.23 show the end results as a proportion of the charter market.



Ship type	DWT >=	DWT <
Wet VLCC	200,000	
Wet Suezmax	120,000	200,000
Wet Afra	80,000	120,000
Wet Panamax	60,000	80,000
Wet Handy	10,000	60,000

Figure 5.22: Proportion of ships on voyage and time charters in the wetbulk sector in 2011



Ship type	DWT >=	DWT <
Dry Cape	100,000	
Dry Panamax	60,000	100,000
Dry Handymax	35,000	60,000
Dry Handysize	10,000	35,000

Figure 5.23: Proportion of ships on voyage and time charters in drybulk sector in 2011

Figure 5.22 above closely matches with Stopford (2008), who shows that the tonnage in wetbulk charter is split similarly, i.e. around 20% of the tonnage is on time charter and remainder on voyage charter. The marginal difference could be explained by two reasons. Firstly, using the market circumstances proposition, one could argue that the 80:20 (voyage to time) ratio in 2007 would increase due to the financial crisis (i.e. cargo owners preferring more ships on voyage charter, to limit their own shipping risk). Secondly, Stopford (2008) measures the proportion in total fleet tonnage (DWT), whereas Figure 5.22 is based on number of ships. Figure 5.23 shows that the drybulk sector charter market is quite opposite of what is seen the wetbulk sector. The following tables allocate the findings according to cases in the principal agent matrix. Table 5.20 shows that on average just under 90% of the wetbulk fleet on charter market is allocated to case four i.e. potentially affected by the usage problem and over 10% of the wetbulk fleet is allocated to case two, potentially affected by the efficiency problem. However, when focussing on the principal agent problems in the context of operational measures this translates to just over 10% of the fleet on the charter market (which originally was on time charter in Table 5.18) and some charterer operated fleet may not face principal agent problems but the same level of the fleet could be affected by the usage problem.

	Charterer selects technology	**Shipowner-operator selects technology, Charterer cannot select technology**
Charterer pays energy bill (Direct energy payment), Shipowner-operator does not pay energy bill	No principal agent problem. Case 1 - Small no. of ships operated by charterers shipping division and under bareboat charters. E.g: 50 BP owned and operated 10 Shell owned and operated 40 Total owned and operated	Efficiency problem. Case 2 - 12% of the fleet on charter market
Shipowner-operator pays energy bill, Charterer does not pay energy bill (indirect energy payment)	Usage and efficiency problem. Case 3 - None	Usage problem. Case 4 - 88% of the fleet on charter market

Table 5.20: Wetbulk sector principal agent problems in technology

	Charterer can select *operational* measure	**Charterer cannot select *operational* measure**
Charterer pays energy bill (Direct energy payment),	No principal agent problem. Case 1 - small no. of charter operated - 12% of fleet on charter market	Efficiency problem. Case 2
Charterer does not pay energy bill (indirect energy payment)	Usage and efficiency problem. Case 3 - none	Usage problem. Case 4 - 88% of fleet charter market

Table 5.21: Wetbulk sector principal agent problems in operations

Table 5.22 shows that over 60% of the drybulk fleet on charter market is allocated to case two, potentially affected by the efficiency problem and just under 40% of the drybulk fleet is allocated to case four, thus potentially affected by the usage problem. However, when focussing on the principal agent problems and operational measures this translates to just over 60% of the fleet (which originally was on time charter in Table 5.18) and some charter operated ships which may not face principal agent problems and the same level of the fleet is affected by the usage problem.

	Charterer selects technology,	**Shipowner-operator selects technology, Charterer cannot select technology**
Charterer pays energy bill (Direct energy payment), Shipowner-operator does not pay energy bill	No principal agent problem. Case 1 - Small no. of ships operated by charterers shipping division and under bareboat charters. E.g: 5 Rio Tinto owned and operated 30 Vale owned and operated	Efficiency problem. Case 2 - 62% of the fleet on charter market
Shipowner-operator pays energy bill, Charterer does not pay energy bill (indirect energy payment)	Usage and efficiency problem. Case 3 - None	Usage problem. Case 4 - 38% of the fleet on charter market

Table 5.22: Drybulk sector principal agent problems in technology

	Charterer can select *operational* measure	**Charterer cannot select *operational* measure**
Charterer pays energy bill (Direct energy payment),	No principal agent problem. Case 1 - Small no. of charter operated - 62% of the fleet on charter market	Efficiency problem. Case 2
Charterer does not pay energy bill (indirect energy payment)	Usage and efficiency problem. Case 3 - none	Usage problem. Case 4 - 38% of the fleet on charter market

Table 5.23: Drybulk sector principal agent problems in operations

100% of the container fleet could be affected by the usage problem and there is no difference in the number of cases principal agent problems related to technology and operational measures. Analysis of the wetbulk and drybulk sectors time charter durations showed that on average fixture lengths were seventeen months for wetbulk, eight months for drybulk and eleven months for container sector (with very high standard deviations). Table B7 in appendix B and Figure 5.24 shows the proportion of ships of different sectors for different time periods (Research on duration of time charters and relationship with ship type and size was conducted during the secondment to Forum for the Future's Sustainable Shipping Initiative that was investigating split incentives in the time charter market for the development of a financing mechanism for retrofitting of energy efficiency measures). The results suggests that around 70% of ships on time charter have a duration of less than two years, which suggests that payback of many technical measures may not fall within this period, whereas paypack of many operational measures (e.g. trim draft optimisation) has been suggested to be within six months to one year (Wang et al. 2010; Lockley et al. 2011), so in addition to aligned incentives there is even a greater chance of implementation of operational measures under case one.

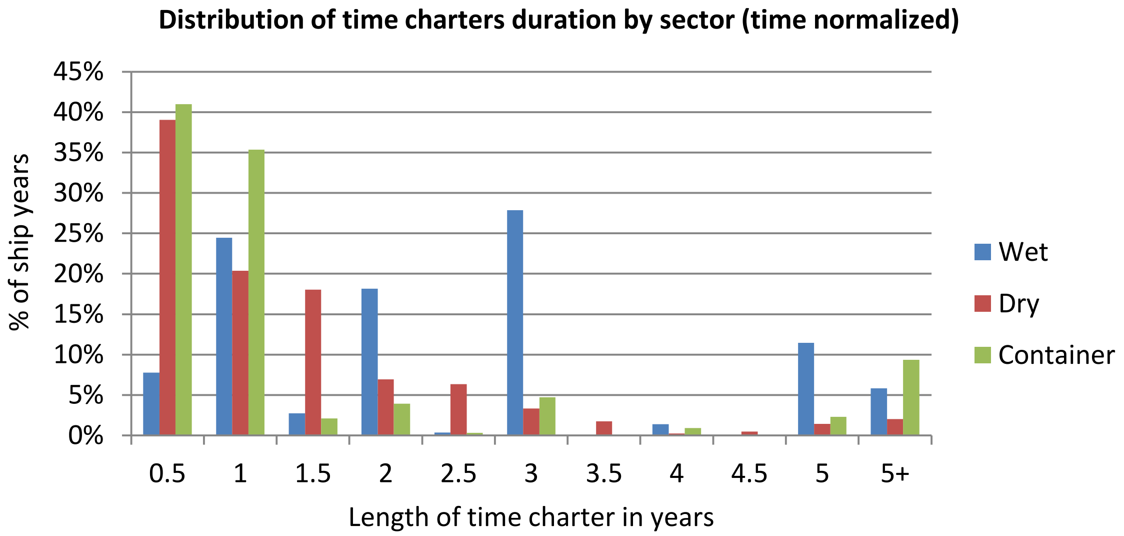


Figure 5.24: Distribution of time charters duration by sector (time normalized)

5.6. Step three: Estimating the energy consumption affected by principal agent problems in shipping

The final step in the principal agent methodology as suggested by Murtishaw and Sathaye (2006), Prindle et al. (2006) and IEA (2007) is to estimate the affected level of energy consumed i.e. the amount of energy consumed by the population of end users estimated in step two. The total affected energy is the sum of energy use falling into cases where principal agent problems exist. As discussed earlier the classification depends on whether a technology perspective or operational measures perspective is taken. According to IEA (2007) affected energy use can be calculated by estimating a devices average energy use and then multiplying it by the affected population. However, in most circumstances IEA (2007) acknowledges that this is rarely straightforward as data on energy consumption is difficult to obtain and requires making assumption of energy use in each of the cases, which is likely to differ as the devices can be used differently. For example IEA (2007) in the context of Japanese and Netherlands offices use average efficiency per unit/square foot and assume the same level of energy efficiency for all cases. In another context in the same report IEA (2007) show that average efficiency is 20% better for owner-occupied offices and those owner-occupied offices had higher implementation of energy saving measures.

5.6.1. Method for estimating energy consumption affected by principal agent problems

In shipping the energy consumption can be estimated using technical details obtained from databases such as the Clarksons World Fleet Register (WFR) and IHS Fairplay fleet database. However, the actual energy use can deviate significantly from the design based energy estimate because of the way a ship is operated. The operational efficiency of a ship is more relevant when looking at principal agent problems in operations. This research attempts to estimate the first part of this step i.e. to estimate the energy efficiency of ships only, instead of attempting to estimate the total energy consumed. To estimate the energy efficiency of ships in operation, data from Smith et al. (2013) are used. Smith et al. (2013) use newly acquired satellite Automated Identification System (S-AIS) data of ships actual movements to calculate the average normalised operational efficiency (ANOE) of ships in grams of CO_2 emitted per tonne nautical mile (gCO_2/t.nm). The technical specifications of the ships are derived from WFR, which gives the average technical efficiency (ATE). The data for ship's operational characteristics (speed, loading condition and voyage characteristics) are obtained from individual ship's AIS transponders for the period beginning from January 2011 to December 2011, which corresponds to the fixtures data used in the above analysis. Missing data on technical and operational data is mainly derived from Buhaug et al. (2009). Ship level data is then aggregated according to ship type or DWT range of ships, which is presented in Table 5.24. The emissions factor for CO_2 emissions is 3.14 i.e. every tonne of fuel burnt (HFO) results in 3.14 tonnes of CO_2. The below analysis is based on CO_2 energy efficiency.

Crude	Size range		ANOE	ATE
	>=	<	gCO_2/t.nm	gCO_2/t.nm
Wet VLCC	200,000		4.3	2.3
Wet Suezmax	120,000	200,000	6.5	3.4
Wet Afra	80,000	120,000	11.3	3.8
Wet Panamax	60,000	80,000	15.8	4.8
Wet Handy	10,000	60,000	25.4	7.4

Table 5.24: Average normalized operational efficiency and technical efficiency in the wetbulk sector
Source: Smith et al. (2013)

As can be seen from the table the average normalized operational efficiency in comparison to technical efficiency is higher by a factor of two for larger ships and by a factor of three for smaller ships, which suggests that smaller ships have higher potential for improvement in their operations. The above data uses aggregate level and average data, and does not split the efficiencies for ships on different types of charter. To test whether there is a difference in normalized operational efficiency among the voyage and time chartered ships, fixtures data available from Clarksons SIN is matched with ship level data used in Smith et al. (2013). Details of ships thought to represent case one (i.e. charter operated and not occurring in the charter market) are obtained for one major oil company that uses its ships to carry 80% of its own cargoes. Fixtures for the year 2011 are obtained for voyage charters and for time charters fixtures for 2009, 2010 and 2011 are used to check if any fixtures are still running in 2011 as shown in Table 5.25. Ship X has been on time charter throughout the 2011 period, ship Y has been on time charter from the mid to end of the year and ship Z has been on time charter from beginning of 2011 to mid 2011.

Time charter	**2009**	**2010**	**2011**		**2012**
Ship X					
Ship Y					
Ship Z					

Table 5.25: Time charter fixtures and analysis period

Fixtures for each ship type falling within the DWT range are matched with Smith et al. (2013) data using the ships IMO number. However, Clarksons fixtures data only reports the name of the ship, thus Microsoft Excel's lookup function is used to return the IMO number from Smith et al. (2013). This lookup had to overcome two problems, firstly names of ships are not unique i.e. repeated names (but only in different ship categories/DWT ranges) and names constantly get changed. In both cases the DWT of the ships is used to validate the matches. Filtering for ships that occur only in one charter market throughout the whole year i.e. they are not sublet nor enter the other market, results in very few cases of ships on time charter for both sectors. Refer to appendix B for analysis on the level of subletting in the time charter market for wetbulk and drybulk sectors and Figure 5.31.

5.6.2. Results

The figures below show that none of the parameters differ at least graphically between cases i.e. voyage, time and charterer operated. Comparing means using independent sample t-tests (95% confidence interval, two tailed tests) for each ship type suggested that the null hypothesis (no difference in means) could not be rejected for each of the parameters (refer to appendix B for examples of SPSS outputs). This suggests that the normalised operational efficiency, technical efficiency and speed ratio of ships on voyage charter, ships on time charter and owner-operated ships are not statistically significantly different. Based on this finding it can be assumed that the initial estimate of emissions into voyage and time charter does not change significantly from Figure 5.22 and Figure 5.23.

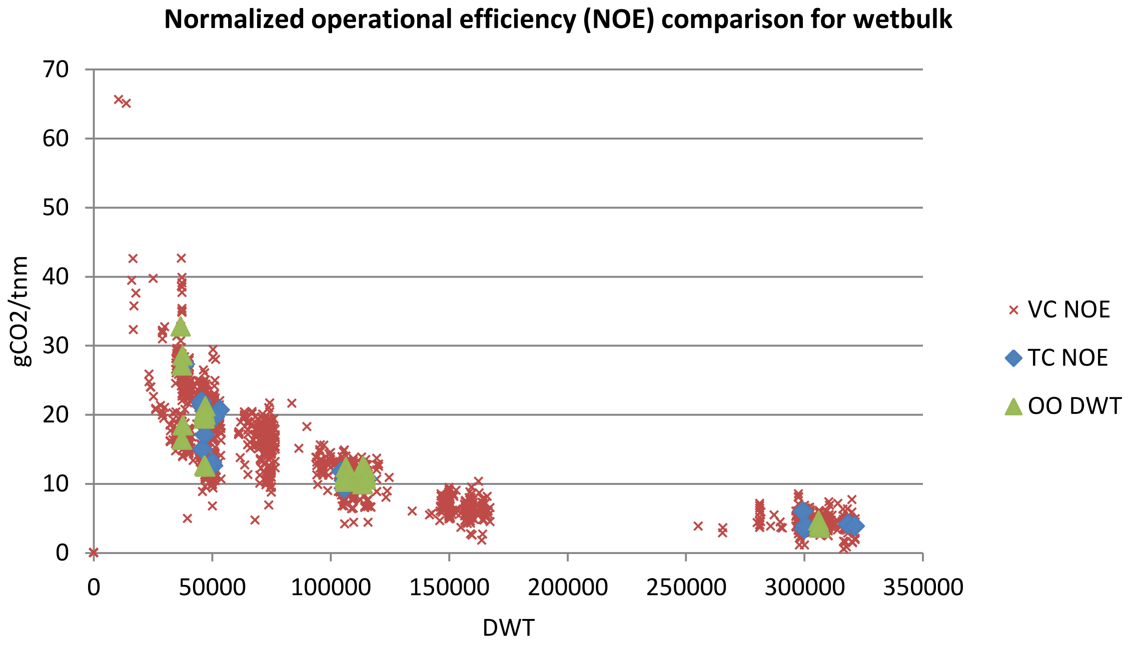


Figure 5.25: Normalized operational efficiency comparison for wetbulk

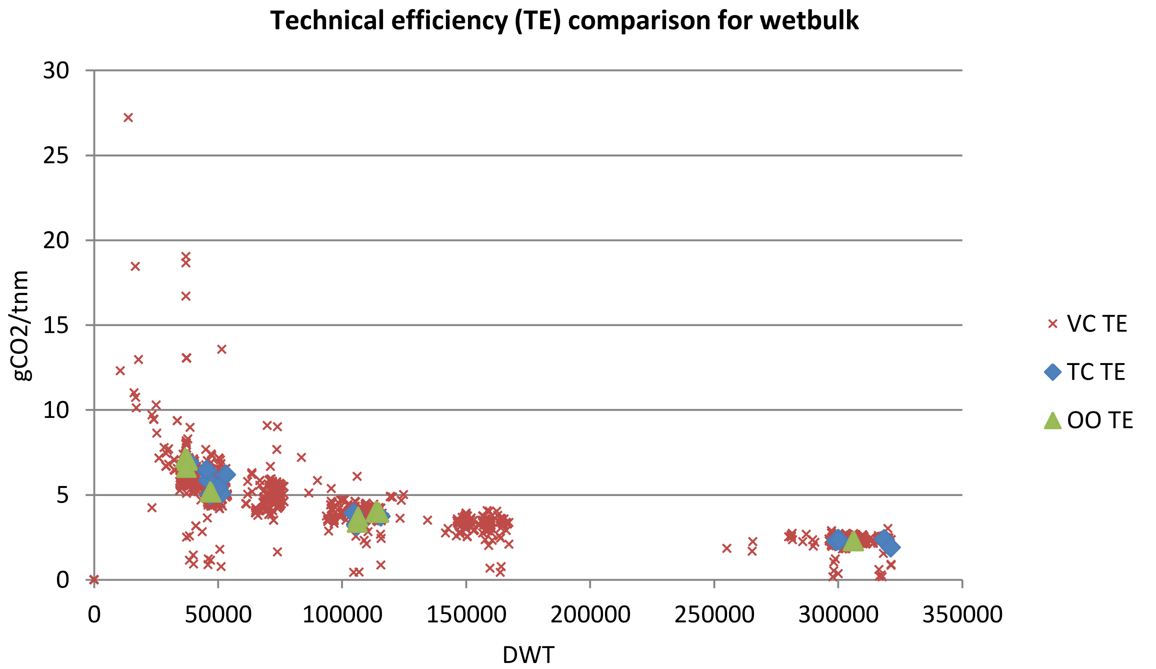


Figure 5.26: Technical efficiency comparison for wetbulk

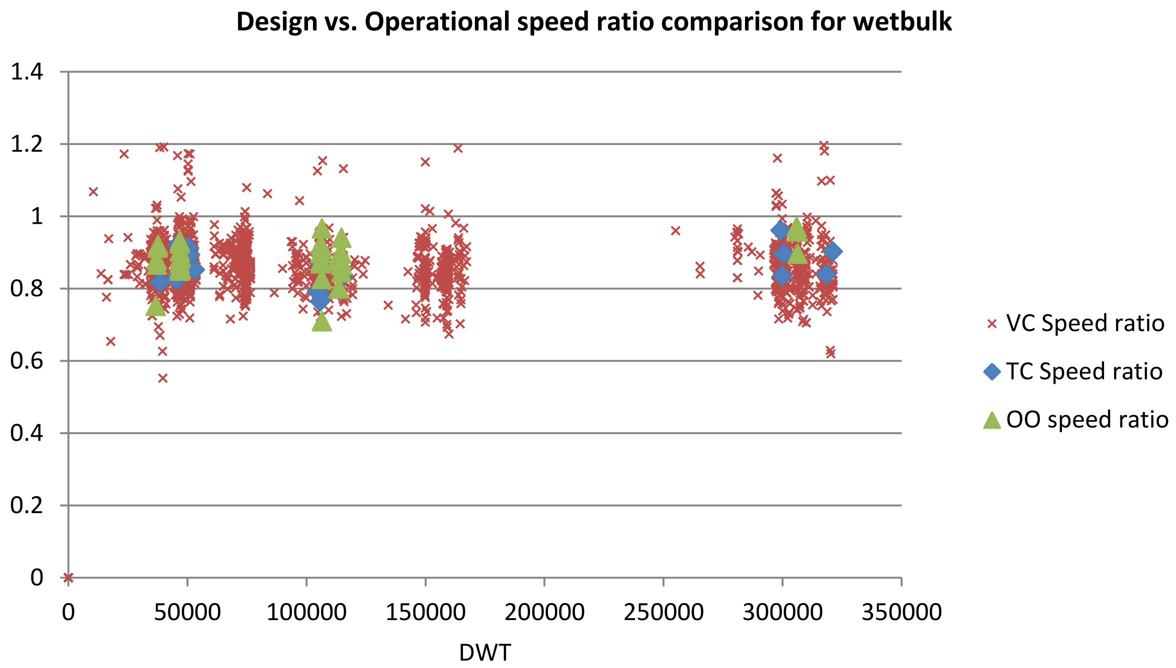


Figure 5.27: Design vs. operational speed ratio comparison for wetbulk

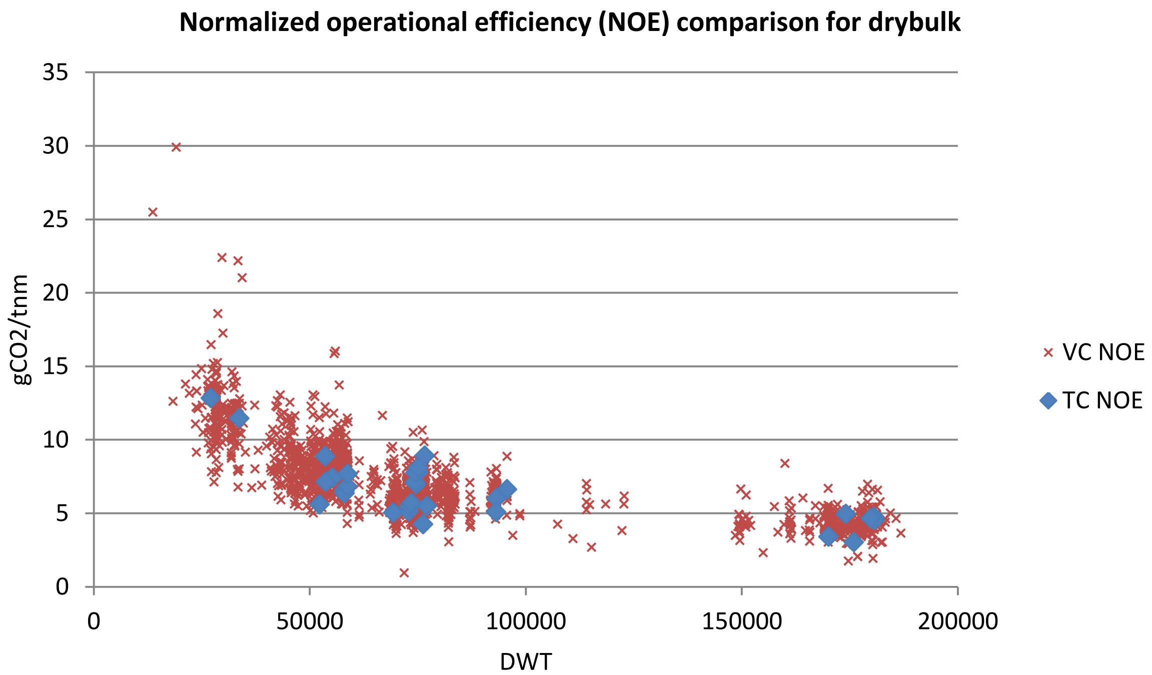


Figure 5.28: Normalized operational efficiency comparison for drybulk

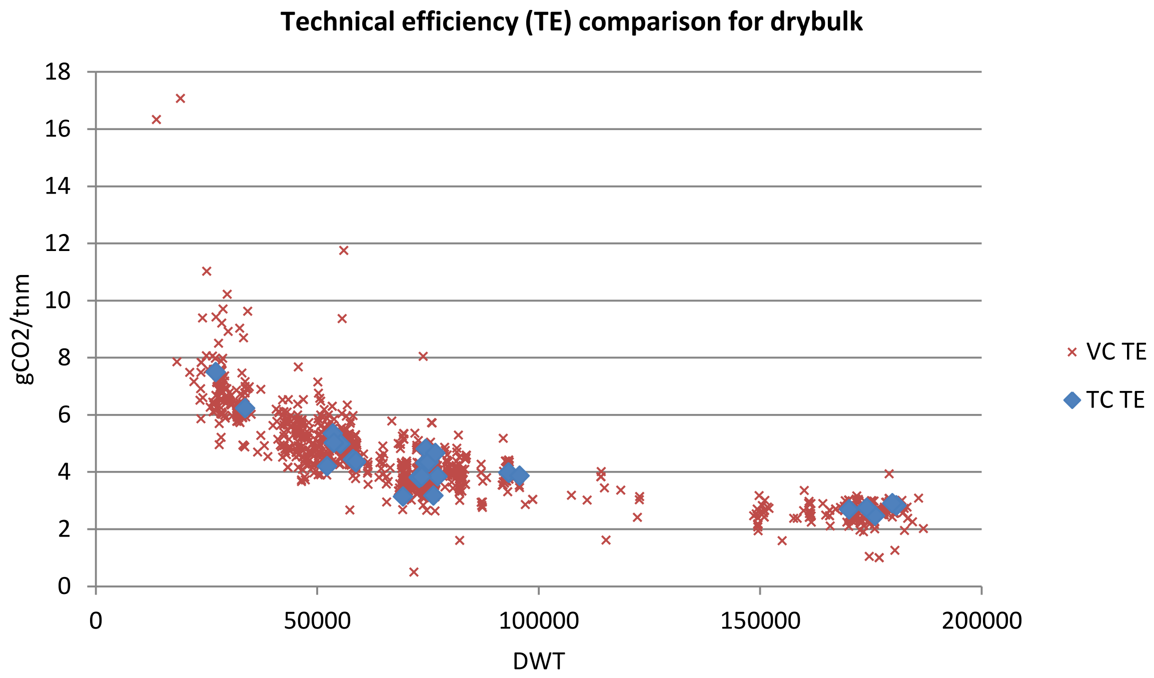


Figure 5.29: Technical efficiency comparison for drybulk

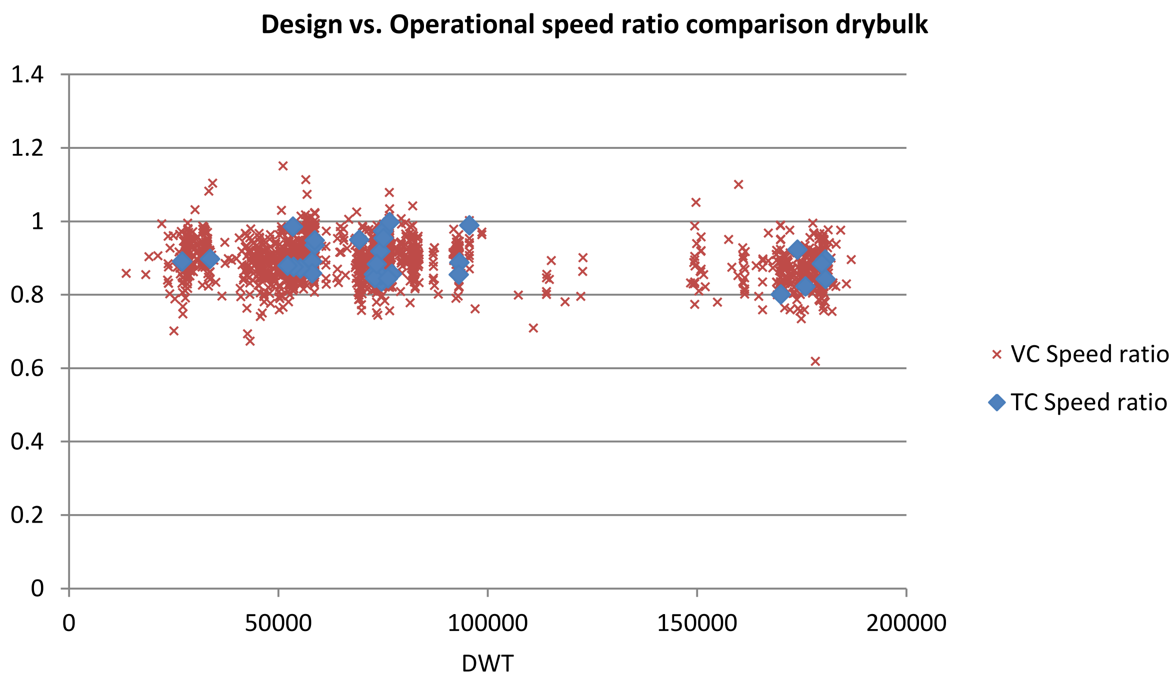


Figure 5.30: Design vs. operational speed ratio comparison drybulk

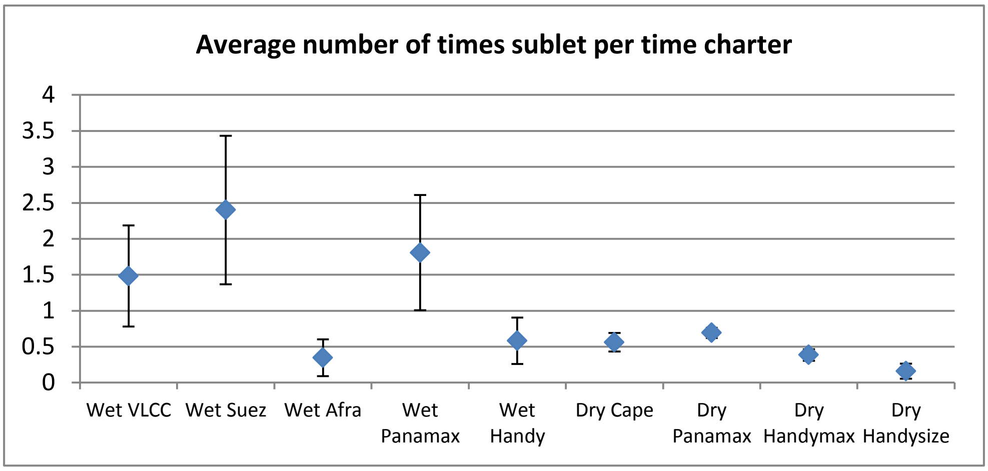


Figure 5.31: Average number of times sublet per time charter

5.7. Concluding remarks

This chapter attempted to answer research questions three and four i.e. estimating the population affected by principal agent problems and how energy efficiency of ships in operations is affected by principal agent problems. The research was done mainly using secondary data and desk research. Using one principal and one agent scenario, it was seen that the time charter could potentially represent the principal agent efficiency problem and the voyage charter representing the principal agent usage problem. However, this was only true for technical measures and it was suggested that in the context of operational measures, the time charterer who pays for fuel also had the ability to implement operational measures and therefore better represented case one, where no principal agent problems occur, at least when focussing only on carriage of goods contracts. The principal agent problem was shown to be more complex than the one principal and one agent situation, due to the long chain of stakeholders involved in the operations, which meant that even when goals may be aligned in one context (e.g. contracts of carriage of goods), they may not be in other contexts (e.g. final sales, design etc.).

In the context of operational measures, a high proportion of the wetbulk ships could be affected by principal agent problems, whereas relatively lower proportion of ships in drybulk sector could be affected by principal agent problems. This seems not to be reflected in the operational efficiency (nor technical efficiency or speed reduction ratio) of the ships however, both voyage chartered ships and time chartered ships had similar levels of efficiency. Furthermore, there was no difference in operational efficiency between the ships that were believed to be representing case one compared with those on the charter market. The following chapter therefore attempts to assess whether the level of implementation of operational measures reported by respondents actually differed for the different principal agent cases.

6. Survey results preliminary analysis

This chapter and the following chapter present the findings of the self-administered online questionnaire that is used to directly answer the research questions on implementation of energy efficiency measures and factors affecting their implementation. The chapter begins with a brief section explaining the data preparation, followed by the demographic profiles of the respondents, i.e. reporting on background measures. This is followed by preliminary analysis of the results using mainly descriptive statistics to explain the dependent variables in the survey such as the implementation of measures, perception of barriers and factors affecting implementation. Thereafter, the results of the independent variables are discussed. The chapter mainly makes use of univariate and some bivariate analysis for the discussion of the above variables and it is hoped that this provides a good context and background for discussion and analysis of relationships that follows in the following chapters. This chapter deals with the implementation of energy efficiency measures, barriers and factors for implementation components of the research framework as proposed in chapter three, highlighted in Figure 6.1.

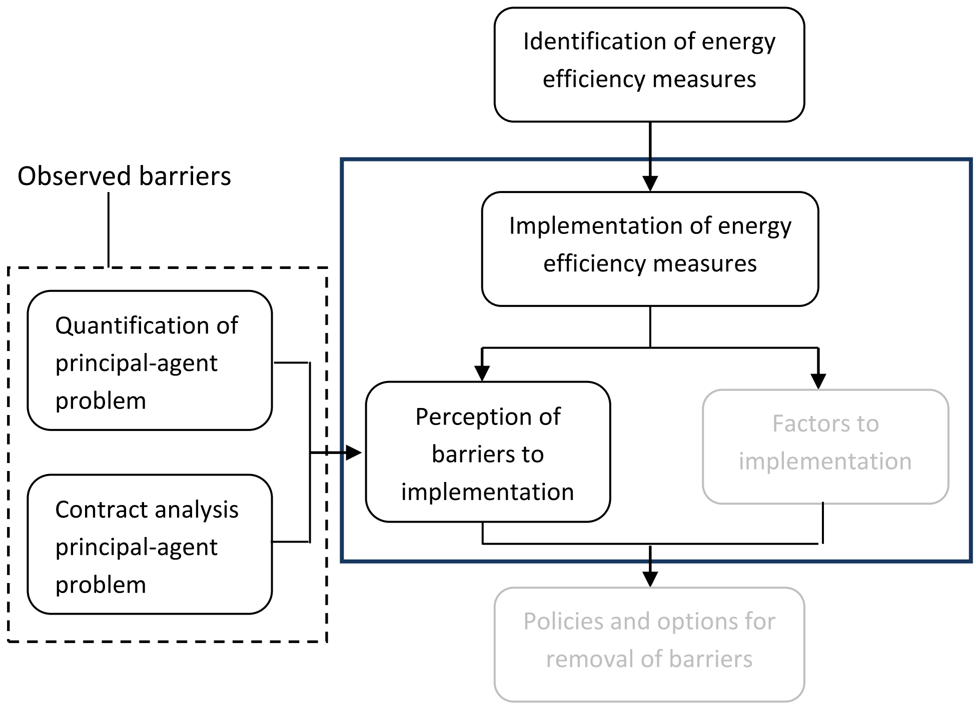


Figure 6.1: Focus of this chapter and the research framework

6.1. Data preparation

Data preparation for analysis of the survey results involved several stages. The first step was to close any open responses of the survey and record them as completed (or partially completed responses), which resulted in a total of 194 responses. Twenty four responses had a very high item non response for questions three onwards and it was decided to delete these cases, which is one of the ways of dealing with missing data, so long as it does not lead to loss of more than 15% of the cases according to Hertel (1976, cited by de Vaus 1995). The final response set of 170, which will be referred to as the N (sample population). The next step was to download the data files from the survey server with representation of answers as values and as labels (as Comma Separated Values .csv). The raw data files were imported into Microsoft Excel 2007 spreadsheet software for further sorting and preparation. The answers were grouped by implementation of measures, specific barriers to specific measures were re-grouped by generic barriers. For missing values especially in the background variables and independent variables (chartering ratios), respondents were contacted again through phone and email to remove item non-response. Results to most univariate analysis were obtained from computations in MS Excel, however there was a need to perform further analysis and statistical tests, and the final imputed data was transported to IBM SPSS to perform these. In some instances use of the web survey software’s online reporting was also used to perform drill down or further analysis per respondent.

6.2. Data analysis plan

Analysis of data depends on three factors, the number of variables being examined, level of measurement of variables and whether the data is used for descriptive or inferential purposes (de Vaus 1995). However, before analysis begins there needs to be a clear understanding of what specific questions the analysis will try and answer. These specific questions (operationalized questions and hypotheses) are rooted to the main research questions. Table 6.2 outlines the specific questions that the analysis aims to answer. The operationalized questions then dictate what type of analysis is chosen, which can be univariate, bivariate and multivariate analyses. A key factor in the choice of type of analysis is the level of measurement of the variables being used. The survey mainly made use of categorical nominal level of measurement throughout the survey with the exception of the last questions relating to chartering ratio, which used interval level measurement. The reasons for this choice were explained in chapter four. Following on from determining the level of measurement and the choice of type of analysis, there is a need to choose the right method of analysis. Table 6.1 below shows some of the methods suggested by de Vaus (1995). Correlation matrix can also be included in the bivariate analysis as a method to summarise the association or relationships between two variables. The method of analysis depends on the complexity of the research questions, i.e. if the question involves only one variable e.g. which measure had the highest implementation, then the appropriate method of analysis is univariate analysis under nominal level of measurement (because the implementation was measured in five categories) thus resulting in the frequency distribution method as the appropriate method for analysis. The method of analysis and level of measurement will affect the choice of statistics, both descriptive and inferential, so for example for nominal level data and frequency distribution the appropriate descriptive statistic for central tendency is the mode and for dispersion is the variation ratio, and the appropriate inferential statistic is standard error for the binomial distribution. Figure 6.2 below shows the plan of analysis with the choices made appropriate for this research.

Univariate analysis	Bivariate analysis	Multivariate analysis
• Frequency distributions	• Crosstabulations • Scattergrams • Regression • Rank order correlation • Comparison of means	• Conditional tables • Partial rank order correlation • Multiple and partial correlation • Multiple and partial regression • Path analysis

Table 6.1: Some methods of analysis of survey results
Source: de Vaus (1995)

6.2.1. Review of research questions for survey data analysis

Main research questions	**Specific research questions for survey data analysis**
RQ1 - To what extent are energy efficient operational measures implemented in shipping?	RQ1a - What is the level of implementation of operational energy efficiency measures in shipping? RQ1b - How does the level of implementation of operational measures vary across the different shipping sectors and size of firms? RQ1c – Is the implementation of energy efficient operational measures higher for time chartered ships compared to voyage chartered ships.
RQ2 - What factors are perceived to be the most important in explaining the lack of implementation of energy efficient operational measures?	RQ2a – What are the perceived barriers to the implementation of operational energy efficiency measures in shipping? RQ2b - How does the perception of barriers vary between different shipping sectors, size and chartering ratio for each operational measure? RQ2c - What are the factors leading to the implementation of operational measures?

Table 6.2: Main research questions divided into specific research questions for survey data analysis

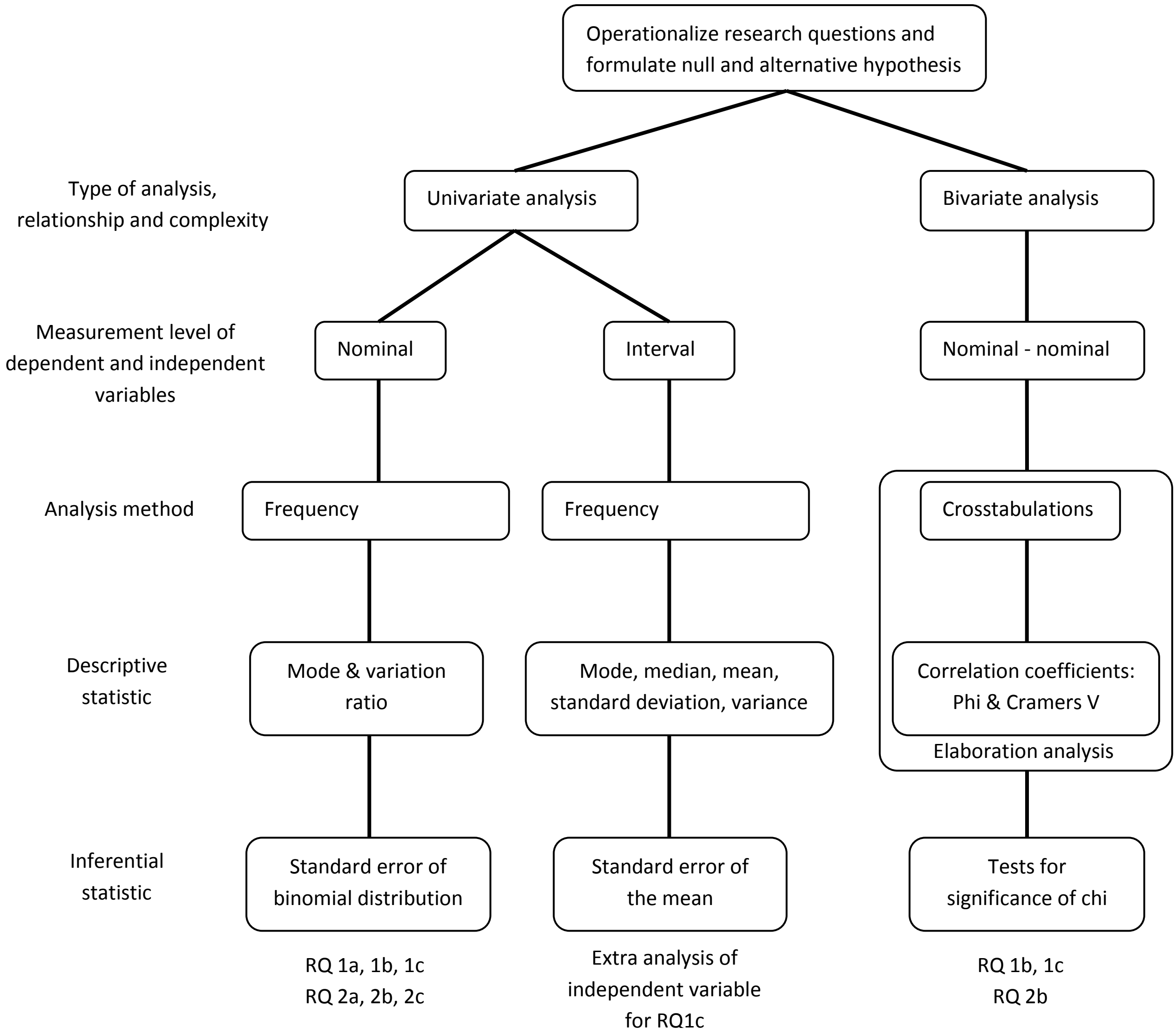


Figure 6.2: Data analysis path and choices for answering specific research questions

6.3. Demographics

This section presents the results of the background measures. The online survey asked respondents demographic questions on the size of the company by number of ships, number of employees and annual fuel use (all with mutually exclusive choices). These demographic questions as well as others were asked towards the final sections of the survey in a simple categorical format, in order to reduce survey attrition but their placement towards the end may result in relatively higher item non response. This was deemed acceptable because the survey respondents would have in any case completed other questions on dependent variables. As mentioned in chapter four, size of companies can be measured in various ways and it was decided that all of these would be relevant, however the measurement that is finally used is the number of ships or fleet size of the company. Figure 6.3 shows the proportions for each of the size measures and includes the responses with missing answers in other dependent variable questions, which will in the later stages be excluded from the analysis as per recommendations by de Vaus (1995). The responses from medium sized companies are approximately in proportion to the population (or the stratified sampling frame) as shown in Table 4.1 in chapter four, and similar to NAPA (2012) survey.

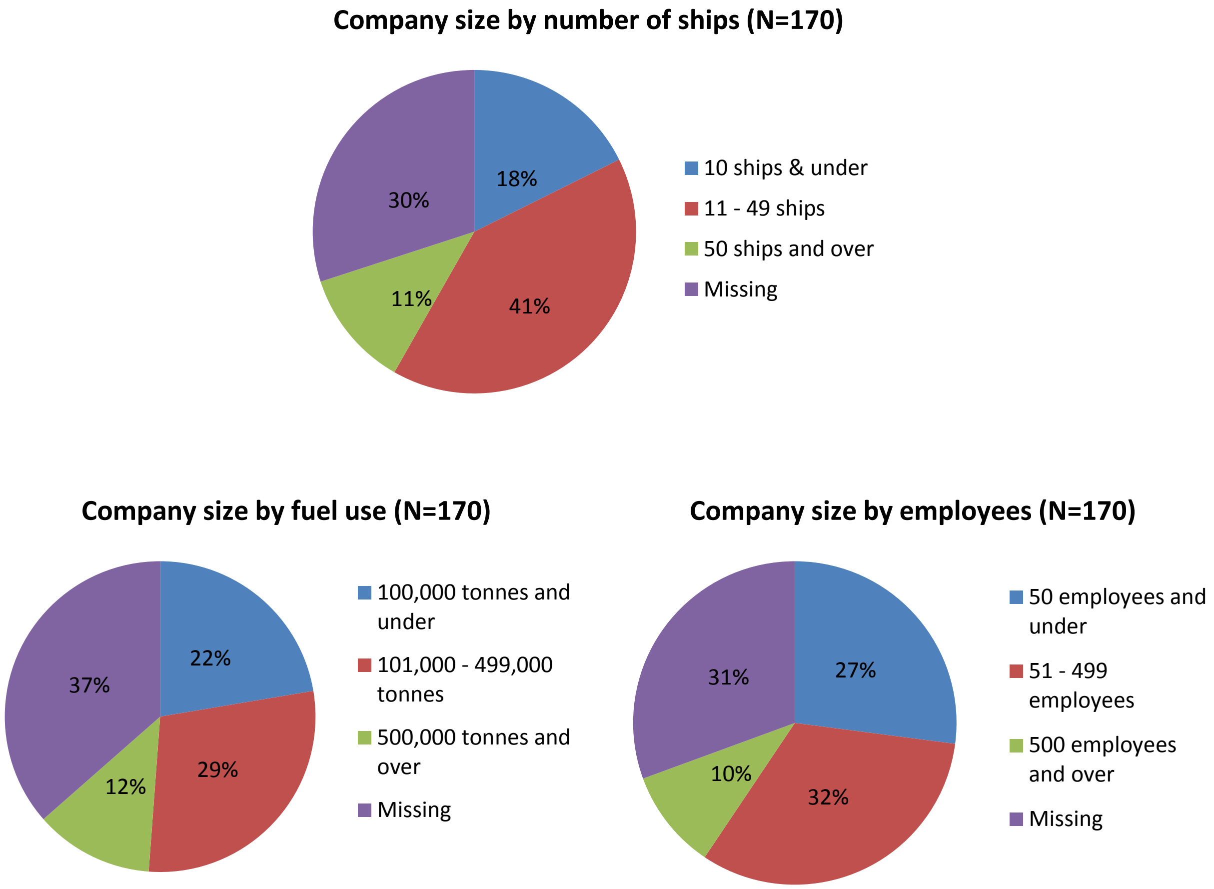


Figure 6.3: Company size by number of employees, ships and annual fuel use

The following demographic question asked the respondents to identify which company types would best describe their company structure. The question did not have mutually exclusive choices i.e. had multiple response data, hence the number of pure ship-owning, operating and management companies was slightly lower. Figure 6.4 shows those respondents who identified themselves as purely one type of company. Since the sampling frame was mainly representing ship-owning and operating companies and management companies these types exceed chartering companies and shipping divisions. The distribution of company types are very similar to that achieved by NAPA (2012), which also had low levels of representation from shipping divisions and charterers.

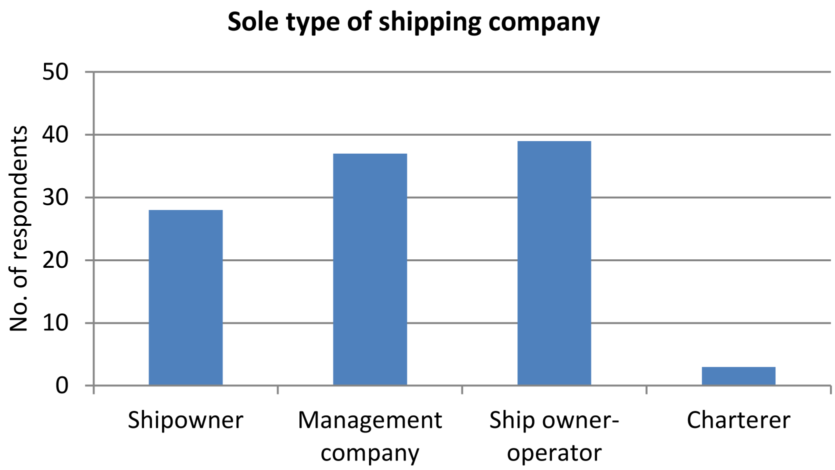


Figure 6.4: Respondents to the survey by type of shipping company

The last background measure captured in the online survey is the sector that the company mainly operates in. The question did not have mutually exclusive options as it is thought that companies especially bulk shipping companies would operate in wetbulk and drybulk sectors. The survey was primarily focussed on the wetbulk, drybulk and container sectors, hence all other responses suggesting different sectors have been re-coded as 'other' sectors. The responses from the wetbulk and drybulk are representative or proportionate to the population, however the container sector was significantly under-represented. Figure 6.5 shows respondents who identified themselves as purely operating in each sector (i.e. had 90% or more of their fleet engaged in one sector). Mixed shipping sector is when a company operates in either container and drybulk sectors or container and wetbulk sectors. The total number of companies operating in two or more sectors is forty.

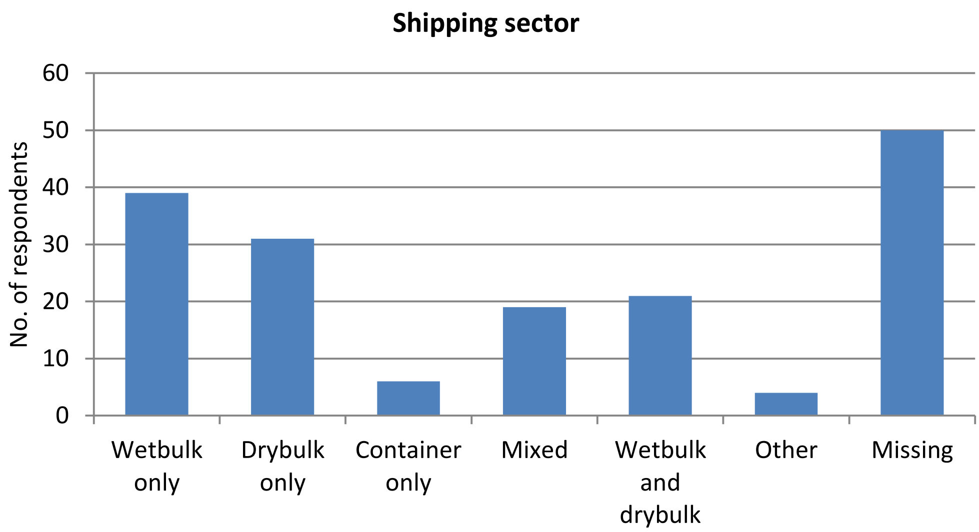


Figure 6.5: Respondents to the survey by shipping sector

Figure 6.6 shows the geographical dispersion of the respondents. Although this was not captured in the survey explicitly, the online survey could track the locations of respondents. As can be seen an overwhelming majority of the responses were from the EU region, over representing the region, this is twice of that observed in the sampling frame, over 50% of the shipping companies are headquartered in EU and twice of that achieved by NAPA (2012) and Norton Rose (2012). This will clearly affect the generalizability of the results unless the responses are weighted by region.

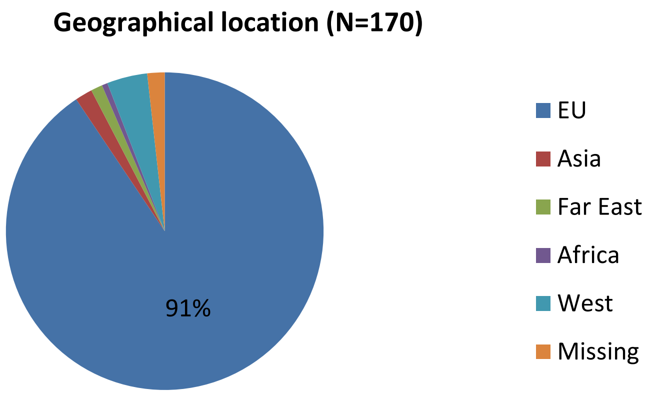


Figure 6.6: Geographical location of respondents

Figure 6.7 shows the job roles of the respondents who answered the questionnaire. As illustrated, most of these were operational managers or technical superintendents who are responsible for and are aware of implementation of operational measures in the company.

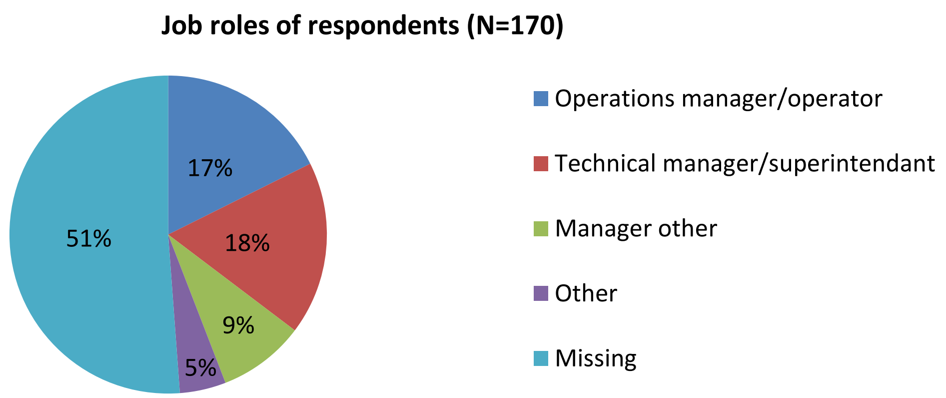


Figure 6.7: Job roles of respondents

This section summarises the background measures that provide context to the respondents to the survey. The next section presents the key findings of the survey, in a question by question format connected to the research questions.

6.4. Preliminary analysis

The main part of the survey directly sought to answer the research questions regarding the level of implementation and perception of barriers to implementation. This section will mainly focus on the univariate analysis of the dependent variables and to some extent their relationship with background variables (bivariate analysis), followed by univariate analysis of the independent variable. According to de Vaus (1995) an appropriate method for univariate analysis of nominal variables is the frequency distribution method, which is the method that is widely used in this section. The first question asked respondents to select the top five operational measures that they believe have the highest fuel saving potential. Figure 6.8 shows the measures that were selected by the respondents. Fuel consumption monitoring, weather routing and general speed reduction measures were cited by around 70% of the respondents as measures that have the highest potential. This is followed by four measures that were selected by around 50% of the respondents to have the highest potential. Around 10% of the respondents believed there were other measures that also had high fuel saving potential, however these were a mixture of technical (which are beyond the scope of this study), maintenance and operational measures such as LNG propulsion, foul release coatings, regular hull bottom cleaning etc. Around 60% of the 'other' measures were technical measures and the remainder were operational measures. The majority of the of the operational measures were related to hull maintenance such as hull condition monitoring, hull and propeller cleaning, regular underwater grit blasting etc.

Before proceeding with the univariate analysis which is presented mainly using frequency tables and frequency graphs (de Vaus 1995) there is a need to clarify frequency methods used in this chapter. Many of the survey questions required more than one response for an individual question i.e. contained multiple response data. For example, question one asks respondents to select five measures, other questions ask respondents to select three most important categories pertaining to implementation. There are two types of percentages that can describe this, percent of cases and percent of responses. Percent of cases (respondents) is a count for a particular variable divided by the total number of cases or respondents for that question. Percentage of responses is the count or frequency of that particular variable divided by the total of all the counts or frequencies for that particular question, which will always result in a sum of 100%. The analysis below uses both these methods to present frequency graphs, represented in the Y axis of the following figures, since percentage of cases provides better context for analysis and percent of responses provides a better picture for comparison.

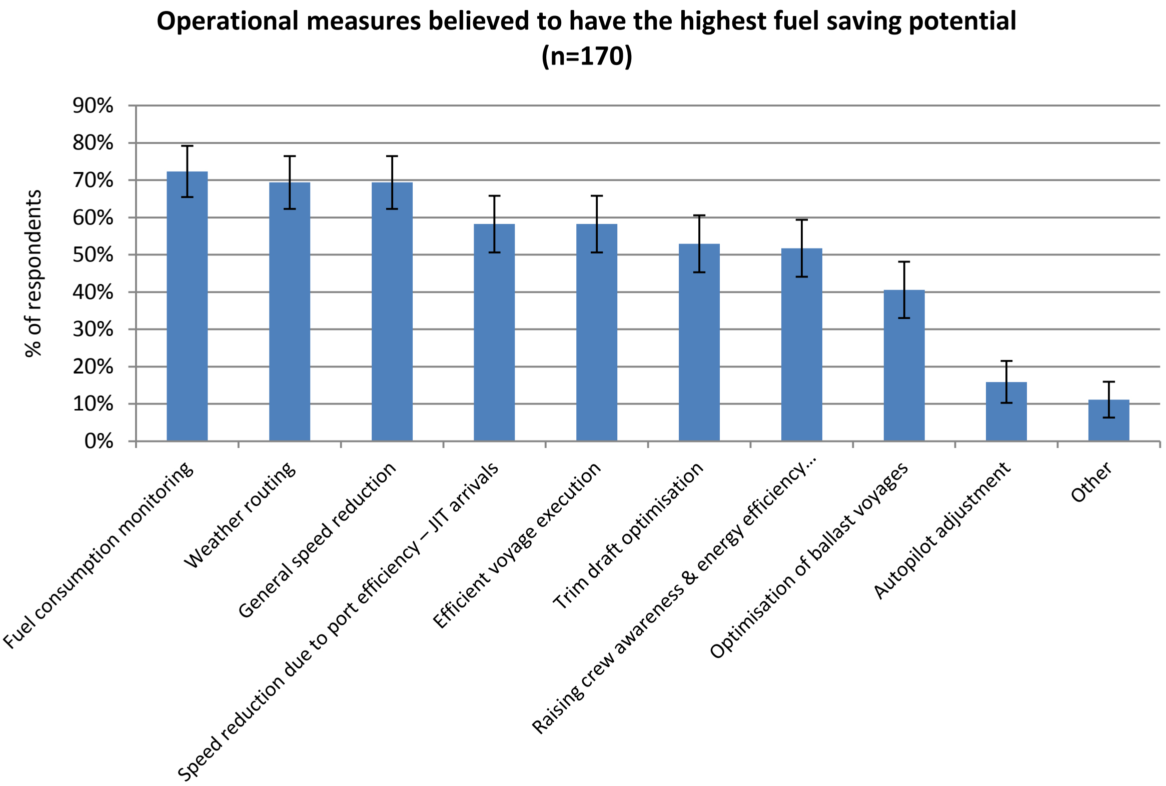


Figure 6.8: Operational measures believed to have the highest fuel saving potential

The results of the first question show that there are three modes (which is the best indicator of central tendency for nominal level data) for operational measures believed to have highest fuel saving potential. The respondents who selected fuel consumption monitoring, weather routing and general speed reduction on average represented 42% of the total responses to this question. The variation ratio (measure of dispersion for nominal data) cannot be calculated because the choices are not mutually exclusive. Because the survey used nominal variables, in order to make inferences to the population mean, Figure 6.8 above uses the standard error for the binomial distribution for interval estimation for each measure at 95% confidence level. Generally, because the survey had a relatively smaller sample size, the ranges for the population mean would lie between +/- 5% and 7% of the sample results. This procedure will be followed throughout this chapter, wherever nominal variable interval estimates or inferences are made. To some extent a representative sample was achieved (for most strata) as shown below in Table 6.3, with which some inferences can be made to the population (with some margin of error and confidence level as discussed in section 4.1.3.4). The discussion that follows is for the purposes of visually identifying relationships between the variables and to detect initial relationships or zero order relationships i.e. not controlled for intervening or test variables. According to de Vaus (1995) this is the first step towards elaboration analysis.

Sector	**Actual results**	**Size**	**Actual results***
Wetbulk	39	Large	8
		Medium	17
		Small	9
Drybulk	31	Large	3
		Medium	17
		Small	10
Container	6	Large	1
		Medium	4
		Small	1
Mixed	40	Large	6
		Medium	27
		Small	5
Total	116		108

* The actual results may be higher than what is shown for each stratum because not all respondents completed demographic questions.

Table 6.3: Final results in each stratum

When the results of the first question are disaggregated according to the size and sector of firms, the results show some interesting patterns (Figure 6.9 and Figure 6.10). For most measures, the belief in the highest fuel saving measures does not vary considerably by the company size and the range between large and small company responses generally did not exceed 15%. However, for some measures there exists some relationships between the views of large and small companies, for example trim draft optimisation. The range of responses by company sector was much more variable, ranging between 5% and 40% between sectors. Most of the operational measures were shown to be cost-effective energy efficient measures and therefore "should be implemented" (Thollander and Ottosson 2008, p23). According to the market barriers and failures proposition and looking at existing literature, the high fuel saving potential measures should have already been implemented broadly. The following section therefore focuses on the level of implementation of measures.

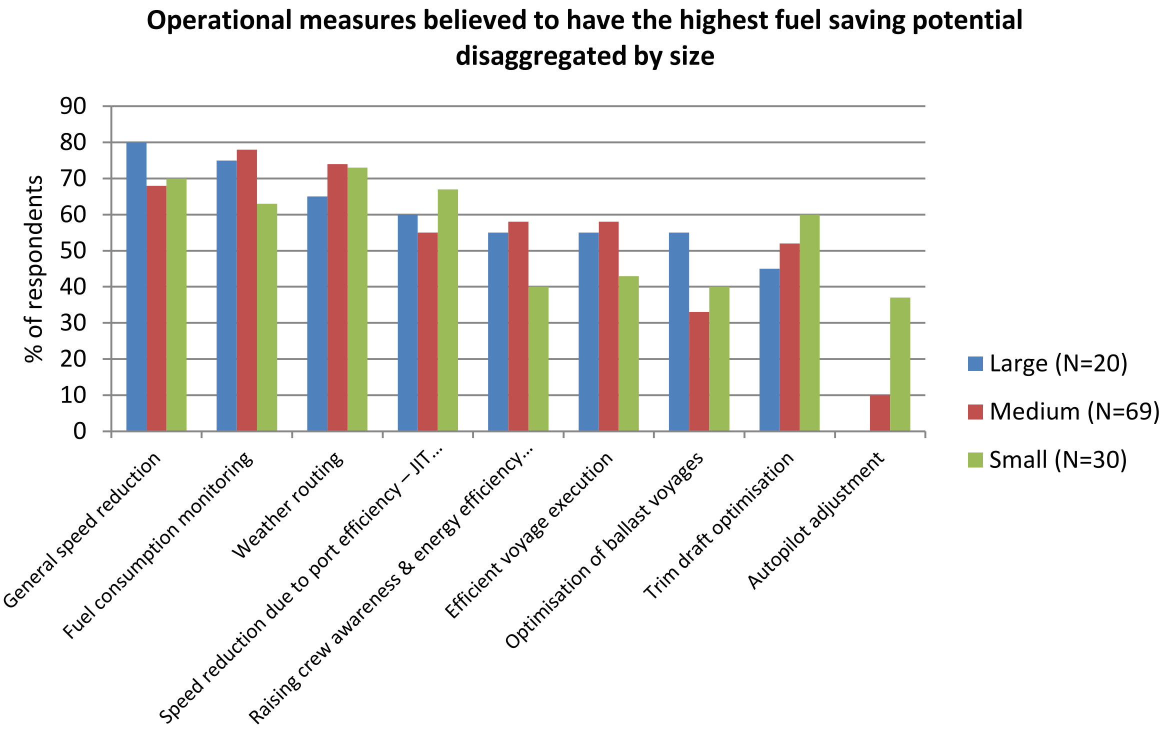


Figure 6.9: Operational measures believed to have the highest fuel saving potential by size

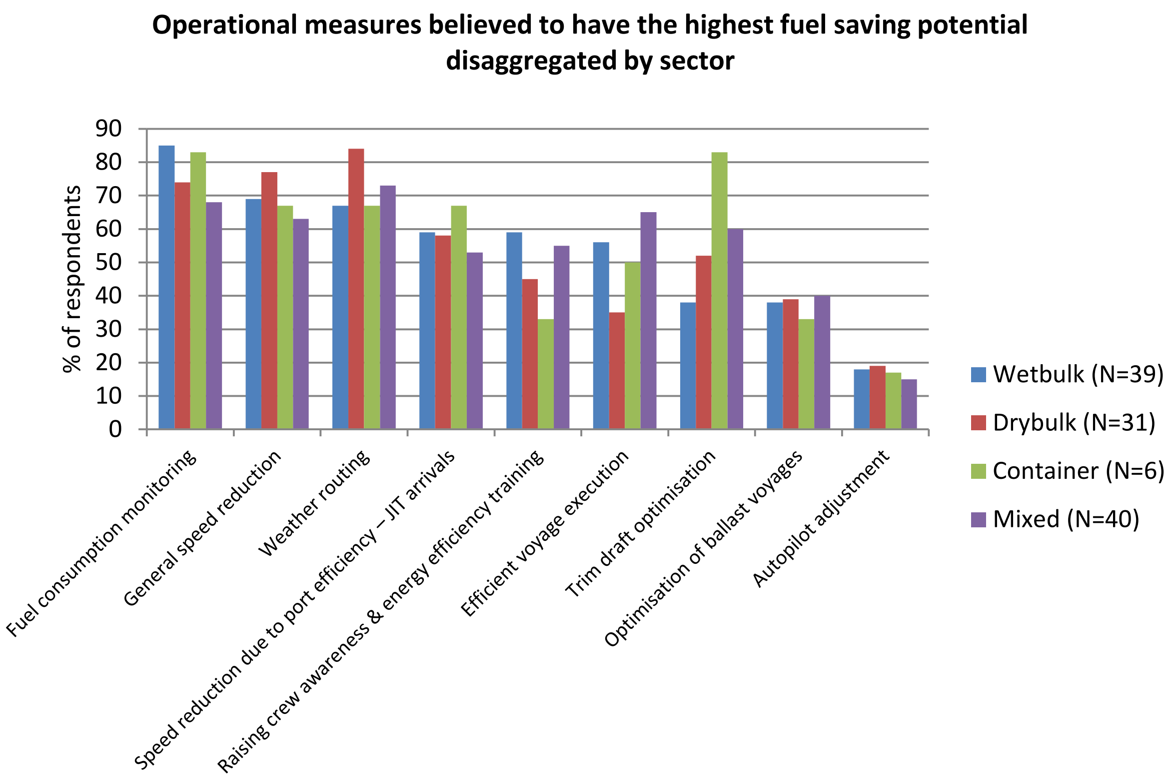


Figure 6.10: Operational measures believed to have the highest fuel saving potential by sector

6.4.1. Implementation of measures

The follow on survey question asked respondents the level of implementation of the five measures they selected and thereafter reasons for not selecting the remainder, which would highlight why some measures were believed to have a low fuel saving potential. There could be several reasons (as discussed in chapter two) why cost-effective operational measures would not be implemented according to their fuel saving potential. For this research it is hypothesised that if implementation rates for high fuel saving potential measures are low then there exist market barriers that hinder the uptake of such measures, which is in line with what has been claimed in the barriers literature i.e. failure to realise the potential has been attributed to various market barriers and failures, resulting in an energy efficiency gap. Figure 6.11 shows whether the highest fuel saving potential measures selected by the respondents have been implemented. The implementation in the survey was originally based on five choices; 'considering or trialling', 'considered and decided against', 'plan to implement', 'already implemented' and 'did not consider'. These have been later recoded as implemented (already implemented) and not implemented (which includes the remainder categories) as this will allow for crosstabulation later on and according to de Vaus (1995) is one of the options available if the variables have too many categories.

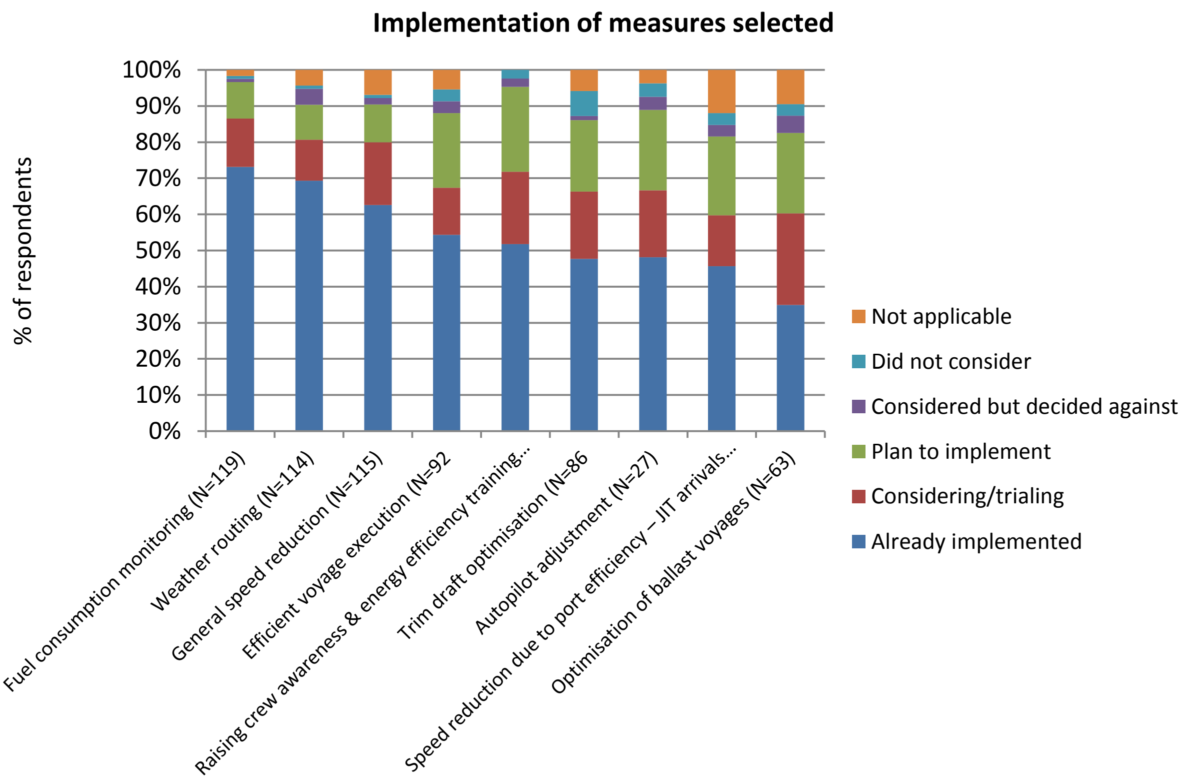


Figure 6.11: Implementation of measures selected as having high fuel saving potential

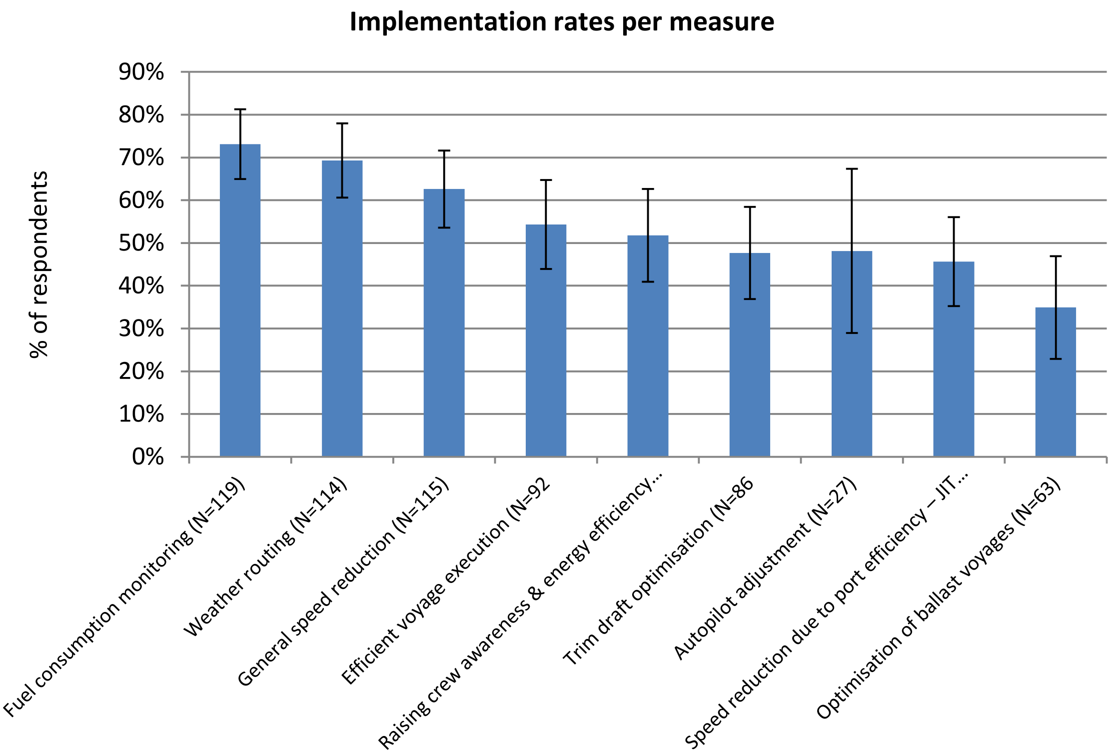


Figure 6.12: Recoding for implementation of measures

Many MACC studies assume that measures with negative costs would have been fully implemented or would have been implemented under a certain fuel price. From the above it can be seen that even the top three cost-effective operational measures that were deemed to be of highest potential have actual implementation rates of around 60-70% (+/-9% for 95% confidence level). The average implementation across all the measures the implementation rate drops to around 50%, ranging from 35% to 70%. Combining the 'already implemented' and 'planning to implement' categories, the average across all the measures is just under 70%. The answers to this question clearly show that despite the easiness of implementation and short payback of most operational measures (IMO 2009; Wang et al. 2010; Lockley et al. 2011; etc.) some measures still do not see high implementation rates. This analysis answers the first specific research question regarding the implementation of operational energy efficiency measures. Elaborating on this finding, Figure 6.13 below shows the number of measures already implemented by each company. Just fewer than 50% of the companies have implemented three to four measures and only 15% of the companies have implemented all five measures that they believe have the highest fuel saving potential. On average each company had implemented just under three measures (with a standard deviation of 1.6). The standard error of the mean is 0.12, which suggests that the population mean could be anywhere between 2.5 to 3 measures for a 95% confidence level.

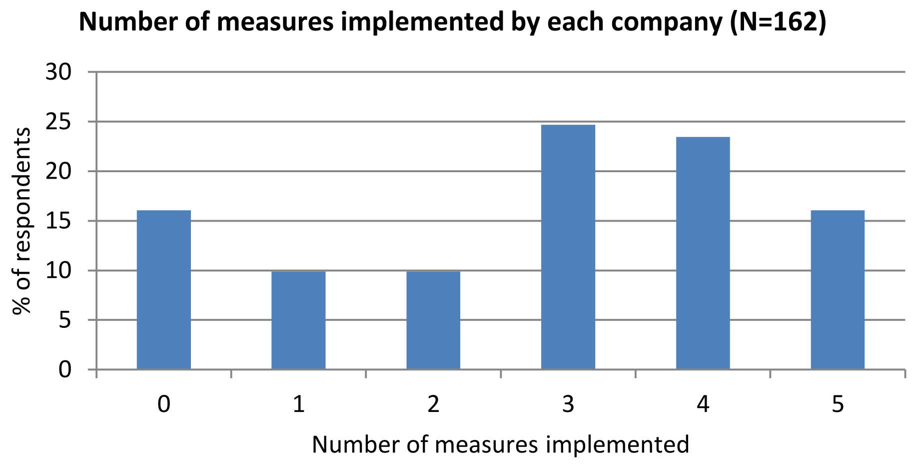


Figure 6.13: Number of measures implemented by each company

Earlier it was shown that when the results of the first question are disaggregated according to the size and sector of companies, the belief in the highest fuel saving measures varied slightly by the company size but varied considerably when disaggregated by sector the company operates in. Figure 6.14 shows the implementation of measures disaggregated by size. There is a large difference between the levels of implementation by the different sized companies amongst the different measures. Note that the percentage of respondents is for respondents who selected a particular measure and then implemented it, for example weather routing implementation for large companies is 75%, of those who selected the measure (N=13) and not 75% of large companies (N=20). Thus the N varied considerably between each of the measures and is therefore shown as a separate table in Table 6.4 and Table 6.5. For four measures the small sized companies have higher implementation compared to the large companies, and similarly large companies higher implementation in four other measures. Some trends can be observed for five measures such as weather routing, fuel consumption monitoring, trim draft optimisation but these are not in consistent manner and in opposite directions. It is not clear at this stage why this is the case, the correlation could be due to some other intervening variable such as the chartering ratio of the firm, which will examined in later sections. A possible explanation of the difference in implementation rate could perhaps be due to the small sized fleet of small firms, which may make investment manageable or conversely the large sized companies not investing due to comparatively higher outlay. It is thought that the recoding exercise into ‘implemented’ and ‘not implemented’ may also have masked the level of implementation (de Vaus 1995), for example, further analysis of the data shows that the larger companies are still either ‘considering or trialling’ or ‘planning to implement’ those measures, hence shown to have relatively lower implementation.

Disaggregating the implementation of measures by sector reveals similar patterns as seen earlier in Figure 6.14, i.e. there is a large difference between implementation rates between sectors. One can see that for example weather routing implementation rate for drybulk sector is three times that of container sector. A possible explanation to this could be that container sector operates on fixed schedules or liner service, hence the benefits of weather routing on a specific voyage within a string would be minimal. On the other hand, the container sector has over three times more implementation of 'raising crew awareness' measure when compared to the drybulk sector. Since these are zero order relationships, it could suggest that there is a spurious relationship between sector and implementation, so for example, the variation in implementation could be due to the chartering or ownership structure of the container sector which is quite different to the bulk sectors. In chapter five it was noted that almost 50% of containerships were owned and operated by the carrier, which would suggest that the owner-operator has a long term interest in the crew and the fuel savings that could be achieved through training and incentivising them. The difference in the implementation of the speed reduction measure could be due to the contractual requirements for speed which are specific to those sectors, which are further investigated in chapter eight.

Figure 6.16 shows the number of measures already implemented by each company broken down by size. Nearly 70% of small, medium and large companies have implemented three to five measures. All three sizes contributed almost equally to the implementation of all five measures they believed to have the highest fuel saving potential. On average the small and medium sized companies had slightly higher implementation rate compared to the overall average and that of large companies as shown in Table 6.6. Figure 6.17 shows the number of measures already implemented by each company broken down by sector they operate in. Once again there is quite a large spread of the number of measures implemented by sector. On average the drybulk and mixed sector companies had considerably higher implementation rates compared to the overall average and that of companies operating in container and wetbulk sectors as shown in Table 6.6. Section 6.5 looks at how the distribution of implementation varies by chartering level.

The analysis presented here only answers to some extent research question 1b, because it only presents the initial uncontrolled zero order relationships, thus further elaboration is required. The implementation of each measure and its relationship with size, sector and chartering ratio is further elaborated using bivariate analysis and specifically the crosstabulations method, which are discussed in chapter seven.

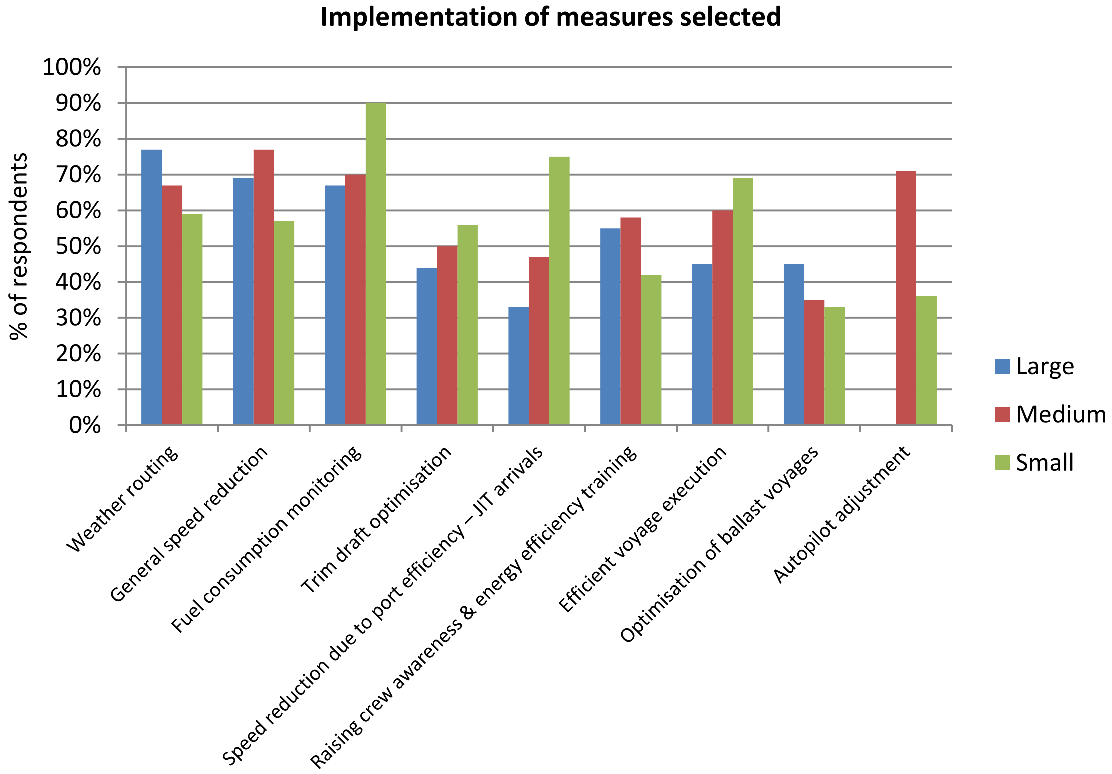


Figure 6.14: Implementation of measures by company size

	Large	**Medium**	**Small**
Weather routing	13	51	22
General speed reduction	16	47	21
Fuel consumption monitoring	15	54	19
Trim draft optimisation	9	36	18
Speed reduction due to port efficiency – JIT arrivals	12	38	20
Raising crew awareness & energy efficiency training	11	40	12
Efficient voyage execution	11	40	13
Optimisation of ballast voyages	11	23	12
Autopilot adjustment	0	7	11

Table 6.4: Total number of respondents for question two by size.

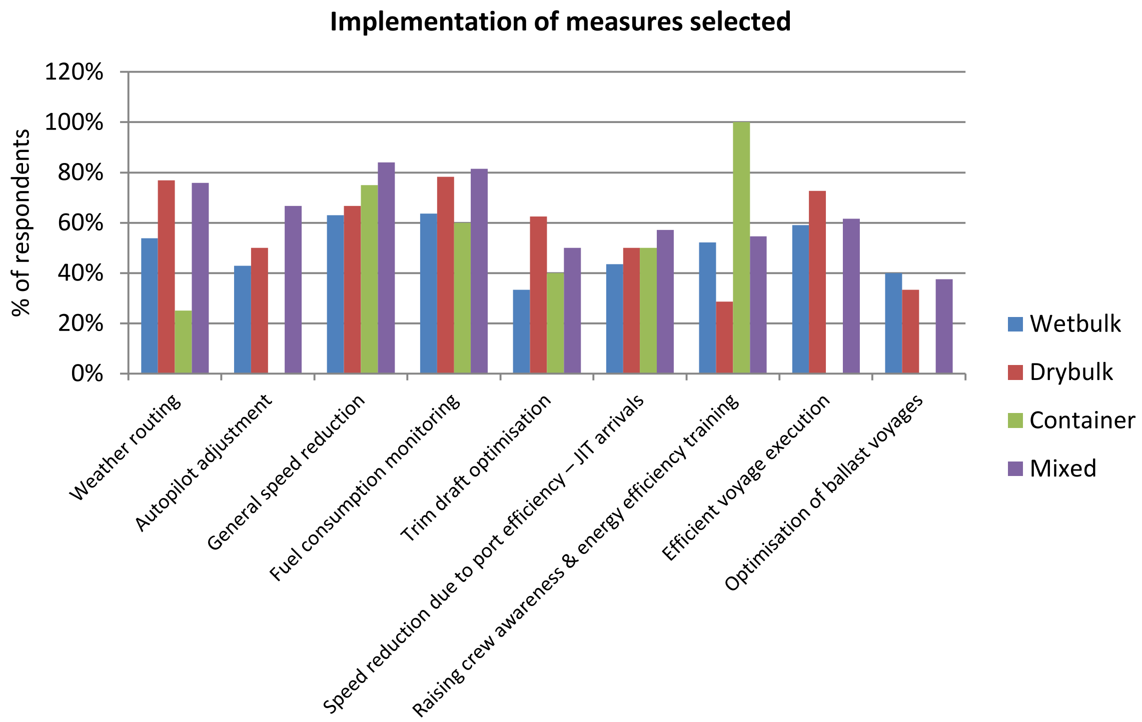


Figure 6.15: Implementation of measures by sector

	Wetbulk	Drybulk	Container	Mixed
Weather routing	26	26	4	29
Autopilot adjustment	7	6	1	6
General speed reduction	27	24	4	25
Fuel consumption monitoring	33	23	5	27
Trim draft optimisation	15	16	5	24
Speed reduction due to port efficiency – JIT arrivals	23	18	4	21
Raising crew awareness & energy efficiency training	23	14	2	22
Efficient voyage execution	22	11	3	26
Optimisation of ballast voyages	15	12	2	16

Table 6.5: Total number of respondents for question two by sector

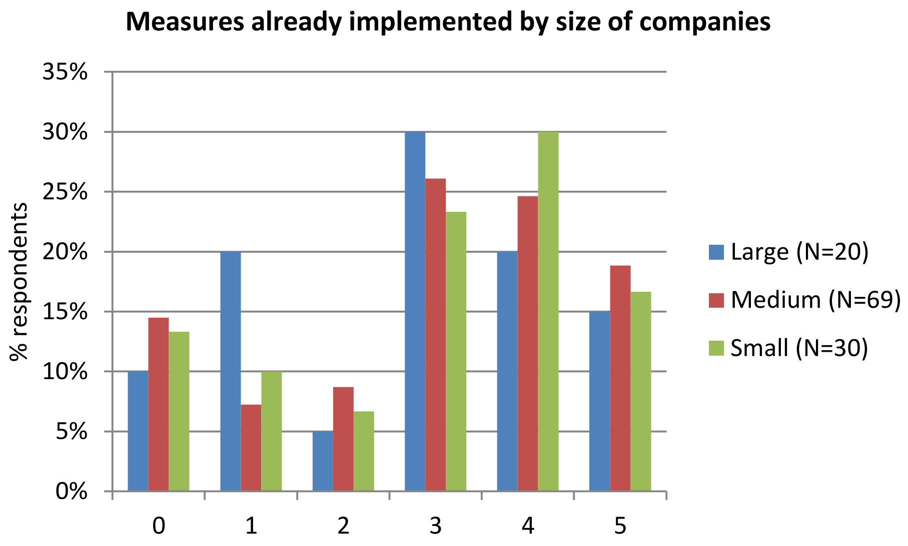


Figure 6.16: Number of measures implemented by company size

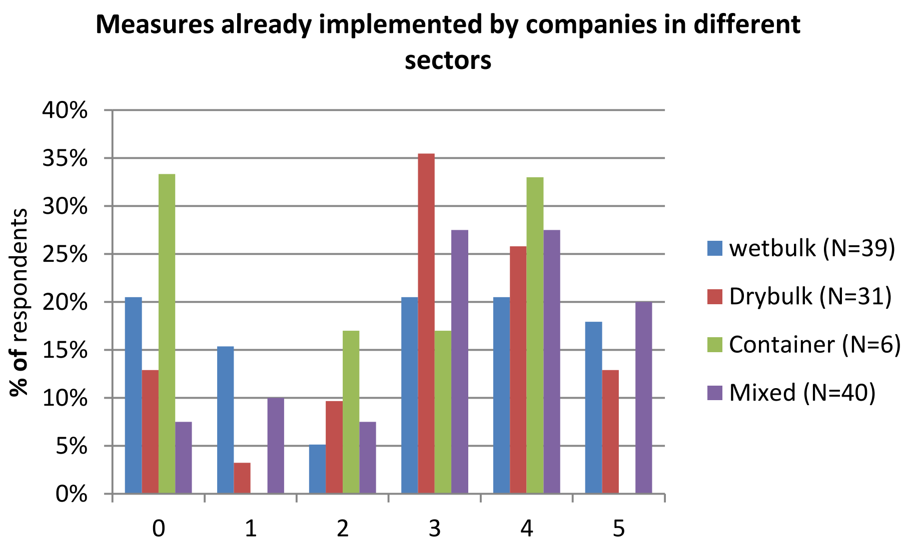


Figure 6.17: Number of measures implemented by sector

	Large	Medium	Small			wetbulk	Drybulk	Container	Mixed
Mean	2.75	2.96	2.97		**Mean**	2.6	3.0	2.17	3.17
St Dev	1.62	1.65	1.65		**St Dev.**	1.8	1.5	1.835	1.5
SE	0.36	0.2	0.3		**SE**	0.29	0.27	0.75	0.24
95% CI	2 – 3.5	2.6 – 3.4	2.4 – 3.6		**95% CI**	2 – 3.2	2.4 – 3.5	0.7 – 3.7	2.7 – 3.6

Table 6.6: Summary statistics for implementation by firms in different size and sectors

6.4.2. Perception of barriers

The second purpose of the survey was to gauge the perception of barriers to operational energy efficiency measures. This was measured in two ways; the first method is brief and uses general barriers classification in a single grid for the measures that were not selected in the first question (Figure 4.7). The second method is through asking respondents follow-up questions on the measures they had selected as having high potential but they had not yet implemented (i.e. trialling, plan to implement, etc., in the second question, see Figure 4.6). Table 6.7 shows the response choices that were presented to the respondents and the barriers categories they fall into. This approach of providing more specific choices and then recoding them as general barriers is adapted from previous research by Sorrell et al. (2000) and Thollander & Ottosson (2008). Sorrell et al. (2004) group choices such as 'other priorities for capital investment', 'strict adherence to capital budgets', 'lack of capital' into capital barriers. Similarly, they group choices such as 'departments not accountable for energy costs', 'low priority given to energy management', 'conflict of interest within organisation', 'energy objectives not integrated into procedures' into the split incentives barrier. This approach is also very similar to building scale items as described by de Vaus (1995). Summated scaling consists of respondent's answers to a number of questions. "Summated scales simply require that we measure the strength of some opinion on some matter by assessing 'position' on a number of questions".

Response choices in brackets were dropped for the barriers analysis, which is similar to the deleting variables solution according to Hertel (1976, cited by de Vaus, 1995) as they were only relevant to the speed reduction measures. They are however revisited in analysis of barriers to speed reduction measures. Figure 6.18 shows that in general the top three barriers across all the measures that were not selected (i.e. seemed to have lower fuel saving potential) were 'difficult to implement under some types of charter', 'lack of reliable information on cost and savings' and 'lack of direct control over operations'. Due to item non response this survey question had an even smaller sample size, therefore the interval estimate ranges for the population mean would lie between +/- 7% and 9% of the sample results. Together the responses to the above three categories represented around half of all the responses to this question. The broader barrier categories these top response choices fall into are the informational problem and split incentives barrier, which suggests that market failures are a primary reason for companies to at least initially not consider the operational energy efficiency measures. The difficulty in implementing the operational measures could be due to lack of direct control over operations and charterparty clauses, cited by nearly 50% of the respondents. Nearly 20% of the respondents made use of the 'other – please specify' category. Most of the respondents noted in the 'other' category that their reason for not selecting a measure was the materiality or lack of savings as the quotes show below. According to Kollamthodi et al. (2008), some measures may be ignored by decision-makers due to their limited impact (Hobson et al. 2007). Some noted that they have already implemented the measures but they did not select the measure in the first question because they agreed that those measures had low impact on fuel savings. Other responses suggested that there were hidden costs involved with the time and skill required to evaluate the measures.

"None of these are unattractive for investment, just not the top ones"- Global container line
"Not always feasible"- Medium sized EU based shipping company
"*Already being done but savings are less than measures"*- Small US based shipping company
"Small effect"- Anonymous
"Impact rather low"- Large EU based shipping company
"Low fuel savings" – Medium sized tanker operator
"Minimal savings" – Large Management company
"Only small influence" – Small container ship owning company
"Small impact" – Medium sized drybulk operator
"Good but not in top 5 savers" Medium sized drybulk Management company
Other respondents noted that they already implement the non-selected measures but believe they do not have the highest fuel saving potential, as highlighted below:
"We do use weather routing and believe fuel saving is about 2%, worth having but just not in top 5, ditto the other 4" – Large drybulk ship owner operator
"Already being done but savings are less than measures" Small mixed fleet shipowner operator
"We are also doing this but the other Q1 statements have higher impact" Large container line
"This is already implemented and minimum impact in saving" Large tanker operator
"Crew awareness and training: Important factor but not a top five choice" Medium sized tanker operator
"Already implemented without positive effect" Medium sized mixed fleet operator

Other responses in the 'other – please specify' category were:

"Not always feasible" Medium sized mixed fleet owner operator
"Not clear how to evaluate and what to do" Medium sized mixed fleet owner operator
"No time for it" Medium sized drybulk shipowner operator

Survey response choices	Barrier	Type
a) Savings cannot be fully recouped b) Lack of direct control over operations c) Difficult to implement under some types of charter d) (Divided responsibility for fuel costs)	Split incentives	Market failures
a) Lack of reliable information on cost & savings b) (Lack of information sharing on savings among parties)	Informational problems	
a) Uncertain/long payback b) Immature technology c) Sailing off design conditions	Risk	Market barriers (non-market failures)
a) Lack of access to capital	Capital	
a) Additional costs e.g. transactional b) Opportunity costs	Hidden costs	Modelling artefacts
a) Unsuitable to trade/route of operation b) Incompatible with other measures	Heterogeneity	
a) Not allowed due to charterparty clauses b) Standard charterparty clauses c) Inadequate port infrastructure	General/other specific to shipping	

Table 6.7: Choices available to respondents and their grouping into barriers to energy efficiency

Analysis of the responses to the third question shows that there are specific barriers pertaining to each of the measures, as shown in Table 6.8. Lack of reliable information on cost and savings are mainly related to the more technical operational measures such as weather routing, autopilot adjustment, trim/draft optimisation. Weather routing, autopilot adjustment and trim/draft optimisation have been shown to be mature technologies (Maddox Consulting 2012) for which information is readily and reliably available (Lockley et al. 2011). This suggests that there may be other underlying factors such as the principal agent problem as a result of which, there could be issues regarding the level of trust due to information asymmetry, lack of or cost monitoring of performance or savings of those measures. On the other hand, for measures mainly related to speed (general speed reduction and Just In Time arrivals) or those that had an element of speed (efficient voyage execution and optimisation of ballast voyages) the respondents mainly cited that these were difficult to implement under different types of charter and that charterparties did not allow for implementation. Under the time charter, the charterer who has operational control of the ship is mainly responsible for the speed of the ships and under voyage charter where the shipowner has operational control of the ship the speed is set through use of charterparty, therefore, in general only in the ballast leg is a shipowner operator allowed to decide the speed of the vessel. The speed at which a ship travels varies according to many factors such as the sector it operates, publisher of charterparties, the power of agents involved etc, which will be further investigated in chapter eight. The subject of speed reduction and its potential in different charters is discussed in section 8.4.1.

Figures C7 and C8 in appendix C show the perception of all the barriers disaggregated by size of companies and sectors they operate in. This time the variation in size (between small and large) is almost similar to the variation found in sector (wetbulk and container). Nonetheless, there are some trends or patterns that can be observed in each. For example, the lack of capital and its relationship with the size of the company or additional costs and its relationship to size of the company. According to Faber et al. (2009) smaller ship owners and operators may experience high transaction costs as they cannot spread the costs of e.g. gathering information over a large number of ships. Similarly, the choices; 'difficulty in implementing in different types of charter', 'savings cannot be fully recouped' and 'lack of direct control over operations', are cited more by companies in the wetbulk sector than drybulk and container sector. The answers to this will be obtained from bivariate analysis of barriers and the chartering ratio independent variables, controlling for size and sector, as it may be that this is a spurious relationship that exists due to another variable. This elaboration analysis in the following chapter will further explore the key relationships.

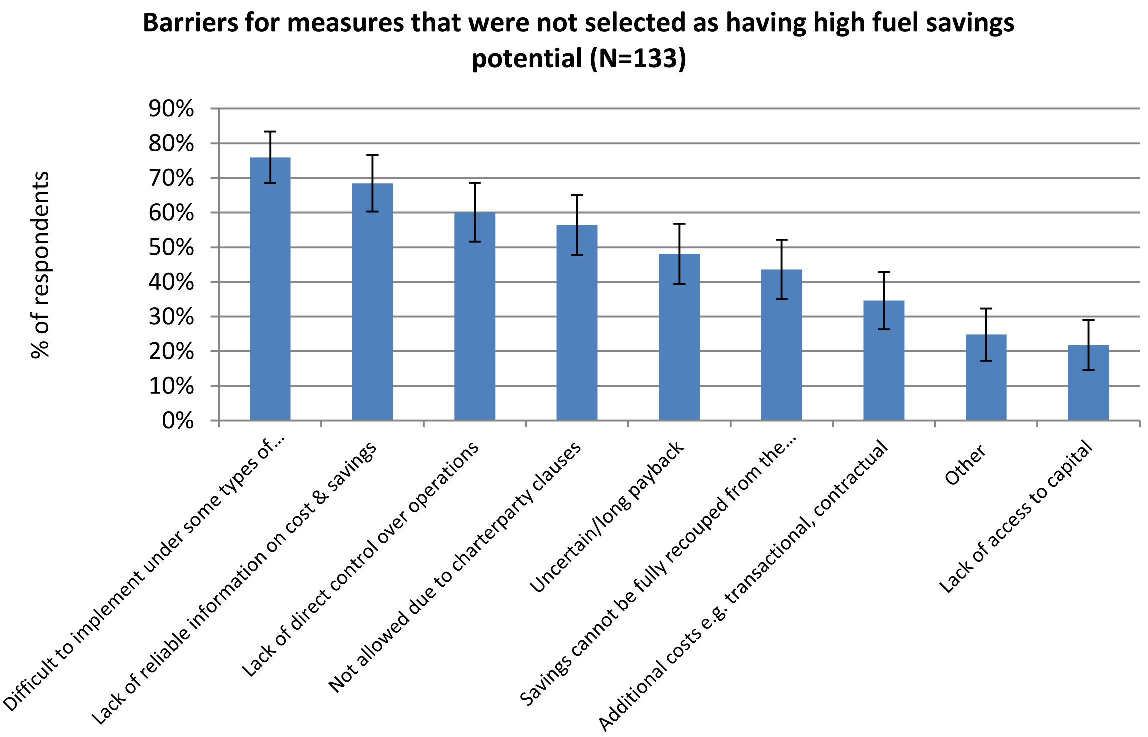


Figure 6.18: Most important barriers for measures that were not selected

Barrier \ Measure	Weather routing	Autopilot adjustment	General speed reduction	Fuel consumption monitoring	Trim/draft optimisation	Speed reduction JIT arrivals	Raising crew awareness & training	Efficient voyage execution	Optimisation of ballast voyages
Lack of reliable information on cost & savings	24%	27%	6%	15%	26%	7%	22%	16%	15%
Savings cannot be fully recouped from the investment	4%	12%	9%	11%	7%	5%	13%	6%	8%
Difficult to implement under some types of charter	16%	7%	29%	5%	21%	26%	6%	24%	24%
Lack of access to capital	4%	6%	2%	4%	3%	4%	4%	1%	5%
Additional costs e.g. transactional, contractual	9%	8%	10%	13%	7%	6%	7%	4%	7%
Uncertain/long payback	11%	14%	3%	22%	12%	6%	20%	5%	8%
Not allowed due to charterparty clauses	5%	4%	28%	4%	4%	26%	3%	17%	15%
Lack of direct control over operations	17%	13%	10%	15%	10%	17%	13%	20%	15%
Other (Please specify)	9%	9%	2%	13%	8%	2%	13%	8%	3%
Total responses	75	197	87	55	121	121	112	107	164

Table 6.8: Most pertinent barriers for each operational energy efficiency measure

Perception of barriers was also measured through tailored questions for respondents that had selected 'considering or trialling' or had 'considered and decided against' implementing a particular measure. Figure 6.19 is an extension of Figure 6.18 shown above and includes all of the responses in the survey regarding barriers, i.e. total number of barriers cited by a respondent. It is important to note that not all respondents had an equal chance to see the questions on barriers, as it depended on the specific response in question one and two of the survey. Moreover, the barriers response choices were not uniformly distributed across all the measures. This is either because some choices are more common than others or some measures have specific response choices, for example inefficient port infrastructure is more relevant to speed related measures than other measures. Thus the figure below shows the unweighted results on the perception of barriers. The top most barriers cited by respondents remained the same as before, with most responses concentrating around the market failures categories rather than market barriers.

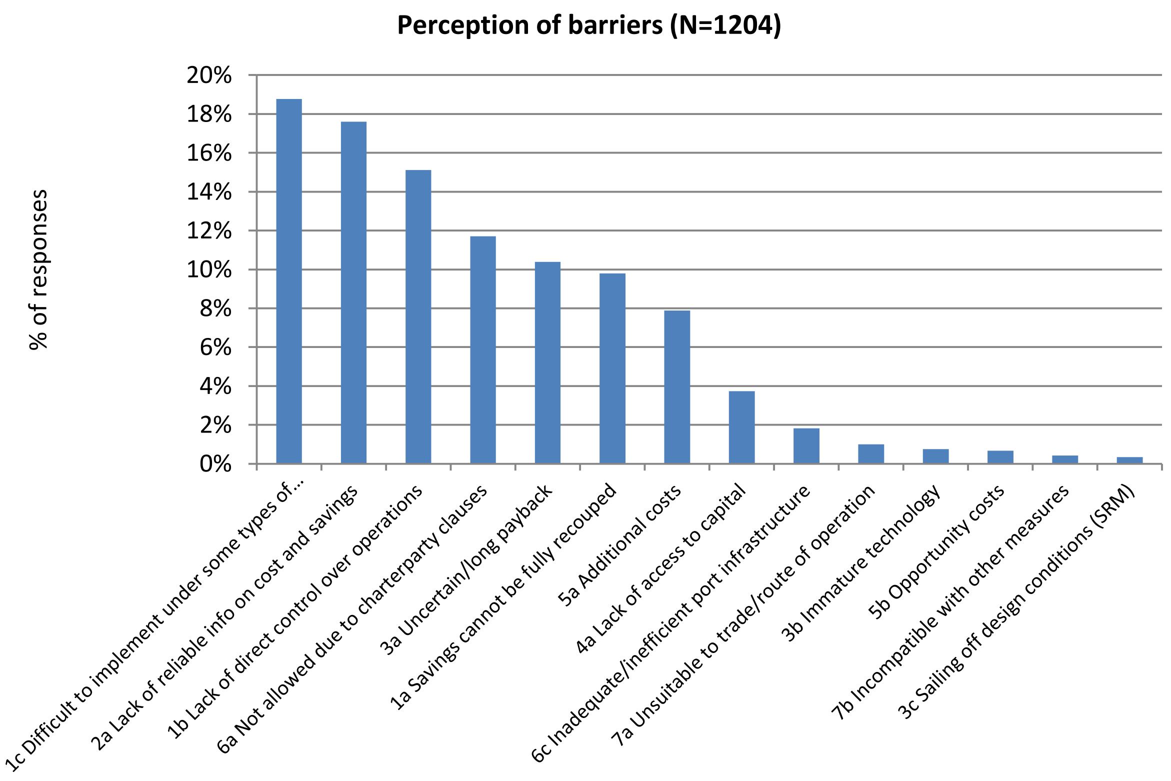


Figure 6.19: Barriers cited by respondents across the survey

In summary, the respondents perceived the split incentives barrier as the most important barrier to implementation of operational energy efficiency measures. These combined with informational problems as market failures outweighed the non-market failures (market barriers) such as risk, costs etc. as shown in Figure 6.20 below. There is a possibility that this imbalance is partly due to the aggregation of three response choices into the split incentives barrier, however the same was also the case for other barrier categories such as risk and 'specific to shipping' barriers category, which also had three response choices recoded into a single barrier category. Analysing in detail the responses to barriers questions, it was observed that there are specific barriers pertaining to each of the measures.

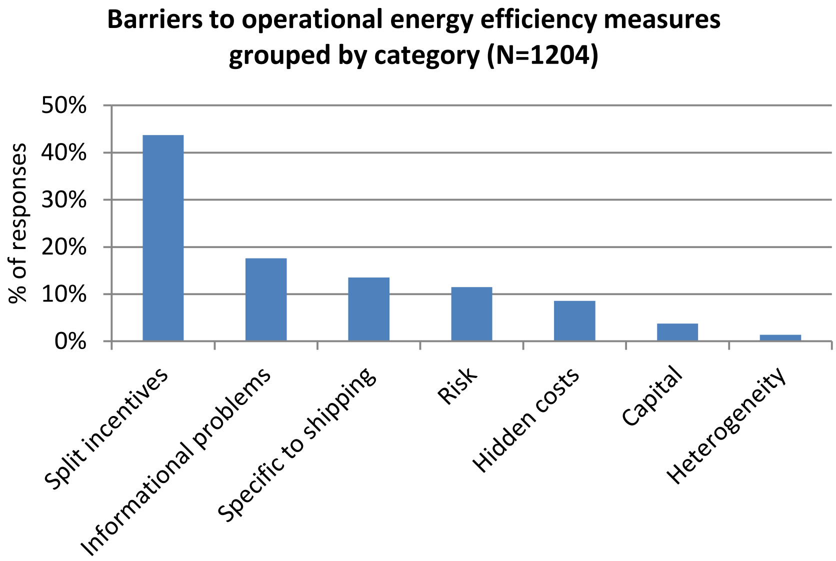


Figure 6.20: Barriers to operational energy efficiency measures grouped by category

6.4.3. Factors affecting implementation

Just as there are barriers affecting implementation of measures, it has been proposed in the barriers literature that there are also factors that drive implementation of measures. Rohdin, Thollander & Solding (2007) and Thollander and Ottosson (2008) provide a good overview of drivers to energy efficiency, which have been incorporated into their survey. They define a driving force as "the opposite of a barrier, in other words, different types of factors that stress investment in technologies that are energy efficient and cost-effective" (Thollander and Ottosson 2009, p26). Up to eleven high level drivers and twenty three specific drivers are discussed ranging from market related driving forces, regulatory, to company strategy as shown in Table 2.3 in chapter two. Although these drivers did not form the key part of the research framework, it is thought that an understanding of these would complement the barriers discussion, perhaps shed light on the opportunities for energy efficiency and suggest plausible ways to address barriers. The reasons that were cited for those who implemented the measures were generally because savings from the investment could be fully recouped, the operations were under direct control and that there were no additional costs involved, which are interestingly the opposite of the top barriers that were cited by the respondents. Since this question is based on the respondent's initial choice the actual response (N) varied widely but the response rate per question generally was just under 80% (N = 125). Similar to the response choices for barriers, not all measures had the same choice of factors, however some choices were always present to the respondent e.g. savings can be fully recouped, access to capital, and direct control over operations. Despite always being available as a response choice, access to capital was least cited as a factor influencing implementation, which tallies with previous response to the question on barriers to measures where lack of access to capital ranked lowest amongst other categories of barriers. This shows that capital (cost or access) is not a deciding factor when operational energy efficiency measures are concerned and that there may be other hindrances or motivation to carry them out. As mentioned earlier reliable information on cost and savings for a measure was cited as a key barrier to implementation and from what can be seen below, it is suggested that when this information is available it can be a driving factor for implementation. However, the key factor in driving implementation of the operational measures was that savings can be fully recouped from the investment (i.e. non-existence of split incentives), which was hardly cited as a barrier in the previous question on barriers to energy efficiency. This requires further analysis of each of the respondent's demographics to see how much fuel is used and who pays for fuel using their chartering ratio and will be discussed in the bivariate analysis section. Many respondents made use of the 'other – please specify' category and some of the factors leading to implementation, some are shown below:

"Despite the initial investment the results have been very successful with short periods for return on investment.1) Reduced fuel consumption. 2) Shorter stay in drydock for future drydockings. 3) Good for the image of the company" Far East Global Container line

"No brainer - restoring the underwater hull profile to/close to original reduces frictional resistance in service and will reduce fuel consumption by at least 6% if done every 10 years. Superintendents in dry dock could, if their budget is under pressure, reduce on grit blasting and painting to balance their budget - this at the expense of future fuel consumption - in setting out this policy we have taken away their right to reduce this blasting and it is defined company policy increasing fuel prices and a worsening market in 2008 focused attention on fuel saving initiatives - this was the first and easiest to implement" Large Dry bulk shipping company

Figures C9 and C10 in appendix C break down the responses to factors leading to implementation by sector and size. There do not seem to be any consistent trends or visual relationships, which is in contrast to what was found when perceptions of barriers were disaggregated in by the same independent variables.

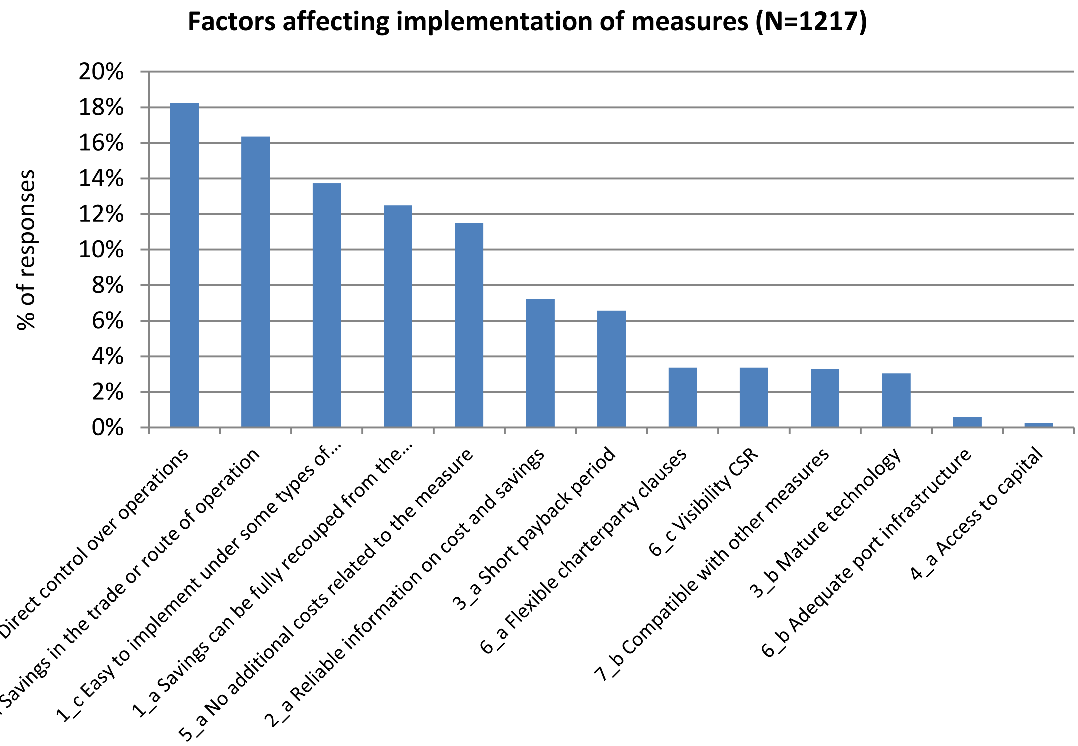


Figure 6.21: Factors affecting implementation

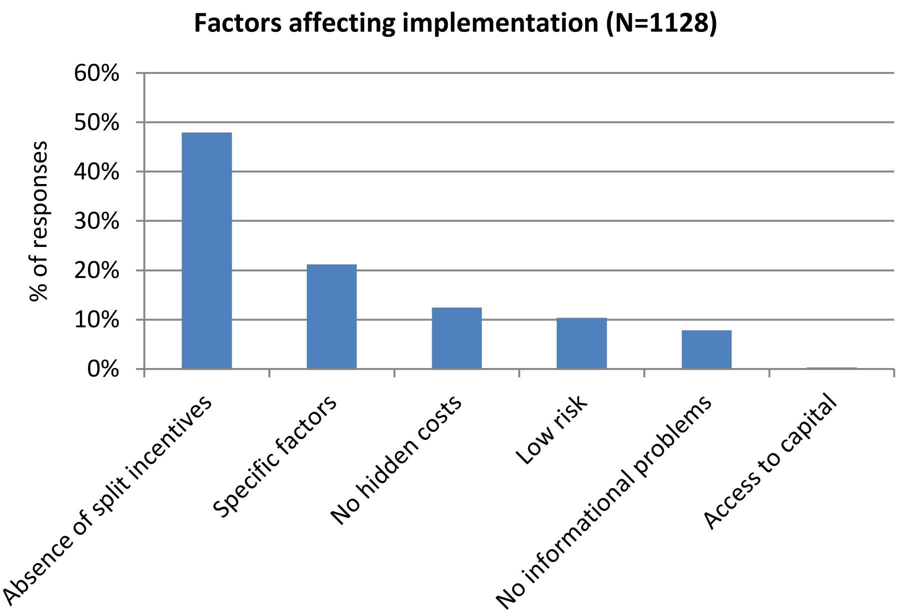


Figure 6.22: Factors affecting implementation

6.4.4. Analysis of measures related to speed

In chapter one, it was highlighted that the speed reduction measure had the highest potential for CO_2 reductions in shipping. The focus of this research is on this operational measure and therefore, it justifies the discussion of this measure separately from the other operational measures that have been suggested. In figure 6.11 it was seen that general speed reduction measure had the implementation rate of just over 60% on average for all those who saw this measure to have a high savings potential. Figure 6.23 decomposes this by sector, it can be seen that the wetbulk and drybulk sectors have similar implementation rate, with the container sector having 75% implementation of the measure (this is not necessarily representative of the whole sector due to the small sample size). This illustrates the heterogeneity amongst the sectors, which arises due to operation in different geographical markets, sector specificity such as the charterparty and bill of ladings etc. Speed reduction due to port efficiency – Just In Time arrivals, has a third less implementation compared to general speed reduction measure (as shown in figure 6.11), which could be because it requires many parties or stakeholders to come together, share information and act upon the information with an increased role by the port or terminal operators. Lack of information sharing between stakeholders as a barrier was cited by 30% of the ninety nine respondents who answered the question on barriers to speed reduction.

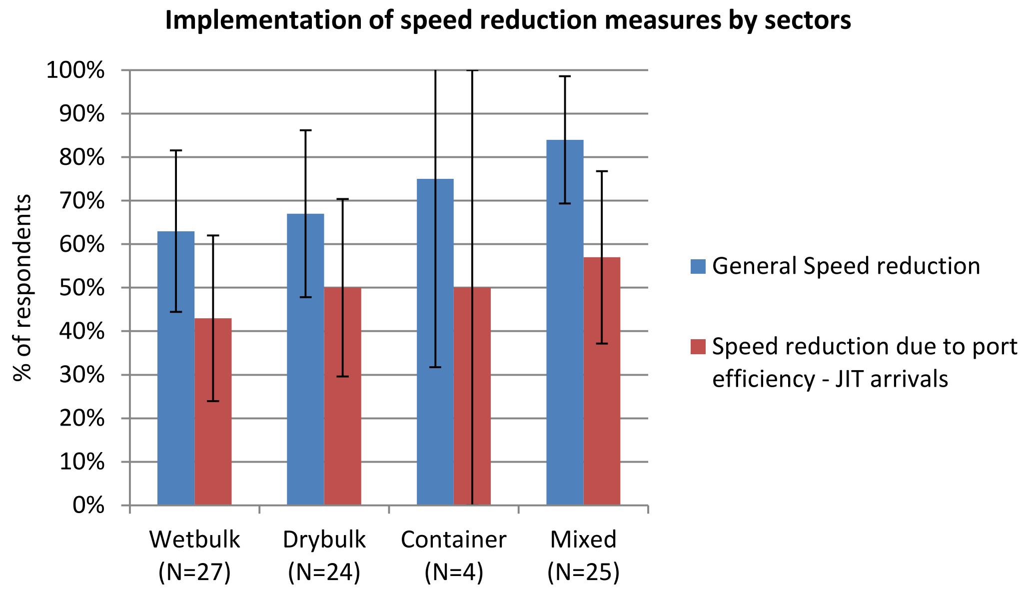


Figure 6.23: Implementation of speed reduction measures by sector

6.4.4.1. Barriers to speed reduction

The respondents who selected 'considering or trialling' or 'considered and decided against' the speed related measure were asked which barriers would prohibit or had prohibited them from implementing the measure. It was clear from their responses that most of them believed it would be difficult to implement speed reduction measures under different types of charter and that charterparty clauses were an important hurdle. For most it is also the case that there may not be enough savings due to the nature of their operations or the costs may outweigh the benefits of such savings e.g. piracy. At this stage the respondents did not think that there was significant risk in sailing ‘off design conditions’ or technical problems would amount to lack of implementation.

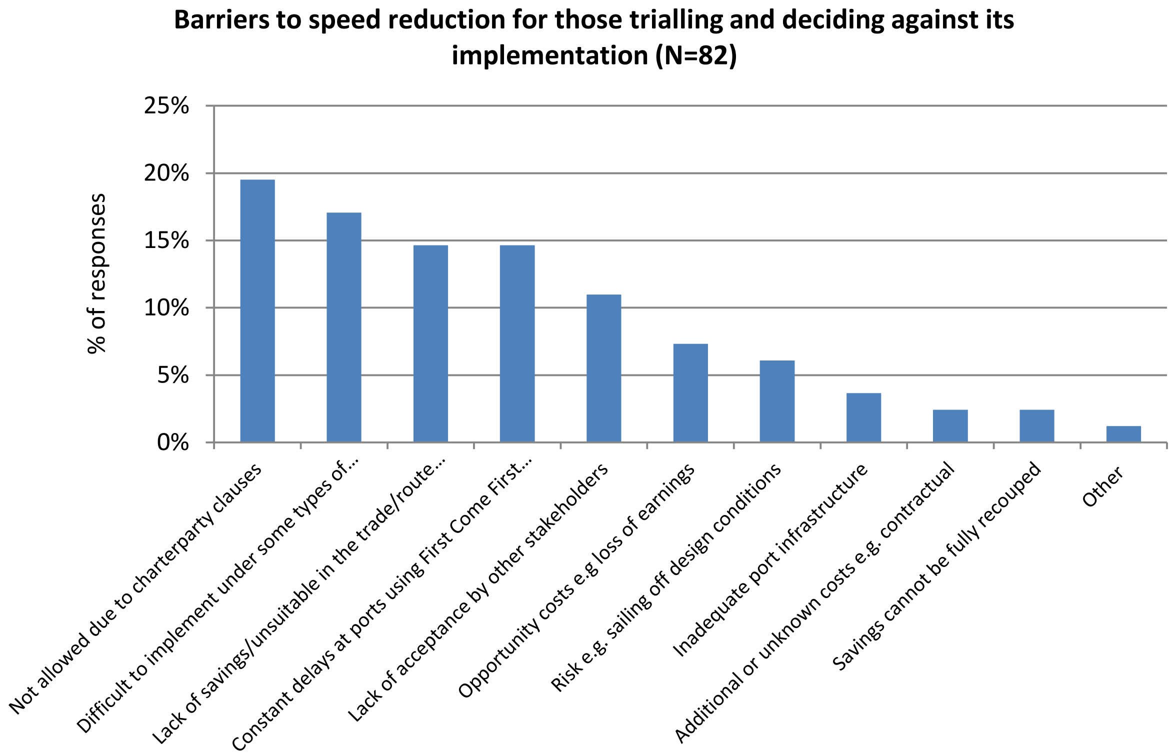


Figure 6.24: Barriers to speed reduction for those trialling and deciding against its implementation

Some of the respondents also noted that it is the charterer who sets the speed in time charters and that the shipowners were not in control of this under this charter;

“*Requested by Charterer*” Large Ship management company

“*Charterers' instructions on Time Chartered vessels*” Anonymous

This to some extent agrees with the following question that asked whether speed reduction is achievable in time and voyage charters. There was a small difference in the respondents’ perception on achievability of speed reduction under voyage and time charters as shown in Figure 6.25 and Figure 6.26. Figure 6.26 breaks down those who said that it was achievable by sector and shows that more wetbulk respondents were of the view that speed reduction is achievable in time charter compared with drybulk respondents who believed that it was achievable almost equally in both types of charter. This view suggests that there may be sector specific issues, such as bargaining power of charterers, sector charterparties, which are resulting in differences in implementation of speed reduction measures. Chapter eight investigates whether and how the charterparties are affecting implementation of speed reduction measures.

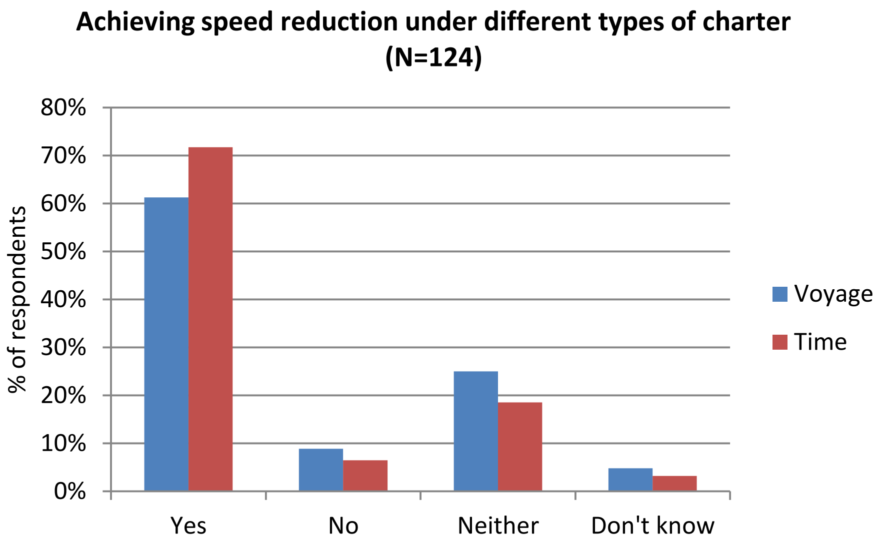


Figure 6.25: Achieving speed reduction under different types of charter

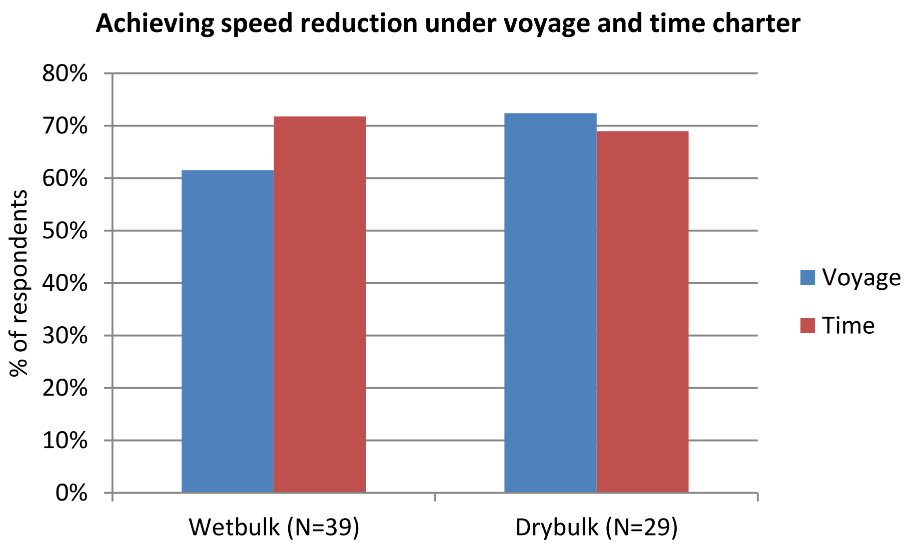


Figure 6.26: Achieving speed reduction under different types of charter by sector

Figure 6.27 shows the responses to the final survey question that was answerable by all survey respondents. Two of the top three barriers to speed reduction are sector specific (similar to institutional barriers in other barriers literature) followed by the lack of information barrier. Many respondents made use of the 'other – please specify' choice to provide their views on barriers to speed reduction, most pointed towards technical problems and opportunity costs, some examples of these are;

"Stakeholder (customer) demands" Medium sized wetbulk shipowner operator

"Voyages fixed at slow speed anyway. We cannot slow down further than the engine will alow - running an engine at slow speed entails operational difficulties. This is the biggest single reason we cannot move ships glacially slow at the moment" Large wetbulk operator

"Competition between shipping lines" Large containership line

"non-commercial due to high hire rate" Large drybulk shipowner-operator

"Main engine limits" Large mixed fleet shipowner-operator

"Engine design" Medium sized drybulk and container shipowner-operator

"Ship engine not designed for long navigation at reduced speed" Medium sized drybulk shipowner-operator

"Technical problems" Small sized wetbulk ship management company

"Charterer orders" Medium sized drybulk shipowner

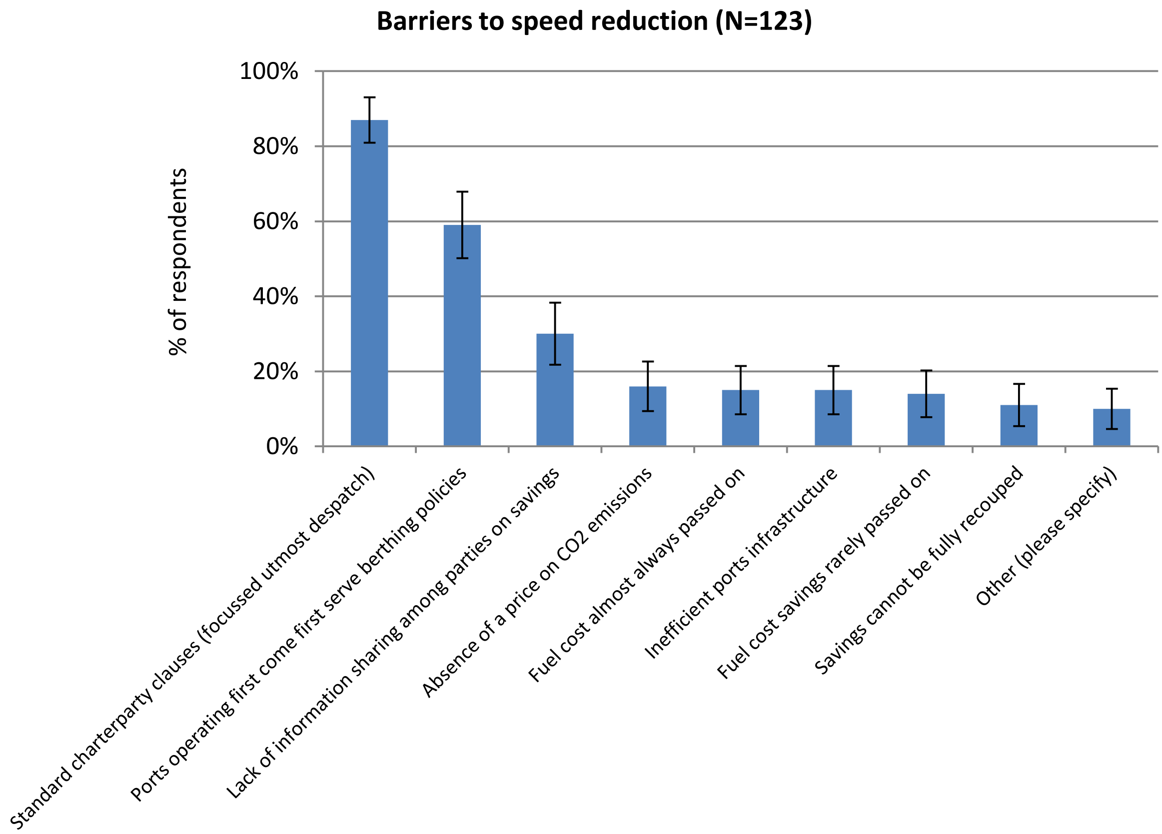


Figure 6.27: Barriers to speed reduction in general

6.4.4.2. Factors driving speed reduction

The respondents who had already implemented or planned to implement speed related measures were asked what factors had the most influence on their decision to implement the measure. The results show that the speed related measures will only be applied if there are sufficient savings in the trade or route of operation, which reflects the heterogeneity of the shipping industry, as not all sectors and trades are the same e.g. coastal shipping and feeder services. Following this, the three most important factors were ‘direct control over operations’, ‘easy to implement under different types of charter’ and ‘ability to recoup savings’. These factors are later analysed in the context of the chartering ratios of the companies in order to examine whether the implementation of measures is affected by the different chartering arrangements of the company. Some of the respondents in the ‘other’ category noted the following:

“Market forces - given very low charter rates, a vessel’s fuel consumption has become very important” Medium sized tanker owning company
“Most efficient measure of all”- Medium sized dry bulk company

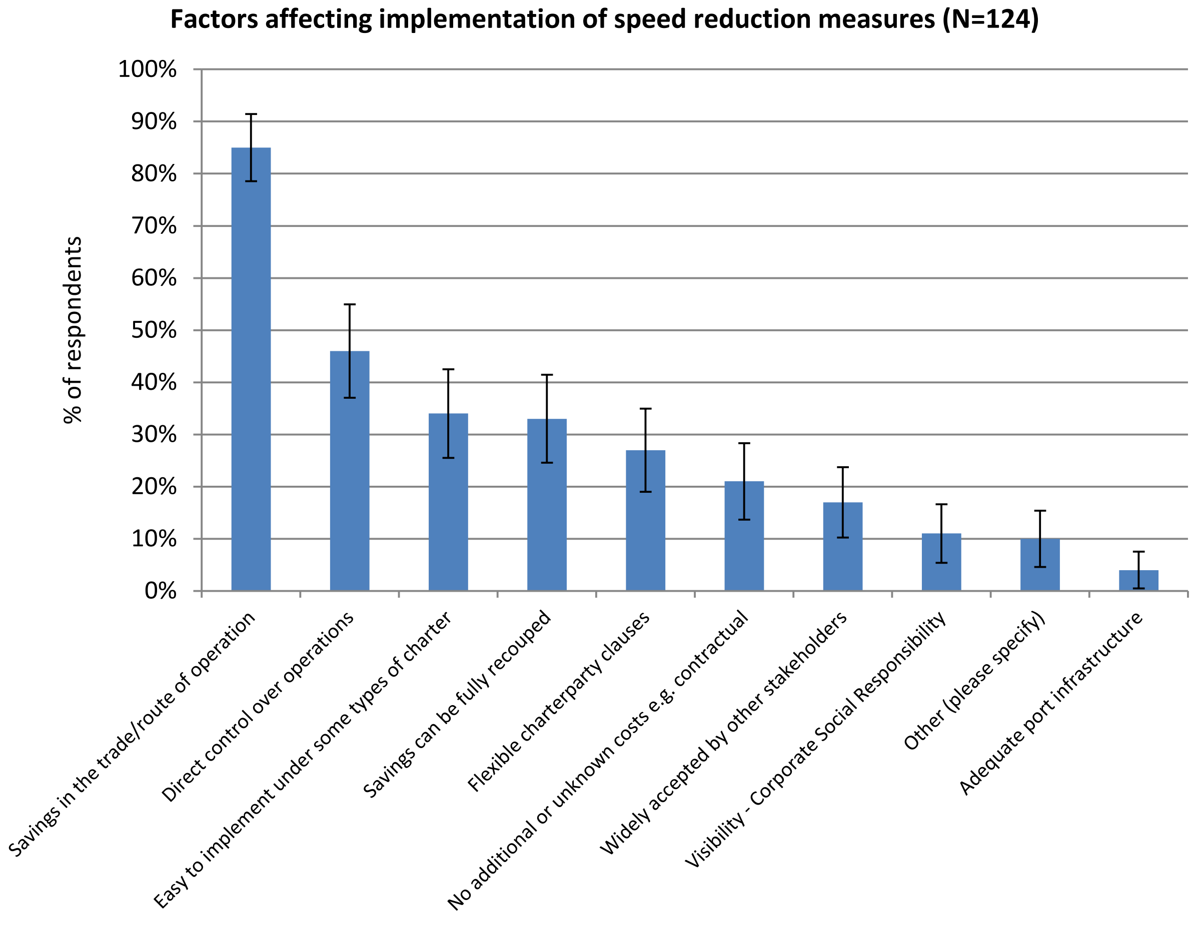


Figure 6.28: factors affecting uptake of speed reduction measures

6.5. Univariate analysis of the chartering independent variable

As mentioned earlier, most of the survey used categorical nominal level measurement of data. However, the final question in the survey asked respondents to enter their fleet profile by asking them what percentage of ships they own and ‘charter in’ and what percentage of these ships do they ‘charter out’ under various arrangements. As mentioned in chapter four and five, this is one of the ways of assessing the level of principal agent or split incentive barrier in shipping. This section describes the data collected on this variable and how this is transformed for use in elaboration analysis in the next chapter. Table 6.9 shows the response rates on this question.

Full responses	100	59%
Partial responses	6	3.5%
Missing responses	64	37.5%
	170	100%

Table 6.9: Response rate for chartering questions

In order to perform bivariate analysis and crosstabulations, the interval level data can be reduced to nominal level data (de Vaus 1995). The responses to the chartering ratio question are split into the following groups shown below in Table 6.10. As can be seen the total number of responses that have been categorised in groups is 71 (42%), whereas there were 100 full responses to the question. The remainder that have not been grouped either did not have similar characteristics to be grouped or were not as prevalent e.g. there were only three cases where majority of the fleet is time chartered in and voyage chartered out.

Group	Description	Grouping rule	N
1	Majority of the fleet is owned and majority of the fleet is chartered out on voyage charter.	>50% owned & > 50% chartered out on voyage	21
2	Majority of the fleet is owned and majority of the fleet is chartered out on time charter.	>50% owned & > 50% chartered out on time	21
3	Management company with majority of its managed fleet out on voyage charter.	>50% chartered out on voyage	9
4	Management company with majority of its managed fleet out on time charter.	>50% chartered out on time	20
			71

Table 6.10: Splitting the chartering ratio interval level data into nominal level data (Grouping A)

For each of the above groups frequency distributions and summary statistics are analysed in order to question how well the interval variable fits in the category. The shapes of the histograms and summary statistics (in appendix C) show that there is a good fit and allocation is valid i.e. in most cases despite the cut of points being 50%, the values generally lay towards the extremes either closer to 100% or 0% as required in each group, with the exception of group one. Other grouping options (grouping B) have also been tested and equally result in as good distributions as the previous grouping. In this second grouping the four subgroups shown above in Table 6.10 have been collapsed into two subgroups as shown in Table 6.11, where the grouping does not take into account the ownership of the fleet, rather it is just concerned with the chartering out levels. This grouping has more responses in each category and will therefore allow for more simpler and populated crosstabulations. In the following chapter both of these groupings are used in the crosstabulations, depending on the level of complexity and iterations required in the elaboration analysis.

Group	**Description**	**Grouping rule**	**N**
1	Majority of the fleet is chartered out on voyage charter.	> 50% chartered out on voyage	30
2	Majority of the fleet is chartered out on time charter.	> 50% chartered out on time	41
			71

Table 6.11: Splitting the chartering ratio interval level data into nominal level data (Grouping B)

Using the second grouping option as shown in Table 6.11 above, the implementation level of the two groups is shown in Figure 6.29 and Figure 6.30 along with summary statistics on the average rate of implementation of the two groups in Table 6.13. Figure 6.29 shows that in most instances, the implementation by the group that has the majority of its fleet chartered out time (group two) exceeds that of the group that has the majority of its fleet chartered out on voyage (group one). On average, three measures were implemented by group one compared to a slightly higher average of 3.24 by group two. A comparison of means test suggests that the means of the two groups are not statistically different (95% CL). Although this is a zero order relationship (not controlled for other background variables), Figure 6.29 suggests that there may be some difference in implementation even if it is not statistically significant at the aggregate level.

The difference in implementation between the two groups can be explained by the principal agent problem and the analysis conducted in the preceding chapter. It was suggested that principal agent problems would not be as pervasive in the time charter in the context of operational measures because the fuel cost is borne by the charterer and the charterer is in some control of the operations. Therefore, it could be said that operational measures are more favourable to time charterers e.g. weather routing and fuel consumption monitoring (which enable monitoring) and general speed reduction (due to the power of dictating charterparty speed) and thus have a higher implementation in those chartering groups.

Figure 6.33 shows the differences in perception of barriers to energy efficiency of the two chartering groups (grouping B). The majority of the differences lie in the indicators of split incentives barriers. Comparing the perception of respondents with actual implementation there seems to be some contradiction in the conclusions. The above analysis on implementation showed that the group with a majority of the fleet on time charter had higher implementation on average across all the measures but it seems that at the same time this group perceived the lack of direct control and difficulty in implementing under various types of charter more of a problem than the other group. The following chapter investigates the relationship of the top three measures with the chartering group, controlling for other independent variables to test whether the implementation of measures and perception of barriers hold, which would describe more validly how the principal agent problem affects the implementation of measures.

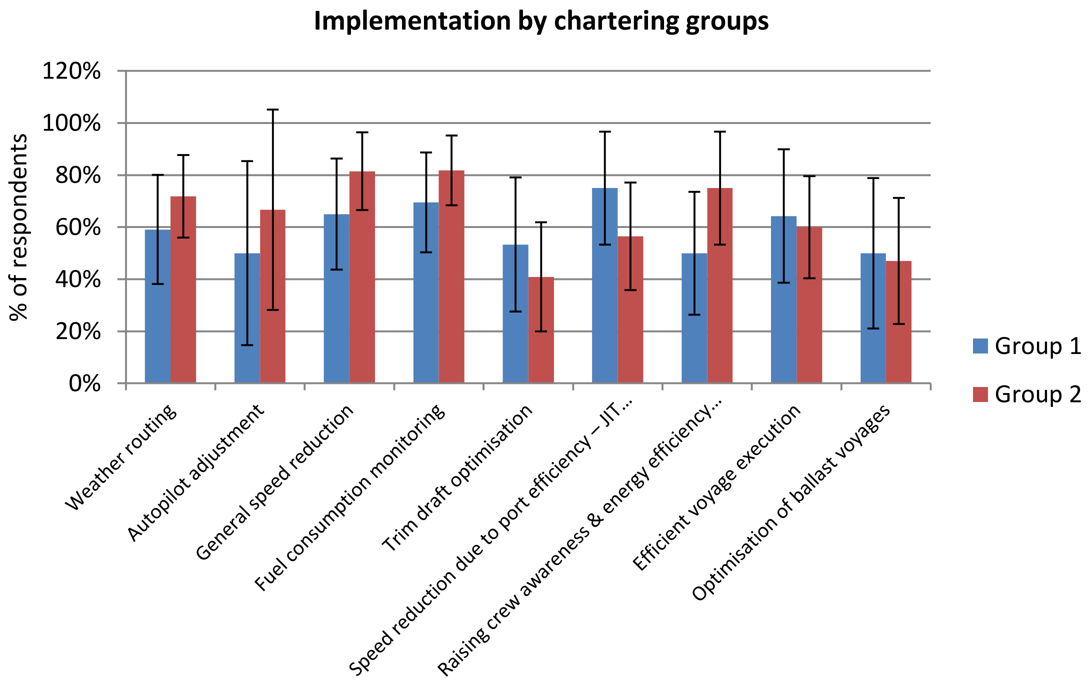


Figure 6.29: Implementation of operational measures by chartering groups

	Group 1	**Group 2**
Weather routing	22	32
Autopilot adjustment	8	6
General speed reduction	20	27
Fuel consumption monitoring	23	33
Trim draft optimisation	15	22
Speed reduction due to port efficiency – JIT arrivals	16	23
Raising crew awareness & energy efficiency training	18	16
Efficient voyage execution	14	25
Optimisation of ballast voyages	12	17

Table 6.12: Total number of respondents for implementation per measure by chartering group

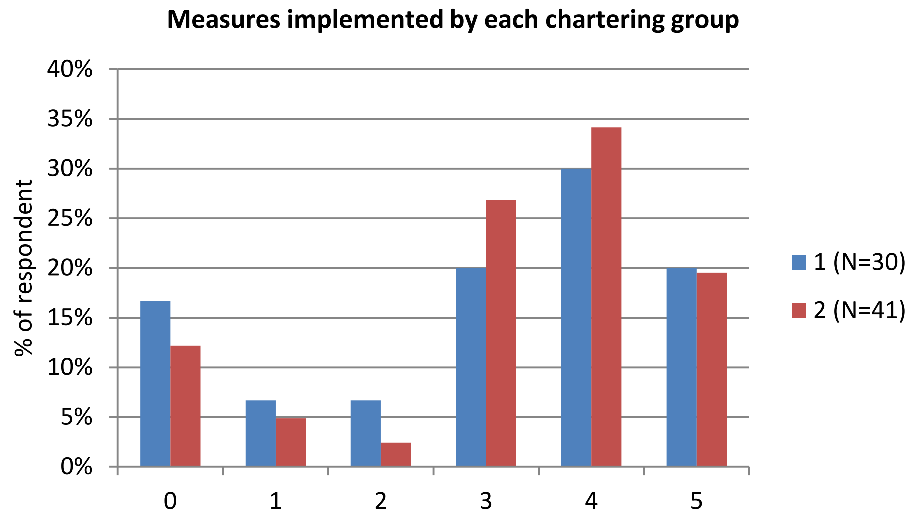


Figure 6.30: Number of measures already implemented by chartering groups

	Group 1	Group 2
Mean	3.00	3.24
St Dev	1.74	1.56
SE	0.318	0.244
95% CI	2.36 – 3.64	2.76 – 3.73

Table 6.13: Summary statistics for number of measures implemented by chartering groups

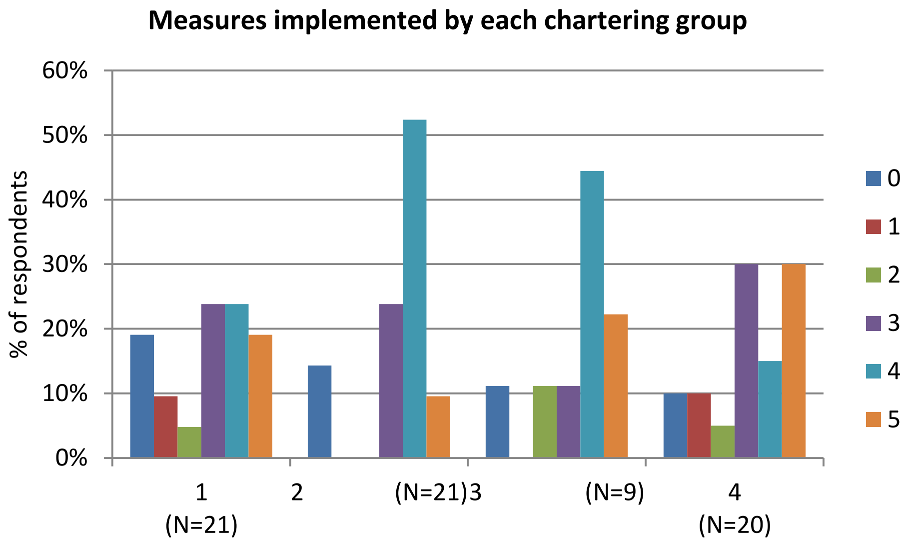


Figure 6.31: Measures implemented by each chartering group

	Group 1	Group 2	Group 3	Group 4
Total Measures already implemented	59	69	31	64
Maximum measures that could be implemented	105	105	45	100
Average number of measures implemented	2.8	3.3	3.45	3.2

Table 6.14: Summary statistics for measures implemented by each chartering group

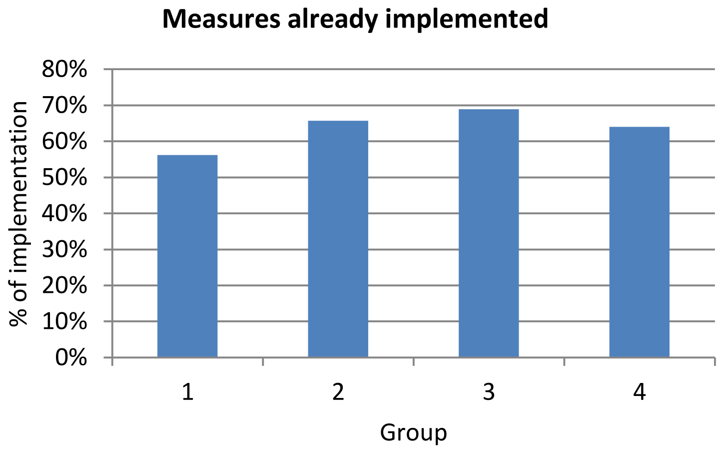


Figure 6.32: Average rate of implementation by chartering groups

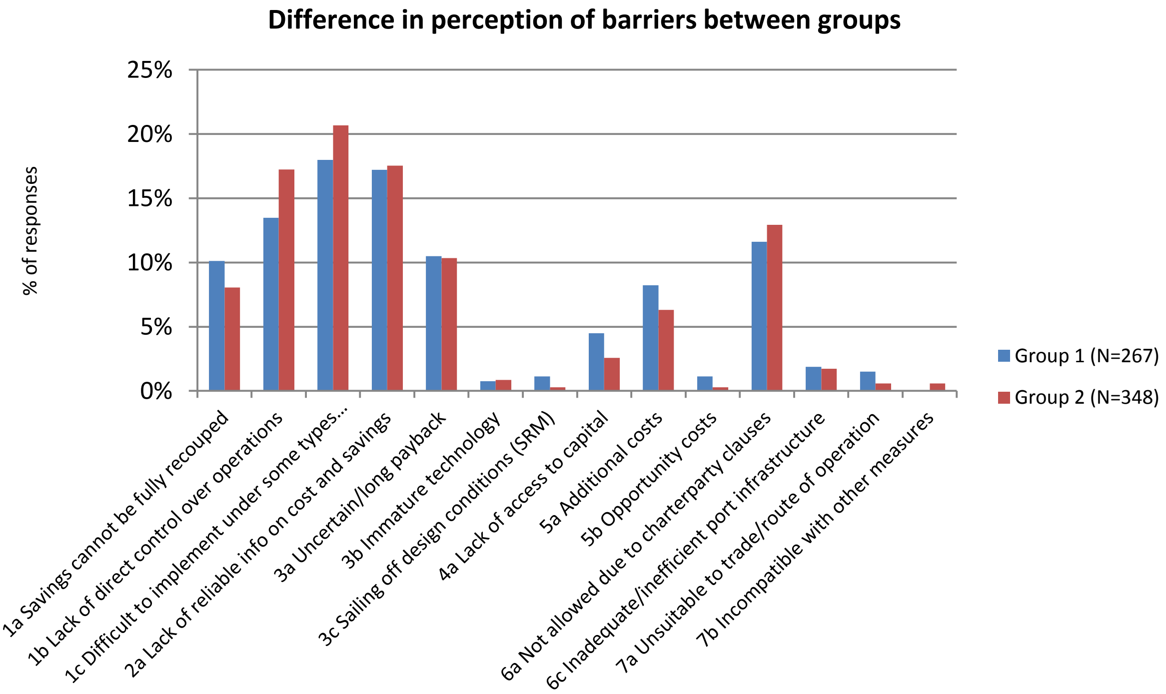


Figure 6.33: Difference in perception of barriers between chartering groups

6.6. Concluding remarks

The respondents to the survey generally represented well the stratified sampling frame (by size and sector), although there was a very high number of responses that came from European countries, which represent 55% of the large and medium firms in the census population. The measures believed to have the highest fuel saving potential, especially the top three measures, were also highly implemented, suggesting a high correlation between potential of the measures and their implementation, however these were not as high as expected, which suggests that to some extent there may be some factors affecting their implementation. The key barriers to the implementation of all the operational measures as perceived by the respondents were the difficulty of implementation under different types of charter, lack of reliable information and lack of direct control over operations. These respondent choices were indicators for the split incentives and informational problems, suggesting that the main type of barriers to implementation of operational measures are market failures rather than non-market failures. It is also observed that there are specific barriers pertaining to each of the measures, informational problems mainly affect the more technical operational measures such as weather routing, autopilot adjustment, trim/draft optimisation, whereas split incentive barriers affect measures mainly related to speed (general speed reduction and Just In Time arrivals) or those that had an element of speed (efficient voyage execution and optimisation of ballast voyages). In chapter five it was concluded that the time charter will be less exposed to the principal agent efficiency problem because the charterer pays for fuel and has some control over the vessel or operations, but that this exposure varied between wetbulk and drybulk. The preliminary analysis of the chartering group variable corroborates with this conclusion, as it showed that the group with a majority of the fleet on time charter generally had higher implementation, but it was not possible to disaggregate these results further by sector, in order to verify the sector specific conclusions from the preceding chapter. This chapter provided a first analysis of the survey results, however the analysis presented could not result in specific and valid conclusions as many relationships between the variables were not controlled for. The following chapter attempts to answer the research questions by focussing on a few measures in order to draw some conclusions through controlling relationships between the independent and dependent variables.

7. Survey results further analysis

In this chapter, variables that were discussed in the univariate analysis are revisited in order to further explore and investigate relationships that may exist between them, which will enable answering aspects of research questions one and two that involve more than one variable. This chapter concentrates mainly on one method of bivariate analysis as shown in Table 6.1, the crosstabulation. Crosstabulations are a way of displaying data so that association between two variables can be fairly readily detected (de Vaus 1995). This method is used in parallel with the basic procedures of the elaboration model as well as combining the use of descriptive and inferential statistics, in order to make broader generalisations and inferences for the specific research questions on implementation of energy efficiency measures and barriers to their implementation.

The chapter begins with a brief section explaining the elaboration model, followed by elaboration analysis for implementation of the top three operational measures and perception of the top two barriers to energy efficiency. This chapter deals with the implementation of energy efficiency measures and barriers to implementation components of the research framework as proposed in chapter three, highlighted in Figure 7.1. In chapter nine the discussion will bring together the findings from this analysis with analysis from other methods to explain why particular effects and relationships are observed.

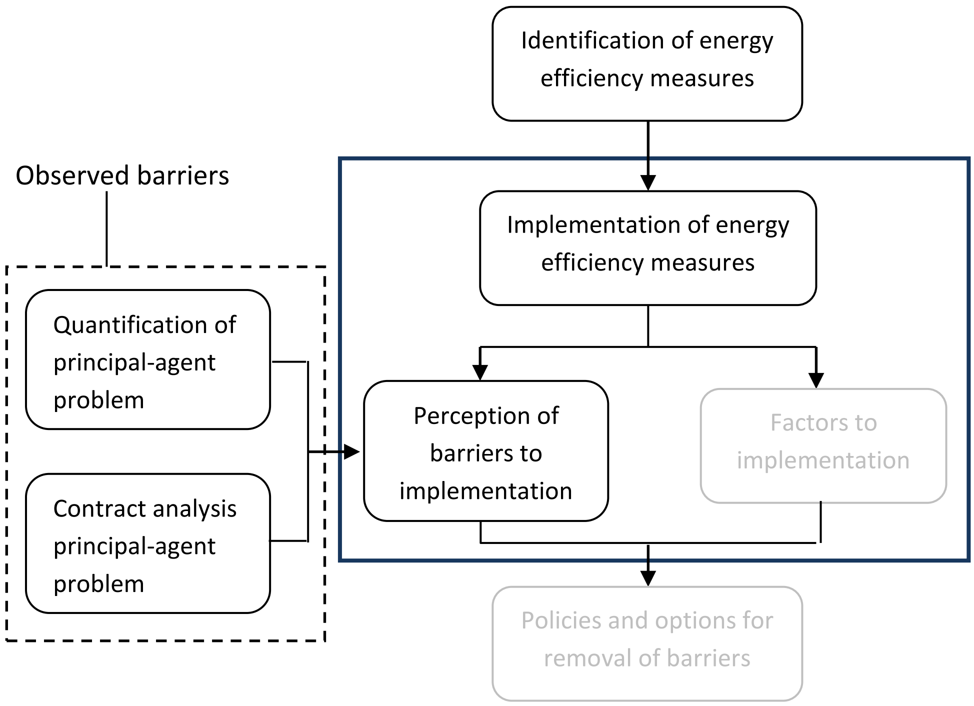


Figure 7.1: Focus of this chapter and the research framework

7.1. Bivariate elaboration analysis

Bivariate analysis is the analysis of two variables at a time in order to uncover whether two variables are related (Bryman 2008). "The heart of bivariate analysis is to see whether two variables are related or associated" (de Vaus 1995, p154). Bivariate analysis is the first step in explaining the differences that are seen in univariate analysis. It can be used to partly explain relationships which could then be further analysed through multivariate analysis. Bivariate analysis and use of crosstabulations is relevant to this research because of the cross-sectional research design that is employed and the use of categorical (nominal) variables in most of the survey questions. Alternative methods of bivariate analysis such as comparison of means, scattergrams, regression analysis etc. are of limited value to the analysis because nominal level data is lower than interval level measurement.

Once an initial relationship is established between two variables, elaboration analysis will allow for investigation of this relationship under a variety of different conditions. The elaboration model was developed principally by Paul Lazarsfeld and his associates in 1950 (Babbie 2004). Elaboration analysis can help to answer why a relationship exists, what is the nature of the relationship (causal or non-causal) and the generality of the relationship (de Vaus 1995) by introducing controls (comparing like with like) at the data analysis stage. Thus, the elaboration analysis is moving further from correlation (or establishing relationships) and is more about causality or causation "Elaboration analysis enables us to refine our understanding of the means by which X affects Y" (de Vaus 2002, p 299). The elaboration model has been suggested by Babbie (2004) to offer the clearest available picture of the logic of causal analysis in social research. Apart from elaboration analysis, other techniques for bivariate analyses are effects analysis, path and flow analysis (Davis 1985). Elaboration analysis is relevant to this research because it is one of the various "survey-based approaches to analysing survey data" (de Vaus 2002, p.297). The survey variables, recalling from chapter four, are:

- Dependent variables – what the research is trying to explain, in this case implementation of measures, perception of barriers and driving factors.
- Independent variables – causal variables, in this case sector, size and chartering group.

The survey sample respondents can be divided into groups (i.e. sample subgroups) on the basis of which category of the independent variable they belong to and these subgroups are compared with other independent variable subgroups in terms of the dependent variable. So for example the sample could be divided in size groups and their responses to perception of barriers can be compared. Differences in groups might be taken to be the influence of group membership, but this can only be said if the groups are alike in all other respects (de Vaus 1995). Elaboration analysis makes use of multiple statistical controls to control for other variables for explanation of the zero order relationship i.e. when other things are equal does X (independent variable) make a difference to Y (dependent variable). This approach is to some degree limited in its use in this research because controlling for more than two test variables simultaneously leads to very small subgroups and sparsely populated crosstabulations resulting in inflated correlations and problems of statistical reliability.

7.1.1. The elaboration model

This section delves further into the elaboration model and it is important to detail this here because the majority of this chapter will rely on the interpretations of the elaboration model. The basic procedure of elaboration analysis has four steps as outlined by de Vaus, (1995 and 2002);

1) Look at zero order relationship
2) Select a test variable and assess the new conditional relationship
3) Compare conditional relationship with zero order relationship
4) Interpret using the below interpretations.

It is also important to visually examine the conditional tables (crosstabulation for each category of the test variable) to describe the relationship in context of the data and zero order relationship (Babbie 2004). When statistical controls are introduced the following outcomes are possible;

- Explanation: this is when spurious relationships are detected i.e. when two variables have apparently high correlation, yet have no direct causal connection, thus both could be a consequence of another common cause. A relationship is said to be spurious when the third variable is held constant or controlled and the relationship between the initial two variables (zero order relationship) disappears. This implies that the conditional relationship is small or the relationship can be explained away (Babbie 2004). The test variable is determined before (in time) independent and dependent variables, and thus called the antecedent variable (Babbie 2004) or extraneous variable (de Vaus 2002). The independent variable must be capable of being changed by test variable and the test variable must precede both independent and dependent variable in time, for a relationship to be called spurious (de Vaus 2002).

  Rule: If zero order relationship (correlation coefficient) decreases for independent and dependent variables = spurious relationship

If zero order relationship (correlation coefficient) persists for independent and dependent variables = no spurious relationship, it could be any of the outcomes below.

- Interpretation: This is when indirect causal relationships are detected. Two variables can be said to be causally linked by an intervening (mediating) variable. An intervening variable is one that occurs between the independent and dependent variable, providing an indirect causal link between variables. The patterns of results detected are the same as spurious relationships but the differentiating factor is the logical or theoretical understanding of the variables and the timeliness of the intervening variable (i.e. in between X and Y variables) (de Vaus 1995). The test variable comes between (in time) independent and dependent variables, thus called mediating variable (Babbie 2004) and therefore the test variable must also be capable of being changed by the independent variable (de Vaus 2002).

  Rule: If zero order relationship (correlation coefficient) decreases for independent and dependent variables = intervening variable found

  If zero order relationship (correlation coefficient) persists for independent and dependent variables = no intervening variable found, it could be any of the outcomes below.

- Specification: This is when the relationship between the original two variables differs according to the category of the test variable, i.e. the relationship holds for some categories of the test variable and does not hold for another category of the same test variable. In other words the relationship between independent and dependent variable might be specific to some subgroups. When this happens the original relationship can be said to be moderated by the test variable, thus called the moderator variable (Bryman 2008). This means that the original independent variable does not have an effect on its own but has a special effect when it occurs in combination with a particular category of the test variable. Babbie (2004) defines statistical interaction when partial relationships differ significantly from each other and therefore the above rule from de Vaus (1995) in direction of the conditional relationship is not necessary.

  Rule: If zero order relationship (correlation coefficient) decreases for one category of test variable and increases (or persists) for another category = specification effect found

- Replication: This is when a zero order relationship persists for all categories of the test variable which means that the initial relationship is not due to the influence of the test variable. The more control variables tested for, the tougher the test of the original relationship and it increases our confidence that it is a real and direct relationship which cannot be easily explained away (de Vaus, 1995). In the elaboration analysis that follows it may not be possible to control for multiple variables simultaneously, because of the large sample sizes needed.

Rule: If zero order relationship (correlation coefficient) decreases = no replication found, could be any of the above outcomes.

If zero order relationship (correlation coefficient) persists = replication found

Relationships	**Interpretation**
When conditional relationship is significantly less than zero order relationship (and test variable comes before X and Y variables)	Spurious relationship (non-causal), explanation
When conditional relationship is less than zero order relationship (and test variable comes in time between X and Y variables)	Indirect causal relationship with intervening variable, Interpretation
When conditional relationship is split with zero order relationship	Specification
Conditional relationship is much the same as zero order relationship	Replication (directly causal)

Table 7.1: interpretation of conditional relationships summary

7.1.2. Extensions to the elaboration model

The preceding section presented the main logic of the elaboration model. Several attempts have been made to refine the model to reflect the variety of results from real life data e.g. Rosenberg (1968). de Vaus (2002) further expands on the different types of relationships between two variables. The difference in this extension is that a relationship can also be 'partial' i.e. some combination of the aforementioned outcomes. This is more realistic of the real life data analysis but results in numerous types of relationships, for example previously there was only one definition of a spurious relationship, however in this extended model three types of spurious relationship can exist, i.e. spurious with direct, spurious with indirect and purely spurious relationship. Table 7.2 below shows the various relationships that may be found in the elaboration analysis of the survey results.

One outcome that has not been discussed in detail in the literature and is thought to be important or relevant to this research (as shall be seen in the conditional table summaries) is how does one explain the outcome where one category of the conditional relationship is similar to the zero order relationship and the other category of the conditional relationship is even stronger? Babbie (2004) describes only briefly that this means that one has specified one condition under which the original relationship holds, but at the same time one has also specified another condition under which it holds even more clearly. Similarly, other outcomes of the elaboration analysis observed in this research come from further refinements to the elaboration model from Babbie (2004) regarding suppressor variables, variables that conceal the original zero order relationship between two variables. This is when the zero order relationship does not show any relationship between the independent and dependent variable, but when a test variable is controlled for, the original relationship between categories of the test variable show an improvement, thus the test variable can be said to suppress the original relationship (Babbie 2004). When the original relationship is not controlled, the relationship would be weaker than it otherwise would be (Rubin & Babbie 2008). This is because the suppressor variable and the independent variable may be related. Given this relation, some prefer to call the suppressor variable an enhancer variable (McFatter 1979 cited by Pandey & Elliot 2010).

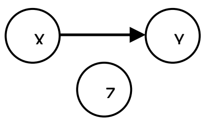
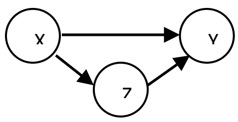
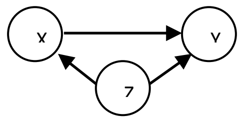
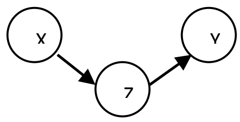
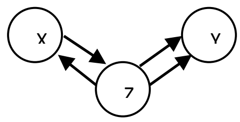
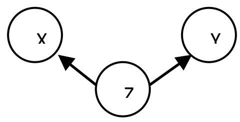
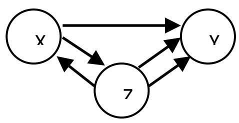
	Directly causal	Indirectly causal	Spurious
Directly causal			
Indirectly causal			
Spurious			
Spurious, indirect and direct 			

Table 7.2: The extended elaboration model

7.2. Data preparation and data analysis plan

7.2.1. Collapsing categories

In many instances, the original survey categories have been collapsed or combined into few categories, e.g. implementation and chartering groups variables. This was most importantly done because using bivariate elaboration analysis results in a separate table for each category of the test variable and having too many conditional tables will not allow for meaningful interpretation. Other justification for collapsing categories are that only the categories that are of interest to the research are reflected, in order to keep the cells in crosstabulation adequately populated in order to avoid distortion of some statistics (de Vaus 1995).

7.2.2. Summated scaling

Several indicators of various barriers were placed in questions throughout the survey. In order to represent the barriers perception of respondents, a summated scale of choices to the questions is produced. This scale score is then used to indicate the respondent's position on the perception of barriers. According to de Vaus (1995) one can produce satisfactory scales by conceptually and empirically testing the scale. The survey captured perception on barriers in two main ways as explained in section 6.4.2. These were summed into a scale using only the conceptual method, i.e. ensuring the categories conceptually belong together, which is also followed by Sorrell et al. (2000 and 2004).

In chapter six, the interval level data on chartering ratio was reduced to nominal level data by creating groups, which is similar to grouping the exact age or income (interval variable) into several groups or bands (categorical variable) (de Vaus 1995). The chartering ratio data were broken down into four different groups of chartering ratio (grouping A) or two different groups of chartering ratio (grouping B). The grouping into four chartering subgroups reflected ownership and chartering out of the fleet and the distribution better reflected the characteristics (i.e. frequencies in opposite ends) but the problem encountered was the small size of the subgroups, whereas the second grouping option leads to larger sample size but does not result in as good a fit as the former approach. For the crosstabulations method of analysis this is not a problem, however for the appropriate inferential statistic (Pearson's chi-square test) small sample sizes are a problem because in "small samples, the approximation (to the chi square distribution) is not good enough" (Field 2009) as it results in expected frequencies that are too low (less than five). Fisher's exact test can accurately calculate the exact probability of the chi square statistic when the sample size is small. It can be used on two by two crosstabulations as well as larger crosstabulations. This means that the four subgroups can be used as well as the two subgroups, with varying descriptive and inferential statistics. Subsequently, four chartering subgroups are used because it is thought that the ownership of fleet will provide more context to the analysis. The size and sector independent variables also have three and four categories. Since the container sector had very low response rate, it is removed as a category of the sector variable. Since the variables are all nominal (or reduced to nominal level in the case of chartering group) crosstabulations analysis will only reveal the strength of the relationship between the independent and dependent variables, direction and linearity of relationships are not possible for nominal level data. Figure 7.2 below takes this into account and shows the relevant statistics for this analysis.

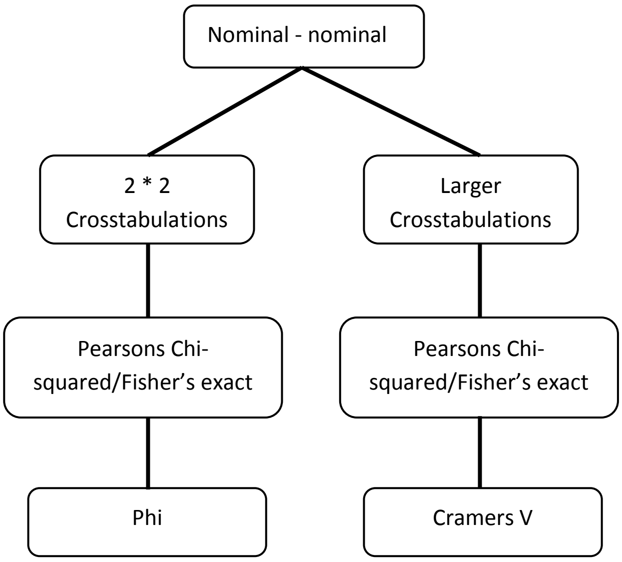


Figure 7.2: Selection of methods and relevant statistics in elaboration analysis

		Holding/test variables		
Dependent variables relationship with...		**Size**	**Sector**	**Chartering group**
	Size	Zero order relationship	Conditional relationship	Conditional relationship
	Sector	Conditional relationship	Zero order relationship	Conditional relationship
	Chartering group	Conditional relationship	Conditional relationship	Zero order relationship

Chi-squared Fisher's Exact	Sig Sig
Phi Cramer's V	Sig Sig

Table 7.3: Elaboration analysis in this research

7.3. Statistics and procedures appropriate for this analysis

This section very briefly describes the aforementioned statistics used to assess the strength of relationships between variables in the survey data. The information about the association shown in crosstabulation table can be summarised using correlation coefficient, which is an index that describes the character of relationship between two variables (de Vaus 1995). Of relevance to this research (because of nominal level data) are chi square based coefficients. These statistics show how the actual frequencies in the crosstabulation differ from the expected frequency i.e. when there is no association (Field 2009). The raw chi square figure is converted into an index using phi and Cramer's V. Phi is used with two by two crosstabulations and Cramer's V is used when one or both of the variables have more than two categories (Field 2009).

In the previous chapter, the univariate analysis of nominal variables mainly used interval estimates to make inferences to the population. In this chapter, after assessing the association of two variables, inferences are made using tests of significance. These tests assess the likelihood of the sample obtained being inaccurate due to sampling error, thus lower significance levels suggest that the observed association is likely to persist in the population. Conventionally 0.05 and 0.01 are used as the critical points, which are arbitrary but as a rule of thumb for small samples it is suggested to use 0.05 as the critical point (de Vaus 1995). In chapter four, Table 4.3 showed that this would not be possible due to the small sample size, which reduces even further during crosstabulation. Because of the small sample sizes it is recommended to use the Fisher's exact test, as it overcomes the problem that with small samples the sampling distribution deviates from the chi square distribution (Field 2005a). There has been considerable debate on the weight that has been placed on statistical inference. Field (2005) and Ellis (2010) suggest that effect sizes are more important (examples of which are correlation coefficients aforementioned) because they provide an objective measure of the importance of an effect. Cohen's (1988) widely accepted interpretation of effect sizes is that; 0.1 is a small effect size, 0.3 is medium or moderate effect size and 0.5 is a large effect size. de Vaus (1995) suggests that both, descriptive and inferential statistics complement the data analysis, however knowing that the sample results will hold in the population is useful additional information but is ineffective unless the sample data is first thoroughly and imaginatively analysed.

It is also important to briefly review some of the assumptions that lie behind some of the statistics that will be used for the analysis. The correlation coefficients aforementioned assess whether there is a linear relationship between the variables of interest. It may be that some of the relationships are non-linear for example, implementation of a measure with chartering ratio. Secondly, a response distribution of 50% is used for all statistics, this means that the prediction about the general population is symmetrical, for example 50% of the population will answer 'yes' and 50% will answer 'no' to a question e.g. on implementation. In reality this may be different but changing this parameter to a different level e.g. 60:40 split, requires support from existing literature, therefore setting the response distribution to 50% is the most conservative assumption (de Vaus 1995).

7.4. Assessing correlation between the test variables and independent variables

The second step of the elaboration model requires controlling for a test variable. de Vaus (2002) suggests the following criteria for selecting the appropriate test variables;

1. They must be from among the variables in the data set
2. Must make sense theoretically
3. Test variable must be correlated at zero order level with both independent and dependent variables.

This section mainly tests for the correlations between size, sector and chartering group variables, which are interchangeably used as independent and test variables. The justification for this is that it is not known whether there exists a causal relationship between the aforementioned variables, e.g. it could be that size of the company affects the chartering group or vice versa, or it could be that sector affects the chartering level of the firm or that a certain size group is more prevalent in a particular sector (i.e. related). Secondly, unlike social research variables, such as gender, it is not possible to assess the timeline of the variables, e.g. which of the above variables come first in time, allowing for determining causation.

From Table 7.4 below it can be observed that there are almost three times more large companies in the wetbulk sector compared to drybulk sector. Table 7.6 shows there are more of chartering groups one and two in drybulk sector compared to the wetbulk sector and vice versa for groups three and four. Grouping the charter groups by voyage charter and time charter for each of the sector as shown in Table 7.7, does not reveal similar patterns to that observed in chapter five for each sector, which shall be discussed in the discussion chapter.

	Small (N=28)	Medium (N=65)	Large (N=19)
Wetbulk	43%	26%	47%
Drybulk	36%	26%	16%
Container	4%	6%	5%
Mixed	18%	42%	32%

Table 7.4: Correlation between size and sector (all)

	Small (N=16)	Medium (N=47)	Large (N=8)
Group 1	38%	26%	38%
Group 2	25%	34%	13%
Group 3	6%	15%	13%
Group 4	31%	26%	38%

Table 7.5: Correlation between size and chartering group

	Wetbulk (N=20)	Drybulk (N=18)	Container (N=4)	Mixed (N=26)
Group 1	20%	56%	0%	23%
Group 2	20%	33%	75%	23%
Group 3	20%	6%	0%	15%
Group 4	40%	6%	25%	38%

Table 7.6: Correlation between sector and chartering group

	Wetbulk (N=20)	Drybulk (N=18)
Majority on voyage charter	40%	62%
Majority on time charter	60%	38%

Table 7.7: Correlation for types of charter prevalent in the bulk sectors

From the above analysis and summary Table 7.8, it can be seen that there is a strong and significant relationship between sector and chartering group and when controlling for size the relationship gets even stronger and is still found to be significant, suggesting that size is a suppressing variable for the zero order relationship. The implication of this strong relationship is that in the following analysis when the relationship between size and a dependent variable controlling for chartering group or sector will overlap, thus the impact of chartering group or sector as test variables would be inflated.

	Size and sector	**Size and charter group**	**Sector (bulk) and Charter group**
Zero order relationship	Chi^2 = 8.04 (p .234) FE = 8.19 (p .195) CV = .190 (p .234) Phi = .268 (p .234)	Chi^2 = 3.109 (p .820) FE = 3.241 (p .804) CV = .148 (p .820) Phi = .209 (p .820)	Chi^2 = 10.139 (p .015) FE = 9.892 (p .015) CV = **.517** (p .015) Phi = .517 (p .015)
Controlling for	Charter group	Sector (bulk only)	size
	Group 1 Chi^2 = 8.54 (p .075) FE = 7.5 (p .064) CV = **.462** (p .075) Phi = .653 (p .075)	Wetbulk Chi^2 = 5.79 (p .533) FE = 5.36 (p .551) CV = .381 (p .533) Phi = .538 (p .533)	Small Chi^2 = 6.67 (p .071) FE = 5.55 (p .071) CV = **.816** (p .071) Phi = .816 (p .071)
	Group 2 Chi^2 = 8.44 (p .173) FE = 7.73 (p .134) CV = .471 (p .173) Phi = .667 (p .173)	Drybulk Chi^2 = 4.11 (p .368) FE = 3.91 (p .368) CV = .478 (p .368) Phi = .478 (p .368)	Medium Chi^2 = 7.93 (p .045) FE = 7.3 (p .054) CV = **.575** (p .045) Phi = .575 (p .045)
	Group 3 Chi^2 = 2.57 (p 1) FE = 3.79 (p 1) CV = .378 (p 1) Phi = .535 (p 1)		Large All large companies only in wetbulk sector.
	Group 4 Chi^2 = 2.26 (p .940) FE = 3.574 (p .940) CV = .238 (p .940) Phi = .337 (p .940)		

Table 7.8: Zero order and conditional relationships between independent variables.

7.5. Implementation of measures

This section aims to investigate the relationship or association between the implementation of a particular measure (whether it has been implemented or not) and the characteristics of firms, such as their size, sector in which they operate and their chartering levels. This is done only for the three most implemented measures (representing almost 50% of total responses) from question two of the survey that were believed to have the highest fuel saving potential, not only because it is believed that deeper understanding on these would provide a rich picture of the interactions of the variables, but also the high number of respondents would mean that data analysis would not suffer from small sample sizes.

The null hypothesis in the following analysis would be that there is no relationship between the implementation of a measure and each of the independent variables. The alternative hypothesis is that there is a relationship between implementation of a particular measure and each of the independent variables, however since there is no knowledge of the direction of the relationship, a two tailed significance test is used for each test. The following analysis follows the elaboration model steps outlined in section 7.1, beginning with zero order relationships and then moving to conditional relationships.

7.5.1. Weather routing implementation

In the preliminary analysis chapter it was seen that 70% of the respondents thought that weather routing measure had the highest fuel saving potential and just under 70% (78 out of 114) of the respondents who selected this measure had already implemented this measure. Bar charts that disaggregated these results in the preliminary analysis at the zero order level showed that large companies had the highest level of implementation followed by medium sized and lastly small companies with the lowest level of implementation. This section tests for the relationship that exists between its implementation and other firm characteristics.

7.5.1.1. Relationship of implementation of weather routing with size

The alternative hypothesis being tested here is that there is a relationship between implementation of weather routing measure (Y variable) and size of the company (X variable). In order to see how (i.e. spuriously, directly, indirectly etc.) size (X) affects implementation of weather routing measure (Y) (zero order direct relationship) two test variables are introduced separately, the sector (Za) the firm operates in and the firm's chartering level (Zb). Sector is introduced as a test variable because it is plausible that the difference in implementation may be partly explained by this variable. From the survey preliminary analysis (Figure 6.15) it was found that there was varying degree of implementation of measures amongst the sectors, for example speed reduction due to port efficiency was implemented in the bulk sectors, raising crew awareness was highly implemented in the container sector. Chartering group is also introduced as a test variable separately because it is plausible that it may also partly explain the zero order relationship. From Figure 6.29 above it can be seen that implementation varied amongst the different chartering groups. It is also introduced because it is used as an indicator of the principal agent problem which is thought to affect the implementation of measures. These justifications are used for the analysis of the remaining two measures being investigated in the elaboration analysis.

Although a clear linear relationship can be seen in Figure 7.3, the descriptive statistic for showing the strength of association showed a weak relationship between size and implementation coupled with a highly non-significant relationship. This zero order relationship had Chi-squared test result of 1.17 (sig 0.559) and Cramer's V of 0.117 (p 0.559).

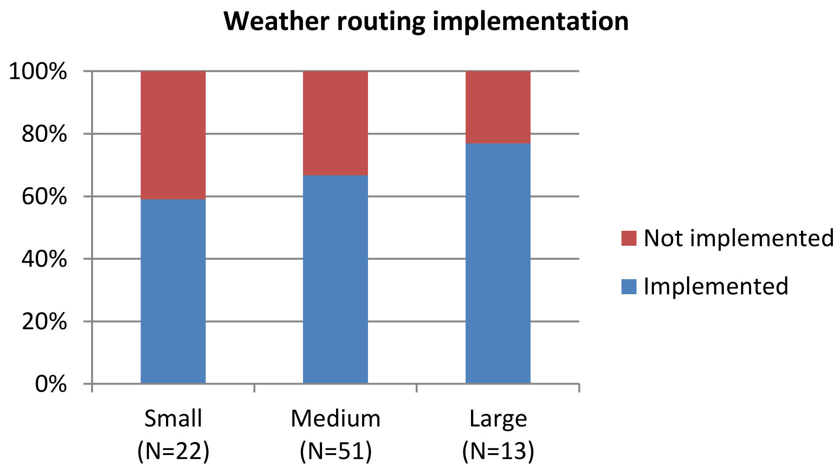


Figure 7.3: Zero order relationships between weather routing and size variable

The effect size further increased for conditional relationships i.e. when controlling for sector, to moderate level for drybulk sector (Cramer's V = 0.25, p = 0.517) and marginally for wetbulk sector (Cramer's V = 0.136, p 0.876). This difference in association between sectors (categories of test variables) suggests a specification effect, thus implying that size on its own does not have an effect on implementation of weather routing but when it occurs in combination with a specific sector there seems to be some relationship. So when sector is controlled the differences in size seem to affect the implementation of weather routing measure more for drybulk sector than for wetbulk sector, i.e. the relationship holds more for the drybulk and less for wetbulk sector. This is supported by findings in Figure 6.15 and Table 7.9 below which shows on average around 50% of the respondents in the wetbulk sector had implemented it whilst on average nearly 80% in the drybulk sector had implemented the measure, with marked differences amongst the size categories. Although effect sizes showed an increase, the null hypothesis (that there is no association between the original relationships) could not be rejected due to the highly non-significant relationship.

	Wetbulk				Drybulk		
	Small (N=7)	Medium (N=14)	Large (N=5)		Small (N=8)	Medium (N=15)	Large (N=2)
Implemented	43%	57%	60%		63%	80%	100%
Not implemented	57%	43%	40%		38%	20%	0%

Table 7.9: Conditional tables by sector for size and weather routing implementation

When controlling for the chartering group the original association showed interaction effects (specification) for the various groups (Table 7.11), with the relationship getting stronger when controlling for chartering groups one and three (voyage chartered out fleet), and decreasing for chartering groups two and four (time chartered out fleet). This suggests that implementation of weather routing and size of a company is more related with certain types of chartering levels, and in this case it affects the implementation of firms which have a majority of their fleet chartered out on voyage charter. A closer examination of the conditional tables shows reversal of patterns across sizes. For chartering group one 50% of the small sized companies had implemented weather routing compared to 100% of large sized companies. For chartering group three 100% of small sized companies had implemented this measure compared to none of the large sized companies. For group two and four the implementation levels were around 60% across all size categories. This finding seems to confirm the earlier finding from Figure 6.29, which showed that groups with a majority of their fleet chartered out time had higher implementation and the relationship with size does not matter, but at the same time suggesting that the implementation for groups with a majority of the fleet on voyage charter is also partly due to the sizes of companies in those chartering groups. The next section therefore attempts to assess the relationship of implementation with chartering group.

7.5.1.2. Relationship of implementation of weather routing with chartering group

The alternative hypothesis being tested is that there is a direct relationship between implementation of weather routing measure (Y variable) and chartering level of the company (X variable). In order to see how chartering group (X) affects implementation of weather routing measure (Y) (zero order direct relationship) two test variables are introduced separately, the size (Za) of the firm and sector (Zb) the firm operates in. Size is introduced as a test variable separately because it is plausible that it may also partly explain the zero order relationship. Sector is introduced as a test variable because it is plausible that the difference in implementation may be partly explained by this variable.

For the zero order relationship between implementation of weather routing measure and chartering the effect size showed a modest increase (Cramers V = 0.252), which can be said to be between weak and moderate association. The actual levels of implementation are shown in Figure 7.4. It can be seen that when not controlling for other variables groups one and three (majority out on voyage) actually have lower average implementation than groups two and four (majority out on time). Earlier, it was seen that group three on average across all the measures had the highest level of implementation, whereas for the weather routing measure the group appears to have the lowest level of implementation. The explanation provided earlier regarding operational measures being applicable to group two and four also applies here, since weather routing is predominantly a measure favoured by time charterers for monitoring and control purposes as well.

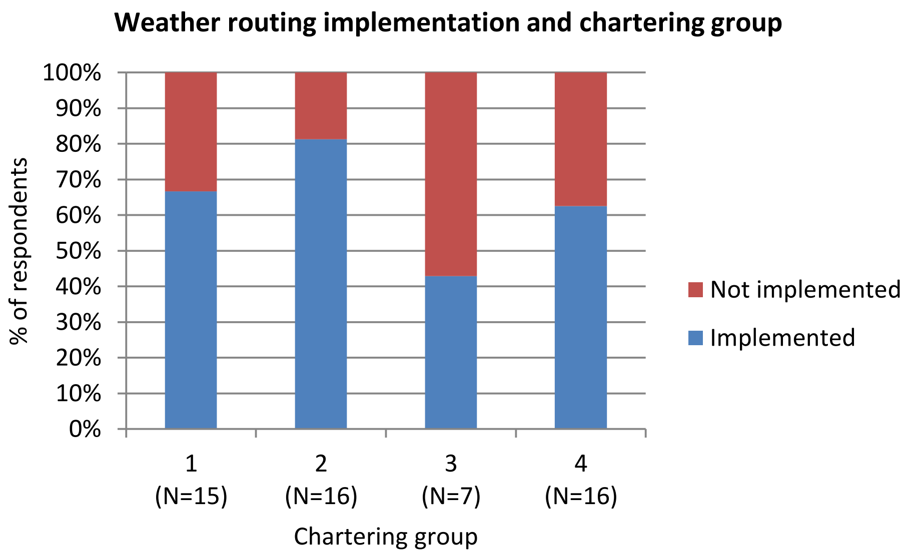


Figure 7.4: Zero order relationship between weather routing and chartering group

When controlling for sector the original relationship improves for both categories of sector but the chi squared statistic only improved significantly for the conditional table for the drybulk sector. The relationship can be said to have been replicated as the association persists for both categories of the test variable, but it can also be said that relationship holds more for one category of the test variable, since the association increases considerably and significantly to correlation coefficient of 0.647 (p .021) when controlling for drybulk and to 0.418 (p 0.685) when controlling for wetbulk. This suggests that when holding other things equal (sector) the chartering group seems to have a stronger relationship to the implementation of the weather routing measure especially in the drybulk sector. Although the relationship is found to be statistically significant for the drybulk sector, Table 7.10 below suggests the split of implementation between voyage (group one and three) and time charter (group two and four) is more apparent in wetbulk sector.

	Wetbulk					Drybulk			
	Grp. 1 (N=1)	Grp. 2 (N=3)	Grp. 3 (N=3)	Grp. 4 (N=6)		Grp. 1 (N=10)	Grp. 2 (N=6)	Grp 3 (N=1)	Grp 4 (N=1)
Implemented	0%	67%	33%	67%		70%	100%	0%	0%
Not implemented	100%	33%	67%	33%		30%	0%	100%	100%

Table 7.10: Conditional tables by sector for weather routing and chartering group

When controlling for the size variable the original zero order relationship showed replication effects, as well as showing that the relationship holds more for large sized. The replication of similar and higher correlation coefficients for the test variable suggests that the relationship between chartering group and implementation of weather routing is robust. This implies that implementation of weather routing is affected by the chartering level of a firm.

7.5.1.3. Relationship of implementation of weather routing with sector

The alternative hypothesis being tested here is that there is a direct relationship between implementation of weather routing measure (Y variable) and sector in which the company operates (X variable). In order to see how sector (X) affects implementation of weather routing measure (Y) (zero order direct relationship) two test variables are introduced separately, the size (Za) of the firm and chartering group (Zb) the firm operates in. Size is introduced as a test variable separately because it is plausible that it may also partly explain the zero order relationship. Chartering group is introduced as a test variable because it is plausible that the difference in implementation may be partly explained by this variable.

The effect size showed a small increase (compared to that of chartering group and weather routing implementation) in the zero order relationship between implementation of weather routing measure and sector (Cramers V = 0.295, p 0.058), which can be said to be statistically significant and represents moderate association which is the highest level of association observed so far. The actual levels of implementation are shown in Figure 7.5. It can be seen in this zero order relationship that the container sector has the least level of implementation of the measure. So although the four container sector respondents thought that weather routing had a high fuel saving potential this was not followed by its implementation, which would suggest that either this measure is not applicable to the container sector or there are barriers are preventing uptake of the measure. The same applies to the wetbulk sector which had lower implementation compared to the drybulk sector.

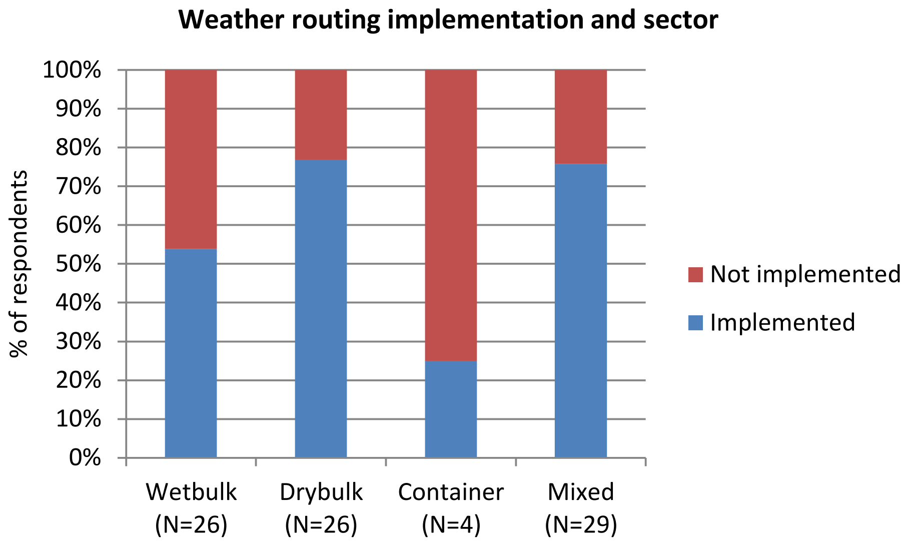


Figure 7.5: Zero order relationship between weather routing implementation and sector

Controlling for size, the conditional relationship continues to show very similar levels of association, i.e. a replication effect, which suggests that the original relationship was not due to the influence of the size variable, hence sector is also a strong variable affecting implementation of weather routing. When controlling for chartering group the conditional relationships increase reasonably for all chartering groups reaching moderate to strong levels of association, suggesting the replication of the original zero order relationship with some level of specification effects. The association between implementation of weather routing and sector occurs in all conditional relationships explored reaching statistical significance in the zero order relationships, which implies that there exists an association between the two, thus the null hypothesis can be rejected.

From the above findings one can conclude that the sector variable has the most influence on the adoption of the weather routing measure. The chartering group variable can also be said to be affecting the implementation of the weather routing measure. Furthermore, when controlling for sector, the chartering group's relationship with implementation improves substantially and significantly. The size variable only in specific conditions affects the implementation of weather routing. However since all the variables are not controlled for simultaneously, their individual impact on the implementation of the measure remains unknown. It can be concluded that sectoral heterogeneity coupled with principal agent problems may be affecting the implementation of the weather routing measure and chapter eight will attempt to explore the causes of these.

Relationship Implementation of weather routing with	Holding/test variables								
	Size			**Sector**		**Chartering group**			
Size	Chi^2 = 1.171 (p .559) FE = 1.130 (p .62) CV = .117 (p .559) Phi = N/A			Wetbulk Chi^2 = N/A FE = .608 (p .876) CV = .136 (p .876) Phi = N/A	Drybulk Chi^2 = N/A FE = 1.343 (p .784) CV = .25 (p .517) Phi = N/A	Group 1 Chi^2= 1.5 (p .72) FE = 1.528 (p .72) CV = .316 (p .72) Phi = .316 (p .72)	Group 2 Chi^2= .515 (p 1) FE = CV = .179 (p 1) Phi = -.179 (p 1)	Group 3 Chi^2= 2.1 (p 1) FE = 1.98 (p 1) CV = .548 (p 1) Phi = .548 (p 1)	Group 4 Chi^2= .071 (p 1) FE = .386 (p 1) CV = .067 (p 1) Phi = .067 (p 1)
Sector	Small Chi^2 = 3.08 (p .353) FE = 2.92 (p .353) CV = .383 (p 353) Phi = .383 (p .353)	Medium Chi^2 = 3.414 (p .33) FE = 3.408 (p .28) CV = .264 (p .331) Phi = .264 (p .331)	Large Chi^2 = 1.33 (p .773) FE = 1.208 (p 1) CV = .333 (p .773) Phi = .333 (p .773)	Chi^2= 7.421 (p .058) FE = 6.997 (p .064) CV = **.295 (p .058)** Phi = .295 (p .058)		Group 1 Chi^2= 1.95 (p .685) FE = 1.937 (p .685) CV = .373 (p .685) Phi = .373 (p .685)	Group 2 Chi^2= 3.09 (p .346) FE = 3.564 (p .346) CV = .440 (p .378 Phi = .440 (p .378)	Group 3 Chi^2= 1.56 (p 1) FE = 1.603 (p 1) CV = .471 (p 1) Phi = .471 (p 1)	Group 4 Chi^2= 3.91 (p .379) FE = 3.63 (p .379) CV = .494 (p .379) Phi = .494 (p .379)
Charter group	Small Chi^2 = 1.03 (p 1) FE = 1.32 (p 1) CV = .281 (p 1) Phi = .281 (p 1)	Medium Chi^2 = 3.99 (p .27) FE = 3.915 (p .25) CV = .333 (p .263) Phi = .333 (p .263)	Large Chi^2 = .232 (p 1) FE = 2.09 (p 1) CV = .667 (p 1) Phi = .667 (p 1)	Wetbulk Chi^2 = 2.270 (p .685) FE = 2.324 (p .685) CV = .418 (p .685) Phi = N/A	Drybulk Chi^2 = 7.532 (p .0.21) FE = 6.638 (p .021) CV = **.647 (p .021)** Phi = N/A	Chi^2 = 3.442 (p .327) FE = 3.44 (p .327 CV = .252 (p .348) Phi = .252 (p .348)			

Table 7.11: Summary of elaboration analysis for weather routing measure

Chi^2 = Chi-squared test

FE = Fisher’s exact test

CV = Cramer’s V

p. = significance level

Underlined values show a moderate and strong relationship

Bold values show a statistically significant relationship

7.5.2. Fuel consumption monitoring

In the preliminary analysis chapter it was seen that over 70% of the respondents thought that fuel consumption monitoring had the highest fuel saving potential as well as also being the highest implemented measure, over 70% (85 out of 119) of the respondents who selected this measure had already implemented this measure. Bar charts that disaggregated these results in the preliminary analysis showed that small sized companies had the highest level of implementation followed by medium sized and lastly large companies with the lowest level of implementation, quite opposite to the pattern observed for weather routing implementation. This section tests for the relationship that exists between implementation fuel consumption monitoring measure and size, sector and chartering group variables.

7.5.2.1. Relationship of implementation of fuel consumption monitoring with size

From Figure 7.6 below a clear relationship can be observed, the descriptive statistic for showing the strength of association showed a weak relationship between size and implementation coupled with a highly non-significant relationship. This zero order relationship had Chi-squared test result of 3.12 (p 0.241) and Cramer's V of 0.189 (p 0.208). This zero order relationship is much higher than that of the weather routing measure in the same context.

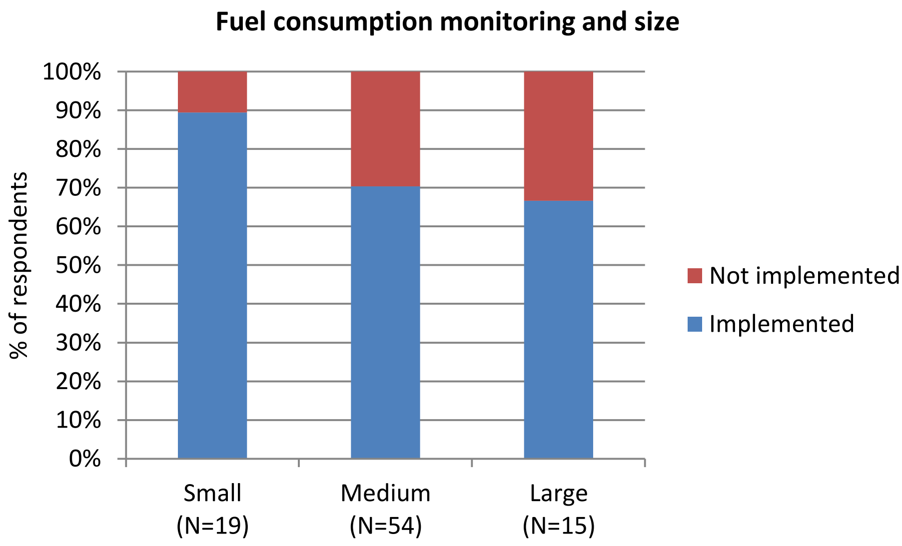


Figure 7.6: Zero order relationship between fuel consumption monitoring and size

The conditional relationship for the implementation of fuel consumption monitoring measure and size when controlling for sector reveals a specification or statistical interaction effect, which is also found to be statistically significant for the wetbulk sector. When controlling for the wetbulk sector the association strengthens significantly (Cramer's V = 0.413, p 0.085), whereas controlling for drybulk the zero order relationship weakened. So when sector is controlled the size differences in implementation of the measure mainly exist for the wetbulk sector. 90% of the small sized companies in the wetbulk sector respondents (N=10) had already implemented the fuel consumption monitoring measure whereas under 40% of the large companies (N=8) had implemented the measure in the same sector as shown in conditional Table 7.12. Thus, the original zero order relationship pattern remained for the wetbulk sector but did not apply to the drybulk sector.

	Wetbulk				Drybulk		
	Small (N=10)	Medium (N=14)	Large (N=8)		Small (N=6)	Medium (N=15)	Large (N=1)
Implemented	90%	64%	38%		83%	73%	100%
Not implemented	10%	36%	63%		17%	27%	0%

Table 7.12: Conditional tables by sector for size and implementation of fuel consumption monitoring

When controlling for chartering group, the changes in the associations show a similar pattern to that which was observed for weather routing implementation, a specification effect i.e. relationship for voyage chartered out fleet is much stronger than that for groups which have more of the fleet chartered out on time. Once again this finding corroborates with the hypothesis that implementation in time chartered fleet is higher regardless of the size, but the above finding also suggests that implementation of fuel consumption monitoring is affected by size for groups which have a majority of their fleet chartered out on voyage. A closer examination of the conditional tables confirms this for chartering groups one and three (i.e. those with a majority of fleet voyage chartered out) show a relationship with highest implementation by small firms followed by medium and lowest implementation by large firms in those chartering groups. This relationship is not observed in the chartering groups two and four. This implies that for firms where fuel is mainly paid for by the shipowner (chartering group one), smaller companies have higher implementation of the measure. This is contrary to the commonly held view that larger companies would invest in this measure (this is supported by anecdotal literature from industry press, which almost always cites larger companies investment in this measure). Possible explanation of the higher implementation could be that the materiality of savings is envisaged easily by smaller firms coupled with the lower absolute capital expenditure, as a result of fewer ships.

	Chartering group 1				Chartering group 2		
	Small (N=3)	Medium (N=16)	Large (N=4)		Small (N=7)	Medium (N=24)	Large (N=2)
Implemented	100%	69%	50%		100%	75%	100%
Not implemented	0%	31%	50%		0%	25%	0%

Table 7.13: Conditional table by chartering group for size and fuel consumption monitoring

7.5.2.2. Relationship of implementation of fuel consumption monitoring with sector

Figure 7.7 below shows the number or respondents who implemented the measure and the sector in which they operate. The relationship cannot be visually summarised, the zero order relationship had Chi-squared test result of 3.182 (sig 0.390) and Cramer's V of 0.19 (p 0.390), which is very similar to that obtained for the zero order relationship of this measure with the size variable. The observed pattern of implementation by the different sectors is also very similar to that observed for weather routing and sector relationship. The associated high significance values mean that there is high chance of sampling error affecting the findings, thus the confidence in the strength of association is low.

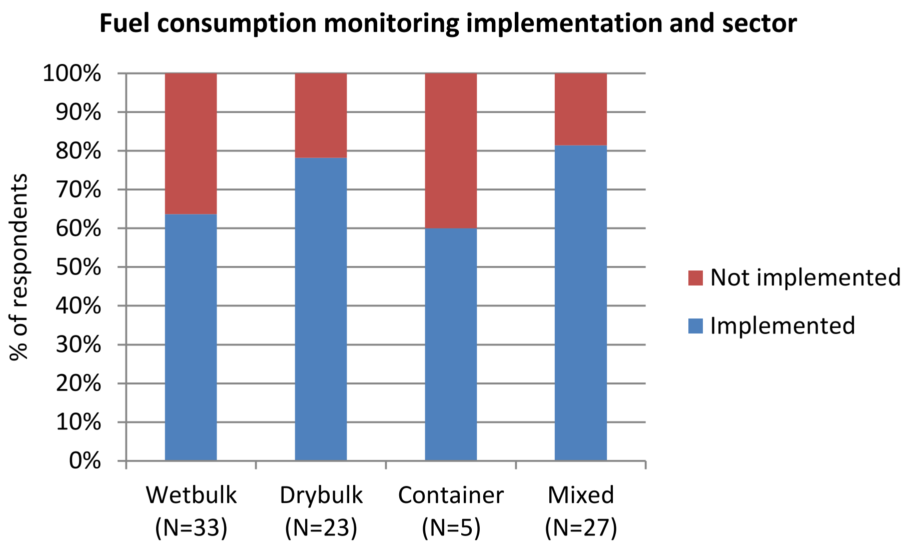


Figure 7.7: Zero order relationship between fuel consumption monitoring and sector

Controlling for the size, the conditional relationships were lower for small and medium sized companies compared to zero order relationships but increased considerably among large sized companies with Chi-squared 5.833 (p 0.119) and Cramer's V 0.645 (p 0.119). This seems to suggest a specification effect, which means that although there may not be a high relationship initially between sector and implementation of fuel consumption monitoring, breaking down this relationship by size suggests that the pattern of implementation by sector among the size groups is somewhat different, i.e. when size is controlled the sectoral differences in implementation of fuel consumption measure tends to be much more amongst large sized companies. This implies that there is more sectoral heterogeneity and differences within large firms across the sectors. Looking at the conditional table for large and small companies shows that an average (across the sectors) 90% of small sized companies (N=18) had already implemented this measure, whereas for large sized companies an average (across sectors) of 65% of large companies had implemented this measure (N=14).

	Small					Large			
	Wetbulk (N=10)	Drybulk (N=6)	Cont. (N=0)	Mixed (N=2)		Wetbulk (N=8)	Drybulk (N=1)	Cont. (N=1)	Mixed (N=4)
Implemented	90%	83%		100%		38%	100%	100%	100%
Not implemented	10%	17%		0%		63%	0%	0%	0%

Table 7.14: Conditional tables by size for fuel consumption monitoring and sector

The conditional relationships increase when holding for various chartering groups, although not as much for group one. This is the same pattern that was observed in conditional relationships of weather routing and sector. This suggests that the chartering group variable has a moderating effect on the original relationship. When chartering group is controlled the sectoral differences in implementation of fuel consumption measure persists for all chartering groups but more so for groups two, three and four (although at highly non-significant levels). There is significant difference in correlation coefficients or relationships of implementation of this measure by sector between chartering group one and three (Table 7.16). The difference in these groups did not exist earlier and perhaps can be explained by the ownership structure of the groups. Chartering group one is owner operated fleet with majority chartered out on voyage, whereas group three is management company operated fleet with majority chartered out on voyage, who can be said to have higher demands on accurate fuel reporting from both owners and charterers, secondly their incentive may be the ability to save fuel costs as one of their key performance indicators, which is an important feature in the negotiation of their contract renewals with owners.

7.5.2.3. Relationship of implementation of fuel consumption monitoring with chartering group

The zero order relationship between implementation of fuel consumption monitoring measure and chartering group showed the highest level of association (Cramer's V 0.216) compared to zero order relationships of the measure with size of companies and sector they operated in. Figure 7.8 below shows the average implementation level amongst the chartering groups.

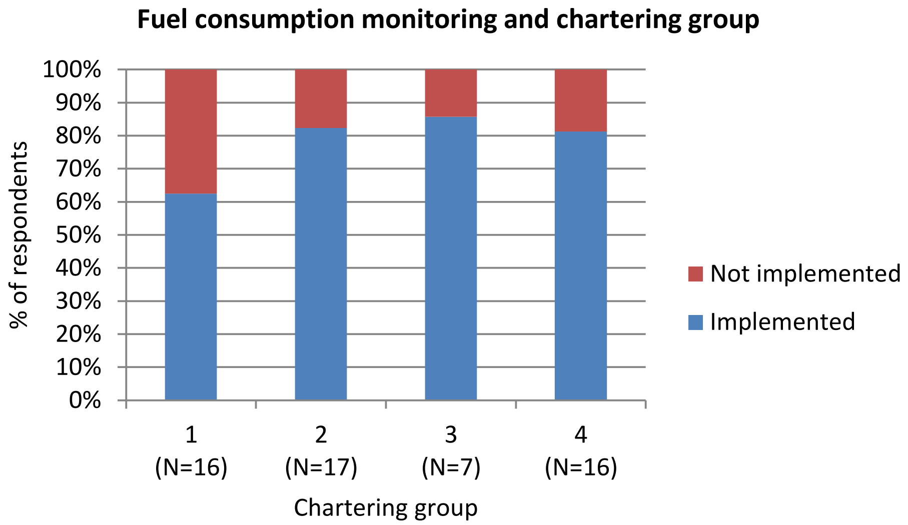


Figure 7.8: Zero order relationships for fuel consumption monitoring and chartering group

The conditional relationship when controlling for size revealed replication effects where controlling for medium size companies the association remained similar to the zero order relationship, and increased substantially when controlling for the large size category. Comparing the conditional tables, it can be observed that for the large sized firms there is significant variation in implementation across the chartering groups (partly because of the lower sample size), whereas for small sized firms implementation remained constant across all the chartering groups. The conditional tables controlling for size show that all the chartering groups in the small size category had 100% implementation of the measure, which declines to just over 70% average of chartering groups for medium sized companies and over 65% average of chartering groups in the large sized companies. There is no theoretical explanation as to why such a variation is observed nor do the results show previously observed differences between chartering group implementation.

Conditional relationships when controlling for sector results in specification effect where the level of association controlling for the wetbulk improves the relationship and reduces when controlling for the drybulk sector. Examining the conditional tables suggest that the hypothesis on difference in implementation by chartering group holds in the wetbulk sector but not as much in the drybulk sector, i.e. group one and three have lower implementation in the wetbulk sector but this is not applicable to the drybulk sector. This to some extent explains the higher implementation average for energy efficiency measures in the drybulk sector.

	Wetbulk sector					Drybulk sector		
	Group 1 (N=4)	Group 2 (N=4)	Group 3 (N=3)	Group 4 (N=8)		Group 1 (N=7)	Group 2 (N=6)	Group 3 (N=1)
Implemented	50%	75%	67%	88%		71%	83%	100%
Not implemented	50%	25%	33%	13%		29%	17%	0%

Table 7.15: Conditional tables by sector for fuel consumption monitoring and chartering group

From the above analysis on implementation of fuel consumption monitoring it was observed that the size variable seemed to influence implementation only in combination with other firm characteristics especially the sector in which the firm operates in and the chartering level. The same can be said for the sector and chartering group variables, which seem to only be replicated for one test variable rather than both. This suggests that all the variables, the size of the firm, the sector in which the firm operates and the firm's chartering level affect the implementation of fuel consumption monitoring. This is slightly different to what was observed for the variables affecting implementation of the weather routing measure, where only the sector and chartering group were mainly affecting the measure's implementation.

		Holding/test variables									
		Size			**Sector**		**Chartering group**				
Relationship Implementation of fuel consumption monitoring with	**Size**	Chi^2 = 3.142 (p .241) FE = 3.221 (p .215) CV = .189 (p .208) Phi = .189 (p .208)			Wetbulk Chi^2 = 5.45 (p .085) FE = 5.238 (p .085) CV = **.413 (p .085)** Phi = .413 (p .085)	Drybulk Chi^2 = .552 (p 1) FE = .730 (p 1) CV = .158 (p 1) Phi = .158 (p 1)	Group 1 Chi^2 = 1.519 (p .753) FE = 1.317 (p .753) CV = .308 (p .753) Phi = .308 (p .753)	Group 2 Chi^2 = .781 (p .599) FE = N/A CV = .214 (p .377) Phi = .214 (p .377)	Group 3 Chi^2 = 7.00 (p .286) FE = 4.753 (p .286) CV = 1.00 (p .286) Phi = 1.00 (p .286)	Group 4 Chi^2 = 2.21 (p .330) FE = 1.559 (p .679) CV = .372 (p .330) Phi = .372 (p .330)
	Sector	Small Chi^2 = .45 (p 1) FE = .929 (p 1) CV = .158 (p 1) Phi = .158 (p 1)	Medium Chi^2 = 1.151 (p .88) FE = 1.390 (p .782) CV = .149 (.801) Phi = .149 (.801)	Large Chi^2 = 5.833 (p .119) FE = 5.227 (p .119) CV = .645 (p .119) Phi = .645 (p .119)	Chi^2 = 3.182 (p .390) FE = 3.278 (p .354) CV = .19 (p .390) Phi = .19 (p .390)		Group 1 Chi^2 = .518 (p .825) FE = .756 (p .825) CV = .18 (p .825) Phi = .18 (p .825)	Group 2 Chi^2 = 1.979 (p .842) FE = 2.221 (p .710) CV = .363 (p .842) Phi = .363 (p .842)	Group 3 Chi^2 = 1.55 (p 1) FE = 1.968 (p 1) CV = .471 (p 1) Phi = .471 (p 1)	Group 4 Chi^2 = 4.63 (p .25) FE = 3.44 (p .35) CV = .538 (p .25) Phi = .538 (p .25)
	Charter group	Small	Medium Chi^2 = 3.965 (p .275) FE = 3.546 (p .299) CV = .315 (p .275) Phi = .315 (p .275	Large Chi^2 = 3 (p .6) FE = 2.551 (p .6) CV = .707 (p .6) Phi = 707 (p .6)	Wetbulk Chi^2 = 2.024 (p .807) FE = 2.411 (p .807) CV = .326 (p .807) Phi = .326 (p .807)	Drybulk Chi^2 = .566 (p 1) FE = .911 (p 1) CV = .201 (p 1) Phi = .201 (p 1)	Chi^2 = 2.619 (p .514) FE = 2.328 (p .544) CV = .216 (p .514) Phi = (p .514)			

Table 7.16: Summary of elaboration analysis for fuel consumption monitoring measure

Chi^2 = Chi-squared test

FE = Fisher's exact test

CV = Cramer's V

p. = significance level

Underlined values show a moderate and strong relationship

Bold values show a statistically significant relationship

7.5.3. General speed reduction

In the preliminary analysis chapter it was seen that 70% of the respondents thought that general speed reduction had the highest fuel saving potential as well as being the third most implemented measure, over 60% (69 out of 115) of the respondents who selected this measure had already implemented this measure. Bar charts that disaggregated these results in the preliminary analysis did not show a clear trend. This section therefore tests for the relationship that may exist between its implementation and other firm characteristics.

7.5.3.1. Relationship of implementation of general speed reduction with size

Here it is hypothesized that there is direct relationship between the size of a company and its implementation of the measure. The zero order relationship between the implementation of general speed reduction measure with size shows a weak association with Cramer's V 0.178 (p 0.286) and a low chi-squared test figure of 2.6 (p 0.286). This level of association is similar to that observed for zero order relationships for other measures and their relationship with size. Based on this initial relationship it can be said that there isn't a good association between size and implementation of speed reduction measure.

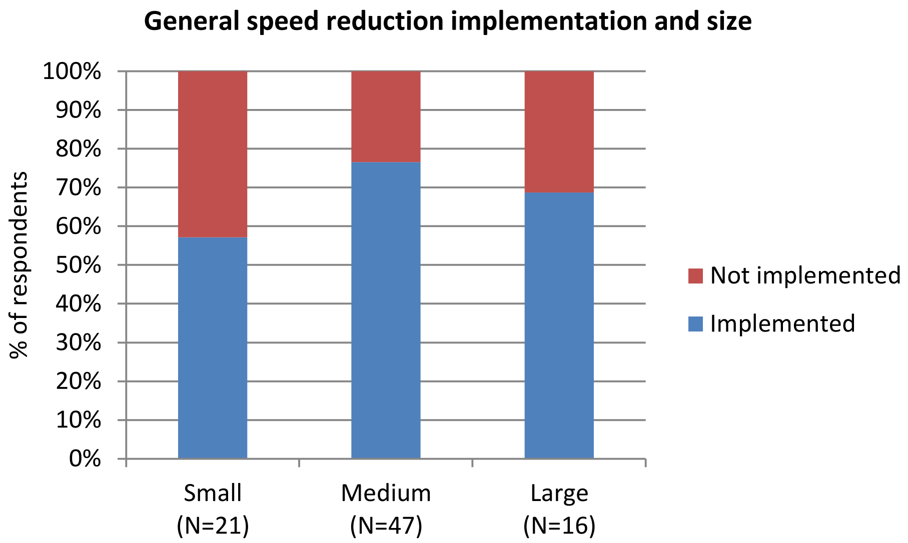


Figure 7.9: Zero order relationship between general speed reduction and size

The conditional relationship when controlling for sector showed statistical interaction i.e. split effects. For the wetbulk sector the strength of the original relationship remained similar but increased considerably and significantly when controlling for drybulk (Cramer's V = 0.547, p 0.029). So when sector is controlled the difference in implementation among the size groups mainly persists for the drybulk sector. This explains the Table 7.17 below where it can be seen that small companies in the wetbulk sector are more likely to have implemented this measure than those in drybulk sector. In the wetbulk sector 78% of the small sized companies had implemented this measure which is the highest amongst other size groups in that sector. However in the drybulk sector there seems to be a considerable difference in the implementation with only 29% of small sized companies implementing general speed reduction which is the lowest compared to other sizes in that sector. This is analogous to the conditional relationship observed for implementation of the fuel consumption monitoring measure. The higher implementation by smaller firms in the wetbulk sectors for both the measures could be due to the relatively higher bargaining power of the major charterers in the wetbulk sector. Since the Cramer's V statistic does not measure linear association the direction of the association cannot be said to be negative or positive.

	Controlling for wetbulk				Controlling for drybulk		
	Small (N=9)	Medium (N=10)	Large (N=7)		Small (N=7)	Medium (N=14)	Large (N=2)
Implemented	78%	60%	57%		29%	86%	50%
Not implemented	22%	40%	43%		71%	14%	50%

Table 7.17: Conditional tables by sector for general speed reduction and size

Conditional relationships when controlling for chartering group shows that the original relationship persists in all four chartering groups, suggesting a replication effect with an even stronger relationship for group three (Cramer's V = 0.447). This suggests that size of a company can be said to be a robust variable affecting the implementation of general speed reduction.

7.5.3.2. Relationship of implementation of general speed reduction with sector

In Figure 6.23 it was seen that there existed some differences in the implementation of this measure amongst the different sectors in which companies operated. Therefore it is hypothesized that there could be some direct relationship between the sector a company operates in and implementation of the measure. The zero order relationship between the implementation of general speed reduction measure with sector shows a weak and a non-significant association (Cramer's V 0.199, p 0.372), which is similar to that observed for zero order relationships of other measures and sector, although this zero order relationship is marginally higher compared to that of size and implementation of general speed reduction.

Controlling for the size variable the zero order relationship between implementation of general speed reduction measure and sector increases the strength of the association to medium effect size for all three size groups. This pattern was also observed for the weather routing measure, however the same conditional relationships showed a specification effect for the fuel consumption monitoring measure. Since the conditional relationship shows an increase in association for all three categories of the test variable, although not statistically significant, it implies replication of the zero order relationship i.e. there is a direct and robust relationship between sector and implementation of general speed reduction.

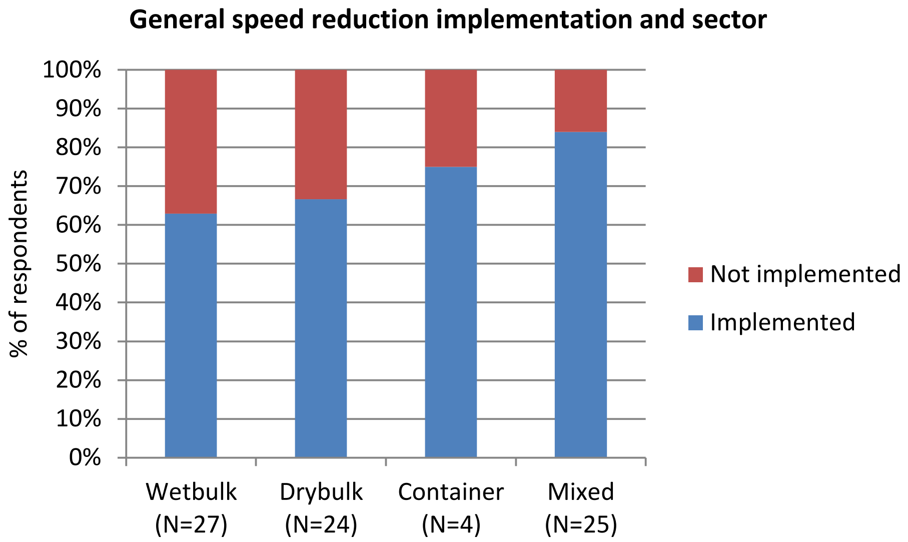


Figure 7.10: Zero order relationship between general speed reduction and sector

The conditional relationships when controlling for the chartering group variable showed that the original relationship improves substantially for group two and three and remains similar for group one and four. The relationship was also found to be statistically significant for group two with chi-square statistic of 13 (df. 3) (p 0.077). This difference amongst the different categories of the test variable suggest that there is replication coupled with statistical interaction between the original relationship, in other words the relationship holds more or can be said to be specific to groups two and three. A closer examination of the conditional tables for groups two and three shows that actually the relationship is quite opposite between the two. For chartering group two (majority of the fleet owned and chartered out on time), the wetbulk and drybulk sectors had 100% implementation compared to no implementation at all in the wetbulk and drybulk sectors for chartering group three (management company with majority fleet out on voyage). So, group one and three (majority of the fleet on voyage charter) have lower levels of implementation compared to group two and four (majority of the fleet on time charter) thus again confirming the hypothesis that time chartered groups will have higher implementation of the speed reduction measure since fuel cost is being borne by the principal who is in control of implementing the measure i.e. incentives being aligned. This can be said to be more of the case in the wetbulk sector.

	Wetbulk sector			Drybulk sector	
	Group 1 (N=4)	Group 2 (N=10)		Group 1 (N=7)	Group 2 (N=6)
Implemented	25%	80%		57%	100%
Not implemented	75%	20%		43%	0%

Table 7.18: Conditional tables by sector for general speed reduction and chartering group

7.5.3.3. Relationship of implementation of general speed reduction with chartering group

Analysis from section 5.6 shows that the speed reduction measure (ratio of operating speed to design speed) was not statistically different for voyage and time chartered ships in the wetbulk sector and drybulk sector, therefore the null hypothesis could not be rejected. The alternative hypothesis for the survey data analysis is that there is a relationship between the chartering group and implementation of speed reduction measure. The initial relationship between implementation of general speed reduction measure and chartering group shows very similar level of association found with chartering group and other measures, as well as being the strongest relationship compared to other independent variables (size and sector) related to the implementation, although this is once again a highly non-significant finding. Visually analysing Figure 7.11, it can be seen that group one and three (fleet chartered out on voyage) had lower implementation compared with group two and four (fleet chartered out on time), a finding which corroborates with the analysis in section 6.4.4 and Figure 6.25 (achieving speed reduction under different charters). The pattern is also very similar to that observed for weather routing and chartering group, in Figure 7.4.

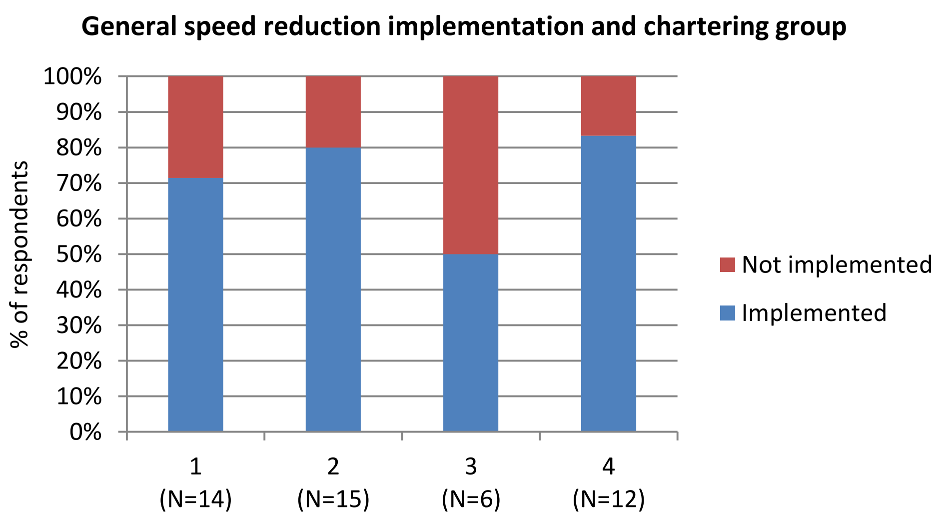


Figure 7.11: Zero order relationship between general speed reduction and chartering group

When controlling for the sector of the companies, the zero order relationship increased markedly for both wetbulk and drybulk sectors. The replication suggests that the relationship between implementation of speed reduction and chartering group is robust even when controlled for sector. When adding extra categories of the test variable i.e. container sector the conditional relationship is the highest, but this could also be due to the relatively lower number of responses (N=2) resulting in many blank cells in the conditional tables. Because of the almost significant values the findings in the drybulk sector can be said to be inferable to the larger drybulk population. From Table 7.19 below it can be seen that the original pattern observed in the zero order relationship persists in the drybulk and wetbulk sector i.e. group one and three have lower implementation compared to group two and four in both sectors, which supports hypothesis 1c.

	Wetbulk					Drybulk			
	Grp. 1 (N=2)	Grp. 2 (N=3)	Grp. 3 (N=2)	Grp. 4 (N=7)		Grp. 1 (N=6)	Grp. 2 (N=6)	Grp 3 (N=1)	Grp 4 (N=0)
Implemented	50%	100%	0%	71%		67%	100%	0%	-
Not implemented	50%	0%	100%	29%		33%	0%	100%	-

Table 7.19: Conditional tables for general speed reduction implementation and chartering group

The conditional relationships when holding for the size of companies showed specification effects as seen previously for other measures, when controlling for size. When controlling for larger companies the chartering group had a very strong association with implementation and when controlling for small companies the chartering group showed completely no association, thus statistical interaction/specification effect could be established. In other words the relationship between chartering group and implementation is more specific for large companies. On average across all chartering groups the larger firms had the highest implementation rate of over 80%, followed by medium sized firms at 75% and small sized firms' implementation rate of just over 65%. The conditional relationship however does not have a similar pattern as observed above, rather the implementation rate across the chartering groups for all size categories are almost constant, suggesting that the null hypothesis regarding implementation and chartering group cannot be rejected.

The above analysis suggests that the size of the firm, sector in which it operates and the chartering level are important factors in explaining the implementation of the general speed reduction measure. However the most important factor that seems to be causing variances in the implementation of this measure is the sector variable, which suggests sectoral heterogeneity (non-market failure), could be a barrier to implementation for general speed reduction. This means that although being the measure with highest fuel saving measure, sector specific issues such as the level of slow steaming allowed, charterparties, bill of ladings, route specific issues e.g. piracy are resulting in different levels of adoption of this measure.

7.5.4. Concluding remarks

This section of the chapter attempted to answer specific research questions 1b and 1c regarding the level of implementation. All of the top three measures believed to have the highest fuel saving potential had varying degree of implementation when disaggregated by size, sector and chartering group. For the fuel consumption monitoring and general speed reduction measures the conditional relationships showed replication effects in the majority of the cases, which suggests that the size of the firm, the sector in which it operates and chartering group have some causal effect on implementation. Whereas, for the weather routing measure the sector of operation and chartering level were the key causes of different levels of implementation and the size of the firm was not considered to be causing the differences in implementation.

Where the chartering group is controlled or used as a test variable, a consistent theme amongst the conditional relationships was observed that is in agreement with the third hypothesis i.e. implementation of energy efficient operational measures will be higher for time chartered ships compared to voyage chartered ships, which confirms the effect of the principal agent problem in implementation of the operational measures analysed.

The above analysis implies that both sectoral heterogeneity (non-market failure) coupled with principal agent problems (market failure) could be affecting the implementation of measures. This finding is only to some extent reflected in the preliminary analysis of the perception of barriers, (section 6.4.2) where mainly the split incentives were perceived to be the most important barriers. The following section attempts to compare the findings from this section with conditional relationships of perceptions of barriers.

Relationship of general speed reduction with	Holding/test variables: Size			Sector		Chartering group			
Size	Chi^2 = 2.648 (p .286) FE = 2.684 (p .256) CV = .178 (p .286) Phi = .178 (p .286)			Wetbulk Chi^2 = .949 (p .667) FE = 1.046 (p .667) CV = .191 (p .667) Phi = .191 (p .667)	Drybulk Chi^2 = 6.941 (p .029) FE = 6.857 (p .029) CV = **.549 (p .029)** Phi = .549 (p .029)	Group 1 Chi^2 = .933 (p .784) FE = .911 (p 1) CV = .258 (p .784) Phi = .258 (p .784)	Group 2 Chi^2 = .606 (p 1) FE = 1.23 (p 1) CV = .201 (p 1) Phi = .201 (p 1)	Group 3 Chi^2 = 1.2 (p 1) FE = 1.588 (p 1) CV = .447 (p 1) Phi = .447 (p 1)	Group 4 Chi^2 = 1.029 (p 1) FE = 1.3 (p 1) CV = .293 (p 1) Phi = .293 (p 1)
Sector	Small Chi^2 = 4.023 (p .18) FE = 3.863 (p .18) CV = .460 (p .18) Phi = .460 (p .18)	Medium Chi^2 = 3.77 (p .308) FE = 3.865 (p .282) CV = .293 (.308) Phi = .293 (.308)	Large Chi^2 = 1.436 (p .860) FE = 1.757 (p .860) CV = .309 (p .860) Phi = .309 (p .860)	Chi^2 = 3.163 (p .372) FE = 3.311 (p .334) CV = .199 (p .372) Phi = .199 (p .372)		Group 1 Chi^2 = .638 (p 1) FE = 1.011 (p 1) CV = .222 (p 1) Phi = .222 (p 1)	Group 2 Chi^2 = 13.00 (p .077) FE = 6.127 (p .077) CV = **1.00** (p .077) Phi = 1.00 (p .077)	Group 3 Chi^2 = 6.00 (p .10) FE = 5.088 (p .10) CV = **1.00** (p .10) Phi = 1.00 (p .10)	Group 4 Chi^2 = 1.71 (p .576) FE = 1.715 (p .576) CV = .378 (p .576) Phi = 378 (p .576)
Charter group	Small Chi^2 = 0 (p 1) FE = 0 (p 1) CV = 0 (p 1) Phi = 0 (p 1)	Medium Chi^2 = 1.635 (p .667) FE = 1.788 (p .697) CV = .226 (p .667) Phi = .226 (p .667)	Large Chi^2 = 6.00 (p .333) FE = 4.398 (p .333) CV = 1.00 (p .333) Phi = 1.00 (p .333)	Wetbulk Chi^2 = 5.60 (p .147) FE = 4.837 (p .189) CV = .632 (p .147) Phi = .632 (p .147)	Drybulk Chi^2 = 5.489 (p .105) FE = 4.659 (p .105) CV = **.650** (p .105) Phi = .650 (p .105)	Chi^2 = 2.695 (p .488) FE = 2.623 (p .498) CV = .239 (p .488) Phi =.239 (p .488)			

Table 7.20: Summary of elaboration analysis for general speed reduction measure

Chi^2 = Chi-squared test

FE = Fisher's exact test

CV = Cramer's V

p. = significance level

Underlined values show a moderate and strong relationship

Bold values show a statistically significant relationship

7.6. Perception of barriers to energy efficiency

This section aims to investigate the relationship or association between the perception of barriers to energy efficiency and the characteristics of firms, such as their size, sector in which they operate and their chartering levels. This will enable the answering of specific research question number two; how is the perception of barriers related to size, sector and chartering ratio? This question was partly answered in chapter six sections 6.4.2, where the same question was investigated but at a general level. The focus in this section is mainly on market failures i.e. split incentives and informational problems, the top most selected barriers by the respondents of the survey. Figure 7.12 below shows the distribution of the number of respondents who cited these as barriers. In order to perform the same type of elaboration analysis as above, a number of options are available for crosstabulation. One could use the absolute number (the frequency or number of times barrier cited) in the crosstabulations, which would result in large tables with many empty cells but still within the guideline limit of 8*8 table as suggested by de Vaus (1995). This would make tables unreadable visually and leave the analysis dependent heavily only on the descriptive statistics (e.g. the correlation coefficient). Alternatively, it was decided to employ collapsing or combining of categories approach for the split incentives barrier, which is advised by de Vaus (1995) if too many nominal categories are present. The frequency of citations were grouped into three groups, high (>=5) medium (3 – 4) and low (<=2), which results into equal split of the histogram frequency (33% of respondents for each group). Responses to informational problems did not vary as much, 98% of respondents cited the barrier between zero and four times throughout the survey and therefore there wasn't a need to collapse the categories.

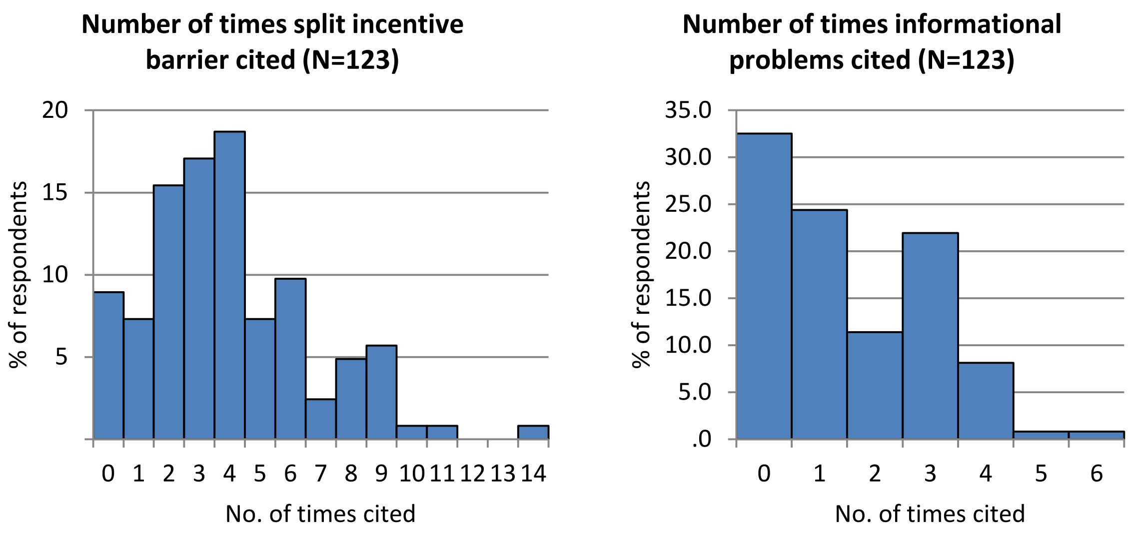


Figure 7.12: Frequency distribution of split incentives barrier and information problem

The survey captured perception on barriers in two main ways as explained in 6.4.2. From these an approach similar to the summated scale is used to identify the position of the respondent regarding that barrier. An attempt was made to disaggregate the perception of barriers by size of companies and sector (figures C1.7 and C1.8 in appendix C). Some relationships could be visually identified for the size variable but it was not possible to identify relationships between sector and perception of barriers. In this section an in-depth analysis is carried out for the original relationships in order to assess whether these relationships are subgroup specific or apply generally.

7.6.1. Perception of the split incentives barrier

In section 6.4.2 it was seen that the split incentives barriers were the top rated barriers for four operational measures, which were mainly speed related fuel saving measures (general speed reduction, speed reduction – JIT arrivals, efficient voyage execution and optimisation of ballast voyages). There were mixed responses on each of the questions measuring the position of the respondent on this hence relationships were difficult to assess.

7.6.1.1. Relationship of split incentives barrier perception with size

Figure 7.13 below shows the zero order relationship between size of the company and perception of split incentives barrier. There were more respondents in large companies who did not perceive split incentives as an important barrier compared with medium and small sized companies. There was a weak but statistically significant association between size and perception (Cramer's V = 0.181, p 0.098).

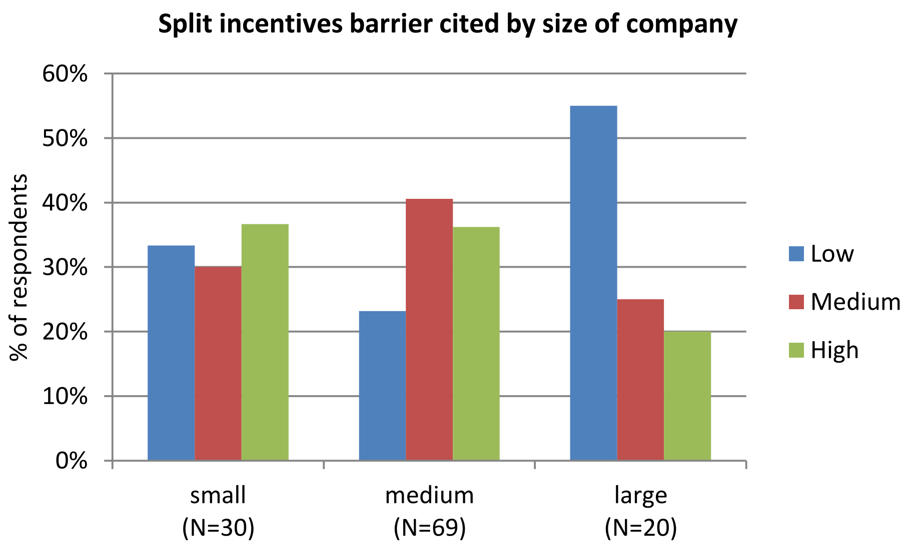


Figure 7.13: Zero order relationship between perception of split incentives and size

When controlling for sector, this original relationship showed a very marginal increase in association, the replication suggests that the relationship is not a spurious one. However, when controlling for chartering group the relationship between size and perception improved considerably and even significantly for chartering group four (management companies majority of fleet chartered out on time). A closer inspection of the conditional table reveals that 100% of this chartering group and chartering group two large firms had low citation of the split incentive barrier. Thus one can conclude that although the association between size and perception of the barrier persists amongst all groups, it holds more for specific subgroups of the sample. The finding suggests that larger firms with a majority of their fleet on time charter do not perceive the split incentive as barriers to implementation of energy efficiency operational measures. This is corroborated with high levels of implementation for the weather routing and the general speed reduction measure but contradicts the high level of implementation of the fuel consumption monitoring measure by small firms in chartering group one.

7.6.1.2. Relationship of split incentives barrier perception with sector

Zero order relationship between split incentives perception and sector showed a weak association or no association which is also highly non-significant (Cramer's V = 0.06, p 0.993). This can also be seen from Figure 7.14 below, where all the companies in the sectors uniformly perceived the split incentive barrier.

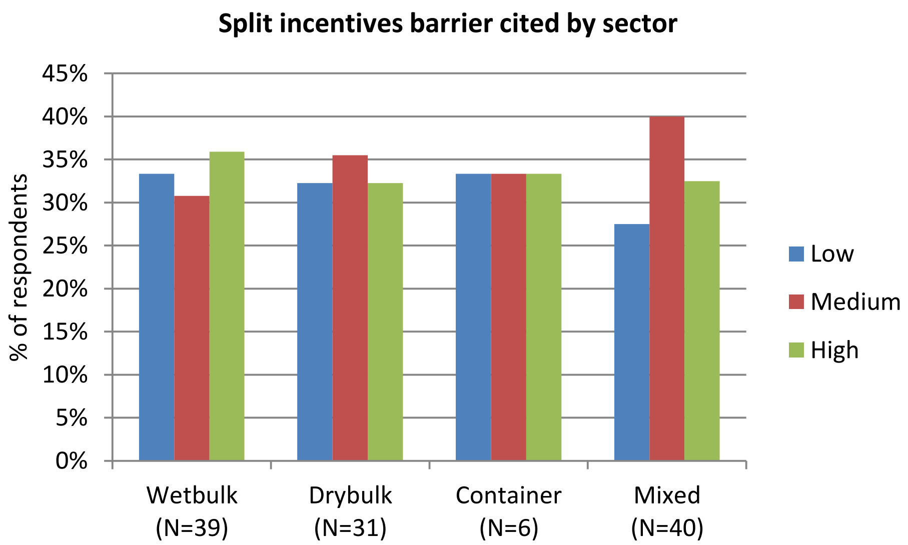


Figure 7.14: Zero order relationship between perception of split incentives and sector

Conditional relationship between perception of the split incentive barrier and sector controlling for size showed a modest increase in associations from the zero order relationship. This increase was observed for all categories of the size variable, in other words the original relationship strengthened when controlling for small, medium and large companies. The highest relationship was found to be when controlling for large companies. Large sized companies in all sectors were found to be clustered around the low level citation of the split incentives barrier, over 50% of the 19 respondents in the large size group fell in the low citation group, compared to 20% and 30% for medium and small sized groups, stressing on the previous zero order relationship between the split incentive barrier and size.

When controlling for the chartering group, once again the strength of association increases for all four chartering groups and is similar across the groups. The increase is quite large compared to the zero order relationship, which suggests that chartering group is probably a suppressing variable which confounds the original relationship. Closer inspection of the conditional tables does not show any visual patterns or differences by sector and chartering groups, instead for all chartering groups the respondents are evenly spread across the perception categories. Therefore the perception of split incentives cannot be said to be different for each chartering group between the sectors. The higher conditional relationships therefore could be an artefact of the lower sample size resulting in sparsely populated crosstabulations cells.

7.6.1.3. Relationship of split incentives barrier perception with chartering group

The zero order relationship between perception of split incentives barriers and chartering group showed a weak and insignificant relationship (Cramer's V = 0.172, p 0.661), similar to that seen for zero order relationship between split incentives perception and size. Figure 7.15 below shows this zero order relationship and it can be noted that there is a clear pattern for one of the chartering groups, which could be due to other variables that are investigated in conditional relationships that follow.

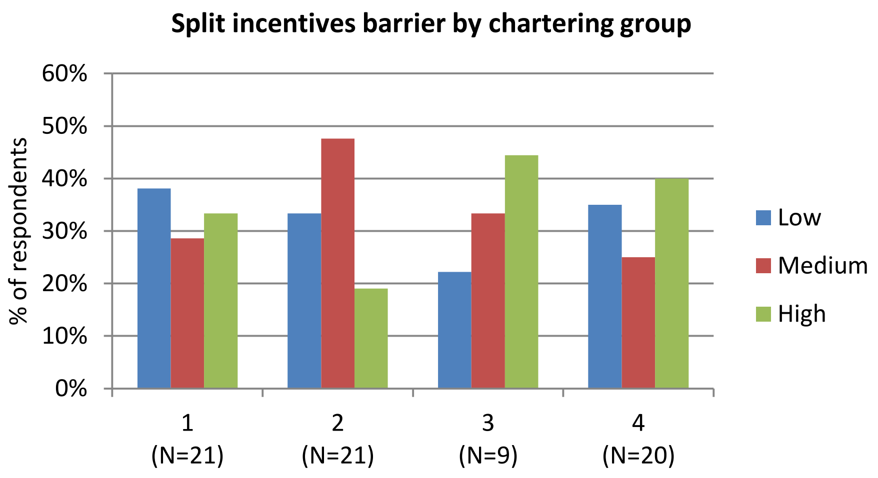


Figure 7.15: Zero order relationship between perception of split incentives and chartering group

Controlling for the size variable shows some interesting results. The strength of association improves for all size categories but substantially when controlling for small and large sized companies, which suggests that the relationship observed in Figure 7.15 could be due to the size of companies, which as shown before is true for large companies. 75% of the respondents in the large size group were found to be in the low citation category across all chartering groups, as opposed to around 30% of respondents in the small and medium size groups in the same citation category across the chartering groups.

	Small					Large			
	Group 1 (N=6)	Group 2 (N=4)	Group 3 (N=1)	Group 4 (N=5)		Group 1 (N=3)	Group 2 (N=1)	Group 3 (N=1)	Group 4 (N=3)
Low	33%	0%	0%	60%		67%	100%	0%	100%
Med	17%	75%	0%	40%		33%	0%	0%	0%
High	50%	25%	100%	0%		0%	0%	100%	0%

Table 7.21: Perception of split incentives barrier and chartering group controlling for size

When controlling for the sector variable the effect size increases considerably for both wetbulk and drybulk sectors to moderate level of association. From the conditional tables below it can be observed that chartering group two respondents (majority of the fleet owned and chartered out on time) have a contrasting perception of the barrier depending on the sector. There were also much larger variances among the groups in the drybulk sector, indicated by the higher Chi squared statistic (9.125, p 0.107) and higher level of association (Cramer's V = 0.503, p 0.107). There isn't a noticeable relationship between the chartering groups in the two sectors and the conditional table does not show previously observed split relationship between each of the chartering groups on voyage and time charter.

	Wetbulk					Drybulk			
	Group 1 (N=4)	Group 2 (N=4)	Group 3 (N=4)	Group 4 (N=8)		Group 1 (N=10)	Group 2 (N=6)	Group 3 (N=1)	Group 4 (N=1)
Low	50%	0%	25%	50%		20%	67%	0%	0%
Med	25%	75%	25%	13%		50%	33%	100%	0%
High	25%	25%	50%	38%		30%	0%	0%	100%

Table 7.22: Perception of split incentives barrier and chartering group controlling for sector

The above findings suggest that the size of the firm has the highest causal effect on the perception of the split incentive barriers. Larger firms are less likely to cite the split incentives problem compared to smaller firms. Moreover, larger firms with a majority of their fleet on time charter do not perceive the split incentive as barriers to implementation of weather routing and general speed reduction measures. Large sized firms in all sectors also did not perceive the split incentives as a barrier to implementation.

The chartering group variable which is also an indicator of split incentives did not have a clear relationship with the respondents' perception of the split incentives. Earlier it was suggested that it is plausible that principal agent problems or split incentives are affecting implementation but the respondents generally thought that this was not as important for their lack of implementation of measures.

Relationship of split incentive with	Holding/test variables								
	Size			**Sector**		**Chartering group**			
	Small	Medium	Large	Wetbulk	Drybulk	Group 1	Group 2	Group 3	Group 4
Size	Chi^2 = 7.823 (p .098) FE = 7.262 (p .12) CV = .181 (p .098) Phi = .256 (p .098)			Chi^2 = 3.207 (p .553) FE = 3.309 (p .564) CV = .205 (p .553) Phi = .291 (p .553)	Chi^2 = 2.604 (p .726) FE = 2.976 (p .564) CV = .208 (p .726) Phi = .295 (p .726)	Chi^2 = 2.667 (p .758) FE = 2.67 (p .776) CV = .252 (p .758) Phi = .356 (p .758)	Chi^2 = 4.172 (p .413) FE = 4.238 (p .372) CV = .315 (p .413) Phi = .446 (p .413)	Chi^2 = 3.214 (p 1) FE = 3.562 (p 1) CV = .423 (p 1) Phi = .598 (p 1)	Chi^2 = 13.5 (p .006) FE = 12 (p .003) CV = **.581 (p .006)** Phi = .821 (p .006)
Sector	Chi^2 = 4.236 (p .742) FE = 4.179 (p. 74) CV = .275 (p .742) Phi = .389 (p .742)	Chi^2 = 2.589 (p .884) FE = 2.987 (p .853) CV = .141 (p .884) Phi = .2 (p .884)	Chi^2 = 3.8 (p .829) FE = 4.554 (p .759) CV = .316 (p .829) Phi = .447 (p .829)	Chi^2 = .828 (p .993) FE = 1.126 (p .992) CV = .06 (p .993) Phi = 0.08 (p .993)		Chi^2 = 5.024 (p .327) FE = 5.073 (p .313) CV = .354 (p .285) Phi = .501 (p .285)	Chi^2 = 5.73 (p .507) FE = 5.981 (p .491) CV = .388 (p .454) Phi = .549 (p .454)	Chi^2 = 2.25 (p .771) FE = 2.663 (p 1) CV = .354 (p .771) Phi = .5 (p .771)	Chi^2 = 5.248 (p .69) FE = 5.139 (p .645) CV = .362 (p .689) Phi = .512 (p .512)
Charter group	Chi^2 = 9.271 (p .14) FE = 8.33 (p .182) CV = .538 (p .14) Phi = .761 (p .14)	Chi^2 = 7.67 (p .276) FE = 7.4 (p .281) CV = .286 (p. 276) Phi = .404 (p. 276)	Chi^2 = 9.778 (p .464) FE = 7.930 (p .464) CV = .782 (p .464) Phi = 1.1 (p .464)	Chi^2 = 6.369 (p .413) FE = 5.829 (p .563) CV = .399 (p .413) Phi = .564 (p .413)	Chi^2 = 9.125 (p .107) FE = 7.793 (p .145) CV = .503 (p .107) Phi = .712 (p .107)	Chi^2 = 4.217 (p .661) FE = 4.273 (p .661) CV = .172 (p .661) Phi = .244 (p. 661)			

Table 7.23: Summary of elaboration analysis

Chi^2 = Chi-squared test

FE = Fisher's exact test

CV = Cramer's V

p. = significance level

Underlined values show a moderate and strong relationship

Bold values show a statistically significant relationship

7.6.2. Perception of informational problems

In chapter 6.4 it was seen that the informational barriers were also the top rated barrier for the four operational measures, which were more technical fuel saving measures (weather routing, autopilot adjustment and trim/draft optimisation). The combination of the split incentives barrier and informational barriers suggested that most respondents perceived the principal agent problems as important barriers to implementation. Having discussed split incentives, the following sections examine the relationship of perception of informational problems with firm characteristics in order to assess whether respondent perceptions are as a result of their belonging to certain population or sub-populations.

7.6.2.1. Relationship of information barrier perception with size

It is thought that there would be a relationship between size of company and the perception of informational problems as seen in the literature on barriers to energy efficiency (Sorrell et al. 2000). Thus, the alternative hypothesis is that there is a relationship between informational problems and size of the company. The initial relationship between perception of this barrier and size shows that large firms had perceived this to be less of a barrier than small sized firms. Figure 7.16 below shows that 50% of the large companies (ten respondents) did not cite this even once throughout the survey as opposed to small and medium sized companies. This suggests that there is some association between the size of companies and perception of this barrier, which is also indicated by the moderate effect size with Cramer's V of 0.215 (p 0.556). To test the accuracy of this relationship, sector and chartering group variables are controlled for.

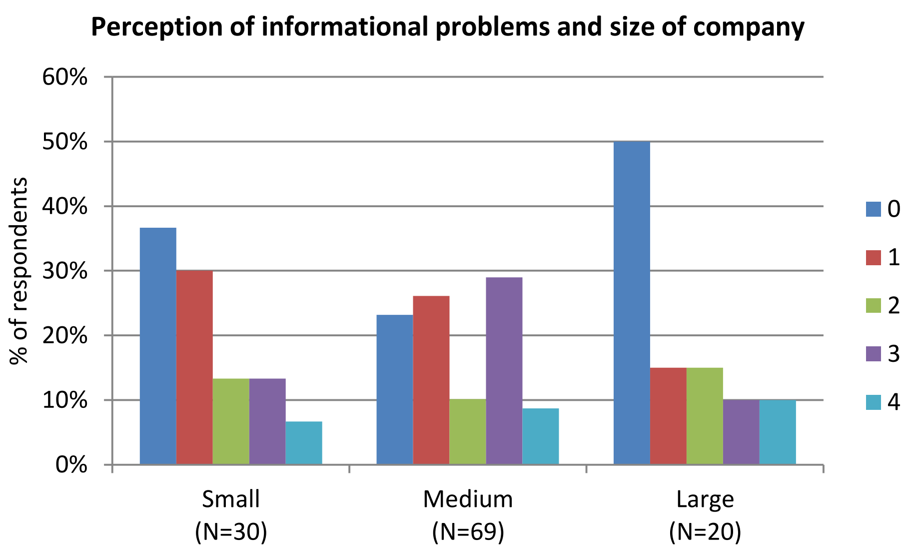


Figure 7.16: Zero order relationship between perception of informational problems and size

When controlling for sector, the original relationship gets stronger for the wetbulk sector and persists for the drybulk sector. This implies that the zero order relationship applies more for the wetbulk sector than for the drybulk sector. Looking at the conditional tables for wetbulk sector, larger companies tend to cite this barrier more than the larger companies in the drybulk sector. A possible explanation to this could be because of the greater scrutiny faced in the wetbulk sector (e.g. through vetting) from major wetbulk charterers, which makes it an attractive market for suppliers or vendors of operational efficiency measures e.g. trim/draft optimisation, to concentrate their efforts in gaining market share in that sector, perhaps making the market inundated with a variety of information on costs and savings.

Controlling for chartering group, the effect sizes increase to moderate effect sizes for all the chartering groups, suggesting the zero order relationship is replicated and therefore robust under all the controlled conditions. Examination of the conditional tables reveals that the small sized firms in chartering groups two and four (majority of the fleet out on time charter) perceived less informational problems compared to small sized firms in chartering groups one and three (majority of the fleet out on voyage charter). The same trend was not observed for large sized firms. The extent to which this perception affects implementation of small size firms is unclear, since implementation by small firms for all three measures controlling for chartering group showed no difference in implementation levels.

7.6.2.2. Relationship of information barrier perception with sector

The zero order relationship between perception of the barrier and sector is not as easily visualised compared to the relationship of informational problems and size. The crosstabulation is also difficult to read, however just using the descriptive statistic for measuring association, Cramer's V 0.235 (p 0.375), shows a weak to moderate relationship between the variables. This is very similar to that observed for the preceding variables (size and perception) zero order relationship but this correlation coefficient is much higher than that observed for zero order relationship between sector and split incentives.

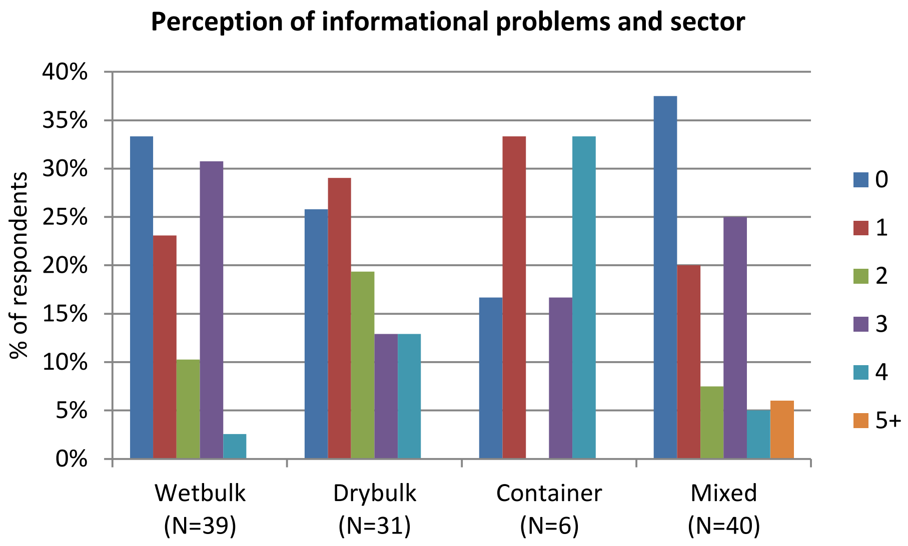


Figure 7.17: Zero order relationship between perception of informational problems and sector

The conditional relationships when controlling for size showed similar patterns of association as seen in previous conditional relationships between split incentives perception and sector. The effect size increases considerably when controlling for large sized companies. Conditional tables show that informational problems are perceived as less important barriers in small and medium wetbulk firms and perceived as important barriers for small and medium sized firms in drybulk sector. This is opposite of what is observed for large sized firms where informational problems are considered to be important in the wetbulk sector rather than drybulk sector. Chapter nine discusses why this is observed, despite larger firms according to theory and literature on barriers to energy efficiency facing less informational problems due to their resources to verify the credibility, source, quality of information on energy efficiency.

Holding for chartering group, the strength of association increases for all the chartering groups, although all of the conditional relationships are highly non-significant. The conditional tables replicate the patterns observed above where the wetbulk sector perceived lower informational problems compared to drybulk sector.

7.6.2.3. Relationship of information barrier perception with chartering group

According to agency theory, the principal agent relationship leads to two problems; diverging interests and informational problems (costs of monitoring, obtaining information, etc.). The indicator for diverging interests in the survey was the citation of split incentive barrier as well as the chartering level. Correlation between split incentives and informational problems shows a statistically significant positive and moderate correlation of 0.335, $p < 0.01$, although the scattergram shows a very wide spread. Here, the second measurement is used to hypothesize that there is some relationship between actual chartering level and informational problems cited. Zero order relationship between information barrier and chartering group is the highest that has been observed so far, Cramer's V = 0.288 (p 0.30). Figure 7.18 below shows the number of respondents citing information barrier by the chartering group. Although there isn't a visual relationship it can clearly be seen that group three had the highest proportion of respondents that perceived no information related problems as a barrier affecting implementation.

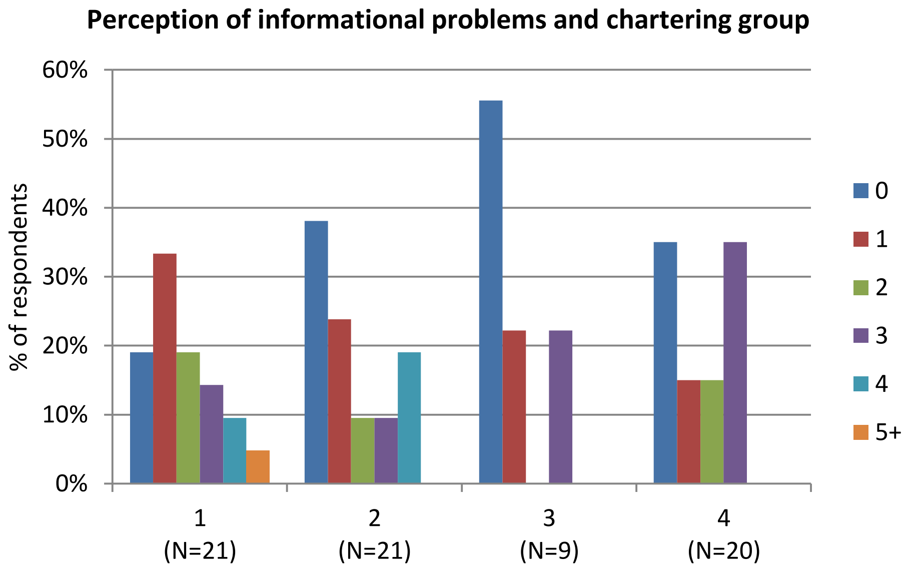


Figure 7.18: Zero order relationship between informational problems and chartering group

When controlling for sector, the strength of the relationship improves to moderate levels for both the wetbulk and drybulk sectors but at statistically non-significant levels. Conditional tables show that in the wetbulk sector the differences amongst the different chartering groups citing no informational problems is not as wide ranging compared to the conditional tables of the drybulk sector, where chartering group one and two respondents perception is markedly different to group three and four. This pattern was also observed in the conditional relationship between split incentives and the chartering group.

Controlling for size of companies, for small sized companies the effect size is substantial and statistically significant (Cramer's V = 0.693, p 0.048), which suggests that there is a good possibility of a strong relationship between chartering group and perception of information barrier for small sized companies in the population. The conditional table for the small sized firm displays the hypothesised relationship where perception of the barrier is lower for chartering group two and chartering group four. This was not the case for medium sized and large sized firms. This relationship is similar to that when the size variable was treated as independent and chartering group variable is used as a test variable.

7.6.3. Concluding remarks

The above analysis suggests that in most cases the larger firms perceive more informational problems than medium and small sized firms and this is mainly in the wetbulk sector. The explanation for this is provided in chapter nine, where it is discussed in the context of the findings from other methods. This finding is in contrast to the perception of split incentives barriers where they consider it as a less important factor that is affecting their implementation of measures. This suggests that sized based heterogeneity could also be influencing the uptake of operational measures. This sized based difference was also noted in two instances where the small sized firms in chartering groups two and four (majority of the fleet out on time charter) perceived less informational problems compared to small sized firms in chartering groups one and three (majority of the fleet out on voyage charter). This trend was not observed in the analysis of the perception of split incentives.

<table>
<tr><th rowspan="2">Relationship of information barrier with</th><th colspan="9">Holding/test variables</th></tr>
<tr><th colspan="3">Size</th><th colspan="2">Sector</th><th colspan="4">Chartering group</th></tr>
<tr><td>Size</td><td colspan="3">Chi^2 = 11.015 (p .556)
FE = 11.177 (p .452)
CV = .215 (p .556)
Phi = .304 (p .556)</td><td>Wetbulk
Chi^2 = 12.624 (p .10)
FE = 11.1 (p .135)
CV = <u>.408</u> (p .103)
Phi = .576 (p .103)</td><td>Drybulk
Chi^2 = 2.92 (p .982)
FE = 3.588 (p .985)
CV = .221 (p .982)
Phi = .312 (p .982)</td><td>Group 1
Chi^2 = 10.875 (p .42)
FE = 10.11 (p .407)
CV = <u>.509</u> (p .416)
Phi = .720 (p .416)</td><td>Group 2
Chi^2 = 5.906 (p .735)
FE = 6.934 (p .736)
CV = <u>.375</u> (p .735)
Phi = .530 (p .735)</td><td>Group 3
Chi^2 = 4.629 (p .72)
FE = 4.291 (p .722)
CV = <u>.507</u> (p .722)
Phi = .717 (p. 722)</td><td>Group 4
Chi^2 = 8.09 (p .257)
FE = 7.538 (p .219)
CV = <u>.450</u> (p .257)
Phi = .636 (p .257)</td></tr>
<tr><td>Sector</td><td>Small
Chi^2 = 6.808 (p .902)
FE = 8.776 (p .937)
CV = .285 (p .902)
Phi = .493 (p .902)</td><td>Medium
Chi^2 = 16.876 (p .51)
FE = 17.8 (p .476)
CV = .294 (p .505)
Phi = .510 (p .505)</td><td>Large
Chi^2 = 13.077 (p .46)
FE = 11.087 (p .715)
CV = <u>.479</u> (p .460)
Phi = .830 (p. 460)</td><td colspan="2">Chi^2 = 19.268 (p .375)
FE = 19.388 (p .353)
CV = .235 (p .375)
Phi = .408 (p .375)</td><td>Group 1
Chi^2 = 7.194 (p .833)
FE = 8.036 (p .736)
CV = <u>.424</u> (p .833)
Phi = .6 (p .833)</td><td>Group 2
Chi^2 = 10.07 (p .726)
FE = 10.318 (p .708)
CV = <u>.420</u> (p .726)
Phi = .728 (p .726)</td><td>Group 3
Chi^2 = 0.9 (p 1)
FE = 2 (p 1)
CV = .224 (p 1)
Phi = .316 (p 1)</td><td>Group 4
Chi^2 = 7.286 (p .75)
FE = 8.271 (p .657)
CV = .348 (p .75)
Phi = .604 (p .75)</td></tr>
<tr><td>Charter group</td><td>Small
Chi^2 = 23.06 (p .048)
FE = 14.772 (p .204)
CV = <u>.693</u> (p .048)
Phi = 1.201 (p .048)</td><td>Medium
Chi^2 = 18.77 (p .214)
FE = 16.101 (p .288)
CV = <u>.365</u> (p .214)
Phi = .635 (p .214)</td><td>Large
Chi^2 = 5.867 (p 1)
FE = 9.084 (p 1)
CV = <u>.494</u> (p 1)
Phi = .856 (p 1)</td><td>Wetbulk
Chi^2 = 6.25 (p .807)
FE = 6.584 (p .821)
CV = <u>.323</u> (p .807)
Phi = .559 (p .897)</td><td>Drybulk
Chi^2 = 10.6 (p .718)
FE = 11.983 (p .588)
CV = <u>.443</u> (p .718)
Phi = .767 (p .718)</td><td colspan="4">Chi^2 = 17.721 (p .3)
FE = 16.290 (p .3)
CV = .288 (p .3)
Phi = .5 (p .3)</td></tr>
</table>

Table 7.24: Summary of elaboration analysis

Chi^2 = Chi-squared test

FE = Fisher's exact test

CV = Cramer's V

p. = significance level

Underlined values show a moderate and strong relationship

Bold values show a statistically significant relationship

7.7. Concluding remarks

Taking the above findings on implementation of measures and perception of barriers into account one can conclude that the chartering group variable i.e. the principal agent problem has a modest impact on the implementation of the three measures analysed. This is consistent with the theory and confirms the hypothesis that firms with a majority of the ships on time charter will have higher implementation of operational measures compared to firms with a majority of the ships on voyage charter. To some extent the sector variable also influences the implementation of the operational measures analysed, therefore sectoral heterogeneity i.e. non-market failures also affect the implementation of operational measures. The specific nature or direction of this influence or relationship remains unknown for the shipping sector and thus it could not be ex ante hypothesised which sector would have had higher implementation of the measures.

In general, the size variable was important in defining perceptions of barriers, both for split incentives and informational problems. Some theories and literature exist, specifically for shipping and in the context of barriers to energy efficiency, they suggest that smaller firms would face higher information problems and fewer split incentives, but the results on the perception of the barriers above suggest otherwise. So the emerging picture appears to imply that market failures, specifically the principal agent problem and to some extent sectoral heterogeneity are an important factor explaining the lack of and differences in implementation of energy efficiency operational measures. On the other hand, sectoral and size heterogeneity seem to affect the respondents' perception of barriers to implementation.

In elaboration analysis one seeks to assess how much of the zero order relationship remains after the contribution of the test variables have been removed. Generally, the relationship strength decreases (meaning spurious relationship detected or intervening variables detected), remains the same (replication) or increases for one category of the test variable and decreases for another (specification). In most of the above cases of conditional relationships the strength increases for one category of the test variables and remains the same for other categories of the test variable. This implies that when holding other things equal, the original zero order relationship between the dependent variables with size, sector and chartering group (independent variables) are replicated. Hence all these variables have an impact on the dependent variables. Rosenberg (1968, cited by Peyrot 1996) and Babbie (2004) notes the possibility of situations where the relationship gets even stronger for one category of the test variable and remains constant for another category of the test variable. Since in the elaboration analysis above only one variable has been controlled each time, the conditional relationships only reflect control for one variable and ignore the remaining variable. It is possible to control for several variables simultaneously in bivariate crosstabulations above but since the number of responses achieved in the survey is relatively small, it results in even smaller number of respondents in each cell to allow any meaningful interpretation. Furthermore, as described by Peyrot (1996), determining clear causality is seldom achievable because “variables introduced as test variables are themselves correlated, therefore it is not possible to tell whether their impact on the original relationship overlaps and if so by how much?” Peyrot (1996, p.8). This issue affects the internal validity of the quantitative self-administered questionnaire (whether conclusions incorporate causal relationships) and as explained in section 3.2.1, the mixed methods design strategy should help to overcome some of the weaknesses of the methods used. The next chapter thus uses a more qualitative method to investigate the principal agent problem in shipping.

8. Content analysis of charterparties

This chapter combines the content analysis method and the principal agent theory framework as proposed by Eisenhardt (1989) to assess the barriers to and potential for improving energy efficiency. It is hoped that the content analysis method for analysing shipping contracts (charterparties) can reveal practical barriers that may be inhibiting uptake of operational measures, thus answering research question five. The aim of this chapter therefore is to provide completeness and comprehensiveness to the survey results discussed in the preceding chapters. An analysis of charterparties will also give a detailed context of the principal agent barriers that may be hindering the uptake of operational measures.

The chapter begins with a brief section explaining the agency theory framework or propositions for the contract that governs the principal agent relationship. This is followed by the coding and categories development section that extracts relevant parts of the theory and framework in order to apply content analysis in a structured way. This is followed by the findings of the qualitative content analysis pertaining to the different types of contracts in shipping. As shown in Figure 8.1 below, this chapter deals with the highlighted components of the research framework as proposed in chapter three. Chapter nine then collates the findings from the various strands of research to explain implementation of measures and barriers to their uptake.

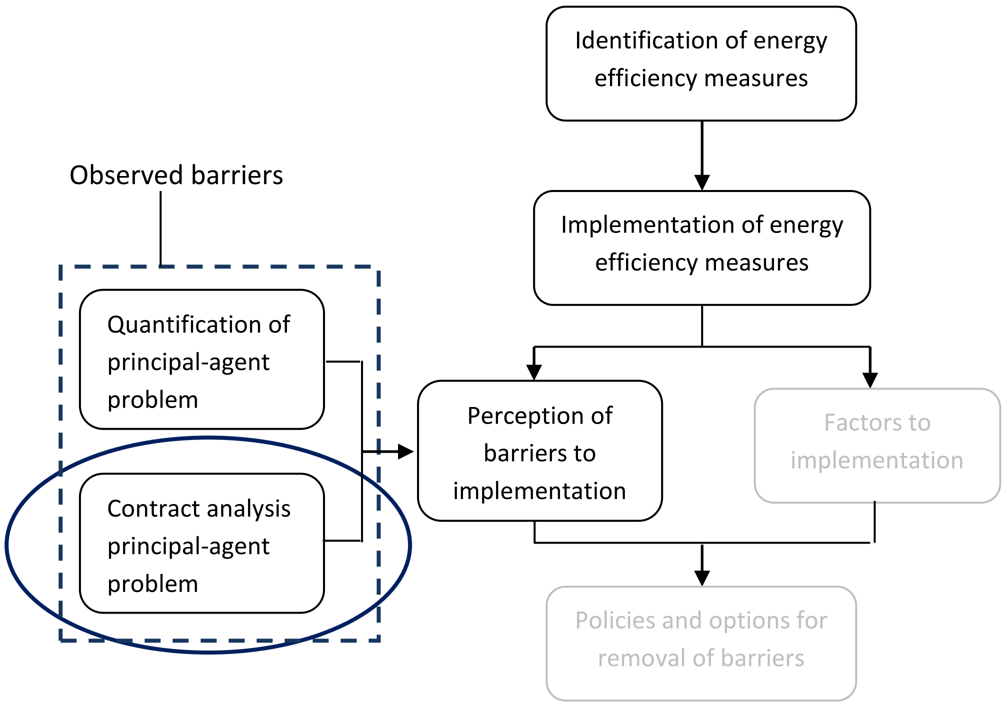


Figure 8.1: Focus of chapter eight in context of the framework

Since this research employs the sequential explanatory design (Creswell 2009), the findings from the quantitative data collection and analysis from the previous chapter are used to build on and inform the qualitative data collection and analysis. “A sequential explanatory design is typically used to explain and interpret quantitative results by collecting and analysing follow-up qualitative data” (Creswell 2009, p.211). The qualitative data will help to explain the results in more detail. According to Krippendorff (2004) there are two reasons for starting the content analysis with research questions in advance of any inquiries; to gain efficiency and empirical grounding. The survey findings showed that operational measures had varying implementation when disaggregated by size, sector and chartering group. More specifically, the results showed that for speed related measures (general speed reduction and JIT arrivals) or ones that had an element of speed (efficient voyage execution and optimisation of ballast voyages) the respondents mainly cited that these were difficult to implement under different types of charter and that charterparties did not allow for their implementation (refer to Table 6.8). Charterparty clauses as a barrier were the fourth highest barrier of the total responses received. For the speed reduction measure, standard charterparty clauses were the top most selected respondent choices for lack of implementation. It is also suggested that the inability to implement a measure under different types of charter is also to some extent due to the charterparty clauses. Using these claims as a starting point for the inductive research, this chapter seeks to answer research question five which asks; how do the agency problems in contracts affect the implementation of energy efficient operational measures?

A principal agent relationship is affected by several agency problems, problems of information asymmetry, goal conflict, risk bearing etc. (Eisenhardt 1989 and Wright, Mukherji & Kroll 2001). The goal of agency theory is to resolve these problems (Eisenhardt 1989) in order to maximise the principal’s welfare (Wright, Mukherji & Kroll 2001). One way in which this is done is through determining the most efficient type of contract given the agency problems. This chapter uses Eisenhardt’s (1989) propositions or framework and the content analysis method to distil the content of shipping contracts in order to identify the key agency problems and their effect on the implementation of energy efficient operations. In chapters five and seven it was observed that the type of contracts can have an impact on implementation. The conclusions from chapter five, and supporting analysis from the survey results show that operational measures implementation were believed to be more of a problem under voyage charter than in time charter. In this chapter the investigation delves deeper into understanding the content of the shipping contracts to examine how and why they affect the implementation of energy efficient operational measures.

8.1. The contract in the context of agency theory and energy efficiency

This section examines the applications of agency theory, the research methods used to investigate contracts and to what extent has existing research combined these two in the context of energy efficiency. In chapter two agency theory (Ross 1973; Jensen and Meckling 1976; Fama & Jensen 1983) with its assumptions and linkages to the barriers to energy efficiency literature were examined. The shipowner and the charterer can be said to be involved in an agency relationship, in which one party (the principal i.e. charterer) delegates work to another (the agent i.e. shipowner), who performs that work (Ross 1973; cited by Eisenhardt 1989) or when one individual depends on the action of another (Pratt and Zeckhauser 1985). These two parties are linked via a contract. Agency theory is concerned with creating the most 'efficient' contracts that overcome the problems of agency i.e. goal conflict and informational problems between the principal and agent, as well as problems of risk. Whilst much of positivist research has applied agency theory in organisational contexts e.g. owner-manager, shareholder perspectives (Ahimud and Lev 1981; Walking and Long 1984; Wolfson 1985; etc) the application of agency theory to barriers in energy efficiency has only been applied in quantification exercises seeking to quantify the amount of fuel or energy falling under various principal agent cases (e.g. IEA 2007; Murtishaw and Sathaye 2006; Vernon and Meier 2012) as examined in chapter five.

Furthermore much of the principal agent research is based on research methods such as questionnaire (Eisenhardt 1985 and 1988), and other data analysis such as meta-data analysis (Ahimud and Lev 1981) with very limited agency theory research focussing on the contract itself or contract design (Crocker and Reynolds 1993; Aubert et. al. 1997; Molinie and Abran 1999; Stremitzer 2005; etc.). The studies that focussed on contract design and agency theory (e.g. Aubert et. al. 1997; Masten & Saussier 2000; etc.) did not use the content analysis method but rather used a case study design using interviews and questionnaire methods for analysing contractual outcomes of two organisations. Having also attempted quantification of principal agent problems in chapter five, this research further seeks to extend this (agency theory and barriers to energy efficiency) by investigating the nexus between the principal and the agent, the contracts. More generally, contracting practices in shipping in the context of agency theory only have been examined by Pirrong (1993), Bergantino and Veenstra (2002), Tamvakis (1995), Tamvakis & Thanopoulou (2000) and Veenstra and Dalen (2011). These studies have not extended the examination of contracts in the context of energy efficiency. Very little grey literature exists regarding this subject e.g. Devanney 2011a; Faber et al. (2012) and much of this is legal e.g. Zerman (2011), Makkar (2005), Williamson (2012), which lack a theoretical view. Although some studies point towards contracts that are geared towards objectives that override energy efficiency (e.g. Lovins 1992), to date there has not been an analysis of contracts in any industry to see specifically how individual contracts or clauses (during design or operation) affect the potential of energy efficiency. In summary:

- Agency theory has generally been applied in an organisational economics context e.g. shareholder perspectives, owner-manager, etc.
- Agency theory and its implications on contract design have produced limited research and testable hypothesis.
- Agency theory and contract design research are based on research methods other than content analysis, thus a suitable framework for this research is lacking.
- Agency theory and barriers to energy efficiency literature that uses agency theory have mainly focussed on quantification of the principal agent problem.
- Agency theory has seen limited application in the examination of shipping markets and contractual practices
- Contract analysis in shipping i.e. charterparties have been discussed in other aspects e.g. laytime and demurrage, etc.
- Grey literature on charterparties and energy efficiency mainly focussed on speed clauses.
- Contracts in shipping have therefore not been investigated thoroughly in the context of agency theory and energy efficiency.

8.1.1. Framework for agency theory and contract analysis

Since the literature on conducting agency theory and energy efficiency content analysis of contracts is scarce, Eisenhardt's (1989) framework is thought to help with the initial category development for content analysis of charterparties in the context of agency theory and energy efficiency. Eisenhardt (1989) defines two types of contracts; behaviour oriented and outcome oriented. Outcome based contracts tie agent compensation to agent performance e.g. piece rate (Sharma 1997), stock options, commission component etc. whereas behaviour based contracts tie compensation to monitored agent behaviour e.g. hourly rate (Sharma 1997), salaries etc.

The question that agency theory aims to answer is which of the aforementioned two types of contracts is more efficient given the situation or circumstances and assumptions regarding the entities e.g. agent opportunism, risk aversion, goal conflict, information availability, task programmability etc. In order to do this a good understanding of the situation and the parties is crucial. To that end, Eisenhardt (1988) uses empirical research methods to investigate the above circumstances to predict the best type of contract that is used in compensation of retail staff. In this research, the information regarding the above is derived from informal ethnographic methods such as observations, the survey method, literature research and grey literature (e.g. industry specific news and reports).

According to Eisenhardt (1989) options for observing behaviour (pre contract i.e. adverse selection and post contract i.e. moral hazard) are to invest in information systems or contract on outcome based contracts. The core of agency theory is therefore the trade-off between the cost of measuring behaviour and the cost of measuring outcomes and transferring risk to the agent (Eisenhardt 1989). Table 8.1 summarises the suitability of the contracts in each situation based on Eisenhardt's (1989) propositions for the type of contracts based on the above features:

- Proposition 1: When contract between principal and agent is outcome based, the agent is more likely to behave in the interests of the principal.
- Proposition 2: When the principal has information to verify agent behaviour, the agent is more likely to behave in the interests of the principal.
- Proposition 3: Information systems are positively related to behaviour based contracts and negatively related to outcome based contracts.
- Proposition 4: Outcome uncertainty is positively related to behaviour based contracts and negatively related to outcome based contracts.
- Proposition 5: The risk aversion of the agent is positively related to behaviour based contracts and negatively related to outcome based contracts.
- Proposition 6: Risk aversion of the principal is negatively related to behaviour based contracts and positively related to outcome based contracts.
- Proposition 7: The goal conflict between principal and agent is negatively related to behaviour based contracts and positively related to outcome related contracts.
- Proposition 8: Task programmability is positively related to behaviour based contracts and negatively related to outcome based contracts.
- Proposition 9: Outcome measurability is negatively related to behaviour based contracts and positively related to outcome based contracts.
- Proposition 10: The length of the agency relationship is positively related to behaviour based contracts and negatively related to outcome based contracts.

Research type	Agency theory component	Behaviour based contract	Outcome based contract
Basic and Positivist type	Goal conflict/self interest	Suitable when there is goal congruency	Suitable when there is goal conflict
	Information	Suitable when information to verify agent behaviour is available	Suitable when information to verify agent behaviour is not available
Extended and principal-agent type	Risk	Suitable when agent is risk averse (and principal can take extra risk)	Suitable when agent is less risk averse (and principal risk averse)
	Task programmability	Suitable when task is programmed	Suitable when task is less programmed
	Outcome measurability	Suitable when outcome is less measurable	Suitable when outcome is measurable
	Outcome certainty	Suitable when outcome is uncertain	Suitable when outcome is certain
	Length of relationship	Suitable in a long term relationship	Suitable in a short term relationship

Table 8.1: Suitable contracts in different situations

	Behaviour based contract	Outcome based contract
Goal conflict/self interest present		✓
Information is available	✓	
Risk averse agent	✓	
Task is programmable	✓	
Outcome is certain		✓
Outcome is measurable		✓
Long relationship	✓	

Table 8.2: Use of contracts in different situations

Sharma (1997) extends the above propositions to cater for principal agent relationship where the professions are concerned, for example the level of coproduction, agent investments, competition between agents etc. Four sets of propositions are discussed, of which the most relevant to the shipping context are the agent investment and competition propositions. When there are many competing providers of the same or similar services (substitutes), agents are more likely to assume greater risk in order to accommodate the principals (Sharma 1997), this means that the risk aversion of the agent is lower therefore outcome based contracts can be used in competitive exchanges. Regarding the contract specific investment, according to Sharma (1997) "The professional agent is less likely to behave opportunistically when the institutional context permits principals to require that agents make investment in assets specific to the exchange" (Sharma 1997, p.786). The example given here is that of 'no win no fee' type institutional practices by lawyers, thus compensation is based on the outcome making it an outcome based contract. An example of this in shipping is investment by shipowners to comply with some charterers strict vetting procedures in order to proceed to the next stage of selection.

The above propositions shall now be applied to shipping to verify the analogies presented in chapter five. The above two types of contracts, behaviour based and outcome based, can be said to be analogous to the two most prevalent contracts for carriage of goods in shipping, the voyage charter and the time charter. The time charter is where the agent gets paid a certain amount per day which can be said to be a behaviour based contract e.g. salaries and hourly rates, since the compensation is based on some time period over which behaviour of the agent is monitored. The voyage charter, where the agent gets paid a certain amount per tonne of cargo of carried or delivered, can be said to be an outcome based contract e.g. piece rates, commission, because the compensation of the agent is based on certain measured outcomes e.g. delivery of goods (in good time and good condition). Other hybrid forms of carriage of goods contracts as mentioned in section 5.2 are beyond the scope of investigation. Having established shipping contracts with broad level agency contracts, each of the above propositions is briefly tested to see whether it relates to the right type of contract in shipping. This is done for both, in general and in the context of energy efficiency. Similar type of analysis is performed by Eisenhardt (1985 and 1988) to empirically test (using questionnaires) whether the proposition and features of sales personnel in retail are related to the choice of contracts. The propositions in general and in the context of energy efficiency are thereafter tested against the evidence from the charterparty content analysis. Examining how agency problems manifest themselves in shipping contracts and in the context of energy efficiency measures will then allow for answering the research question, on how contracts (charterparty or specific clauses) can affect the implementation of energy efficient operational measures. Understanding this relationship would enable the research to corroborate findings from survey results on whether or not charterparties or clauses are a barrier to implementation of measures.

Research type	**Agency theory component**	**Behaviour based contract** **($/day) Time charter**	**Outcome based contract** **($/tonne) Voyage charter**
Basic and Positivist type	Goal conflict/self interest	Suitable when there is goal congruency Case two of principal agent matrix where time charterer can implement measures as seen in chapter five	Suitable when there is goal conflict Case four of principal agent matrix (quasi usage problem) as seen in chapter five
	Information	Suitable when information to verify agent behaviour is available Noon reporting, weather routing, hull condition monitoring	Suitable when information to verify agent behaviour is not available Charterer has no access to shipowners operational efficiency e.g. speed, other measures, hull condition
Extended and principal-agent type	Risk	Suitable when agent is risk averse During a recession shipowners prefer the time charter market (Stopford 2008) Offhire stoppage to mitigate principal’s risk (Shaddick 2012)	Suitable when agent is not risk averse During an upturn shipowners prefer the voyage market (Stopford 2008) Demurrage payment to mitigate agent’s risk (Shaddick 2012) Voyage charter generally is more risky (Girvin 2007; Wilson 2010; Chong 1993).
	Task programmability	Suitable when task is programmed Shipowners actions are dependent on charterers instructions, inventory schedule, etc.	Suitable when task is not programmed Laycan, Laytime, Laydays, Bad Weather Allowances, Notice of Readiness all vary in a voyage charter suggesting contract is versatile

	Outcome measurability	<u>Suitable when outcome is not measurable</u> Main outcome is ship seaworthiness, not being off hire, meeting speed and consumption guarantee, which are difficult to measure	<u>Suitable when outcome is measurable</u> Delivery of goods (through Bill of Ladings), 'Arrived ship' rules affecting demurrage and laytime calculations
	Outcome certainty	<u>Suitable when outcome is uncertain</u> Performance outcome of agent is unknown Principal's cargo schedules may be unknown	<u>Suitable when outcome is certain</u> Charterer can expect cargo delivery with reasonable certainty within a specific time range
	Length of relationship	<u>Suitable in a long term relationship</u> Behaviour of shipowner is monitored over a longer period of time, operational efficiency is ascertained over this time	<u>Suitable in a short term relationship</u> Behaviour of shipowner is not known due to little monitoring and contact

Table 8.3: Eisenhardt (1989) propositions and type of contracts applied to shipping

8.2. Charterparties and principal agent contracts

Under Hague-Visby rules and English common law there are several obligations placed on the shipper (charterer) and the shipowner. A shipowner has implied obligations from these sources which are; that a ship is seaworthy, that the ship will proceed with reasonable despatch and that the ship will proceed without unjustifiable deviation (Girvin 2007). A shipper has obligations to not ship dangerous goods and to nominate safe ports (Girvin 2007). Table 8.4 below shows these split according to the type of charter. For the purpose of this analysis, the shipowners obligations seem to be the most relevant to focus upon for energy efficiency.

	Shipowner	**Shipper**
Voyage charterparty	• Ship is seaworthy • Proceed with reasonable despatch • Without unjustifiable deviation	• Not to ship dangerous goods
Time charterparty	• Ship is seaworthy at commencement	• Use between good and safe ports • Not to ship dangerous goods

Table 8.4: Obligations of the shipowner and shipper under voyage and time charters

Furthermore, it can be seen that the shipowner's obligations are concentrated in the voyage charter, which has been referred to as a risky adventure (Chong 1993). Thus in the voyage charter the shipowner is exposed to higher risk, than in a time charter, making the outcome based contract more suitable. There are four stages in the performance of a voyage charterparty; the preliminary voyage to the loading point, loading operation, laden voyage to delivery point and discharging operation, as shown in Figure 8.2. Responsibility for stages one and three fall on the shipowner and stage two and four fall jointly between shipowner and charterer (Girvin 2007). From Table 8.5 below it can be seen where the potential conflict of interest lie between the agent and the principal in a voyage charter and the following sections show how charterparty clauses deal with each conflict.

Voyage leg	Shipowner	Charterer
Stage 1 - Sea passage to loading port	- Reach before (become an arrived ship and tender Notice of Readiness - NOR) before laycan - To have a flexible date of arrival or expected readiness to load	- Arrive in time for laytime - Wants a fixed date of arrival or expected readiness to load to organise cargo
	Slow or optimal steam to load port	Utmost despatch towards load port
Stage 2 - Loading operations	Minimise delay (opportunity cost), but also gain income from demurrage	
	Prefer all round 24 hour period in which to give NOR	Prefer specific time period in which to give NOR
	Prefer port charter (transfer risk of delay to charterer)	Prefer berth charter (transfer risk of delay to shipowner)
Stage 3 - Sea passage to discharging port	Slow or optimal steam to discharge port	Utmost despatch towards discharge port
	Have liberty to deviate to ports for bunkering or loading extra cargo and maintenance	Strictly no deviation allowed except for saving a life or property.
	Use weather routing for efficient route	Most direct contractually agreed route
Stage 4 - Discharging operations	Prefer all round 24 hour period in which to give NOR	Prefer specific time period in which to give NOR
	Prefer port charter (transfer risk of delay to charterer)	Prefer berth charter (transfer risk of delay to shipowner)

Table 8.5: Potential conflict of interests between principal and charterer in the voyage charter

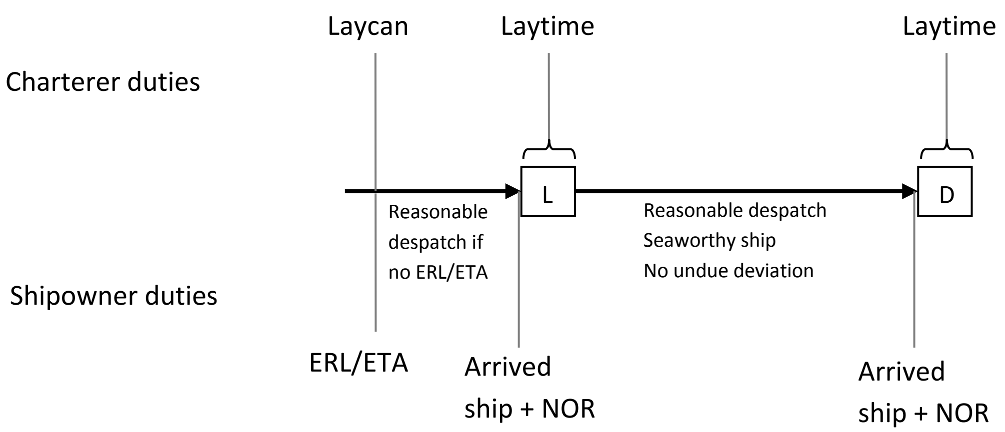


Figure 8.2: Components of a voyage charter

8.3. Categories and coding development

Chapter four outlined the content analysis method and stages that are used in this research as well as describing the unit of analysis and sampling procedures relevant for the content analysis used in this research. Having familiarised with the purposive sample of the most prevalent or important charterparties, the next step in the content analysis is to generate some broad categories that will guide further reading of charterparties. This step is similar to the operationalization stage of the survey method. In content analysis the most important step is to define the categories within the data. As Berelson (1952; cited by GAO 1989) states:

"Content analysis stands or falls by its categories. Particular studies have been productive to the extent that the categories were clearly formulated and well adapted to the problem and to the content." (Berelson 1952, p. 147)

The research is interested in assessing whether the implementation of measures varies by types of charter and whether this is caused by specific clauses in the types of charter. Thus it is reasonable to begin with contextual units (charterparty clauses) that deal with each of the measures. The initial categories are obtained from the survey research method and familiarisation of a few charterparties (following inductive content analysis and using previous research and data specific categories), which then guided the content analysis. The initial categories attempted to relate various charterparty clauses to the relevant operational measures as shown in Table 8.6.

	Speed related measures	**Trim/draft optimisation**	**Weather routing**	**Measure X_i**	**Measure X_{ii}**
Voyage charterparty	Utmost despatch clause	Trimming clause	Deviation clause		
Time charterparty	Slow steaming clause	Trimming clause	Deviation clause		

Table 8.6: Initial categories for content analysis of charterparties

The categories then also draw from agency theory contracting literature as described in section 8.1.1 and 8.2. This was further refined through an iterative reading so that the categories applied to all measures. The first three categories are the most important to positivist type agency theory research and it is found that these easily manifest or exhibit themselves within the contracts, as shown in Table 8.7.

Type of contract	Agency propositions (coding categories)	Speed related measures	Trim/draft optimisation	Weather routing
Voyage charterparty	Goal conflict	Utmost despatch		
	Information			
	Risk	Place of NOR		
	Task programmability			
	Outcome measurability	NOR clause		
	Agent competition			
Time charterparty	Goal conflict			
	Information	Type of reporting		
	Risk			
	Task programmability			
	Outcome measurability			
	Agent competition			
	Contract specific investment			

Table 8.7: Further category development from inductive content analysis of charterparties

From the above matrix category format and using examples from Mayring (2000) the final coding agenda focussed on the goal conflict categories, information categories (positivist type) and one proposition from the remaining extensions of the principal agent theory (refer to appendix D for full coding scheme). These categories were sometimes latent and at times easily manifested themselves in the contract. For example the voyage charterparty (outcome based contract) manifested clearly the goal conflict between the principal and agent, and clauses were used specifically to address this issue. Coding was limited to the contextual units (i.e. charterparty clauses of interest) and took place through multiple iterations over time. Initial coding of each contextual unit began with manual annotation of the charterparty text (for close reading). The relevant text was then transposed to a spreadsheet, grouped according to sector and type of charterparty as shown in Table 8.8. By systematically organising the data in this way, emerging patterns and relationships were easily observed. The next section provides a brief description and context of some of the clauses (shown in Table 4.8) that are thought to be affecting the implementation of two of the top three (by potential and implementation level) energy efficient operational measures as suggested by the survey results.

	Publisher	**Year**	**Utmost despatch**	**NOR & Laytime**	**Deviation**	**Additional other**
Wetbulk						
Charterparty 1						
Charterparty 2						
Drybulk						
Charterparty 1						
Charterparty 2						
Container						
Charterparty 1						
General						
Charterparty 1						

Table 8.8: Voyage charterparties content organised in a spreadsheet

	Publisher	**Year**	**Utmost despatch**	**Performance**	**Deviation**	**Drydocking**	**Other**
Wetbulk							
Charterparty 1							
Charterparty 2							
Drybulk							
Charterparty 1							
Charterparty 2							
Container							
Charterparty 1							
Charterparty 2							
General							
Charterparty 1							

Table 8.9: Time charterparties content organised in a spreadsheet

8.3.1. Clauses affecting speed reduction measure

8.3.1.1. Utmost despatch clauses

Utmost despatch, all convenient speed and due despatch are often the opening clauses used in voyage charterparties (as an express obligation imposed on the shipowner) to instruct the owners to proceed at full speed once the cargo is loaded i.e. when ship is chartered for the voyage or even when the ship is on hire under time charter. According to Chong (1993) the obligation to proceed with utmost despatch means a vessel must commence voyage to the port at such time as it is reasonably certain that proceeding ‘normally’ she can arrive at the port by the stipulated date. The shipowner's obligation to proceed with reasonable despatch applies both to the voyage to load port (stage one) and the voyage to discharge port (stage three), whereas other obligations such as seaworthiness and deviation do not apply to the approach voyage (Wilson 2010). However, performance of this obligation is judged, not on a strictly objective basis, but in relation to what can reasonably be expected from the shipowner under the actual circumstances existing at the time of performance. The rule is of general application, and is not confined to contracts for the carriage of goods by sea. In the case of other contracts the condition of reasonable time has been frequently interpreted; and has invariably been held to mean that the party upon whom it is incumbent duly fulfils his obligations notwithstanding ‘protracted delay’, so long as such delay is attributable to causes beyond his control, and he has neither acted negligently nor unreasonably (Wilson 2010). Mankabandy (1975) explains “The test of reasonableness is whether a prudent person having control over the voyage, would have permitted the relevant delay or would have ordered the vessel to proceed on her voyage” (Mankabandy 1975 p.637). According to Girvin (2007) and Chong (1993) utmost despatch is applicable when there is no time specified for a particular obligation as shown in the case of Hick v Raymond. When time is specified in the form of expected readiness to load (ERL) or estimated time of arrival (ETA) by the shipowner, the clause results in:

“Absolute obligation on the part of the shipowner to commence the approach voyage on a date where proceeding with reasonable despatch, the chartered vessel would be reasonably certain of arriving at the port of loading by the expected ready to load date” Chong (1993, p. 411)

There are conflicting interests with regards to fixing a date, a charterer desires a fixed date in order to procure the cargo, whereas the shipowner on the other hand desires flexibility given that the voyage is connected to a previous voyage, intermediary voyages and other delays (Chong 1993; Wilson 2001; Spurin 2004). To accommodate these two conflicting interests the ERL clause is used. This means that the shipowner is duty bound to start the approach voyage which would enable the chartered ship to arrive at the load port by the stipulated expected ready to load (ERL) date. The calculation (counting back) of the time required to meet the ERL date is then based on ‘normal’ time required, which consequently determines the start time (referred to as ‘start in’ time) (Chong, 1993).

From Hick v Raymond utmost despatch is described as “the party upon whom it is incumbent fulfils his obligations notwithstanding protracted delay...” (Girvin 2007). There are several legal cases that define what reasonable despatch is and when the obligation begins, as shown below (Wilson 2010):

Voyage charter

- EL Oldendorff & Co GmbH v Tradax Export SA
- Monarch Steamship Co Ltd v Karlshamns Qijefabriker AB– The Wilhelm
- Suzuki & Co Ltd v T Benyon & Co Ltd
- Hick v Raymond
- Louis Dreyfus & Co v Lauro

Time charter

- Whistler International Ltd v Kawasaki Kisen Kaisha Ltd – The Hill Harmony case
- Mitsui OSK Lines v Garnac Grain Co Inc – The Myrtos case

From the brief analysis of the above cases and their description from Wilson (2010) and Girvin (2007), it is difficult to assess at what speed a ship is required to travel whilst on the approach voyage and discharge voyage in the voyage charterparty. However the following clause shows that it is clearly not to be the most economical or ship owner's optimal speed with the use of the word 'unless otherwise agreed'.

"It is hereby agreed between owners and charterers that the vessel be presented at the loading port... and there being in every respect fitted for carriage of the cargo shall load the cargo, which the charterers bind themselves to supply, and carry it with all possible despatch (unless economic speed to conserve is fully expressed) to the port of discharge.." Nuvoy 1984

Under a time charterparty reasonable despatch is not an issue (Spurin 2005). However, time charterparties have also been found to contain these clauses (Girvin 2007). A possible reason for this could be due to bill of lading requirements, subletting on time and voyage charters as seen in the Hill Harmony case and Myrtos case (Girvin 2007). The following quote from BIMCO special circular on slow steaming clauses emphasises that compliance with charterers' instructions in terms of slow steaming will not constitute a breach of any obligation that the owner may have under the charterparty or contracts of carriage to proceed with due despatch. This once again confirms that utmost despatch is not an economical or reduced speed with respect to fuel consumption:

"*Sub clause e: For the avoidance of doubt, where the Vessel proceeds at a reduced speed or with reduced RPM pursuant to Sub-clause (a), then provided that the Master has exercised due diligence to comply with such instructions, this shall constitute compliance with, and there shall be no breach of, any obligation requiring the Vessel to proceed with utmost and/or due despatch (or any other such similar/equivalent expression*)" (BIMCO 2011)

According to Zerman (2011) slow steaming, eco steaming, etc. in order to conserve fuel (where the contract of carriage does not contain an express liberty clause permitting it to do so) is almost certainly considered to be unjustified. Slow steaming in a legal context is in fact a deviation (discussed below) and thus an owner would have to make considerations in implementing these into the charterparty and bill of lading (Zerman 2011). A Bill of Lading holder also has an equal and valid reason to expect the cargo to be delivered in the discharge port without unreasonable delay or undue deviation (Zerman 2011). Consequently, this would mean that any voyage charterparty with utmost despatch clauses will automatically confer to the relevant bill of lading, except in very few cases such as the liner or container trade as seen above.

8.3.1.2. Virtual Arrival clauses

Virtual Arrival (OCIMF and INTERTANKO 2010) is a process whereby a vessel's speed is reduced in order to meet a revised arrival time, thus enabling the vessel to arrive at a port at the right time (Just in Time - JIT). The process is in recognition of the current state of shipping operations which may not be optimal from an energy efficiency perspective. Above it was seen that the current contracting process through the use of standard voyage charterparty clauses stipulates that vessels proceed at utmost despatch towards a port, this is regardless of the prevailing conditions at that port. Therefore conditions that affect the berthing of the vessel such as temporary congestion or lack of cargo space (quay side, oil tank space, etc.) are simply ignored in the current system. It is therefore inefficient for a vessel to steam at full speed and then wait at anchor for a berth or storage space to become available. Virtual arrival therefore shifts the port waiting time into extra sailing time, resulting in fuel cost savings from speed reduction, without affecting demurrage income that would have been gained had laytime been exceeded. Laytime (see section below) starts counting from the original Estimated Time of Arrival (ETA) and Notice of Readiness (Virtual NOR) and not the new ETA after reduced speed. An example of how savings are calculated is shown in appendix D.

8.3.1.3. Slow steaming clauses

Whilst most standard form voyage and time charterparties require utmost despatch in the discharge voyage and on the approach voyage (if ERL is not agreed), some may allow for economic speed in order to save fuel as shown in the quote below. In a time charter, since the charterer is generally in control of the speed at which the ship travels, slow steaming clauses are a common practice.

"*Charterers shall be entitled from time to time to instruct the vessel to proceed at reduced speed for economic or other reasons subject to prior consultation with owners concerning the characteristics of the vessel and its machinery in this respect....*" Intertanktime charterparty

8.3.1.4. The laytime provisions and related clauses

In a voyage charterparty the charterer is regarded as having paid for the time required to load and discharge the cargo in the freight rate i.e. stage two and stage four of the voyage (Wilson 2010). The amount of time allowed for these operations is called laytime or lay days (generally 72 hours) and when this time has been exceeded, the charterer is liable to pay compensation to the shipowner generally in the form of liquidated damages called demurrage. The most intractable issue is to define at which point laytime begins (Wilson 2010; Girvin 2007, Spurin 2005). The starting point for laytime is determined by two conditions that have to be met; first, the ship must be an 'arrived ship' by reaching the agreed destination either berth, dock or port (these are clauses for shifting risk of delay between parties), secondly, the ship must tender a valid notice of readiness (NOR) at that specified place and at the specified time. Close reading of charterparties showed that there was variation in the different types of charter regarding the place and times for NOR. There were also differences as to the commencement of laytime after both conditions had been met (some charterparties mentioned six hours and some twelve hours). With regards to times of tendering NOR, some allowed NOR to be tendered any time of the day and any time of the year whereas some only in business hours in working weekdays only. These clauses are thought to have direct implications on the speed at which the ship will travel. According to Capt. Habibi (personal communication, February, 2012), it is in the owners interest to time the arrival of the ship at the agreed destination prior to the NOR beginning time so as to avoid unexpected delay arising from pilotage or manoeuvring at port. Where the NOR time has elapsed and the owner has not reached the agreed destination, then there is little negotiation as to what could be done, the shipowner is bound to proceed at the destination at charterparty speed and wait for the next available NOR tendering time (Habibi 2012). Having defined utmost despatch clauses, slow steaming and laytime clauses, the next section looks at another implied and expressed obligation of the shipowner, the obligation not to deviate, which is thought to be affecting implementation of operational measures.

8.3.2. Clauses affecting weather routing and efficient voyage execution measures

8.3.2.1. Deviation clauses

The obligation by law on the shipowner is that he is to proceed in that ship by the 'usual and customary course' (Girvin 2007). A deviation is therefore a deliberate and unjustifiable departure from this course in the third stage of the voyage (discharge voyage). When there isn't an express route given by the charterer, the usual route is direct geographical route (Girvin 2007) and in practice, very few standard charterparties make an express provision for the route to be followed (Wilson 2010). From Reardon Smith Line v Black Sea and Baltic General Insurance, the direct geographical route can be modified in many cases for navigational or other reasons. Furthermore the case describes that it is not the geographical route but the usual route which has to be followed, though in many cases they may be the same as each other. Thus the direct geographical route is the benchmark (Girvin 2007) but it is upon the shipowner to show that a different route is customary (Girvin 2007). Under the implied obligation of not to deviate, a departure from the direct route in order to take on bunkers may be only be justified if it can be shown that it is usual practice. The only other justifiable deviations that are allowed by common law and Hague-Visby rules are that of saving life (in some cases also property) and avoiding danger to the ship and cargo. It has become a common practice to include in the contract so called liberty clauses e.g. Gencon 1994. These are express clauses that allow departure from the usual route and generally allow the shipowner to call at any port for 'whatever' reason. However they are interpreted narrowly by courts because they are normally drafted in favour of the shipowner (Wilson 2010). From this analysis it can be seen that there are several levels of liberty or deviation that can found in charterparties and this was also established in the close reading of charterparties. This is reflected in the categories of the coding agenda as narrow or strict level of liberty.

8.4. Results and analysis

The content analysis was conducted on standard form voyage and time charterparties in order to see how the contracts addressed the principal agent problems and consequently their effect on the implementation of energy efficiency measures. The analysis focussed mainly on two out of the four aspects of the implied and expressed obligations of the carrier; reasonable despatch and deviation. These clauses can be said to be related to two energy efficiency operational measures; general speed reduction and weather routing. The results of the content analysis below are for the speed reduction measures and its categories as per the coding agenda (as shown in appendix D).

8.4.1. Speed reduction measures

As seen in chapter seven the implementation of speed reduction measures for firms whose fleet was chartered out mainly on voyage charter was around 65% compared to firms whose fleet was chartered out on time charter which had around 80% implementation rate. Can the difference in speed reduction measure between voyage and time charter be explained by contracts that aim to reduce agency costs or agency loss through stricter charterparty clauses and as a result have an adverse effect on the implementation of this measure? In chapter five, it was hypothesised that for operational measures in time charter there would be less exposure to the 'efficiency' principal agent problem because the charterer pays for fuel and also makes the decision on implementation, whereas operational measures (mainly related to speed) in voyage charter would be prone to quasi 'usage' problem because the charterer does not pay for the fuel directly and cannot select the energy saving measure. The preceding section discussed reasonable despatch concept and in the coding agenda its relationship with energy efficiency and speed reduction measure was outlined. The results of the content analysis are presented in the following sections.

8.4.1.1. Speed reduction in voyage charterparties

8.4.1.1.1. Goal conflict

It was seen earlier that reasonable despatch was an obligation in order to mitigate the risk that is borne by charterers with respect to their cargo and counterparty. It was also understood that the speed of the vessel was not the energy efficient speed for both the approach and the discharge voyage. Close reading of the charterparties revealed that there were different express obligations of utmost despatch, which are consequently coded into four categories under the goal conflict proposition of the principal agent theory. Focussing on the voyage charterparties, most of the charterparties require owners to proceed at utmost despatch for the approach and discharge voyage (Girvin 2007). The use of utmost despatch in both legs means that there is no potential for speed reduction. The typical clause read:

"The vessel shall proceed with due despatch to a safe port, berth, dock.... for loading the cargo, as ordered by charterers... and being so loaded proceed as ordered on signing of B/L ... as ordered by charterers" Bimchemvoy 2008, Intertanko 1976 and Asbatankvoy.

There were differences, however, in the use of express obligation for reasonable despatch, where some charterparties expressly mentioned reasonable despatch only for the laden leg and some for both legs. This suggests that the contract has some potential for speed reduction. In these cases the negotiation on the ETA/ERL date can have a potential for implementation of speed reduction. The typical clause read

"*It is mutually agreed between the owners and charterers that the vessel being in every respect fit for carriage of cargo shall proceed to the loading port or loading range ...and there load the cargo. Being so loaded the vessel shall carry the cargo with all possible despatch to the port of discharge or discharging range..."* Polcoalvoy 1997

Another difference that was observed was that a small proportion of charterparties did not expressly mention reasonable despatch for both the approach and discharge voyage. These could be said to be providing an opportunity to implement general speed reduction. The typical clause read as follows:

"The said vessel shall proceed to the loading port....and being so laoded the vessel shall proceed to the discharging ports..." Scancon

The only charterparties that allow for a balanced negotiation are Orevoy & Nuvoy, neither have utmost despatch clause for approach voyage and have an option of waiving utmost despatch in laden leg:

"Clause 7: After completion of prior commitments as may be stated in box 8, the vessel shall proceed to the loading port or berth. The vessel shall carry the cargo with possible despatch to the ports or berths stated. However, unless 'no' is inserted in box 17 Part A (Reduced voyage speed), the owners may order the vessel to proceed at reduced speed solely to conserve fuel" Orevoy

"Clause 1: being in every respect fitted for carriage of the cargo shall load the cargo, which the charterers bind themselves to supply, and carry it with all possible despatch (unless economic speed to conserve is fully expressed) to the port of discharge.." Nuvoy 84

On tabulating the results as shown in Table 8.10 it was clear that there was a relationship between use of utmost despatch clauses and sector (wetbulk, drybulk and general charterparties). The different categories discussed above belonged to specific sectors, for example the lack of express mention of reasonable despatch was only found in general form charterparties (used for trades for which no specifically approved form is in force). Gencon makes no mention utmost despatch for the loading or discharging leg. The Gencon 1976, despite being the most commonly used general purpose charterparty (Faber et al. 2012) has been criticized by UNCTAD (1990) which presents several cases that show ambiguity in the wording of the charterparty and describes it as insufficiently comprehensive which requires an undue number of additional clauses in every case. These results are consistent with the survey findings, which showed that the standard charterparty clauses as barriers were higher for the bulk sectors compared to the container sector. The difference between the bulk and container sector can be explained by the use of bill of ladings, where liner bill of ladings e.g. Conlinebill 2000, permit the owner-operator to slow steam.

"Sub-clause (e) sets out how to deal with the 'due despatch' obligations common to charterparties and contracts of carriage. In the liner trade, this is not an issue because liner terms and conditions normally confer on the owners/vessel operators a right to slow steam (see for example Clause 5 (Scope of Carriage) of Conlinebill 2000 which gives an express right to slow speed without liability for delay). However, in other trades where such rights are not given and due despatch obligations apply, some mechanism needs to be included in the clause to permit slow steaming without liability for delay" BIMCO (2011, p4).

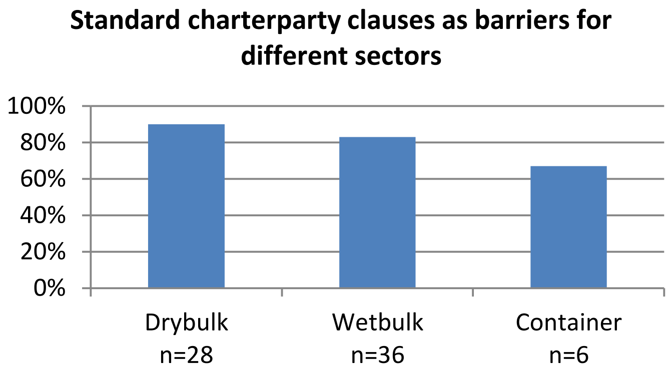


Figure 8.3: Perception of standard charterparty as barriers for speed reduction

Utmost despatch clauses are not an issue in the container sector because liner terms and conditions normally confer on the shipowner or vessel operators a right to slow steam (BIMCO 2011). This is due to a historic bargaining power enjoyed by carriers, which the Hague-Visby rules sought to address (Wilson 2010). The obligation to prosecute voyages at utmost despatch is still removed from container related bill of ladings (contract between shipper and operator) such as the Conlinebill 2000, which give an express right to slow speed without liability for delay (BIMCO 2011). It is perhaps due to this reason that the container sector has seen significant reduction of operating speed. In addition to this, there are several other reasons for reduction of speed, there is a longer chain of principals and agents in the container sector (as shown in chapter five) and therefore individual shippers or cargo owners as principals in the voyage charter generally don't have control over the speed of the ship (compared to that of the bulk voyage charterer). The freight rates paid by the shippers do not reflect the cost savings achieved by the operators due to speed reduction (unlike the BPvoy charterparty shown above), which means that operators have a greater incentive for speed reduction.

In the container sector the relationship between the principal (shipper) and agent (owner-operator) is similar to that found in the voyage charter (outcome based contract) and is an example where two of the agency problems are prominent. The principal and agent have goal conflict on the issue of speed (principal generally has the incentive to receive goods quickly due to inventory and opportunity costs and supply chain demands, whereas agent has the incentive to reduce speed to save on fuel costs, thus the use of outcome based contract according to Eisenhardt (1989) proposition one). Secondly there is also an information problem (hence the use of outcome based contract based on Eisenhardt's proposition two and three) as the principal generally does not have the information on the speed of the ship to be able to demand a discount or reduction in freight rates that arise as a result of the agent's actions, as illustrated by analysis above. The information asymmetry as a result of the 'one to many relationship' instead leads to a favourable position for the agent, where the agent not only keeps the savings from speed reduction (E.g. Maersk Line saved $300 million annually through slow steaming) but is also is able to demand higher freight rates as a result of increase in fuel costs, suggesting a split freight rate and fuel cost elasticity. This split elasticity is highlighted by the two quotes below:

"Inttra chief executive Ken Bloom said: "Unless and until shippers are willing to pay for shorter transit times, carriers will take the prerogative, which is theirs to take, to get savings from slow steaming even if doing so increases the customer's total supply chain cost" Lloyds List (2013)

"St. Amand also mentioned bunker adjustment factors (BAFs), a tool used by liners to protect themselves against fuel price increases, saying some BAFs were so effective that some owners are rooting for fuel prices to go up" Sustainable Shipping News (2011c)

Only in very rare situations has a container line (owner-operator) lowered the fuel surcharges based on the savings achieved from speed reduction, resulting in 5 – 10% reduction in the BAF for the shipper (Sustainable Shipping News 2011a).

Sector	Voyage charterparty	Utmost despatch to load port	Utmost despatch to discharge port
Wetbulk	BIMCHEMVOY	✓	✓ through B/L
	INTERTANKVOY	✓	✓ through B/L
	ASBATANKVOY	✓	✓ through B/L
	BEEPEEVOY 4	Stated speed	Stated speed
	SHELLVOY 6	✓ + stated speed	Stated speed
Drybulk	COALOREVOY	✗	✓
	OREVOY	✗	✓ or reduced speed
	NIPPONORE	✓	✓
	POLCOLVOY	✗	✓
	SYNACOMEX	✓	✓
	BHPBVOY03	✓	✓
	NIPPONCOAL	✓	✓
	NUBALTWOOD	✓	✓ through B/L
	RIO DOCE ORE	✓	✓
	AMWELSH	✓	✓
	GRAINCON	✓	✓
General	GENCON	✗	✗
	SCANCON	✗	✗
	NUVOY	✗	✓ or reduced speed

Table 8.10: Utmost despatch clauses by sector charterparties and voyage stages

8.4.1.1.2. Information

In a voyage charter the shipowner is the sole entity to make decisions on the speed of the ship, although he is bound by charterparty obligations such as those seen above. It was observed that some voyage charterparties go to the extent of describing the speeds at which the ship ought to travel in both the approach and discharge voyage and the fuel consumption for both legs. This is highly unusual for voyage charterparties and a characteristic of the time charterparty, which contain clauses for adjustment of hire in case of loss of speed or increase in fuel consumption. These voyage charterparties not only rely on voyage outcomes such as delivery of goods but also make use of information systems found in behaviour based contracts to tie performance with remuneration, as shown below:

"Owners undertake that the Vessel shall, upon completion of loading the cargo, proceed at the speed stated in Section B.25 of PART 1 ("Charter Speed"), or at such her speed, not exceeding the speed stated in Section B.26 of PART 11 ("Maximum Speed"), as may be stated in Charterers' Voyage Orders. Charterers shall have the right at any time during the voyage to instruct Owners to adjust the vessel's speed. .....If Owners increase the speed of the Vessel in accordance with Charterers' Voyage Orders, any increase in the freight rate consequent thereon shall be calculated in accordance with the Example set out in Clause 31. If the Vessel fails to maintain Charter Speed, or Owners fail to comply with any instructions in Charterers' Voyage Orders requiring an increase of speed pursuant to this Clause 3, Owners shall, subject to Clause 38, be liable for all loss, damage, cost..." BP Voyage Charterparty

The stated speed was only found in wetbulk charterparties of oil majors. Major drybulk charterers charterparties (e.g. Vale & BHP charterparties) only contain utmost despatch clauses for both the ballast and laden voyages. Both Shell and BP voyage charterparties prescribe specific speeds at which the vessels should perform the voyages. These standard form charterparties have been designed by individual firms with a monopoly in the transport of oil (Wilson 2010). The specific speeds at which the vessel should travel is for both the preliminary voyage and discharge port voyage. Stating the specific speed is highly unusual of the voyage charterparties and is in contrast to those that have been developed by BIMCO, ASBA and other publishers which only incorporate utmost despatch clauses. The above clause from BP and Shell voyage charterparties can also be viewed as an opportunity for energy efficiency because information on the speed of ships is known by both the entities in the relationship. On the other hand the majority of the charterparties that make use of utmost despatch give no information to the charterer regarding the speed of the ship. Furthermore even the charterparties that allow for slow steaming do not require the speed to be stated in the charterparty. Therefore it is likely that in these cases that there is information asymmetry regarding the speed and fuel consumption of the ship.

8.4.1.1.3. Outcome certainty

8.4.1.1.3.1. *ETA/ERL in charterparties*

In the preceding section discussing shipowner's obligation for utmost despatch, it was seen that the obligation to proceed at utmost despatch in the approach voyage is overruled when there is an expected date agreed between the parties. For the standard form charterparties that had specific mention of the ETA or ERL for the loading operation, there could be seen an opportunity for speed reduction, since it is mutually agreed between both the parties. Where this does not exist the obligation to proceed at utmost despatch is present and therefore the opportunity to reduce speed in the approach voyage or ballast leg could be said to have been lost. Findings of the content analysis are presented in Table 8.11 below. All voyage charterparties had some sort of input for agreeing the ETA/ERL between the charterer and shipowner. Additionally some drybulk and general charterparties were also found to contain running days notices (usually of around ten days). The use of the ETA/ERL overrides the utmost despatch in the ballast to the load port (Wilson 2010), therefore it becomes possible for the owner to implement speed reduction as long as the parties agree on the date. The incentives to do this are however very strongly related to the freight market, which brings the question of opportunity costs for both the parties.

8.4.1.1.3.2. *Place of NOR*

As discussed earlier in section 8.3.1.4, in order for the laytime to begin, the vessel must be an arrived ship and present a valid NOR. To be classed as an arrived ship the vessel must reach the specific point specified in the charterparty, which can either be a berth, dock or a port. In the case of berth or dock charters the risk of delay must be borne by the shipowner (Wilson 2010). According to Eisenhardt's (1989) proposition as the agent (shipowner) becomes less risk averse, it becomes attractive to pass the risk to the agent using an outcome based contract, which was thought to be the case with voyage charters. However, when the agent becomes more risk averse, it becomes more expensive to shift the risk to the agent (Eisenhardt 1989). As for the risk averse principal (charterer) it becomes more attractive to pass the risk to the agent (Eisenhardt 1989). In voyage charters the overriding concern to both parties is the question as to which of them will bear the risk of loss resulting from delays of different types (Wilson 2010). It is possible for both parties to transfer the risks and one such clause is the use of specific places in which NOR can be tendered. The use of specific places for NOR tendering is directly related to delays due to congestion. In common law there are no provisions in the charterparty covering delay resulting from congestion in port (Wilson 2010). However, a shipowner in many cases may not be willing to take this extra risk (especially in the case of berth charters) and has the option to shift the risk back to the charterer using several clauses such as the ‘reachable berth’, ‘whether in berth or not’ (WIBON) clauses. The table below shows the type of charters used by various charterparties.

There was a clear difference in the charterparties of the different sectors, wetbulk charterparties generally were found to be port charters whereas most drybulk charterparties were observed to be berth charterparties. The difference in the use of different charters in the sectors could be related to the level of congestion at ports or waiting time for berths, which may be very different for both sectors. In wetbulk charterparties the ships that carry crude oil cargoes often have a few ports for loading cargo, for example half of the crude oil cargoes emanate from the Middle East Gulf (Mokia & Dinwoodie 2002). Mokia and Dinwoodie (2002) discuss the range of delays that occur in the common crude oil loading and discharging regions, ranging from political issues in the Mediterranean/Black Sea and bad weather in the North Sea. This suggests the unwillingness of shipowners to subsume the additional risk despite the major charterers who publish their own charterparties having higher bargaining power (UNCTAD 1990 and Wilson 2010). The unwillingness of shipowners for the additional risk was even found in the drybulk charterparties, where subsequent clauses to berth charters allowed for charters to be port charters in case of congestion, i.e. shifting back the risk (Wilson, 2010).

8.4.1.1.3.3. *<u>NOR times</u>*

As described earlier the purpose of such notice is to inform the charterer that the ship is in all respect ready to load or discharge and to also provide a starting point for the calculation of laytime. Some charterparties require giving advance notice of readiness (sailing telegrams), for example Polcoalvoy, Nipponcoal and Orevoy require master to provide at least ten days written notice of expected readiness. In any case, the simple NOR provides certainty to the charterer (Wilson 2010). In the close reading stage it was observed that there were varying times in which a valid NOR can be tendered, which would affect the speed at which the ship would travel. The table below shows the findings of charterparties that had flexible NOR compared to those that had specific times in which NOR can be tendered.

Once again the wetbulk charterparties had no specific times in which NOR had to be tendered whereas in contrast a majority of the drybulk and general charterparties had specific times in which shipowners had to tender NOR. For example Synacomex charterparty required owners to tender NOR between 0800-1700 on weekdays and Saturdays between 0800-1200, Sundays and holidays excluded. Perhaps one of the reasons for the sectoral differences is the port operation times, where wetbulk terminals generally operate throughout the day (evidenced by the twenty four hour pumping clauses), in contrast to drybulk terminals which suspend operation at night time. Nuvoy along with a few other charterparties allowed the parties to negotiate the NOR tendering times, the options were 24hrs SHINC (Sundays and holidays inclusive), 24hrs SHEX (Sundays and holidays excluded), Office hours SHEX.

Voyage charterparty	**Utmost despatch to load port**	**Utmost despatch to discharge ports**	**ETA/ERL**	**Specific NOR times**	**Specific NOR place**
BIMCHEMVOY	✓	✓ through B/L	✓	×	×
INTERTANKVOY	✓	✓ through B/L	✓	×	×
ASBATANKVOY	✓	✓ through B/L	✓	×	×
BEEPEEVOY 4	Stated speed	Stated speed	✓	×	×
SHELLVOY 6	✓ + stated speed	Stated speed	✓	×	×
COALOREVOY	×	✓	✓	×	✓
OREVOY	×	✓ or reduced speed	✓	×	✓
NIPPONORE	✓	✓	✓	User	✓
POLCOLVOY	×	✓	✓	✓	×
SYNACOMEX	✓	✓	✓	✓	✓
BHPBVOY03	✓	✓	✓	User	✓
NIPPONCOAL	✓	✓	✓	User	✓
NUBALTWOOD	✓	✓ through B/L	✓	✓	×
RIO DOCE ORE	✓	✓	✓		
AMWELSH	✓	✓	✓	✓	✓
GRAINCON	✓	✓	✓	✓	✓
GENCON	×	×	✓	✓	✓
SCANCON	×	×	✓	✓	✓
NUVOY	×	✓ or reduced speed	✓	User	User

Table 8.11: Summary table for speed reduction in voyage charterparties

From the above findings it can be concluded that wetbulk charterparties (especially those of oil majors) seem to have more potential for implementation of speed reduction, followed by the general charterparties and some drybulk charterparties. Yet, Devanney (2011a) notes that wetbulk charterparty speeds remain high, above that which is optimal for the charterer even after accounting for inventory costs. In chapter five and in the beginning of this chapter it was hypothesised that voyage charterparties would be prone to quasi 'usage' problems because the charterer does not pay for the fuel directly, cannot select the energy saving measures (or in this case inability to determine the speed at which the ship would travel through the use of blanket utmost despatch clauses) which would result in higher energy consumption than is reasonable (Meier and Aide 2007). As seen above, the oil major charterparties explicitly stated speeds at which the ship should travel for both ballast and laden legs and also remunerate owners for the increase in speed. An example of this is shown below from BPvoy3.

"Thereupon the vessel shall proceed with such cargo at a speed which owners undertake shall be .... knots ('Base Speed'), as ordered on signing Bills of lading or as provided in Clauses 24 and/or 26 to...."

"Charterers shall have the right at any time during the voyage to order the vessel to increase speed in order to arrive at a port or place on a certain date"

"If vessel fails to maintain Base Speed, or fails to comply with the instructions as to the increase of speed given by charterers pursuant to this clause, owners shall, subject to clause 46, be liable for all costs...."

"If charterers order the vessel to increase speed under the provisions of clause 3 such rate shall be increased by .... New Worldscale points for each knot of increased speed above the Base Speed or on a pro rata basis for fractions of a knot up to a maximum of .... knots. Such increase shall be calculated in accordance with the following example:

Example: The Vessel proceeds at Base Speed of 10 knots, the rate for which is New Worldscale 40. After 10 days the Vessel is ordered to complete the voyage at 12 knots. The remainder of the voyage takes 20 days. The increased speed option provides for a premium of 0.5 of a New Worldscale point per knot of increased speed over Base Speed.

The freight rate for the above voyage would be calculated as follows:

$$\text{Voyage Freight Rate} = \frac{(\text{NW40} \times 10 \text{ days}) + (\text{NW41}^{*} \times 20 \text{ days})}{30 \text{ (total voyage days)}} = \text{NW40.67}$$

(*1 point premium for 12 knots maximum speed)

Figure 8.4: Example of control over speed in BP voyage charterparty

8.4.1.1.4. Addressing agency problems of goal conflict, lack of information and outcome certainty

From the above example of a voyage charterparty (outcome based contract) it is clear that the oil major charterer is well informed of the speed at which the ship should be travelling at (i.e. there isn't a lack of information). This means that the voyage charterparty at best addresses somewhat the informational problems, which leaves the agency problems of goal conflict and outcome certainty to be addressed in those contracts.

Outcome certainty and goal conflict has recently been addressed through determining the way NOR is tendered. The oil major's ability (through the use of their own charterparty) to govern the speed of ships on a voyage charter has been used in the Virtual Arrival process (as briefly mentioned in section 8.3.1.2) to address outcome certainty and take advantage of the current downturn in the market. It is clear that this practice or process (virtual arrival/Just In Time) therefore works well for charterparties where speed is largely controlled by the charterer. The process also relies heavily on good communication and co-ordination with ports or terminals. Many of the ports however do not use advanced scheduling systems to be able to predict the level of congestion at a particular date and time in the future, in fact many drybulk ports around the world have impromptu arrivals based on first come first serve (FCFS) basis (Alvarez, Longva & Engebrethsen 2010).

Figure 8.5 below shows that for berthing ships there is an average delay of around two to three days for drybulk ports and the constant port congestion would mean that any speed reduction en-route would result in further delays as position in the queue is lost. On the other hand oil terminals controlled by oil majors (vertically integrated) tend to have better capabilities and communication with the shipowners or charterers and therefore can make use of the virtual arrival process. The Virtual Arrival process tackles the goal conflict problem between the principal and the agent by creating incentives to reduce speed, but it has yet to address the lack of information on speed in the various prominent voyage charterparties (e.g. BIMCO voyage charterparties) and outcome uncertainty as a result of poor port infrastructure (e.g. developing nation ports). To that end the drafting committee of BIMCO has been trying since 2011 to integrate the Virtual Arrival clauses into its charterparties but the progress has been slow and at the time of writing the clause has yet to be approved and published by the committee.

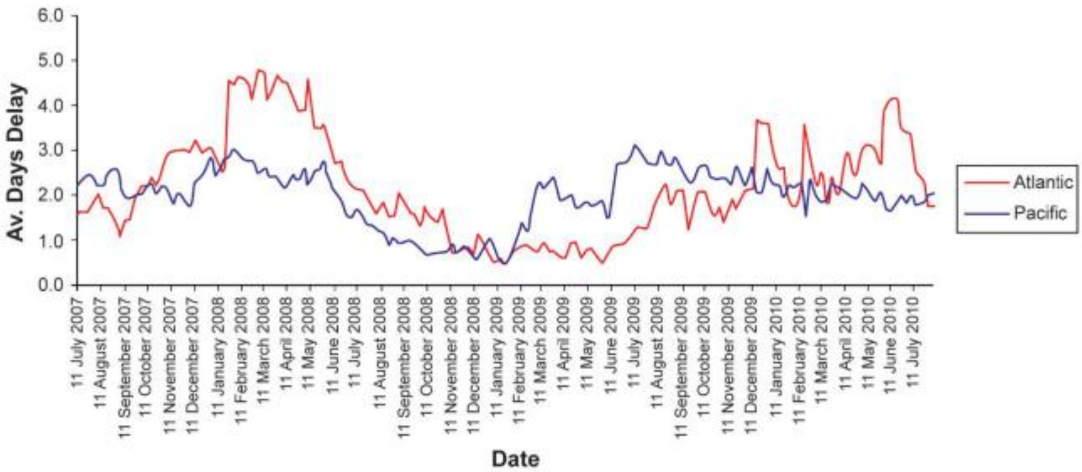


Figure 8.5: Port Congestion Index for drybulk ports
Source: OCIMF and INTERTANKO (2010)

8.4.1.2. Speed reduction in time charterparties

8.4.1.2.1. Goal conflict

For the implementation of operational measures in the time charter it was hypothesized that the principal agent efficiency problem would be less of a problem or incentives would be aligned because the principal is responsible for fuel cost and also deciding upon its implementation i.e. determining speed. However, utmost despatch clauses were also found in time charterparties, even though charterers may have an interest in order to save costs.

Speed reduction in time charterparties is generally governed through the use of slow steaming clauses which allow the charterer to order the master to reduce speed to a certain extent (under normal operating conditions). Table 8.12 below shows the time charterparties with utmost despatch clause and built in slow steaming clause. Conflicts of interest may arise when the shipowner (agent) has obligations towards other third parties such as such as holders of bills of lading and engine manufacturer's recommendations. So even where the owners and charterers have similar or non-conflicting interests in slow steaming, the bill of lading holders must be taken into account as well (Zerman 2011). Another goal conflict arises due to subletting of the vessel under time charters;

"Under a sub-charter party, the sub-time charterers may have a right to request slow steaming and request their disponent owners accordingly. The head charter party may not have a similar clause and head owners would be well within their rights to deny the request given their exposure to cargo interests" (Zerman 2011)

Speaking to an industry expert (head of shipping group of a law firm) on this regard (personal communication, November 2013), the above conflicts may not be as pervasive since charterparties would ensure that similar clauses flow from head charterparty to the sub-charterparty. Secondly, even if a shipowner is in a situation where utmost despatch obligations were not adhered to due to the charterers slow steaming orders, the shipowner has a defence to being sued by cargo interests. In fact, it is the charterer's responsibility to ensure that compliance with slow steaming orders does not lead to the breach by the owner for the contract of carriage (bill of ladings), as highlighted from the BIMCO slow steaming clause:

"The Charterers shall ensure that the terms of the bills of lading, waybills or other documents evidencing contracts of carriage issued by or on behalf of the Owners provide that compliance by Owners with this Clause does not constitute a breach of the contract of carriage. The Charterers shall indemnify the Owners against all consequences and liabilities that may arise from bills of lading, waybills or other documents evidencing contracts of carriage being issued as presented to the extent that the terms of such bills of lading, waybills or other documents evidencing contracts of carriage impose or result in breach of the Owners' obligation to proceed with due despatch or are to be held to be a deviation or the imposition of more onerous liabilities upon the Owners than those assumed by the Owners pursuant to this Clause" (BIMCO 2011)

Time charterparty	**Utmost despatch in all voyages**	**Built in slow steaming clause**
INTERTANKTIME	✓	✓
BIMCHEMTIME	✓	✓*
BPTIME 3	✓	✗
SHELLTIME	✓	✗
BHPBTIME03	✓	✗
BALTIME	✓	✗
GENTIME	✓	✗
NYPE 46	✓	✗
NYPE 93	✓	✗
ASBATIME	✓	✗
BOXTIME	✗	✗

* Clause 11 of BIMCHEMTIME 1984 contains slow steaming clause however no slow steaming clause in BIMCHEMTIME 2005.

Table 8.12: Time charterparties with utmost despatch clause and built in slow steaming clause

8.4.1.2.2. Information

According to Eisenhardt (1989) when the principal has information to verify agent behaviour, the agent is more likely to behave in the interests of the principal. Information systems for verification of agent behaviour are therefore positively related to behaviour based contracts and negatively related to outcome based contracts (Eisenhardt 1989). Therefore information systems in a time charter (a behaviour based contract) play a vital role in the agency relationship. The information systems in the time charter need to counter the problem of adverse selection (pre-contractual opportunism e.g. misrepresentation of ability) and moral hazard (post contractual opportunism e.g. lack of effort or shirking). Thus, it is impossible for a principal to observe an agent's quality and behaviour at no cost (Aubert, Patry & Rivard 2003).

The time charter contract can be seen as an outsourcing contract which seeks to satisfy the need for transporting goods for the charterer. According to Aubert, Patry & Rivard (2003, p. 182) "in outsourcing contracts, the most obvious manifestation of moral hazard is a reduction in the level of effort by the supplier, resulting in lower service quality". Within a time charter contract 'service quality' is measured through two important standards, the speed and consumption guarantee (in specific weather conditions) and offhire clauses in the contract. Both of these standards have different remedies, when a ship does not meet its speed and consumption guarantee, the charterer can claim for underperformance and when the ship is offhire, the charterer can avoid payment of daily charter rate. Information regarding these standards can be obtained by the principal through direct monitoring or observation, using weather routing service providers, supercargo on-board ships, more recently Satellite Automated Identification Systems (AIS was originally intended primarily for collisions avoidance under the IMO Safety of Life at Sea convention) and even using agent's own noon reporting, which has the probability of being less accurate and prone agent shirking. Aubert, Patry & Rivard (2003) also suggest other ways of monitoring such as benchmarking agent's performance with other agents or the market. Finally, additional information on speed can come about as a result of the length of the agency relationship, which is positively related to the behaviour based contract. In long term relationships the principal will learn about the agent and over time be able to assess behaviour more readily (Eisenhardt 1989) thus be able reduce information asymmetry. The typical length of time charters in shipping however tend to be short, with the majority of the fixtures falling within six months for drybulk and container sectors and one year for wetbulk sector, as shown below in Figure 8.6. The short time period also may not justify the cost associated with more advanced monitoring of speed or other measures such as using weather routing transponder technology on-board ships for some time charters (personal communication with head of commercial operations of a large oil major, 2012).

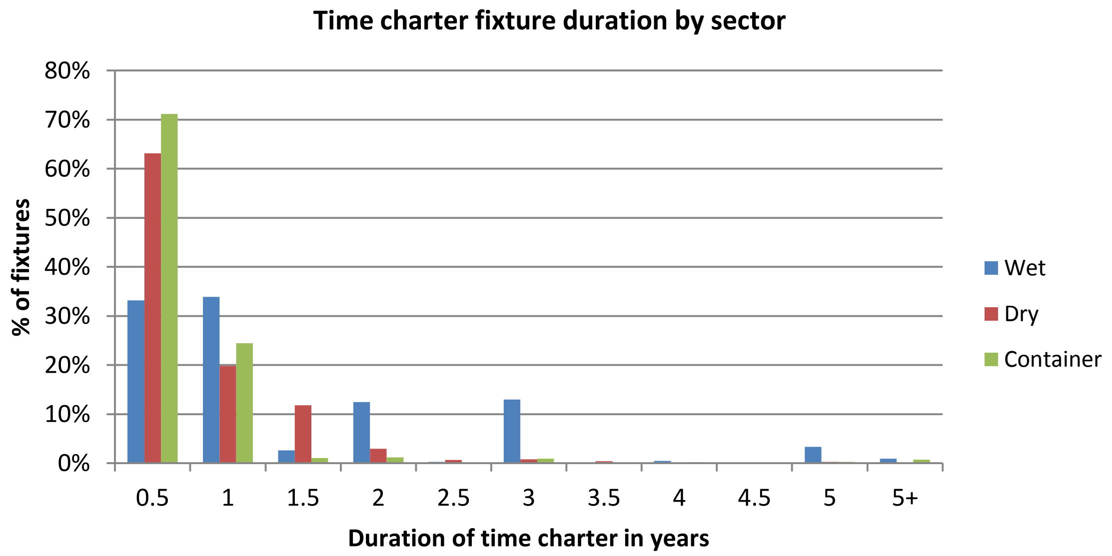


Figure 8.6: Duration of fixtures for different sectors

The speed and consumption guarantee in time charters presents the risk of adverse selection, which will develop if the principal cannot verify the claims of the agent. Although, actual ship speed is observable by calculating duration between port to port or ship log books (Veenstra and Dalen 2011) and even increasingly satellite data, but these are far from being accurate. The same can be said for methods of measuring actual fuel consumption. Devanney (2011b) shows how shipowners overstate their ability (by over specifying speed and under specifying consumption) in order to obtain a long term charter contract, since the penalties for underperformance would outweigh the additional revenue. Veenstra and Dalen (2011) show evidence from analysis of time charter fixtures that suggests otherwise, i.e. shipowners engage in strategic behaviour, quoting lower warranted speed and higher fuel consumption in time charters, that is different not only based on technical (e.g. due to hull fouling) but also because of other market factors, even for the same ships. Although when it comes to longer term contracts they do not find similar understating of speed and overstating of fuel consumption. This exhibits the classical principal agent problem of information asymmetry, where the shipowner has "superior knowledge about the real performance of the ship in terms of speed and fuel consumption and their interest to minimise outcome of the claim process" Veenstra and Dalen (2011, p48). To counter such agent behaviour Aubert, Patry & Rivard (2003) suggest information gathering exercises and better contract designs, which for example impose even heavier penalties, thus repel low quality agents. In some shipping markets, such as the wetbulk and some drybulk markets, there is a practice to protect against such adverse selection through a procedure called ship vetting. Ship vetting includes gathering information of a prospective ship's maintenance record, dates since when the ship is classed by its classification society, the flag it flies, numbers of name changes and ownership changes, dates since last special survey and dry dock, port detentions, and voyage chartering history (Bergantino and Veenstra 2002). Therefore, ship vetting serves as a procedure to extract the quality of ship operators (Bergantino and Veenstra 2002). According to Strandenes (1999, cited by Bergantino and Veenstra 2002) the adverse selection principal agent problem is however more applicable or representative of the voyage charter market than in the time charter market.

Moreover, the source of information (on prevailing weather conditions to determine good weather conditions to test the speed and consumption guarantee) in the time charter contracts has seen much debate. The time charterer has the right to appoint a weather routing company (Makkar 2005), and in the absence of such services the vessel (i.e. master or officers noon reporting and logs) are relied upon. Without the use of weather routing company, charterers are generally 'handicapped' as they only have access to daily noon reporting and four hourly log abstracts (Williamson 2012). Only if there is a major discrepancy between vessels logs and weather routing company, the weather routing company information is relied upon, as shown below (Makkar 2005);

"Under most circumstances, where the differences are not major, most panels will tend to accept the reports of the ship, as the Master and Officers are deemed to be the best judges on the voyage of actual conditions. A heavy burden is placed upon Charterers to show that the ship logs are not reliable and should be disregarded". Note that this is from New York arbitration, but the same rules are followed for London Arbitration.

Makkar (2005) cites a legal case, which shows that the judges found a continuous series of differences between reports from the vessel and weather routing company, and therefore fair weather conditions reported by the weather routing company were deemed more reliable. Table 8.13 shows the results of charterparty content analysis for monitoring agent behaviour.

Time charterparty	Use of weather routing company	Use of agents noon reporting/deck logs	Use of supercargo
INTERTANKTIME		✓	
BIMCHEMTIME		✓	
BPTIME 3		✓	
SHELLTIME		✓	✓
BHPBTIME03	✓	✓	✓
BALTIME		✓	
GENTIME	✓	✓	✓
NYPE 46		✓	✓
NYPE 93		✓	✓
ASBATIME		✓	✓
BOXTIME		✓	✓

Table 8.13: Time charterparties use of the different forms of monitoring for speed

8.4.1.2.3. Outcome measurability

According to Eisenhardt (1989) outcome measurability is negatively related to behaviour based contracts and positively related to outcome based contracts, i.e. when outcome is easily measured outcome based contracts are suitable and when outcome is not so easily measured then behaviour based contracts are suitable. Outcomes in contracts may not be easily measured because of the long time required to complete and difficulty in measuring in a practical amount of time (Eisenhardt 1989), which is representative of the time charter market. The main outcome in the time charter contract is the provision of transport service with a reasonable service quality (i.e. achieving the speed consumption guarantee and not spending time being offhire). Measuring these outcomes through information systems aforementioned can be a complex, costly and time consuming process for the charterer. Most contracts as a result focus only on monitoring under performance and have a relevant clause for deduction of hire or making a claim, though some contracts focus on both under and over performance and remunerate accordingly. Sometimes the outcome measurability is subject to standard criteria and sometimes subject to very stringent criteria for under or over performance. As an example, the speed and consumption performance is subject to a moderate weather condition, whereas in other charterparties the ship performance is supposed to handle very harsh weather conditions, as shown below;

"..Under normal working conditions and in moderate weather (which for the purpose of this clause shall exclude any periods of winds exceeding Force 4 on the Beaufort scale..." Bimchemtime

".. Good weather up till Force 8 on Beaufort scale..." Shelltime

As can be seen from Table 8.14 there seem to sectoral differences in charterparties, where most wetbulk charterparties contain stringent criteria for measuring performance but at the same time oil major charterparties compensating for over performance. This could be related to the bargaining power of major charterers in the wetbulk sector. Faber et al. (2012) also conclude that in the case where the ship underperforms, the shipowner must compensate the charterer but when the ship over-performs in most cases the charterer benefits instead of the owner.

Time charterparty	**Compensate for over performance**	**Moderate criteria**	**Stringent criteria**
INTERTANKTIME			✓
BIMCHEMTIME		✓	
BPTIME 3	✓		✓
SHELLTIME	✓		✓
BHPBTIME03		✓	
BALTIME		*	
GENTIME		✓	
NYPE 46		*	
NYPE 93		User specified	
ASBATIME		*	
BOXTIME		✓	

*Good weather conditions not described

Table 8.14: Outcome measurability in time charter contracts

This section identified the agency problems (goal conflict, information problems and outcome certainty) in time charterparties mainly for speed reduction measures. The goal conflict between the principal and agent in the time charterparty is also manifested through the use of utmost despatch, which may affect the implementation of the speed reduction measures. However there is a greater chance of implementation of this measure because not only is the charterer responsible for fuel costs but was shown to be the responsible entity for ensuring the contracts in the principal agent chain did not conflict, and if they did, the charterer would indemnify the shipowner. On the subject of information asymmetry all charterparties were found to have clauses that require ship masters reporting, with very few charterparties containing express clauses for weather routing companies reporting. The main outcome for a time charter is meeting speed and consumption guarantee and not being offhire and therefore providing good quality transport service. The problem of outcome certainty is linked to monitoring of performance of the two criteria aforementioned. The content analysis showed that in the case where the ship underperforms, the shipowner must compensate the charterer but when the ship over-performs in most cases only the charterer benefits instead of the owner. These principal agent problems can be said to have determining consequences on the implementation of speed reduction measures as well as other operational measures such as hull maintenance.

8.5. Concluding remarks

In this chapter, the propositions of agency theory are used to evaluate voyage and time charter shipping contracts. The survey method was used to explore perceptions of barriers to implementation of measures and the content analysis method in this chapter to explore the observed level of the principal agent problem as a potential barrier in uptake of operational energy efficiency measures in shipping. The nexus of the principal agent problem is the contract and agency theory aims to create efficient contracts that attempt to resolve agency problems (i.e. reduce agency costs). This presents a problem in the context of implementation of energy efficient operational measures because the contracts are often focussed in reducing agency costs e.g. resolving conflicts or aligning incentives, thus they may forego or not prioritise the benefits of energy efficiency. There is very sparse literature on principal agent problems in shipping and there is hardly any investigation into the design of adequate contracts for energy efficiency both in shipping and other industries. Using Eisenhardt (1988 and 1989) and Sharma (1997) propositions, two contracts of carriage in shipping are tested for their being outcome based or behaviour based contracts. It is suggested that the voyage charter is representative of an outcome based contract and the time charter is representative of the behaviour based contract. The voyage charter had more obligations on the shipowner (agent) in all four stages of the voyage which seemed to override or conflict with energy efficiency objectives. For example the voyage contract deals with the different agency problems by obliging the ship to proceed with utmost despatch in both the preliminary and laden voyage and tendering Notice of Readiness in specific time slots and places, all of which have conflicts with the implementation of speed reduction measures. The example of Virtual Arrival is given to show how this intense focus of charterparties on agency has been dealt with. Virtual arrival can be thought of as a way of dealing with the three main agency problems, goal conflict, information asymmetry and outcome certainty.

The results of the content analysis show that the majority of charterparties require utmost despatch in the preliminary voyage. However this was only applicable whenever no time is specified (Wilson 2010). Time is generally specified when settling the contract in the form of Expected Readiness to Load (ERL) date, which is based on the negotiation between the shipowner and charterer, thus there could be potential for implementation of slow steaming at this stage. All charterparties were found to have ERL date stipulated either in the preamble or within the main clauses. There were clear differences in the use of utmost despatch in the preliminary voyage across the sectors, all general voyage charterparties not having any express mention, three out of eleven drybulk charterparties without express mention, whereas all wetbulk charterparties analysed had express mention of utmost despatch or equivalent. One of the possible explanations of the sectoral differences could be the publishers and year of publishing. In the drybulk sector, the three voyage charterparties that did not have express mention of utmost despatch were published by BIMCO between 1980 and 2003. BIMCO was originally more representative of shipowners, however in the last few decades the documentary committee (which is responsible for drafting standard form charterparties) can be said to be representing fairly the interests of both parties (Wilson 2010). Utmost despatch clauses were not an issue in the container sector because operator's liner terms and conditions normally confer on the owner or vessel operators a right to slow steam. Other charterparties making use of express mention tended to be privately published by major charterers or trading houses or associations (e.g. Nipponore, Nipponcoal, Synacomex etc). In the laden leg once again there were sectoral differences on the use of utmost despatch clauses. Only one of the drybulk charterparties and general charterparties had in-built clauses for reduced speed (economical speed to conserve fuel). Oil major charterparties mainly relied on stated speed clauses for voyage charters. With these results it is clear that the focus of the contracts was around the goal conflict within the agency relationship.

Utmost despatch clauses were also found to be expressly mentioned in the time charterparties, even though it was believed that the goal conflict for implementation of operational measures would not exist i.e. charterers paying for fuel and deciding upon implementation of operational measures. Possible reasons for this were sub chartering, obligations to engine manufacturers and bill of lading holders' rights. The results of the content analysis show that only two of thirteen charterparties had built in slow steaming clauses. However there was a greater chance of implementation of speed reduction measure because not only is the charterer responsible for fuel costs but was shown to be the responsible entity for ensuring the contracts in the principal agent chain did not conflict, and if they did, the charterer would indemnify the shipowner. Therefore, on the subject of goal conflict, the above results for both types of contracts show that implementation of speed reduction measures is more problematic in the voyage charter, which supports the conclusions from chapter five and supporting analysis from survey results, which showed that implementation of operational measures and specifically speed reduction, were more of a problem under voyage charter than in time charter.

Indicators of outcome certainty in the voyage charterparty such as place of tendering Notice of Readiness (NOR) and time of tendering NOR were also thought to be important contractual features in the voyage charter that would impact the implementation of speed reduction measures. These are important clauses as they reveal the level of risk assumed either by the principal or the agent and affect the certainty in the contract. There were differences in places of NOR and timings of tendering of NOR in the charterparties of the different sectors, wetbulk charterparties generally were found to be port charters with no specific NOR timings, whereas most drybulk charterparties were observed to be berth charters but with specific NOR timings. This is perhaps due to increased congestion as a result of fewer ports and geopolitical issues in oil terminals and ports which tend to operate 24 hours a day as opposed to many drybulk ports that open for much less time. The implication of the open NOR time and place clauses is that shipowners can better manage the speed reduction or speed profile during the voyage.

For the implementation of speed reduction measure in the time charter another important agency problem is that of information. Information asymmetry between principal and agents leads to adverse selection and moral hazard. The charterer seeks information about the prospective ship through measuring the service quality in two main ways; speed and consumption guarantee and offhire guarantee. Information systems employed to counter adverse selection include ship vetting as a form of screening the agent, and information systems employed to counter moral hazard include supercargo and monitoring through third party sources. The length of the contract generally leads to better information (reduction of information asymmetry), however the majority of the shipping contracts were shown to be for less than three to six months in the drybulk and container sectors and between six months and one year in wetbulk sector. The short duration of the contract also makes it difficult for the charterer to recoup investment in better information systems that are ship specific.

Similar coding agenda was developed for the weather routing measure and the same template can also be used to investigate implementation of other measures in the context of principal agent problems and energy efficiency. It is believed that the various levels of liberty and deviation clauses may impact the implementation of weather routing measure and efficient voyage execution in the voyage charter. The results of the final coding have been difficult to obtain due to lack of time and resources (the use of multiple coders in such type content analysis) and the inability to establish a robust relationship between these clauses and use of weather routing measure. However, from the initial category development some early conclusions can be drawn. On the subject of goal conflict between principal and agent and implementation of weather routing measure, wetbulk and drybulk charterparties were found to have stricter limitations compared to general and container charterparties that contained higher levels of liberty clauses, which allowed for example bunkering enroute, calling at other ports, etc. These liberal clauses are found to have been inserted predominantly for the shipowners benefit and the courts apply the principle of 'contra proferentem – against the drafter' giving them an extremely restricted interpretation (Wilson 2010). On the subject of information asymmetry between principal and agent, oil major charterparties prescribed specific routes to be taken by the ship or when these were not described, the Worldscale routes or BP Shipping marine distance tables were mentioned. On the other hand, in the remainder of the charterparties the principal had no information at all as to what route is being taken by the agent, since they did not prescribe specific routes for the voyage.

The content analysis method combined with Eisenhardt's (1989) agency theory propositions provided a framework to analyse the shipping contracts more systematically and from a theoretical point of view. The agency theory propositions as categories for content analysis for both types of contracts for carriage of goods illustrated agency problems in the contracts more clearly, with which it is possible to conclude that the agency problems in contracts are affecting the implementation of at least the speed reduction measure.

9. Discussion

The aim of this chapter is to triangulate the research findings from the three methods used to answer the research questions. To put the findings in context, the chapter relates these findings with similar studies and explains the key findings with general barriers theory and agency theory. The chapter follows sequentially each of the research questions and hypotheses and concludes with key recommendations from this research and further work required to enhance the understanding of barriers to energy efficiency in shipping.

9.1. Implementation of energy efficiency operational measures

Energy efficiency is one of the means through which rising global CO_2 emissions and dangerous climate change could be avoided. This research reviewed several empirical studies across different sectors and showed that despite the substantial abatement potential at negative costs, cost-effective energy efficiency measures are not always implemented. The lack of implementation results in an energy efficiency gap, which refers to the difference between the actual lower levels of implementation of energy efficiency measures and the higher level that would appear to be cost-effective from the consumers or firms point of view based on techno-economic analysis. Thus the energy efficiency gap can be a result of:

- Modelling artefacts – incorrect energy efficiency potentials based on different viewpoints e.g. technologists versus an economist.
- Rational behaviour – incorrect parameters that do not reflect accurately the situation faced by firms or consumers e.g. cost and access to capital.
- Market barriers and failures – socio-economic barriers e.g. power, culture, and economic market failures e.g. split incentives and information asymmetry.

To date there exists mainly grey literature and a couple of MSc dissertations that have explored barriers to energy efficiency in shipping. These have alluded to the energy efficiency gap and barriers that are affecting implementation but have not done so in a methodologically rigorous manner. A review of the empirical studies on barriers to energy efficiency in other sectors led to the construction of a framework that needed to be followed in order to theoretically and rigorously examine barriers to energy efficiency in shipping. In order to assess whether there is an energy efficiency gap in shipping, it is important to understand the actual level of implementation of energy efficiency measures. To that end, the first research question aimed to investigate the actual level of uptake of energy efficient operational measures. This has not been examined previously, so it is thought that this research creates a baseline on the level of implementation of operational measures in shipping. The online questionnaire method (as discussed in chapter three and four) was employed to answer the research question which asks:

Research question 1: To what extent are energy efficient operational measures implemented in shipping?

Three hypotheses were developed to address the research question regarding the implementation of energy efficient operational measures:

Hypothesis 1a: Energy efficient operational measures are not fully implemented.

Hypothesis 1b: Implementation varies across the measures according to size and sector.

Hypothesis 1c: Implementation of energy efficient operational measures is higher for time chartered ships compared to voyage chartered ships.

General barriers literature proposes that engineering-economic analysis based on cost-effectiveness, would show higher levels of implementation of measures whereas the actual level of implementation may be lower (Golove and Eto 1996 and Brown 2001). The actual implementation rate was measured using two questions in the online questionnaire. The first question attempted to limit the number of measures to five measures with the highest fuel saving potential, similar to Harris (2000) and Velthuijsen (1993). The respondents were then asked whether they had implemented the measure they believed to have high fuel saving potential. The survey showed statistically significantly that, no measure that was believed to have a high fuel saving potential was fully implemented. The average implementation of operational measures was between 45-65% across all the measures (CL 95%) and implementation between the measures ranged between 35-75% (CL 95%). Combining the respondents who have already implemented a measure and those planning to implement a measure, the average across all the measures is between 65-75% (CL 95%). On average each company had implemented between two and three measures (CL 95%). The average implementation rate across all the operational measures is similar to the Faber, Behrends & Nelissen (2011) survey of five shipowners, who report implementation for operational measures of around 60%. Similarly, Maddox Consulting (2012) based on expert judgement report implementation of six operational measures to be around 65%.

In non-shipping sectors, Harris (2000) shows an implementation rate of energy efficient measures implemented by industrial firms to be around 80%. For households or residential sectors Kema-Xenergy, Itron & RoperASW (2004) shows an implementation rate for energy efficient appliances to be around 50% and IEA (2007) show an implementation rate for space heating measures of around

50% as well. Thollander and Palm (2013) cite three government initiatives (based on energy audits and recommendations that aimed to promote implementation of energy efficiency in organisations) had implementation rates between 40-80%. Therefore, the implementation rate of operational measures for shipping can be said to be in the same range as the aforementioned sectors, where the energy efficiency gap has been established.

There has been considerable discussion in other sectors around the lower observed level of implementation of energy efficient measures and a large extent of this has revolved around barriers that may be inhibiting their uptake. In the general barriers theory, market barriers and failures are attributed as the reasons for the lower implementation. The results obtained from the survey method are in line with the first hypothesis (1a) that operational measures are not fully implemented. However, this hypothesis is broad and generalised (in that it is not supported by a specific theory, rather by the general barriers theory), therefore hypotheses 1b and 1c are used to test the results with specific theories.

Other barriers that are not related or rooted to the economic agency theory have also been discussed in the literature, these are generally called market barriers (access to capital, heterogeneity, hidden costs and risk). Each of these market barriers are supported by a separate theory for example hidden costs is explained by transaction cost theory (Willaimson 1979), access to capital and risk is explained by capital asset pricing model and theory (CAPM) (Fama & French 2004) and it is possible for agency theory to explain some aspect of these market barriers. However, it is beyond the scope of this research to investigate each of these in greater detail to explain the energy efficiency gap in shipping, rather this research uses the agency theory to explain the market failures, as the majority of these can be explained by the agency theory alone. Hypothesis 1b states that there is variation across the implementation of measures amongst different groups of respondents, which would be a reflection of some of the above market barriers and therefore the theories aforementioned. For example sectoral differences in implementation would suggest that there is market heterogeneity (i.e. when a measure may be cost-effective in most circumstances but not in others, leading to excessive potential being claimed for the measure). At a general level, average implementation rates by different size groups showed that the small sized firms (with five to ten ships in the fleet) had higher implementation rate than large firms (Table 6.6). Sector average implementation rate showed that the drybulk sector had the highest implementation rate (Table 6.6) followed by wetbulk and container sectors. There is insufficient literature to explain the above findings but it is hoped that by examining relationships at a detailed level would provide some insights into the differences. There is quite a large difference between the level of implementation amongst different measures, when disaggregated by size and sector. Overall the variation among measures did not show any consistent relationship with size or sector across the implementation of measures. When examining the relationship at a more detailed level (i.e. between implementation of a single measure and size or sector and controlling for other variables) for measures that had the highest implementation some statistically significant relationships were observed. Measures that had the highest implementation were weather routing, general speed reduction and fuel consumption monitoring, which were the focus of the detailed analysis.

The bivariate elaboration analysis controlled for one independent variable (test variable e.g. sector) at a time when examining the relationship between implementation of the aforementioned measures and another independent variable (e.g. size). The reason for controlling for only one test variable at a time is to maintain a sufficient level of populated cells in the crosstabulations. Controlling for only one test variable at a time means that each conditional relationship could potentially be affected by the third independent variable, e.g. relationship between implementation of weather routing and size, controlling for sector, could be affected by the correlation between sector and chartering group. Indeed correlations between the latter two independent variables were quite high. For example, it was seen that there are almost three times more large companies in the wetbulk sector compared to drybulk sector and that there are more of chartering groups one and two in drybulk sector compared to the wetbulk sector and vice versa for groups three and four. The implication of these relationships is that in the following analysis the impact of a test variable would be possibly inflated by its relationship to another uncontrolled test variable.

The relationship between implementation of weather routing and size of the firm showed a weak zero order relationship, but when controlling for sector the relationship improved to a moderate level (not statistically significantly) for the drybulk sector. The zero order relationship between implementation of weather routing and sector was also found to have a moderate effect size (measured by Cramer's V correlation coefficient) as well as being statistically significant, which further improved when controlling for size. This finding suggests that when examining relationships at a per measure level, some patterns of association exist between implementation of measures and size as well as sector. The relationship between implementation of other measures with size and sector resulted in very similar results. Four moderate to strong relationships, which are also statistically significant, were observed and will be used for the discussion with results of other methods;

1. Zero order relationship between implementation of weather routing and sector (0.295, p 0.058)

2. Conditional relationship (controlling for sector) between implementation of weather routing and chartering group (0.647, p 0.021, drybulk)
3. Conditional relationship (controlling for sector) between implementation of fuel consumption monitoring and size of the firm (0.413, p 0.085, wetbulk)
4. Conditional relationship (controlling for sector) between implementation of general speed reduction and size of the firm (0.549, p 0.029, drybulk)

From the above results it can be seen that controlling for sector, conditional relationships between a measure and size improve to strong levels, so sector as a test variable results in more stronger and statistically significant relationships. However, it could also be said that there is a lack of consistency in relationships across the measures, for two of the measures the original relationship is for size of the firm, and the remainder two are for sector and chartering group. The meaning of the above results has been explained in further detail in chapter seven but it is important to highlight these here as they may be explained by research findings from other methods. For example could charterparty content analysis method explain why there is a sectoral difference in implementation of weather routing? (relationship one above). Can the sectoral difference be explained by the different types of charterparties in the sectors? Analysis from chapter seven on relationship four showed that in the wetbulk sector 78% of the small sized companies had implemented the general speed reduction measure which is the highest amongst other size groups in that sector. Whereas, in the drybulk sector there seems to be a considerable contrast in the implementation with only 29% of small sized companies implementing general speed reduction which is the lowest compared to other sizes in that sector. This could be explained from the charterparty analysis which showed that major wetbulk charterers have significant bargaining power, which smaller sized firms operating in that sector may be subject to, through oil major's charterparties, which were shown to have the highest speed reduction potential.

Although even more moderate and strong effect sizes were observed in other relationships, based on the few statistically significant results above, hypothesis 1b cannot be fully accepted and the null hypothesis cannot be totally rejected, thus implementation of measures could be said to be to some extent varying for size and sector. The inability to accept the hypothesis is mainly due to the smaller sample sizes for the remainding conditional relationships.

This research however has primarily focussed on one economic theory that is used to explain some of the market failures to energy efficiency, the agency theory, as discussed in chapters two and five. To briefly recap for the purposes of further explanation of the results, the theory states that principals and agents have certain characteristics (e.g. risk aversion) and as a result will face two main problems in an agency relationship; conflict of interests and information asymmetry, resulting in ex-ante and ex-post agency problems. This economic theory has then been applied to the discussion of barriers to energy efficiency and specifically to explain the energy efficiency gap. On one of the aforementioned problems, conflict of interest, several studies categorised the conflict of interest (referred to as 'split incentives') into four cases based on the type of contract, refer to Table 5.8 for further details.

In order to observe the extent of barriers, the non-shipping sector empirical studies then further break down implementation of measures by ownership. Extending the agency theory to the energy efficiency context, under the principal agent problem methodology or matrix, it is hypothesised that implementation of measures will differ according to the four cases. In the two of the aforementioned non-shipping studies (Kema-Xenergy, Itron & RoperASW 2004 and IEA 2007) the implementation of energy efficiency measures differed significantly between owned (owner-occupied) and rented properties, confirming the efficiency principal agent problem. Harris (2000) does not observe significant differences in businesses that own their premises and those that lease their premises, and as mentioned earlier finds the highest level of implementation compared to any other barriers to energy efficiency study. A plausible explanation of this could be the nature of the contracts in the industry such as their length and retrofit clauses as suggested by Meyer (2008). IEA (2007) in the case of energy efficiency measures implemented by owned versus rented residential properties showed that implementation varied significantly across the different measures, in some cases by up to 30% (for roof insulation) between the groups.

The above studies focus on technical energy efficiency and show evidence that the principal agent efficiency problem exists, however there is a problem when investigating operational efficiency, since no study to date has investigated how implementation of operational measures is affected the same cases. For example the studies generally hypothesize that rented households (with no energy included in rent) have lower implementation of technical measures (due to efficiency principal agent problem), and this has been confirmed by many studies (e.g. Gillingham, Harding & Rapson 2011; Maruejols and Young 2011). It is important to extend this hypothesis to investigate that the same rental households (with no energy included rents) may perhaps have better operational efficiency. Conversely, rented households (with energy included in rents) have higher implementation of technical measures but may suffer from lower implementation of operational measures. The key here is the end user's or tenant's (principals) incentives to conserve energy. Whilst operational efficiency in households or other sectors may not be as important (as suggested by the lack of research on this subject), it certainly is in the case of shipping, since operational efficiency can have a higher impact as shown in chapter five. There have been large energy end use studies of households but most of them have concentrated on technical efficiency and whilst some studies have attempted to profile occupant energy use and behaviour (operational) these have fallen short of disaggregating these for different cases of the principal agent matrix (e.g. Zimmermann et al. 2012). There exist only a few anecdotes of occupant behaviour for the different types of principal agent cases e.g. occupant's leaving windows open during the low temperature months when landlords pay for utilities, Levinson and Neimann (2003) and Gillingham, Harding & Rapson (2011).

Using ownership and rent as an indicator of the principal agent problem, and consequently denoting the split incentive market failure, this research attempted to identify the observed extent of the principal agent barrier in shipping. The chartering level is used as a proxy to the ownership type, resulting in four groups based on ownership and chartering (refer to section 6.5 for further details). In chapter three and five it was hypothesised that shipping firms that own a majority of the fleet and charter out their fleet primarily on voyage charter have lower implementation of operational measures compared to those that own the vessels and charter out primarily on time charter. The total number of measures implemented across the groups varied slightly but not significantly. Overall the groups with a majority of their fleet chartered out on time charter had slightly higher (65% compared to 60%) implementation of the all the measures, but the results show there was a non-significant and weak relationship between the chartering group and number of measures implemented when viewed at an aggregate level.

Detailed analysis at per measure level reveals that there is a good level of association between implementation of a particular measure and the chartering group. For instance, the implementation of weather routing, controlling for sector, shows that there is a significant difference in implementation between the different chartering groups. The group that owns and operates on voyage charter had lower implementation compared to the group that owns and operates on time charter and this was more of a case in the drybulk sector. A possible explanation of this observation is that weather routing seems to be more applicable to time charterers who use it for monitoring purposes as well, rather than using it solely for optimal routing. The results of the charterparty content analysis also supported this, as it showed that two of the drybulk charterparties made explicit mention or use of weather routing services for monitoring, despite the precedence given to master's own reporting, whereas none of the wetbulk charterparties had weather routing service clauses. The implementation of the speed reduction measure and its association with chartering group, controlling for sector, reveals a similar pattern, i.e. the group that owns and operates on voyage charter had significantly lower implementation compared to the group that owns and operates on time charter, for both wetbulk and drybulk sectors. Linking this finding with charterparty content analysis, one can see that there were several agency related reasons for voyage charterparties to restrict speed reduction through utmost despatch, notice of readiness time and place clauses in all four parts of the voyage. These results cannot be corroborated with the results of the calculated speed difference between voyage chartered and time chartered ships, investigated in research question four (section 5.6) due to the relatively small sample size of time chartered ships. The survey respondents also thought that speed reduction was more achievable in time charter than in voyage charter, which further supports the hypothesis. These results seem to suggest that hypothesis 1c can be accepted, since the implementation of the operational measures and specifically the speed reduction measure is higher in time charter than voyage charters.

So far the first research question has been concerned with the level of implementation of operational measures and through use of some of the inbuilt survey indicators has been able to explain the variations in implementation of measures. The following section corroborates these results with the respondents' perception of barriers to implementation of energy efficient operational measures and observed level of barriers to energy efficiency.

9.2. Factors affecting implementation

It is acknowledged in the barriers discussion that possible reasons for the difference between the observed lower levels of implementation of energy efficiency measures could also be due to modelling artefacts, inaccurate representations of the real world situation and the existence of barriers that actually affect implementation. This research took a novel approach to investigating the barriers that may be affecting implementation of energy efficiency measures. This was done through measuring inbuilt survey indicators as illustrated in the preceding section, through the perception of barriers and then comparing this to the observed level of barriers. The second research question addresses the perception of barriers to energy efficiency by asking:

Research question 2: What factors are perceived to be the most important in explaining the lack of implementation of energy efficient operational measures?

The hypothesis developed to address the research question was;

Hypothesis 2: Market failures (principal agent problems specifically) are perceived to be more important than non-market failures for lack of implementation of operational measures.

The online questionnaire method was employed to answer the research question in order to explain the lack of implementation of operational measures from the respondent's point of view. The perception of barriers to implementation was measured by two different types of survey questions. A general level question was asked for all those measures that were thought not to have a high fuel saving potential (i.e. after the first survey question). The second survey question was to ask those respondents who had not yet implemented the measures that they believed had a high fuel saving potential. These were more detailed and tailored to the measures in question. Results from the first type of survey question show that there are specific barriers pertaining to each of the measures. Lack of reliable information on cost and savings mainly affects the more technical operational measures, representing a quarter of the responses for each of these measures. For the measures mainly related to speed, the respondents mainly cited that these were difficult to implement under different types of charter and that charterparties did not allow for their implementation, which together represented on average half of all the responses received for each of these measures. Therefore, suggesting that informational problems mainly affect the technical operational measures whereas split incentives affect speed related operational measures. Connecting this with the implementation of speed related measures by sector, which shows that the wetbulk and drybulk sectors have similar implementation rates of around 60%, with the container sector having 75% implementation of the measure, suggests that principal agent problems may be a cause of the lack of implementation. This is supported with the results of the last survey question on speed reduction, where more of the wetbulk and drybulk sector respondents compared to container sector respondents believed it would be difficult to implement speed reduction measures under different types of charter and that charterparty clauses were an important hurdle. The charterparty content analysis further corroborated the observed differences in level of implementation of speed reduction by showing that most of the wetbulk and drybulk sector charterparties had all contained certain clauses that inhibit uptake of the speed reduction measure, whereas general use charterparties contained none.

For all the measures, lack of access to capital barrier was the least cited which could be due to the relatively lower capital expenditure required for operational measures. This is confirmed by Sorrell et al. (2004) and Thollander and Ottosson (2008) (these studies are referenced because they were shown to be methodologically rigorous and therefore their results were more valid than other studies, refer to chapter two for further details) who find that capital barriers to energy intensive production processes generally were regarded as the highest barrier. So from the first question type on barriers to energy efficiency perception, market failures can be concluded to be more important factors than non-market failures affecting the implementation of operational energy efficiency measures.

The results from more detailed questions on barriers to implementation of measures showed that in general, market failure barriers were twice as likely to be cited as barriers compared to market barriers (non-market failures). This is in contrast to Thollander and Ottosson (2008) who show that most respondents cited barriers that were non-market failures. Sorrell et al. (2004) also show that for each of the three case industries, capital barriers were always the most important perceived barrier. Indicators of market failures and split incentives within survey questions from Sorrell et al. (2004) ranked around the middle of all the barriers cited by the respondents. Disaggregating the perception of respondents by size, sector and chartering group, generally did not show a consistent pattern of association between the perception of a barrier and any of the above independent variables. Bivariate elaboration analysis shows three statistically significant relationships between the market failure indicators and the independent variables, as follows;

1. Conditional relationship (controlling for chartering group) between split incentives and size (0.581, p 0.006 for chartering group four).
2. Conditional relationship (controlling for sector) between information problems and size (0.408, p 0.103 for wetbulk)
3. Conditional relationship (controlling for size) between informational problems and chartering group (0.693, p 0.048 for small sized firms)

None of the above relationships are zero order relationships, which implies that they only exist under specific circumstances. Similar to the relationships mentioned in section 9.1, these are mainly found to apply to the size of the firm instead of the sector or chartering group variables. This is an unexpected result, since previous discussion and debate around barriers to energy efficiency has not produced enough on this subject. Economic theory such as the transaction cost theory (Williamson 1985) that suggests different costs for different sized firms has not been well discussed in the context of barriers to energy efficiency. In shipping the size of the firm is briefly discussed by Faber et al. (2009) quoting that “smaller ship owners and operators may experience high transaction costs as they cannot spread the costs of e.g. gathering information over a large number of ships” (Faber et al. 2009, p.98). The size of the firm has been discussed very briefly by DeCanio (1993) in the context of barriers to energy efficiency, and this can be linked to the principal agent problem through use of agency theory. For example large “multidivisional corporations” (DeCanio 1993, p908) face several factors that may result in overly stringent investment criteria despite the lower cost of capital faced by the firm and overly stringent criteria as a result of divergence of preferences (split incentives) between owners and manager or shareholders and executives (Antle & Eppen 1985, Lambert 1986). This suggests that larger organisations may be more susceptible or perceive split incentives to be an important barrier. The first conditional bivariate relationship above suggests that the perception of split incentives has a strong relationship with size for one of the chartering groups. The cross tabulation for chartering group four (management company with a majority of its fleet chartered out on time charter) shows that all of the large firms perceived the split incentive barriers as not important, with small and medium sized companies perceiving split incentive barriers as important. This result is somewhat in line with Thollander and Ottosson (2008) who show that 'slim organisation' is an important barrier to adoption of energy efficiency measures but is quite in contrast to the results of Sorrell et al. (2004) who show that the practices and procedures of large firms (such as energy accountability, level of sub metering and energy objectives of departments thus reflective of the split incentive barrier) are important issues for large organisations "In sum, split incentive problems related to accountability and equipment purchasing are evident within the sector – particularly at large sites – but are only considered of medium importance to energy efficiency" (Sorrell et al. 2004, p216).

The second bivariate relationship suggests a relationship between perception of informational problems and size of the firm that exists mainly for the wetbulk sector. The large firms perceived the informational problems to be more important than small firms. This result is the opposite of what was perceived of split incentives by the large firms. There is no specific theory that predicts the relationship between size of the firm and the level of informational problems, but one can extrapolate from other theories and use empirical evidence on this subject. One can extrapolate from what is known about the purchasing pattern of energy goods, which have been described as credence goods i.e. those whose utility is difficult to ascertain even after purchase. "Imperfect information is more likely to occur when products are purchased infrequently.., which is an unfortunate characteristic of many energy related investments" (Palm and Thollander 2013). From this one can assume that smaller firms are likely to have relatively smaller and infrequent purchases compared to larger firms and therefore smaller firms may be more susceptible to information related problems than larger firms. Secondly, results from the survey conducted by Sorrell et al. (2004) show that "smaller (brewing sector) firms had poorer specific energy consumption and were more likely to lack information" (Sorrell et al. 2004, p217).

The results of the above bivariate relationship thus are opposite to what has just been suggested in theory and literature for split incentives and informational problems and their relationship with size of the firm. One possible explanation to this contradictory finding is that the information problems barrier in the survey was used to encapsulate all types of information problems; information asymmetry, imperfect information (information based adverse selection and moral hazard), lack of information, source of information, form of information and public good attributes of information. It is possible that the respondents of the larger firms were alluding to any one of the above. Sorrell et al. (2004) suggest that lack of information or availability of information may not be a problem but rather the search costs or time required (hidden costs) to discern quality from various sources of information is more of a problem. The fact that the relationship holds in the wetbulk sector also suggests that these might be the problems that are encountered by the firms operating in that sector. Indeed much of the IMO (equivalent of government sponsored) information on energy saving potential in the second greenhouse gas study (Buhaug et al. 2009) has used energy saving potentials directly from one single equipment and engine manufacturer's brochure. Possible reasons as to why this mainly holds for the wetbulk sector could be the heterogeneous nature of the ships themselves, geographical location, the markets and the type of chartering arrangement mainly prevalent in this sector, (discussed further in research question three).

The third bivariate relationship confirms that informational problems are related to the chartering group (statistically significantly only in small firms). In the small sized firms, groups that had mainly chartered their fleet out on time charter had cited lower informational problems compared to those that had mainly chartered their fleet out on voyage charter. This result can be explained using tenets of agency theory and principal agent problem cases. Under the time charter, the time charterer pays for the fuel and is in some operational control of the ship, therefore the charterer would have the incentive to implement operational measures. Combining this with the earlier proposition of frequency of purchases (credence good) the charterer is able to improve his information on several aspects of the contract and operation (e.g. reduce adverse selection, effective monitoring, purchasing good quality information) and thus the operational efficiency of the ship. On the other hand a small shipowner-operator (with less than ten ships) with the majority of its fleet on voyage charter is less likely to be able to learn from frequent purchasing or implementation of operational measures. This is further supported with the moderate and statistically significant correlation between perception of split incentives and informational problems. In section 7.4 it was seen that when controlling for size and sector, the relationship between perception of split incentives and chartering group strengthened to very high levels (close to statistically significant levels, refer to Table 7.23). The correlation would therefore imply a similar pattern of association for information problems as confirmed by the third bivariate relationship. Based on these it can be concluded that only in specific situations market failures are perceived to be more important for operational measures in shipping than non-market failures, thus the second hypothesis can be to some extent accepted.

The previous two research questions attempted to explore the implementation and perception of barriers to implementation of energy efficient operational measures. The following research questions are an attempt to see whether the implementation of measures and the perceptions of respondents are observed in practice. Research question three and four are the result of the secondary or desk research carried out in the first step or stages of this research, in order to gauge the level or pervasiveness of the principal agent problems in shipping. The third research question asks:

Research question 3: What population of ships is affected by the principal agent problem in implementation of energy efficient operational measures?

The hypothesis developed to address the research question was;

Hypothesis 3: A high proportion of the population is affected by the principal agent problem when implementing energy efficient operational measures.

This research question was mainly answered through secondary data analysis. The methodology set out in IEA (2007) is followed. In order to answer this research question it is first necessary to identify situations where principal agent problems may exist (step one of IEA methodology). This is done through an overview of contracts used in shipping which are matched to various cases of the principal agent matrix as shown in Table 5.13. From the principal agent literature in other industries, it is concluded that in carriage of goods contracts in shipping, the charterer is the principal and the shipowner-operator is the agent. To briefly recap for the purposes of further discussion, the cargo owner operator's shipping fleet which are mostly bareboat charters is identified as case one of the principal agent matrix, where no principal agent problems are likely to occur. The time charter was identified to be case two of the principal agent matrix, where the efficiency principal agent problems can occur. The voyage charter was identified to case four of the principal agent matrix, where the usage principal agent problems can occur. No contracts in shipping were identified for case three of the principal agent matrix, where both efficiency and usage problems could occur.

The principal agent discussion is extended to show that the same entity may have a different role in its relationship with other stakeholders even in the same contractual context e.g. carriage of goods, and that there are several dimensions or contexts where principal agent relationships exist other than contracts of carriage. Extending the one principal one agent for case two (time charter) and case four (voyage charter), shows that for a ship there are numerous conflicting interests along the chain of principal agent relationships. According to Murtishaw and Sathaye (2006) and IEA (2007) each energy efficiency measure can represent a different case. For most operational measures the time charter can be said to represent case one of the principal agent matrix where it is likely that no principal agent problem exists, because the principal (charterer) is in operational (although not direct) control of the vessel and can select operational measures to implement. Whereas for operational measures in the voyage charter can be said to represent case four of the principal agent matrix, where the usage problem can occur, because the principal seldom selects the operational measures. From the charterparty content analysis it is found that only in a limited number of situations (in the case of oil major charterparties) can a charterer select the speed (as an operational measure) of the ship, which could be said to be reflecting case one of the principal agent problem. Thus the implementation of operational measures should therefore be higher in time charter than in voyage charter, according to the above classification. This is in line with the results of the survey method which confirmed the hypothesis that the chartering group that had the majority of its fleet chartered out on time charter had higher implementation of operational measures compared to the groups that had a majority of the fleet chartered out on voyage charter.

To estimate the population of ships affected by the efficiency and usage principal agent problems, secondary fixtures data and IEA (2007) methodology were used. The results show that on average across different ship types or categories, just under 90% of the wetbulk fleet on the charter market (carriage of goods contracts) is allocated to case four, therefore a majority of this sector could be said to be potentially affected by the usage problem and over 10% of the charter market wetbulk fleet is allocated to case two, which is can be affected by the efficiency problem. This translates to just over 10% of the fleet on charter market falling under case one for operational measures, where it is likely that no principal agent problems occur. The proportion falling in case one could be higher because of oil major charterparties control on speed reduction measures.

On average across the different drybulk ship types over 60% of the drybulk fleet on charter market is allocated to case two, which can be affected by the efficiency problem and just under 40% of the drybulk fleet is allocated to case four, which could be affected by the usage problem. This translates to just over 60% of the wetbulk fleet on charter market falling under case one for operational measures. For carriage of goods contracts, the whole of the container fleet could be affected by the usage problem (where shipper is the principal and carrier is the agent) and there is no difference in the number of cases affected by principal agent problems related to technology and operational measures.

Table 9.1 shows that the results are to some extent in contrast with the respondent population obtained in the survey, which showed that 60% of wetbulk sector respondents had their fleet chartered out on time and the remaining 40% on voyage charter. The results of the drybulk calculation correspond to some extent to the respondents of the survey. The reasons as to why weighting of the sample was not carried out are:

- The chartering ratio of the firm is not well known prior to selection of the respondent,
- The selection of large and medium size companies was based on a census so can be said to be reflective of the sample if similar response rates are achieved between the strata
- There would be too many categories to weight the sample
- The chartering ratio (interval variable) was arbitrarily reduced to nominal level variable i.e. into groups

	Calculated		Survey	
	Wetbulk	Drybulk	Wetbulk (N=20)	Drybulk (N=18)
Voyage charter	90%	40%	40%	62%
Time charter	10%	60%	60%	38%

Table 9.1: Differences in the proportions of sectors on the charter market

The results obtained from the calculation shown above, are very similar to those obtained by Pirrong (1993) and Stopford (2008). Pirrong's (1993) analysis of bulk shipping markets and contracting practices suggests that voyage contracting is common in oil trades post 1973, whereas for more than half of the drybulk commodities long term contracting or vertical integration is used. Possible explanation for the differences between the calculated population and survey sample could mainly be due to the unit of analysis, where the calculated proportion is based on number of ships, whereas survey proportions are based on arbitrary grouping based on chartering ratio of the firm. Secondly, the difference may be because of the quality of data obtained from Clarkson's SIN, which was shown to be under-representing smaller ships and some Asian market fixtures, but this could also be said for the survey respondents, so it is likely that this is not a cause of the difference. Thirdly, the time periods could to some extent explain the differences, the data for the calculation was derived for the year 2011, whereas the survey was conducted in 2012 and since the charter market is highly liquid, ships could be on time charter in one period and move to voyage charter in another.

The proportion of the shipping population potentially affected by principal agent problems i.e. attribution to principal agent cases, shows that results are not different from that of IEA (2007) case studies looking at commercial office spaces variations across countries. In the Japanese commercial leases nearly 50% is identified as case four, and over 15% identified in cases one and two. In the Norwegian case study almost 90% of the population is attributed to cases two and four, with only 10% of the population attributed to case one. Similarly Vernon and Meier (2012) show a very large proportion of the population of the US trucking industry is affected by the usage problem (i.e. case four). These findings correspond to the results obtained in this research for the wetbulk sector. The Dutch case study of commercial office space (IEA 2007) is the most relevant to this research because it looks at what energy saving investment decisions can be made by the end user (including operational measures) in all four cases but with the caveat that it aggregates all four cases into just two cases, case one and case two (because they assume all energy costs are eventually passed on). The results show that a majority (60%) of the population falls under case one when this approach is used, similar to what was found in this research for the drybulk sector. This approach shows that, rather than just using contracts to identify and attribute principal agent problems, it is important to understand what energy efficiency decisions are being made by each party in the relationship, as advocated by Murtishaw and Sathaye (2006) and further investigated by Maruejols and Young (2011). Therefore, for operational measures in the drybulk sector it can be said that a smaller proportion of the population is affected by the principal agent problem and in the wetbulk and container sector a high proportion of the population is affected by the principal agent problem, thus hypothesis three can be accepted for wetbulk sector and to some extent for the drybulk sector.

Having identified the pervasiveness of the principal agent problem in the shipping sectors the next research question investigated how the principal agent affects the energy end-use through energy consumption and energy efficiency. The purpose of this was to identify if there is a difference between energy consumption and energy efficiency of ships that are attributed to the different cases in research question three and use this as a check for previous analysis and conclusions.

Research question 4: How is the energy efficiency in operations affected by the principal agent problem?

The hypothesis developed to address the research question was;

Hypothesis 4: Operational energy efficiency of ships is better for time chartered ships compared to voyage chartered ships.

This research question was answered through secondary desk research using technical details obtained from databases such as the Clarksons World Fleet Register (WFR) and operational efficiency (using satellite data) from a separate study (Smith et al. 2013). The question is mainly focussed around the operational energy efficiency of ships and how this compares for the voyage and time charter. The results of this analysis would be compared to the results from the survey on implementation of energy efficient operational measures implemented under the two types of charter. Unfortunately, the filtering of both fixtures to compare ships that have purely been on voyage charter and purely been on time charter (including removing those ships that had been sublet on voyage charter) results in very few cases under the time charter, therefore the mean operational efficiency results do not produce statistically significant results. Comparing the operational efficiency averages of the voyage chartered panamax drybulk ships (649 cases) and time chartered panamax drybulk ships (which had fifteen cases, highest number of filtered cases) also did not produce statistically valid results. The operational efficiency means and ratio of operational speed to design speed were found to be identical for both the types of charter. Because of the low number of cases the results cannot be corroborated with the survey findings on the level of implementation of operational measures by the different chartering groups. It is acknowledged in literature (for example IEA (2007)) that finding the real energy efficiency or energy consumption for different cases in principal agent matrix is rarely straightforward and assuming that energy consumption or efficiency in the different cases can also be futile. In fact in some case studies, IEA (2007) make bold assumptions on the level of energy efficiency of cases, whereas in some, cases are assumed to have equal consumption and energy efficiency. Given the low sample size for time chartered ships hypothesis four cannot be accepted. It has to be assumed that the observed operational efficiency of ships is equal for voyage and time chartered ships, despite the survey results suggesting that operational efficiency may be different for both.

Agency theory proposes two key problems that would affect the principal agent relationship, goal conflict and informational problems. It then attempts to create the most efficient contract given the aforementioned problems encountered in an agency relationship. The following research question attempts to identify manifestations or examples of the agency problems in shipping contracts and clauses which could be consequently affecting the implementation of energy efficient operational measures. Thus an understanding of how the agency problems are dealt with in shipping contracts could explain why certain operational measures are implemented or not implemented.

Research question 5: How do the agency problems in contracts affect implementation of energy efficient operational measures?

Hypothesis 5: Agency problems affect the implementation of energy efficient operational measures.

To answer this research question the content analysis method was employed to analyse thirty voyage and time charterparties. Eisenhardt (1988 and 1989) framework and propositions are used to guide the initial category development with the categories further refined using ethnographic content analysis for the speed reduction measure in voyage and time charterparties. It was found that under common law and international treaties there were more obligations on shipowners in voyage charter than any other party or any other charter. In the voyage charterparties, the goal conflict agency problem was manifested through use of utmost despatch clauses, notice of readiness places and times. These are clauses which would mostly impact the level of implementation of speed reduction measures.

Utmost despatch was categorised in four different levels; i) most of the charterparties require owners to proceed at utmost despatch for the approach and discharge voyage, ii) some only in laden, iii) some with no express mention and iv) some allowed users to determine whether utmost despatch or economic despatch. The implication of this is that speed reduction measures became difficult to implement under various voyage charterparites. This supports the survey results that show that the use of utmost despatch clauses were the most important perceived barrier to speed reduction. There was also found to be a good relationship between use of utmost despatch clauses and sector charterparties (wetbulk, drybulk and general charterparties). All wetbulk charterparties made use of the first level of utmost despatch, whereas drybulk charterparties used second and fourth level and general form charterparties making no express mention of utmost despatch. This relationship can explain the the general survey results (uncontrolled for other variables) which showed that the wetbulk sector had the lowest implementation of speed reduction followed by drybulk and then container sector with the highest implementation. Comparing this with the perception of barriers it can be seen that a large number of respondents in the drybulk and wetbulk sectors had perceived standard charterparty clauses whereas many fewer respondents in the container sector thought this to be the case.

There was a clear association between the charterparties of the different sectors and their use of Notice of Readiness (NOR) places (port or berth charters). Wetbulk charterparties generally were found to be port charters whereas most drybulk charterparties were observed to be berth charterparties in the standard form charterparties. The implication of this clause is which party would bear the risk of delays. In the end however both sector charterparties used further clauses to shift back the risk of delays to the principal i.e. charterer. The delays in the voyage are closely related to the port infrastructure and efficiency. The survey results on the 'speed reduction due to port efficiency' measure to some extent are supported with the above results. It was seen that the wetbulk sector had a slightly lower (although not statistically significantly and with a weak relationship) implementation of this measure compared to the drybulk sector, despite the measure being advocated by the wetbulk sector. This result contradicts the perception of the respondents where more drybulk sector respondents compared to wetbulk sector respondents (statistically significantly and moderate relationship) perceived port infrastructure and efficiency to be an important barrier when considering the implementation of speed reduction.

Another closely related clause to the implementation of speed reduction measures which relies on port infrastructure is the time at which NOR can be tendered. Again, there was a clear association in the charterparties in the use of all round NOR or specific timing NOR and the sector. Wetbulk charterparties had no specific times in which NOR had to be tendered whereas in contrast the majority of the drybulk and general charterparties had specific times in which shipowners had to tender NOR. This relationship could be explained by the differing port operation times. The implication of this is that the shipowners have more flexibility and can therefore possibly implement speed reduction as there isn't a rigid time slot which must be adhered to. In the worst case scenario, a specific NOR could incentivise the shipowner to increase speed in order to arrive within the time window in order to tender a valid NOR and be classed as an 'arrived ship'. This analysis would suggest that the wetbulk sector has more opportunities for implementation of speed reduction measure but this is in contrast with the results from the survey mentioned above on the implementation of speed reduction measure due to port efficiency.

In time charterparties agency problems of goal conflict were manifested through use of utmost despatch clauses and informational problems manifested through monitoring clauses. The use of the utmost despatch clause again would mostly impact the level of implementation of speed reduction measures. There were other clauses that were examples of goal conflict such as those for drydocking and hull cleaning, but due to resource constraints and for comparison, only the clauses affecting speed reduction were analysed in detail.

For operational measures in time charterparties the incentives of the principal and agent would be aligned to some extent, as discussed in research question three. The use of utmost despatch clauses in voyage charters was used as an example of goal conflict between principal and agent in the voyage contract. However, the results of the charterparty content analysis show that almost all time charterparties also had utmost despatch clauses. Possible reasons for this conflicting interest could be due to other stakeholders, such as engine manufacturers guarantees, final bill of ladings holders and sublet charterers. Despite these conflicts, it was concluded that the time charter presented more opportunities for speed reduction because of the charterer responsibility not only for fuel costs but also other sub charters or contracts. Connecting this analysis with earlier findings from research question three and research question one, which suggested that the respondents with the majority of their ships on time charter have higher implementation of operational measures and that operational measures in time charters would represent case one, i.e. no conflict of interest, suggests that this is a valid conclusion at least for some operational measures (such as speed reduction). This statement would have benefited from the findings of research question four but no apparent differences in calculated operational energy efficiency between the types of charter were observed.

Behaviour based contracts (i.e. time charterparties) require good information for selecting and monitoring the agent behaviour. It was found that in most standard time charterparties the major source of monitoring information (and the one that gets legal precedence) is the agent itself and only in a couple of charterparties use of independent information is used. Survey results show otherwise, i.e. implementation of weather routing services is higher for vessels chartered out mainly on time than on voyage charter. The opposing results from the methods are perhaps suggesting that in practice things are rather different to the results of the standard form charterparty content analysis, which does not reflect actual clauses used in a contract (probably due to amendments such as charterers rider clauses, deletion of some clauses etc.).It can be concluded from the above that the goal conflict agency problem is present in both voyage and time charterparties but more pervasive in voyage charters than in time charter, therefore the implementation of speed reduction is affected more in the voyage charter than in time charter. The need for information for monitoring the agent in the time charter could be said to result in higher implementation of weather routing measures in time charters. Agency problems can be said to be negatively related to the implementation of speed reduction measures and positively related to the implementation of the weather routing measure. The hypothesis that agency problems affect the implementation of energy efficiency operational measures can therefore be accepted for the aforementioned two measures.

9.3. Concluding remarks

Improved energy efficiency has a key role as one of the strategies to address the challenges of climate change. For policy makers the focus on energy efficiency is expected given that many energy efficiency improvements have been shown to be cost-effective and can be made using existing technologies and practices across many sectors as evidenced by the cross sector empirical studies and MACC’s that are increasingly used to inform policy discussions. Knowing that there exists an energy efficiency gap is renewing the interest from key policy stakeholders on the barriers that may be inhibiting uptake of energy efficiency measures. This is particularly relevant to the shipping sector, where numerous studies have shown significant abatement potential at negative costs. To that end, the IMO at an international level, the EU commission and the UK government at the regional level have commissioned various studies on barriers to energy efficiency in shipping. The reasons for the interest in barriers to energy efficiency are twofold; it enables policy makers to develop policies which would overcome such barriers, since the existence of market failures is a prerequisite for market intervention and secondly barriers may directly be affecting another policy's effectiveness.

The aim of this research was to understand the energy efficiency gap in shipping by examining the level of implementation of energy efficient operational measures and the barriers that may be affecting implementation of such measures. The research aimed to investigate the barriers to energy efficient operations by combining the perception of barriers and the observed level of barriers to energy efficient operations using a mixed methods approach. Previous to this research there were no baselines on the level of implementation of energy efficient operational measures and relatively little research had used agency theory to examine the principal agent problems and other barriers to energy efficient operations in shipping.

9.3.1. Relevance of market barriers and failures

In the shipping industry in recent years, there has been considerable debate on whether there are barriers that are causing the sub-optimal levels of uptake of energy efficiency measures, which result in an energy efficiency gap. The evolution of the literature on barriers in other sectors, dating from the early 1980's to date has suggested that the energy efficiency gap exists and it can be explained by market failures and non-market failures. Empirical analysis based on a variety of methods on this subject has confirmed this hypothesis, to such an extent that this discussion is now being referred to as barriers theory.

This research uses one of the building blocks of the general barriers theory, the economic agency theory, to investigate the barriers to energy efficiency in an in-depth and testable manner. In the context of barriers to energy efficiency, market failures such as the split incentives, informational problems, etc. can be explained by the economic agency theory. Yet, the literature review showed that the theory has been relatively little used in the empirical examination of barriers to energy efficiency in general and in shipping, and only a few studies have applied the tenets of the theory to estimate the different patterns of energy end use.

Barriers to energy efficiency have been well discussed and matured in some sectors such as buildings (residential and commercial) and to some extent in the transport sector. The use of agency theory in the aforementioned sectors has only been applied to estimate how energy end use is affected by the agency problem of split incentives. Given the extensive evidence for an efficiency gap that is presented for other sectors of the economy, it is plausible that the energy efficiency gap exists for shipping. The review of barriers literature in shipping showed that to date there has been very limited methodologically rigorous analysis of the barriers which may be resulting in an energy efficiency gap in shipping. To that end this research used the agency theory to investigate the energy efficiency gap for the shipping sector.

9.3.2. Theoretical framework and method

The application of agency theory in explaining barriers to energy efficiency in other sectors has been investigated mainly for technical measures and using secondary data to estimate the impact of the principal agent problem. In shipping however, there exist many opportunities for firms to improve energy efficiency through operational measures that are cost-effective under current circumstances. The novelty of this research is not only that it applies the agency theory for operational measures but also uses three methods (primary and secondary) to collect data and triangulate between the findings of each of the methods. The survey method is used to understand and create a baseline for the level of implementation of operational measures and how the implementation varies among different cases of the principal agent problem, as well as understanding the perception of barriers. The survey results are compared with observations of the principal agent problem for which data is derived from content analysis of charterparties (carriage of goods contracts between principal and agent) and matching operational efficiency data with fixtures.

Agency theory is believed to be the most relevant theory to use in this research because it can be used to explain a large part of the economic barriers (Figure 1.5) especially that relating to market failures. There are also other economic theories that could be used to examine the barriers in shipping. For example, information economics could also be used to investigate market failures especially that relating to moral hazard and adverse selection. The transaction cost theory could be relevant for investigating market barriers (non-market failures) e.g. cost of capital and hidden costs. Behavioural economics theories (e.g. social capital, diffusions of innovations) could be used to investigate behavioural and social barriers. However, the aforementioned theories are focussed on a subset of barriers and although they may provide depth to the investigation, they may not provide a fuller picture as offered by agency theory on the diverse range of barriers. This is because the agency relationship is applicable in a variety of settings ranging from policy and organisational to an individual level, which makes the theory highly applicable to socio-economic settings. Moreover, agency theory is a solution oriented theory as it attempts to suggest the best contract that reduces agency problems. Because of the broad applicability, applying the theory to examine barriers to energy efficiency in the context of shipping would result in a better explanation of the rationale of the principals and agents in implementation of operational measures. With regards to its solution orientation, it enables focussed analysis of the existing contracts in shipping with a view to identify instances of agency problems that are found in the contracts, which are thought to be directly affecting implementation of energy efficient operational measures. The theory has been mainly applied in organisational research and majority of the research using a variety of empirical methods supports the theory, which makes it testable and empirically valid. Several attempts have been made to create even more testable propositions from the theory (e.g. Eisenhardt 1989; Sharma 1997; Wright et al. 2001; etc.) and some of these have been used in this research to evaluate shipping contracts.

As with any theory, agency theory has its proponents and critics. The chief criticism of the theory is that the theory is not capable of adequately portraying a real world situation. This is to some extent a valid criticism, as seen in chapter five, the one principal and one agent relationship is far from being representative of the shipping industry. Thus, every effort was made to reflect a variety of settings in shipping at a high level but at the micro level analysis always being at the singular level. This research also countered this criticism by using a mixed methods approach to test and validate the propositions made in chapter five. In conclusion, transferring the agency theory from its organisational research origins to new dimensions, in conjunction with the mixed methods used within this research can be deemed suitable for empirically investigating barriers to energy efficiency. This research also shows that combining the positivist type and principal agent type research yields a better understanding of the situation, as opposed to the existing dichotomy in research or application of agency theory.

9.3.3. Appropriateness of methods

Research into barriers to energy efficiency is difficult because they are intangible, though real, and because it is empirically challenging to find the true reason for lack of implementation. Several attempts have been made to empirically examine the phenomenon but only a few rigorous studies were identified. In light of this shortcoming, this research developed a unique approach of combining methods, in order to triangulate and overcome the shortcomings, validity and reliability of using only one method, for the diverse and multifaceted barriers to energy efficiency. The research attempts to identify the observed level of principal agent problems in shipping through two strands of research;

1) Secondary desk research, using a set principal agent methodology and actual ship operational data
2) Primary research through content analysis of shipping contracts (charterparties).

The findings of the observed level of the principal agent problems using the above research techniques are corroborated with primary research from a survey of shipping firms which attempts to gauge the perception of barriers to energy efficiency as well as to provide additional indication for the principal agent problems. The survey at a general level received enough responses to make broader generalisations about the sector, therefore had good external validity but when the population is stratified by size and sector, insufficient responses were achieved in each strata and therefore inferences to the population or specific groups cannot be made, especially in the bivariate elaboration analysis. The number of responses should be viewed in light of the industry specific context, where many similar studies have failed to reach such a high number of responses in methodologically rigorous manner as evidenced in chapter two. The survey method's internal validity relied on accurately measuring the principal agent concept. The chartering ratios of firms, which were then subsequently categorized and were suitable indicators used to measure the principal agent problem, as tested in the piloting stage (explained in section 4.1.5.2). For the content analysis method, the ethnographic technique proved valuable for creating the theory derived categories for the key agency propositions and operational measures. Despite the scarce literature on the application of content analysis method for contract analysis, the method guided by agency theory propositions led to insightful findings of the shipping contracts, which also explained some of the findings of the survey method.

9.3.4. Key findings

Following the literature based principal agent methodology, in the first instance it was concluded that the voyage charter could represent the principal agent usage problem i.e. end user is neither able to select the energy-using technology or make the energy efficiency investment nor pays the energy cost. The time charter could represent the principal agent efficiency problem i.e. end user cannot choose the energy using technology or make an energy efficiency investment, instead the agent selects the energy-using technology and makes the energy efficiency investment, but the end user pays for the energy use. Using fixtures data from Clarksons Shipping Information Network (SIN) and making assumptions on operational parameters e.g. average speed, average haul, based on literature e.g. Buhaug et al. (2009) and Stopford (2008), it was estimated that a large proportion of the wetbulk sector fleet and around 40% of the drybulk sector fleet were on voyage charters. A small proportion of the wetbulk sector fleet and 60% of the drybulk sector fleet was on time charter. The finding from this secondary data implies that for technical measures the drybulk sector fleet would be more prone to the efficiency principal agent problem compared to the wetbulk sector fleet, whereas the wetbulk sector fleet would be more prone to the principal agent usage problem. For operational measures, 60% of the drybulk sector fleet on time charter compared to the small proportion of the wetbulk sector fleet that was on time charter implies that the drybulk sector is less exposed to principal agent problems when implementing operational measures, because the entity that specifies the operation of the ship also pays for the fuel.

	Voyage charter	**Time charter**
Technical measures	*A) Case 4 usage problem* Wetbulk ≈90% of fleet affected Drybulk ≈40% of fleet affected	*B) Case 2 efficiency problem* Wetbulk ≈10% of fleet affected Drybulk ≈60% of fleet affected
Operational measures	*C) Case 4 usage problem* Wetbulk ≈90% or less of fleet affected Drybulk ≈40% of fleet affected	*D) Case 1 no PA problem* Wetbulk ≈10% Drybulk ≈60%

Table 9.2: Population that could be potentially affected by principal agent problems

The secondary analysis also attempted to investigate the differences in operational efficiency of ships on voyage charter versus ships on time charter. This analysis used estimates of operational data for ships (obtained from Smith et al. 2013 using Satellite Automated Identification System, S-AIS) and split the data between ships operating on voyage and time charters (fixtures data from Clarksons SIN). The number of ships on time charter along with their operational efficiency had a very small sample compared to voyage chartered ships, therefore any meaningful comparison of the operational efficiencies between the two was difficult, thus the full extent of observation of barriers has not been possible. It is hoped that over a longer period of data collection, statistical significance could be achieved.

The findings from the analysis above corroborated the survey results which showed that on average more operational measures were being implemented by firms in the drybulk sector than in the wetbulk sector. This was also the case when looking at each measure individually i.e. weather routing, fuel consumption monitoring and general speed reduction. For all the aforementioned measures the implementation of operational measures is also considerably lower by firms in the wetbulk sectors which have a majority of their fleet on voyage charter, supporting the above conclusion. This is also the case for general speed reduction, despite some wetbulk charterparties allowing for implementation as shown in the charterparty analysis, suggesting that the opportunity to implement speed reduction is not taken up. The reasons for the lack of take-up of this operational measure are explained in detail in section 6.4.4.1. This observation is also emphasised by the respondents' perceptions in those sectors, more drybulk sector respondents thought they could achieve speed reduction in the voyage charter than wetbulk sector respondents. However, in contrast, throughout the survey the split incentive indicators were perceived to be less important barriers by more wetbulk respondents under voyage charter than drybulk respondents. Therefore, for the measures and population investigated the observed level of principal agent problem can be said to be not completely matching with the perception of principal agent problems.

The final piece of the jigsaw to triangulate with was the charterparty content analysis. The principal agent usage problem (end user is neither able to select the energy-using technology or make the energy efficiency investment nor pays the energy cost) in the voyage charter is confirmed with the wide use of the utmost despatch clause in the voyage charter. For example most drybulk sector voyage charterparties were found to contain the utmost despatch clause, which could be due to the inability to negotiate speed and freight rate based on speed, thus the principal i.e. the charterer is neither able to implement the measure nor sees the direct costs/savings related to that measure. The voyage charterparties also contained several other clauses such as the notice of readiness (NOR) time and place clauses, linked to agency theory propositions of risk and outcome certainty, which were thought to affect the implementation of speed reduction measures.

It was clear from the survey results that market failures were perceived to be more important barriers to operational energy efficiency measures compared to non-market failures. Although non-market failures could be more impeding for technical measures, but this is beyond the scope of this research. Based on the above analysis, (informed by the chartering ratio, on perception and charterparty analysis) the principal agent problem in shipping sector is a plausible explanation for some of the energy efficiency gap in implementation of operational measures in the charter market. The full extent of the principal agent problem in shipping could not be verified because of the limitations of the operational data estimates but this research has shown that the problem exists in operations, is significant and it affects the wetbulk sector fleet more than the drybulk sector fleet in the charter market. Other plausible reasons for the lack of implementation of operational measures could be attributed to non-market failures (market barriers) such as lack of finance, this seems to be an industry wide perception even though most of the operational measures would require relatively lower capital investment compared to technical measures. In the present market shipowner-operators may be finding it difficult to make investments off the balance sheet and traditional forms of finance such as bank loans are difficult to obtain. Although the survey indicated that lack of finance may not be a barrier for operational measures, it is possible that access to finance may be an issue, but to what extent it affects each of the sectors and size of the firms, is yet to be investigated. Another plausible explanation for the lack of uptake of measures could be a combination of organisational barriers such as culture combined with another non-market failure, risk. The shipping industry has been described as a more risk averse industry compared to other transport industries, where the investment in energy efficiency is determined by the trade-off between higher operational costs of an inefficient ship versus higher risk premiums by investors for an efficient ship, and given the culture and norms of the majority of the industry the most fuel efficient may not always be the best outcome.

9.3.5. Recommendations

This research mainly explored the issue of split responsibility for capital and operational costs between entities in the shipping industry. Key recommendations from this research can be divided into three; recommendations to academia, industry and policy.

Key recommendations to academic researchers researching the subject of barriers to energy efficiency in shipping and other sectors are:

- In order to investigate barriers to energy efficiency, it is suggested that a suitable existing and testable theory is used. This has the benefit that it provides the emerging barriers research credibility and firmly grounds it on a specific discipline e.g. economic, psychological. This necessitates focus and depth to cover some of the barriers in detail rather than attempting to discuss the breadth of all the barriers to energy efficiency.
- The subject of barriers to energy efficiency is relatively new but complex and therefore requires more than one method for the research to be valid. This research showed that the use of mixed methods i.e. combining quantitative and qualitative, as well as methodological and data triangulation yields a better insight on the subject of barriers to energy efficiency. However, the mixing of methods requires careful consideration in terms of research design and its connection with the use of the underlying theory.
- Literature on barriers to energy efficiency has predominantly focussed on measuring perceptions of barriers to energy efficiency in different sectors. This research has shown that it is equally important to compare the perceptions with the observations of barriers to energy efficiency. This can be done through the framework that has been developed in this research which provides a step by step approach to combining the barriers investigation with different methods and theories to compare perceived and observed barriers to energy efficiency, which can be applied to newer contexts such as other transport sectors e.g. aviation.
- This research used a mixed methods strategy and one specific theory to investigate the barriers to energy efficiency. The challenge was to translate the organisational research based agency theory to investigate energy efficiency in operations, thus expanding the theory to richer contexts in accordance with Eisenhardt (1989) recommendations. Typically agency theory

empirical research, even when based on organisational research, has used mono-methods, so one could say that the deployment of mixed methods in the order used in this research has helped to deepen the positivist type agency theory research. As an example, the broader or higher level contractual dichotomy was enough in devising the survey but the agency theory propositions stemming from principal agent type research were required in constructing the categories of the content analysis method. This suggests that for exploring new applications or contexts of agency theory and its offerings, it is helpful to use both positivist and principal agent type research and combine these with a variety of research methods.

This research investigated barriers to energy efficient operations through methods which made the research well connected to the shipping industry and as such the problems faced in the industry were better understood. Table 5.15 briefly described key problems that were observed in the shipping industry and which were mainly affecting implementation of operational measures. The recommendations for the industry to overcome some of the problems that are relevant to this research are:

- Both voyage and time charterparties need to be reviewed from an energy saving point of view and be able to align the incentives of the shipowners and charterers for implementing operational measures. The Virtual Arrival clause is just one example of how incentives for implementing weather routing and speed reduction measures have been aligned for the shipowner and charterer. There is potential to improve the operational efficiency by redrafting the clauses that tackle the split incentives in the maintenance of ships which directly affect operational efficiency, for example hull cleaning routines, hull coatings, propeller polishing, dry-docking etc.
- Information systems for verification are pivotal, especially to time charter contracts. Currently the majority of shipping companies rely on manual data transfer between ship and shore. Investment by shipping companies into more reliable forms of data capture related to fuel consumption can provide better transparency of the vessels overall fuel consumption as well as to ascertain the impact of individual measures on fuel consumption. Equipped with this information the shipping company can be in a better position to negotiate and possibly obtain a higher premium on the time charter rates and make a return on energy efficiency investment.
- Innovative financing models that require zero capital expenditure from the shipowner and charterer are needed to overcome split incentives that arise as result of contractual arrangements and duration which affect the implementation of some operational energy efficiency measures requiring larger initial outlay. The need for this innovative thinking would become more clear as implementation moves from well-known operational measures or 'low

hanging fruits' to more technical retrofit measures to improve energy efficiency and measures requiring greater collaboration between the stakeholders.

Understanding of barriers to energy efficiency can help policy in either addressing the barrier directly or overcoming the barrier to improve the effectiveness of other policies. Recommendations for policy to address the split responsibility and operational efficiency are:

- The principal agent problem in operations has largely been overlooked by regulators. The EEDI as a minimum efficiency standard attempts to improve technical efficiency of ships at the design stage and to some extent reduce the principal agent problem that exists at design. The ship energy efficiency management plan (SEEMP) as a mandatory requirement may prompt the shipowners and charterers to think about energy efficiency in operations but because it does not mandate the implementation of operational measures, ships in-use efficiency and emissions remain uncontrolled and have been shown in this research to be susceptible to principal agent problems. A possible instrument through which both design and operational efficiency can be improved is through market based measures but careful consideration needs to be given to the correct level of incentivisation of the right stakeholders to be effective given the industry's contractual and institutional modus operandi.
- One of the key corrective policies for market failures such as the principal agent problems, is to improve access to information on energy efficiency. Various sectors make use of the minimum efficiency standards to drive energy efficiency and also make the information publically available, for end users to factor into their purchasing decisions (e.g. A-G ratings on fridges, fuel consumption on cars). In shipping, not only is this a problem for technical efficiency, due to lack of publically available verified EEDI scores for example, but for operational efficiency there exists no platform over which ship's operational efficiency can be benchmarked or compared. In the private domain, if a shipowner is better able to portray the energy efficiency of a ship, then there is a greater chance that energy efficiency is rewarded through higher charter rates. Similarly, if the charterer understands the operational energy efficiency of the ship that is on a voyage charter, then there can be better negotiation on implementation of operational measures such as speed reduction, which could consequently affect the freight rate. If operational efficiency is rewarded than it could spur investment into the various operational measures available, this would be possible if information on the savings achieved from various interventions was verified and transparent, possibly from classification societies and government demonstrations, making the information more accessible and reliable.

9.3.6. Future work

The survey that has been conducted to understand the level of implementation and behaviour around operational measures could be extended to include technical measures (newbuilds and retrofits measures) to understand the full extent of the principal agent problem in shipping. Examples of these would be an investigation of maintenance related measures e.g. hull cleaning, propeller polishing, hull coatings etc, which are also believed to be affected by principal agent problems.

The findings from the survey show that the size of the firm is also an important factor to understand when investigating the implementation of measures. Agency theory does not focus on this and therefore it could be examined further using other theories such as organisational theory and theory on diffusion of innovations. Moreover, the survey did not include very small firms with less than five ships, numbering around 6000, due to the time and resources required to construct a reliable and accurate sampling frame. Thus future research could focus on this group which may have a different level of implementation and perception of barriers to energy efficiency. The data obtained through the online questionnaire method contains rich descriptions from respondents on why certain measures are being implemented and explanations of driving forces as well as why certain measures are not being implemented. This data could be further analysed using different methods e.g. content analysis.

Two important questions from this research could have been better answered with the use of more data that would result in improved statistical significance. The comparative analysis of operational efficiency of ships on the different time charters could be extended to cover a longer period, which would result in more ships on time charter. Secondly, the response rates of the survey could be improved for each stratum within the sampling frame, in order to allow for further layers of test variables to be introduced in the bivariate analysis without affecting the statistical significance of the relationships.

The shipping sector is increasingly finding itself in the midst of a plethora of global and regional environmental regulations, ranging from regional MRV to global GHG levy and from global SOx and NOx limits to ballast water regulations. It is clear from this that it is only set to intensify in the future and therefore the fundamental question of which stakeholders to incentivise and target with such policies remains pivotal to the discussion. This research has shown the importance of understanding the incentives of two key shipping stakeholders in the context of energy efficiency, which can affect shipping's transition towards a more resilient, low carbon and sustainable industry.

10. References

Agnolucci, P, Smith, T & Rehmatulla, N 2014, 'Energy efficiency and time charter rates: Energy efficiency savings recovered by ship owners in the Panamax market', *Transportation Research Part A: Policy and Practice*, vol 66, pp. 173-184.

Ahimud, Y & Lev, B 1981, 'Risk reduction as a managerial motive for conglomerate mergers', *Bell Journal of Economics*, vol 12, pp. 605-616.

Altheide, D 1987, 'Ethnographic content analysis', *Qualitative sociology*, vol 10, no. 1, pp. 65-77.

Altheide, D 1996, *Qualitative media analysis*, Sage, Thousand Oaks, California.

Alvarez, F, Longva, T & Engebrethsen, E 2010, 'A methodology to assess vessel berthing and speed optimization policies', *Maritime Economics & Logistics*, vol 12, pp. 327-346.

Antle, R & Eppen, G 1985, 'Capital rationing and organizational slack in capital budgeting', *Management Science*, vol 31, no. 2, pp. 163-174.

Archer, T 2007, 'Charecteristics associated with increasing the response rates of web based surveys', *Practical Assessment Research & Evaluation*, vol 12, no. 12, p. Online.

Archer, T 2008, 'Response rates to expect from web-based surveys and what to do about it', *Journal of Extension*, vol 46, no. 3, p. Online.

Argawal, A & Mandelker, G 1987, 'Managerial incentives and corporate investment and financing decisions', *Journal of Finance*, vol 42, pp. 823-837.

Arrow, K 1971, *Essays in the theory of risk bearing*, Markham, Chicago.

Aubert, B, Patry, M & Rivard, S 2003, *A tale of two outsourcing contracts: An agency theoratical perspective*, viewed 16 January 2012, <http://www.is-frankfurt.de/uploads/down324.pdf>.

Babbie, E 2004, *The Practice of Social Research*, 10th edn, Wadsworth Publishing Co Inc, California.

Baker, G, Jensen, M & Murphy, K 1988, 'Compensation and incentives: Practice vs. theory', *The Journal of Finance*, vol 43, no. 3, pp. 593-616.

Bannock, G, Baxter, R & Davis, E 1992, *The penguin dictionary of economics*, Penguin Books, London.

Barrington, L 2012, 'Fragile snapshot or stable relationships? What the Orange and Rose revolutions reveal about the stability of cross-sectional survey data', *Comparative Political Studies*, vol 45, no. 3, pp. 312-340.

Bazely, P 2002, 'Issues in mixing qualitative and quantitative approaches to research', in R Buber, J Gardner, L Richard (eds.), *1st internation conference - Qualitative research in marketing and management*, University of Economics and Business Administration, Vienna.

Berchling, V & Smith, S 1994, 'Household energy efficiency in the UK', *Fiscal Studies*, vol 15, no. 2, pp. 44-56.

Berelson, B 1952, *Content analysis in communication research*, The Free Press, New York.

Berg, B 2001, *Qualitative Research Methods for the Social Sciences*, Allyn and Bacon, Boston.

Bergantino, A & Veenstra, A 2002, *Principal agent problems in shipping: An investigation into the formation of charter contracts*, viewed 20 January 2011, <http://www.eclac.cl/transporte/perfil/iame_papers/proceedings/Bergantino_et_al_A.doc.>.

Berson, I & Berson, M 2005, 'Challenging Online Behaviors of Youth: Findings from a comparative analysis of young people in the United States and New Zealand', *Social Science Computer review*, vol 23, pp. 29-38.

Best, S & Krueger, B 2008, 'Internet survey design', in N Fielding, R Lee, G Blank (eds.), *The SAGE Handbook of online research methods*, Sage, London.

Bhattacharyya, S 2011, *Energy Economics*, Springer, London.

BIMCO 1989, 'Standard bareboat charter "Barecon 89"', The Baltic and International Maritime Council, Copenhagen.

BIMCO 2011, *BIMCO slow steaming clause for time charterparties*, viewed 23 December 2011, <https://www.bimco.org/en/chartering/clauses/slow_steaming_clause.aspx>.

Birnholtz, J, Horn, D, Finholt, T & Bae, S 2004, 'The effects of cash, electronic and paper gift certificates as respondent incentives for a web based survey of technologically sophisticated respondents', *Social Science Computer Review*, vol 22, pp. 355-362.

Blumstein, C, Krieg, B, Schipper, L & York, C 1980, 'Overcoming social and institutional barriers to energy conservation', *Energy*, vol 5, pp. 355 – 371.

Brannen, J 2005, *Mixed methods research: A discussion paper*, viewed 05 June 2011, <http://eprints.ncrm.ac.uk/89/>.

Breaux, D, Christopher, M, Duncan, C, Keller, D & Morris, J 2002, 'Welfare reform, mississippi style: temporary assistance for needy families and the search for accountability', *Public Administration Review*, vol 62, no. 1, pp. 92-103.

Brennan, M 1992, 'The effect of monetary incentive on mail response rates - new data', *Public Opinion Quarterly*, vol 57, pp. 62-79.

Brown, M 2001, 'Market failures and barriers as a basis for clean energy policies', *Energy Policy*, vol 29, pp. 1197-1207.

Bryman, A 2006, 'Integrating quantitative and qualitative research: how is it done?', *Qualitative research*, vol 6, no. 1, pp. 97-113.

Bryman, A 2008, *Social research methods*, Oxford University Press, Oxford.

Bryman, A & Cramer, D 1994, *Quantitative data analysis for social scientists*, Routledge Publications, London.

Buhaug, Ø, Eyring, V, Corbett, J, Endresen, Ø, Faber, J, Hanayama, S, Lee, S, Lee, D, Lindstad, H, Markowska, A, Mjelde, A, Nelissen, D, Nilsen, J, Pålsson, C, Wanquing, W, Winebrake, J & Yoshida, K 2009, *Second IMO GHG study - Update of the 2000 IMO GHG study*, IMO, London, viewed 06 November 2012, <http://www.imo.org/blast/blastDataHelper.asp?data_id=27795&filename=GHGStudyFINAL.pdf>.

Carbon Trust 2005, *The UK Climate change program: Potential evolution for business and public sector*, viewed 25 November 2012, <http://www.carbontrust.com/resources/reports/advice/uk-climate-change-programme-potential-evolution>.

Cavanagh, A 1999, *Behaviour in public ethics online ethnography*, viewed 12 September 2011, <www.socio.demon.co.uk/magazine/6/cavanagh.html>.

CCC 2011, *Review of UK Shipping Emissions – Supporting Analysis, ,* Committee on Climate Change, viewed 03 July 2013, <http://www.theccc.org.uk/publication/review-of-uk-shipping-emissions/>.

Chai, K & Yeo, C 2012, 'Overcoming energy efficiency barriers through systems approach - A conceptual framework', *Energy Policy*, p. First online.

Chong, D 1993, 'Reasonable despatch in voyage charterparties', *Singapore Journal of Legal Studies*, pp. 401-430.

Chowdhury, N & Dinwoodie, J 2011, 'The potential impact of a levy on bunker fuels on dry bulk spot freight rates', *Low Carbon Shipping conference*, 22 - 24 June 2011, Glasgow.

Church, A 1993, 'Estimating the effects of incentives on mail response rates: a meta analysis', *Public Opinion Quarterly*, vol 57, pp. 62-79.

Coase, R 1937, 'The nature of the firm', *Economica*, vol 4, no. 16, pp. 386-405.

Cobanoglu, C & Cobanoglu, N 2003, 'The effect of incentives in Web surveys: Application and ethical considerations', *International Journal of Market Research*, vol 45, no. 4, pp. 1-14.

Cobanoglu, C, Warde, B & Moreo, P 2000, 'A comparison of mail, fax and web-based survey methods', *International Journal of Market Research*, vol 43, no. 4, pp. 441-452.

Cohen, J 1988, *Statistical Power Analysis for the Behavioural Sciences*, Lawrence Erlbaum Associates, New Jersey.

Collis, J & Hussey, R 2003, *Business Research: a practical guide*, Palgrave Macmillan, Basingstoke.

Cook, C, Heath, F & Thompson, R 2000, 'A meta-analysis of response rates in web or internet based surveys', *Educational and Psychological Measurement*, vol 60, no. 6, pp. 821-836.

Corbetta, P 2003, *Social Research Theory, Methods and Techniques*, Sage Publications, London.

Cotter, J & Zenner, M 1994, 'How managerial wealth affects the tender offer process', *Journal of Financial Economics*, vol 35, no. 1, pp. 63-97.

Couper, M 2000, 'Web surveys: A review of issues and approaches', *Public Opinion Quarterly*, vol 64, no. 4, pp. 464-494.

Couper, M, Traugott, M & Lamias, M 2001, 'Web survey design and administration', *Public Opinion Quarterly*, vol 65, pp. 230-254.

Crawford, S, Couper, M & Lamias, M 2001, 'Web surveys: Perception of burden', *Social Science Computer Review*, vol 9, no. 2, pp. 146-162.

Creswel, J 2009, *Research design: qualitative, quantitative and mixed method approaches.* , 3rd edn, Sage Publications.

Creswell, J 2002, *Research design: qualitative, quantitative and mixed method approaches.*, 2nd edn, Thousand oaks, California.

Creswell, J & Plano Clark, V 2007, *Designing and conducting mixed methods research.*, Sage, London.

Crocker, K & Reynolds, K 1993, 'The efficiency of incomplete contracts: An empirical analysis of air force engine procurement', *Rand Journal of Economics*, vol 24, pp. 124-146.

CSC & WWF 2011, 'The IMO, global MBMs that reduce emissions and the question of Principles', IMO, 3rd Greenhouse Gas –Working Group Interssessional meeting.

Curran, J & Blackburn, R 2001, *Researching the small enterprise*, SAGE Publications Ltd, London.

Davis, J 1985, *The logic of causal order*, Sage Publications, Virginia.

Davis, L 2009, *Evaluating the Slow Adoption of Energy Efficient Investments: Are renters less likely to have energy efficient appliances*, viewed 16 November 2012, <http://www.nber.org/papers/w16114>.

de Groot, H, Verhoef, E & Nijkamp, P 2001, 'Energy-saving by firms: decision-making, barriers and policies', *Energy Economics*, vol 23, pp. 717-739.

de Vaus, D 1995, *Surveys in social research*, Allen & Unwin, North Sydney.

de Vaus, D 2001, *Research design in social research*, Sage, London.

Decanio, S 1993, 'Barriers within firms to energy efficiency investments', *Energy Policy*, vol 21, no. 9, pp. 906-914.

Devanney, J 2011a, *The impact of charterparty speeds on CO2 emissions*, viewed 24 April 2011, <www.c4tx.org/ctx/pub/>.

Devanney, J 2011b, *Are owners and charterers really that stupid?*, viewed 09 July 2011, <http://www.c4tx.org/ctx/pub/>.

Diener, E & Crandall, R 1978, *Ethics in Social and Behavioral Research*, University of Chicago Press, Chicago.

Dillman, D 2000, *Mail and internet surveys: The Tailored Design Method*, 2nd edn, Wiley, New York.

Dillman, D 2007, *Mail and Internet Surveys: The tailored design method update with new Internet, visual, and mixed-mode guide*, 2nd edn, John Wiley & Sons, New York.

Dillman, D 2009, *Internet, mail and mixed mode surveys The Tailored Design Method*, 3rd edn, John Wiley & Sons, New Jersey.

Dillman, D, Tortora, R, Conradt, J & Bowker, D 1998, *Influence of plain cs. fancy design on response rates for web surveys*, viewed 25 October 2011, <http://www.websm.org/db/12/1862/Bibliography/Influence_of_Plain_Vs_Fancy_Design_on_Response_Rates_for_Web_Surveys/?menu=1&lst=&q=dillman1998&qdb=12&qsort=0>.

DNV 2009, *Pathways to low carbon shipping, abatement potential towards 2030*, Det Norske Veritas , viewed 14 January 2010, <http://www.dnv.com/binaries/pathways%20to%20low%20carbon%20shipping%202030_tcm4-400655.pdf>.

DNV 2010, 'Fuel saving guidelines for tankers, drybulkers and containerships', Reports (printed) presented at breakfast seminar on 20th March 2012, Det Norske Veritas, London.

DNV 2012, *Shipping 2020*, viewed 22 November 2012, <http://www.dnv.nl/binaries/shipping%202020%20-%20final%20report_tcm141-530559.pdf>.

Easterby-Smith, M, Thorpe, R & Lowe, A 1991, *Management research: An introduction* , Sage Publications Ltd, London.

Eccles, R 1985, 'Transfer pricing as a problem of agency', in J Pratt, R Zechhauser (eds.), *Principals and agents: The structure of business*, Harvard Business School Press, Boston.

Eide, M, Enderson, Ø, Skjong, R & Longva, T 2009, 'Cost-effectiveness assessment of CO2 reducing measures in shipping', *Maritime Policy and Management*, vol 36, no. 4, pp. 367-384.

Eisenhardt, K 1985, 'Control: Organisational and economic approaches', *Management Science*, vol 31, no. 2, pp. 134-149.

Eisenhardt, K 1988, 'Agency- and Institutional-Theory Explanations: The Case of Retail Sales Compensation', *The Academy of Journal Management*, vol 31, no. 3, pp. 488-511.

Eisenhardt, K 1989, 'Agency theory: An assessment and review', *Academy of Management Review*, vol 14, no. 1, pp. 57-74.

Ellis, P 2010, *The Essential Guide to Effect Sizes*, 1st edn, Cambridge University Press, Cambridge.

Elo, S & Kyngas, H 2008, 'The qualitative content analysis process', *Journal of Advanced Nursing*, vol 62, no. 1, pp. 107-115.

ESRC NCRM 2013, *Exploring online research methods website*, viewed 10 March 2011, <http://www.restore.ac.uk/orm/>.

Ess, C and AOIR Ethics Working Committee 2002, *Ethical decision making and internet research*, viewed 13 September 2011, <http://aoir.org/documents/ethics-guide/>.

Eurostat 2008, *Survey sampling reference guidelines: Introduction to sample design and estimation techniques*, viewed 25 July 2011, <http://epp.eurostat.ec.europa.eu/portal/page/portal/product_details/publication?p_product_code=KS-RA-08-003>.

Eynon, R, Fry, J & Schroeder, R 2008, 'The ethics of internet research', in N Fielding, R Lee, G Blank (eds.), *The SAGE handbook of online research methods*, Sage, London.

Faber, J, Behrends, ,B, Lee, D, Nelissen, D & Smit, M 2012, *The fuel efficiency of maritime transport: Potential for improvement and analysis of barriers*, viewed 06 April 2013, <http://www.cedelft.eu/ce/aviation_and_ocean_shipping/281>.

Faber, J, Behrends, B, Lee, D, Nelissen, D & Smit, M 2012, *The fuel efficiency of maritime transport: Potential for improvement and analysis of barriers*, viewed 12 August 2012, <http://www.cedelft.eu/publicatie/the_fuel_efficiency_of_maritime_transport>.

Faber, J, Behrends, B & Nelissen, D 2011, *Analysis of marginal abatement cost curves*, viewed 05 December 2011, <http://www.cedelft.eu/publicatie/analysis_of_ghg_marginal_abatement_cost_curves/1155?PHPSESSID=9ec0891a1418473f9020106cba2e3441>.

Faber, J, Markowska, A, Eyring, V, Cionni, I & Selstad, E 2010, *A Global Maritime Emissions Trading System: Design and impacts on the shipping sector, countries and regions*, CE Delft, viewed 14 February 2010, <http://www.ce.nl/publicatie/a_global_maritime_emissions_trading_system/1024>.

Faber, J, Markowska, A, Nelissen, D, Davidson, M, Eyring, V, Cionni, I, Selstad, E, Kågeson, P, Lee, D, Buhaug, Ø & Lindtsad, H 2009, *Technical support for European action to reducing Greenhouse Gas Emissions from international maritime transport*, CE Delft, viewed 19 January 2010, <http://ec.europa.eu/clima/policies/transport/shipping/docs/ghg_ships_report_en.pdf>.

Fama, E & French, K 2004, 'The Capital Asset Pricing Model: Theory and evidence', *Journal of Economic Perspectives*, vol 18, no. 3, pp. 25-46.

Fama, E & Jensen, M 1983, 'Separation of ownership and control', *Journal of Law and Economics*, vol 26, pp. 301-325.

Fan, W & Yan, Z 2010, 'Factors affecting response rates of the web survey: A systematic review', *Computers in Human Behavior*, vol 26, pp. 132-139.

FFF 2011, *Sustainable Shipping Initiative - The case for action*, Forum For The Future, viewed 02 June 2011, <http://ssi2040.org/wp-content/uploads/2012/11/SSI_fullreport.pdf>.

Field, A 2005, *Effect Sizes*, viewed 02 February 2012, <www.statisticshell.com/docs/effectsizes.pdf>.

Field, A 2009, *Discovering statistics using SPSS*, 2nd edn, Sage, London.

Fielding, N, Lee, R, Blank, G (eds.) 2008, *The Sage handbook of online research methods*, Sage Publications, London.

Fisher, A & Rothkopf, M 1989, 'Market failure and energy policy', *Energy Policy*, vol 17, no. 4, pp. 397-406.

Forman, J & Damschroder, L 2007, 'Qualitative content analysis', in L Jacoby, L Siminoff (eds.), *Empirical methods for bioethics: A primer (Advances in Bioethics, Volume 11)*, Emerald Group Publishing Limited.

Forrest, J & Schleyer, T 2000, 'Methods for the design and administration of web-based surveys', *Journal of the American Medical Informatics Association*, vol 7, pp. 416-425.

Fricker, R 2008, 'Sampling methods for web and e-mail surveys', in N Fielding, R Lee, G Blank (eds.), *The Sage handbook of online research methods*, Sage Publications Ltd, London.

Fricker, R & Schonlau, M 2002, 'Advantages and disadvantages of internet research surveys: Evidence from the literature', *Field Methods*, vol 14, no. 4, pp. 347-367.

GAO 1989, *Content analysis: A methodology for structuring and analyzing written material*, viewed 10 March 2012, <http://archive.gao.gov/d48t13/138426.pdf>.

GAO 1996, *Content analysis: A methodology for structuring and analyzing written material*, viewed 10 March 2012, <http://www.gao.gov/assets/80/76281.pdf>.

Gerring, J 2007, *Case study research: Principles and practices,* Cambridge University Press, New York.

Gilbert, P, Bows, A & Starkey, R 2010, *Shipping and climate change: Scope for unilateral action*, viewed 03 September 2010, <http://www.tyndall.ac.uk/sites/default/files/Shipping_and_climate_change_0.pdf>.

Gillingham, K, Harding, M & Rapson, D 2011, *Split Incentives in Residential Energy Consumption*, viewed 10 November 2012, <http://www.stanford.edu/~mch/resources/Harding_SplitIncentives.pdf>.

Gillingham, K, Newell, R & Palmer, K 2009, *Energy efficiency economics and policy*, viewed 22 September 2011, <http://www.nber.org/papers/w15031>.

Gillissen, M & Opschoor, H 1994, 'Energy conservation and Investment Behaviour: An Empircal analysis of influential factors and attitudes', *Paper presented at 34th Annual meeting of Regional Science Association on August 22 – 24*, Groningen, Netherlands.

Girvin, S 2007, *Carriage of goods by sea*, 1st edn, Oxford University Press, Oxford.

Gold, R 1958, 'Roles in sociological fieldwork', *Social Forces*, vol 36, pp. 217-223.

Golove, W & Eto, J 1996, *Market barriers to energy efficiency: a critical reappraisal of the rationale for public policies to promote energy efficiency*, Lawrence Berkeley National Laboratory, University of California, Berkeley, viewed 12 October 2011, <http://emp.lbl.gov/sites/all/files/lbnl-38059.pdf>.

Gordon, S 2008, 'Steering towards change: Overcoming barriers to energy efficiency in merchant ships (unpublished MSc dissertation)', Environmental Change Institute, University of Oxford, UK, Oxford.

Goritz, A 2006, 'Incentives in web studies: Methodological issues and a review', *International Journal of Internet Science*, vol 1, no. 1, pp. 58-70.

Gouldner, A 1960, 'The norm of reciprocity: A preliminary statement', *American sociological review*, vol 25, pp. 161-178.

Graus, W & Worrel, E 2008, 'The principal–agent problem and transport energy use: case study of company lease cars in the Netherlands', *Energy Policy*, vol 36, pp. 3745–3753.

Gray, D 2004, *Doing Research in the Real World*, Sage Publications, London.

Greene, J, Caracelli, V & Graham, W 1989, 'Toward a conceptual framework for mixed method evaluation designs', *Educational and Evaluation and Policy Analysis*, vol 11, pp. 255-274.

Greenlaw, C & Brown-Welty, S 2009, 'A comparison of web-based and paper-based survey methods testing assumptions of survey mode and response cost', *Evaluation Review*, vol 33, no. 5, pp. 464-480.

Groves, R 1989, *Survey errors and survey costs*, Wiley, New York.

Groves, R, Fowler, F, Lepkowski, J, Singer, E & Tourangeau, R 2004, *Survey methodology*, John Wiley & Sons, New York.

Gunningham, N, Grabosky, P & Sinclair, D 1998, *Smart Regulation: Designing environmental policy*, Oxford University Press.

Hadre, P, Crowson, M & Xie, K 2012, 'Examining contexts of use for web-based and paper-based questionnaires', *Educational and Psychological Measurement*, vol 72, no. 6, pp. 1015-1038.

Harris, J 2000, 'Investment in energy efficiency: a survey of Australian firms', *Energy Policy*, vol 28, no. 12, pp. 867–876.

Hasanbeigi, A, Menke, C & du Pont, P 2009, 'Barriers to energy efficiency improvement and decision-making behaviour in Thai industry', *Energy Efficiency*, vol online first.

Healey, B, Macpherson, T & Kuijten, B 2005, *An empirical evaluation of three web survey design principles*, viewed 10 November 2011, <http://www.websm.org/uploadi/editor/16872139.pdf>.

Heisman, E & Tomkins, C 2011, *Shipping full report*, viewed 16 January 2012, <http://www.carbonwarroom.com/sites/default/files/reports/Carbon%20War%20Room-%20Shipping%20Report_1.pdf>.

Hertel, B 1976, 'Minimizing error variance introduced by missing data routines in survey analysis', *Sociological Methods Research*, vol 4, no. 4, pp. 459-474.

Hill, J 2010, 'Unlocking the potential for CO2 abatement in ships arriving and departing from UK ports (unpublished MSc dissertation)', Imperial College, London, UK.

Hirsch, P & Friedman, R 1986, 'Collaboration or paradigm shift? Economic vs. behavioural thinking about policy?', *Best papers proceedings*, Academy of Management, Chicago.

Hirst, E & Brown, M 1990, 'Closing the efficiency gap: barriers to the efficient use of energy', *Resources, Conservation and Recycling*, vol 3, no. 4, pp. 267-281.

Hobson, M, Pell, E, Surgand, M, Kollamthodi, S, Moloney, S, Mesbahi, E, Wright, P, Basurko, O & Pazouki, K 2007, *Low carbon commercial shipping*, AEA Energy & Environment, viewed 30 January 2010, <http://webarchive.nationalarchives.gov.uk/20080915105707/http://www.dft.gov.uk/pgr/scienceresearch/technology/lctis/reportaeanewcastleunipdf>.

Howarth, R & Andersson, B 1993, 'Market Barriers to Energy Efficiency', *Energy Economics*, vol 15, no. 4, pp. 262-272.

Howarth, R, Haddad, B & Paton, B 2000, 'The economics of energy efficiency: insights from voluntary participation programs', *Energy Policy*, vol 28, pp. 477-486.

Howarth, R & Winslow, M 1994, 'Energy use and CO2 emission reduction: integrating pricing and regulatory policies', *Energy*, vol 19, no. 8, pp. 855-867.

Hseih, H & Shannon, S 2005, 'Three approaches to qualitative content analysis', *Qualitative Health Research*, vol 15, no. 9, pp. 1277-1288.

Hussey, J & Hussey, R 1997, *Business research: a practical guide for undergraduate and postgraduate students*, McMillan press, London.

IEA 2007, *Mind the Gap: Quantifying Principal-Agent Problems in Energy Efficiency*, viewed 15th October 2011, <http://www.iea.org/publications/freepublications/publication/mind_the_gap.pdf>.

IMO 2009, *Guidance for the development of a ship energy efficiency management plan (SEEMP)*, International Maritime Organisation, viewed 23 August 2009, <http://www.imo.org/blast/blastDataHelper.asp?data_id=26530&filename=683.pdf>, Marine Environment Protection Committee, Circular 683.

IMO 2010a, 'Full report of the work undertaken by the Expert Group on Feasibility Study and Impact Assessment of possible Market-based Measures', Marine Environment Protection Committee, 61st Session, inf.2.

IMO 2010b, 'A further outline of a Global Emission Trading System (ETS) for International Shipping ', Submitted by Norway to Marine Environment Protection Committee, 61st Session, document no 22.

IMO 2010c, *Reduction of GHG emissions from ships- Information to facilitate discussion on GHG emissions from ships (Note by the secreteriat)*, London, viewed 25 July 2010, <http://www.rina.org.uk/article855.html>.

INTERTANKO 2012, *Optimal speed calculations*, viewed 28 August 2012, <https://www.intertanko.com/Members-Information/benchmark/Optimum-speed-calvulator/>.

IPCC 2007, 'Climate change 2007: Synthesis Report', <http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf>.

Jaffe, A & Stavins, R 1994, 'The energy-efficiency gap What does it mean?', *Energy Policy*, vol 22, no. 10, pp. 804-810.

Jensen, M 1983, 'Organization theory and methodology', *Accounting review*, vol 56, pp. 319-338.

Jensen, M & Meckling, W 1976, 'Theory of the Firm: Managerial Behavior, Agency Costs, and Ownership Structure', *Journal of Financial Economics*, vol 3, pp. 306-360.

Johnson, B & Onwuegbuzie, A 2004, 'Mixed methods research: A research paradigm whose time has come', *Educational Researcher*, vol 33, no. 7, pp. 14-26.

Kaczmirek, L 2008, 'Internet survey tools', in N Fielding, R Lee, G Blank (eds.), *The Sage handbook of online research methods*, Sage Publications Ltd, London.

Karamperidis, S, Jackson, E & Mangan, J 2013, 'The use of indices in the maritime transport sector', *Maritime Policy & Management*, vol 40, no. 4, pp. 339-350.

Kema-Xenergy, Itron & RoperASW 2004, *California statewide residential appliance saturation study*, viewed 23 November 2011, <http://www.energy.ca.gov/appliances/rass/>.

Kesicki, F, 2010, 'Marginal abatement cost curves for policy making – Expert-based vs. model-derived curves', UCL Energy Institute.

Kollamthodi, S, Braniggan, C, Harfoot, M, Skinner, I, Whall, C, Lavric, L, Noden, R, Lee, D, Buhaug, O, Martinussen, K, Skejic, R, Valberg, I, Brembo, J, Eyring, V & Faber, J 2008, *Greenhouse gas emissions from shipping: trends, projections and abatement potential*, AEA Energy & Environment, viewed 09 March 2010, <http://archive.theccc.org.uk/aws3/AEA%20shipping%20report%20for%20the%20CCC.pdf>.

Kollamthodi, S, Pueyo, A, Gibson, G, Narkeviciute, N, Hawkes, A, Cesbron, S, Milnes, R, Harries, J, Zamparutti, T, Hemandez, G, Kaltsouni, S, Vancauwenbergh, S, Goldenman, G, Palsson, C, Bengtsson, N, Rydbergh, T, Nilsson, L, Weber, C, Scarborough, T, Whall, C, et al. 2013, *Support for the impact assessment of a proposal to address maritime transport greenhouse gas emissions*, Ricardo-AEA, viewed 15 January 2013, <http://ec.europa.eu/clima/policies/transport/shipping/docs/ghg_maritime_report_en.pdf>.

Koomey, J 1990, 'Energy efficiency choices in new office buildings: An investigation of market failures and corrective policies (Unpublished PhD thesis)', Energy and Resources Group, University of California, Berkeley.

Koomey, J & Sanstad, A 1994, 'Technical evidence for assessing the performance of markets affecting energy efficiency', *Energy Policy*, vol 22, no. 10, pp. 826-832.

Krippendorf, K 2004, *Content analysis: An introduction to its methodology*, 2nd edn, Sage Publications Inc, Thousand Oaks, California.

Krueger, R & Casey, M 2000, *Focus groups: A practical guide for applied research*, 3rd edn, Sage, Thousand Oaks, California.

Kwak, N & Radler, B 2002, 'A comparison between mail and web surveys: Response pattern, respondent profile, and data quality', *Journal of Official Statistics*, vol 18, no. 2, pp. 257-273.

Lambert, R 1986, 'Executive effort and selection of risky projects', *Rand Journal of Economics*, vol 17, no. 1, pp. 77-88.

Lane, J 2005, *Public administration and public management: The principal-agent perspective*, Routledge, London.

Levine, M & Florence, J 1990, 'Regulatory capture, public interest, and the public agenda: Toward a synthesis', *Journal of Law, Economics, and Organization*, vol 6, pp. 167-198.

Levinson, A & Neimann, S 2003, *Energy use by apartment tenants when landlords pay for utilities*, viewed 05 November 2012, <http://www9.georgetown.edu/faculty/aml6/pdfs%26zips/energy.pdf>.

Lincoln, Y & Guba, E 1985, *Naturalistic inquiry*, Sage publications, Beverly Hills, California.

Lloyds List 2012, *Advertisement: Statistics*, viewed 4 December 2012, <www.lloydslist.com>.

Lloyds List 2013, *Banks get behind retrofitting*, viewed 9 January 2013, <http://www.lloydslist.com/ll/sector/ship-operations/article414526.ece>.

Lloyds List 2013, *Shippers 'lose out in slow steaming'*, viewed 07 January 2013, <http://www.lloydslist.com/ll/sector/ports-and-logistics/article414424.ece>.

Lockley, P, Jarabo-Martin, A, Sharma, K & Hill, J 2011, *Ship efficiency: The guide*, Fathom, London.

Loke, S & Gilbert, B 1995, 'Method of psychological assessment, self disclosure, and experiential differences: A study of computer, questionnaire and interview assessment formats', *Journal of Social Behavior and Personality*, vol 10, pp. 255-263.

Longva, T 2011, 'Emission reduction potential in shipping', *Presentation at IMO MEPC 62 on 16th November 2011*.

Lovins, A 1992, *Energy efficient buildings: Institutional barriers and opportunities*, viewed 12 January 2011, <http://www.rmi.org/KnowledgeCenter/Library/199202_EnergyEfficientBuildingsBarriersOpportunities>.

Maddox Consulting 2012, *Analysis of market barriers to cost effective GHG emission reductions in the maritime transport sector*, viewed 12 December 2012, <http://bookshop.europa.eu/en/analysis-of-market-barriers-to-cost-effective-ghg-emission-reductions-in-the-maritime-transport-sector-pbML3213436/;pgid=y8dIS7GUWMdSR0EAlMEUUsWb0000a_8LQxNb;sid=27eLfRnKx26Lbkvc5PAV2nvv3GSNrrsJp-c=?CatalogCategoryID=lPKep2Ix.>.

Makkar, J 2005, *Revisiting speed and consumption warranties in time charterparties*, viewed 22 January 2012, <http://www.pfri.uniri.hr/~bopri/documents/10CASPart7SpeedandConsumptinChartering_000.pdf>

Mangan, J, Lalwani, C & Gardner, B 2004, 'Combining quantitative and qualitative methodologies in logistics research', *International Journal of Physical Distribution & Logistics Management*, vol 34, no. 7, pp. 565-578.

Mankabandy, S 1975, 'Speed and Consumption clauses', *Journal of Maritime Law and Commerce*, vol 6, no. 4, pp. 635-642.

Mark, M & Shotland, R 1987, 'Alternative models for the use of multiple methods', *New directions for program evaluation*, vol 35, pp. 95 -100.

Maruejols, L & Young, D 2011, 'Split incentives and energy efficiency in Canadian multi-family dwellings', *Energy Policy*, vol 39, pp. 3655-3668.

Mason, J 2006, 'Mixing methods in a qualitatively-driven way'', *Qualitative Research*, vol 6, no. 1, pp. 9-26.

Masten, S & Snyder, E 1991, 'The design and duration of contracts: Strategic and efficiency considerations', *Law and Contemporary Problems*, vol 52, pp. 63-85.

Mayring, P 2000, *Qualitative content analysis*, viewed 06 March 2013, <http://www.utsc.utoronto.ca/~kmacd/IDSC10/Readings/text%20analysis/CA.pdf>.

McCollum, D, Gould, G & Greene, D 2009, *Greenhouse Gas emissions from aviation and marine transportation: Mitigation potential and policies*, Pew Center, viewed 12 January 2010, <http://www.c2es.org/docUploads/aviation-and-marine-report-2009.pdf>.

McFatter, R 1979, 'The use of structural equation models in interpreting regression equations including suppressor and enhancer variables', *Applied Psychological Measurement*, vol 3, pp. 123-135.

McMichael, M 2011, 'Social capital and the diffusion of energy-reducing innovations in UK households (unpublished PhD thesis)', Energy Institute, University College London, London.

Meier, A & Eide, A 2007, *How many people actually see the price signal? Quantifying market failures in the end use of energy*, viewed 15 November 2012, <http://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2007/Panel_9/9.077>.

Meyer, B 2008, 'Office leases & landlord investment in energy efficiency (unpublished MSc dissertation)', Department of Architecture, Massachusetts Institute of Technology, Massachusetts.

Millar, M & Dillman, D 2011, 'Improving response to web and mixed-mode surveys', *Public Opinion Quarterly*, vol 75, no. 2, pp. 249-269.

Mokia, Z & Dinwoodie, J 2002, 'Spatial aspects of tanker lay-times', *Journal of transport geography*, vol 10, pp. 39-49.

Molinie, L & Abran, A 1999, *Software outsourcing contracts: An economic analysis based on agency theory*, viewed 5 January 2012, <http://www.researchgate.net/publication/228606557_Software_Outsourcing_Contracts_An_Economic_Analysis_based_on_Agency_Theory>.

Morgan 1998, 'Practical strategies for combining qualitative and quantitative methods: application for health research', *Qualitative Health Research*, vol 8, pp. 362-376.

Morse, J 1991, 'Approaches to qualitative-quantitative methodological triangulation', *Nursing Research*, vol 40, no. 2, pp. 120-123.

Murtishaw, S & Sathaye, S 2006, *Quantifying the Effect of the Principal-Agent Problem on US Residential Energy Use*, viewed 08 November 2012, <http://aceee.org/files/proceedings/2008/data/papers/9_59.pdf>.

Nadel, S 2002, 'Appliance and Equipment Efficiency Standards', *Annual Review of Energy and the Environment*, vol 27, pp. 159-192.

NAPA 2012, *Results of NAPA group's survey - Shipowners, operators and charterers and their readiness for 2013 IMO SEEMP legislation*, viewed 26 October 2012, <http://www.napa.fi/News/Press-Releases/Napa-survey-60-of-market-unaware-of-SEEMP-fuel-saving-potential>.

Neil, K & Morris, J 2012, 'A tangled web of principals and agents: Examining the Deepwater Horizon oil spill through a principal-agent lens', *Politics and Policy*, vol 40, no. 4, pp. 629-656.

Norton Rose 2009, *Transport survey*, viewed 16 January 2011, <http://www.nortonrosefulbright.com/knowledge/publications/69488/the-way-ahead-transport-survey>.

Norton Rose 2010, *Transport survey*, viewed 16 January 2011, <http://www.nortonrosefulbright.com/knowledge/publications/69488/the-way-ahead-transport-survey>.

Norton Rose 2012, *Transport survey - Are you ready?*, viewed 20 February 2012, <http://www.nortonrosefulbright.com/knowledge/publications/69488/the-way-ahead-transport-survey>.

Norton Rose 2013, *The way ahead transport survey - Where are you now?*, viewed 9 June 2013, <http://www.nortonrosefulbright.com/knowledge/publications/69488/the-way-ahead-transport-survey>.

OCIMF & INTERTANKO 2010, *Virtual Arrival: Optimising voyage management and reducing vessel emissions - an emissions management framework*, viewed 11 August 2011, <http://www.intertanko.com/upload/virtualarrival/virtualarrivalinformationpaper.pdf>.

Orr, D 1995, *Fundementals of applied statistics and surveys*, Chapman & Hall, New York.

Pandey, S & Elliot, W 2010, 'Suppressor variables in social work research: Ways to identify in multiple regression models', *Journal of the Society for Social Work and Research*, vol 1, no. 1, pp. 28-40.

Patton, M 1990, *Qualitative evaluation and research methods*, 2nd edn, Sage, Newbury Park, California.

Perrow, C 1986, *Complex organsiations*, Random House, New York.

Petrolia, D & Bhattacharjee, S 2009, 'Revisiting incentive effects: Evidence from a random sample mail survey on consumer preferences for fuel ethanol', *Public Opinion Quarterly*, vol 73, no. 3, pp. 537-550.

Peyrot, M 1996, 'Causal Analysis: Theory and application', *Journal of Pediatric Psychology*, vol 21, no. 1, pp. 3-24.

Pirrong, S 1993, 'lContracting practices in bulk shipping markets: A transactions cost explanation', *Journal of Law and Economics*, vol 36, no. 2, pp. 937-976.

Pratt, J & Zeckhauser, R 1985, *Principal and Agents: The Structure of Business*, Harvard Business School Press, Boston.

Prindle, B, Crossley, D, Watt, G, Takahashi, M, Asano, H, Worrel, E, Joosen, S, de Visser, E, Harmelink, M, Bjorndalen, J, Bugge, J, Baardson, B, Sathaye, J, Murtishaw, S, Walsh, C, Hughes, J, Barnes, J, Aardenne, O, Eide, A, Ettestoel, I, et al. 2006, *Quantifying the effects of market failures in energy end use - Prepared for the IEA*, viewed 16 November 2012, <http://s3.amazonaws.com/zanran_storage/www.aceee.org/ContentPages/4790329.pdf>.

Purdon, S & O'Connor, W 2008, *Methodological review of research with large businesses: Paper 1 - Sampling issues*, viewed 3 June 2011, <http://www.hmrc.gov.uk/research/r60-overview.htm>.

Ray, N, Griggs, K & Tabor, S 2001, *Web bases survey research workshop*, viewed 12 November 2011, <Available at: http://telecomm.boisestate.edu/research.>.

Rehmatulla, N 2011, 'Applying systems thinking approaches for qualitative analysis of GHG emissions regulations in shipping', *First International Conference on Marine & Maritime affairs*, 4 - 5 April 2011, University of Plymouth, Plymouth.

Rehmatulla, N 2012, 'Barriers to uptake of energy efficient operational measures: Survey Report', Energy Institute, UCL, http://www.lowcarbonshipping.co.uk/files/ucl_admin/Rehmatulla_2012_Low_Carbon_Shipping_Survey_report.pdf.

Rehmatulla, N & Smith, T 2012, 'Implementation barriers to Low Carbon Shipping', *Low Carbon Shipping Conference*, 11 - 12 September, University of Newcastle, Newcastle.

Rehmatulla, N, Smith, T & Wrobel, P 2013, 'Implementation barriers to Low Carbon Shipping', *Low Carbon Shipping Conference*, 9 - 10 September, UCL, London.

Rohdin, P, Thollander, P & Solding, P 2007, 'Barriers to and drivers for energy efficiency in the Swedish foundry industry', *Energy Policy*, vol 35, pp. 672-677.

Rosenberg, M 1968, *The Logic of Survey Analysis*, Basic Books, New York.

Ross, S 1973, 'The economic theory of agency: The principals problem', *American Economic Review*, vol 63, pp. 134-139.

Ross, M 1986, 'The capital budgeting practices of 12 large manufacturing firms', *Financial Mangement*, vol 15, no. 4, pp. 15-22.

Rubin, A & Babbie, E 2008, *Research Methods for Social Work*, 6th edn, Thomson Brooks/Cole, California.

Sandelowski, M 2000, 'Combining qualitative and quantitative sampling, data collection, and analysis techniques in mixed method studies', *Reserach in Nursing & Health*, vol 23, pp. 246-255.

Sanstad, A & Howarth, R 1994, ''Normal' markets, market imperfections and energy efficiency', *Energy Policy*, vol 22, no. 10, pp. 811-818.

Sardianou, E 2008, ' Barriers to industrial energy efficiency investments in Greece', *Journal of*.

Sathaye, S, Bouille, D, Biswas, D, Crabbe, P, Geng, L, Hall, D, Imura, H, Jaffe, A, Michaelis, L, Pezko, G, Verbruggen, A, Worrel, E & Yamba, F 2001, *Barriers, opportunities and market potential of technologies and practices, Chapter in IPCC third assessment report - Climate Change 2001*, viewed 02 December 2012, <http://www.grida.no/publications/other/ipcc_tar/?src=/climate/ipcc_tar/wg3/179.htm>.

Sathaye, J & Murtishaw, S 2004, *Market failures, consumer preferences, and transaction costs in energy efficiency purchase decisions*, California, viewed 20 January 2011, <http://www.energy.ca.gov/2005publications/CEC-500-2005-020/CEC-500-2005-020.PDF>.

Saunders, M, Lewis, P & Thornhill, A 2007, *Research methods for business students*, Pearson Education, Harlow, England.

Sax, L, Gilmartin, S & Bryant, A 2003, 'Assessing response rates and nonresponse bias in web and paper surveys', *Research in Higher Education*, vol 44, no. 4, pp. 409-432.

SBSTA 1999, *Methodological Issues – Emissions resulting from fuel used for International Transportation*, Subsidiary Body For Scientific and Technological Advice, viewed 02 February 2010, <https://unfccc.int/methods/emissions_from_intl_transport/items/6142.php>.

Schleich, J 2009, 'Barriers to energy efficiency: A comparison across the German commercial and services secto', *Ecological Economics*, vol 68, pp. 2150-2159.

Schleich, J & Grubber, E 2008, 'Beyond case studies: Barriers to energy efficiency in commerce and the services sector', *Energy Economics*, vol 30, no. 2, pp. 449–464.

Schleyer, T & Forrest, J 2000, 'Methods for the design and administration of web based surveys', *Journal of the American Medical Informatics Association*, vol 7, no. 4, pp. 416-125.

Schreier, M 2012, *Qualitative content analysis in practice*, Sage Publications Ltd, London.

Scott, S 1997, 'Household energy efficiency in Ireland: A replication study of ownership of energy saving items', *Energy Economics*, vol 19, pp. 187-208.

Shaddick, S 2012, 'Charterparties overview, Lecture notes from Chartering in Practice seminar ', 25-26 January , London.

Sharma, A 1997, 'Professional as Agent: knowledge asymmetry in agency exchange', *The Academy of Management Review*, vol 22, pp. 758-798.

Shih, T & Fan, X 2008, 'Comparing response rates from web and mail surveys: A meta-analysis', *Field Methods*, vol 20, no. 3, pp. 249-271.

Shi, H, Peng, S, Liu, Y & Zhhong, P 2008, 'Barriers to the implementation of cleaner production in Chinese SMEs: government, industry and expert stakeholders' perspectives', *Journal of Cleaner Production*, vol 16, pp. 842-852.

Simon, H 1959, 'Theories of decision-making in economics and behavioural science', *The American Economic Review*, vol 49, pp. 253-283.

Sleep, D & Puleston, J 2008, *The survey killer*, viewed 15 October 2011, <http://www.engage-research.co.uk/Sleep_1108.pdf>.

Smith, T & O'Keefe, E 2012, 'What is an appropriate measurement and apportionment strategy for shipping?', *Low Carbon Shipping Conference 2012*, 11 - 12 September, University of Newcastle, Newcastle.

Smith, T, O'Keefe, E, Aldous, L & Agnolucci, P 2013, *Assessment of shipping's efficiency using satellite AIS data*, viewed 15 April 2013, <http://www.theicct.org/sites/default/files/publications/UCL_ship_efficiency_forICCT_2013.pdf>.

Smith, T, O'Keefe, E & Haji, S 2013b, 'What is a fair measurement and apportionment scheme?', *Low Carbon Shipping 2013*, 9 - 10 September, UCL, London.

Smith, T, Parker, S & Rehmatulla, N 2011, 'On the speed of ships', *Low Carbon Shipping conference*, 22 - 24 June, University of Strathclyde, Glasgow.

Smyth, J, Dillman, D, Christian, L & McBride, M 2009, 'Open-ended questions in web surveys: Can increasing the size of answer boxes and providing extra verbal instructions improve response quality', *Public Opinion Quarterly*, vol 73, no. 2, pp. 325-337.

Songer, D, Segal, J & Cameron, C 1994, 'The hierarchy of justice: Testing a principal-agent model of supreme court-circuit court interactions', *American Journal of Political Science*, vol 38, no. 3, pp. 673-696.

Sorrell, S, Mallet, A & Nye, S 2011, *Barriers to industrial energy efficiency: A literature review*, viewed 10 November 2012, <http://www.unido.org/fileadmin/user_media/Publications/Research_and_statistics/Branch_publications/Research_and_Policy/Files/Working_Papers/2011/WP102011%20Barriers%20to%20Industrial%20Energy%20Efficiency%20-%20A%20Literature%20Review.pdf>.

Sorrell, S, O’Malley, E, Schleich, J & Scott, S 2004, *The Economics of energy efficiency: Barriers to cost-effective investment*, Edward Elgar, UK.

Sorrell, S, Schleich, J, O'Mallye, E, Trace, F, Boede, U, Ostertag, K & Radgen, P 2000, 'Barriers to energy efficiency in public and private organization', SPRU—Science and Technology Policy Research, University of Sussex, Brighton.

Spens, K & Kovacs, G 2006, 'A content analysis of research approaches in logistics research', *International Journal of Physical Distribution & Logistics Management*, vol 36, no. 5, pp. 374 - 390.

Spurin, C 2004, *Trade and carriage*, viewed 4 December 2012, <http://www.nadr.co.uk/articles/articles.php?category=4>.

Stanton, J 1998, 'An empirical assessment of data collection using the internet', *Personnel Psychology*, vol 51, no. 3, pp. 709-725.

Stern, P & Aronson, E 1984, *Energy use: The human dimension*, W.H. Freeman and Company, New York.

Stewart, D & Shamdasani, P 1990, *Focus groups: Theory and practice*, Sage, California.

Stinchcombe, A 1968, *Constructing social theories*, University of Chicago Press, New York.

Stopford, M 2008, *Maritime economics*, 3rd edn, Routledge, London.

Stott, P 2013, 'A retrospective review of the average period of ownership with implications for the potential payback period of retrofitted equipment', *Journal of Engineering for the Maritime Environment*, vol 0, no. 0, pp. 1-13.

Strandenes, S 1999, 'Is there a potential for a two-tier tanker market?', *Maritime Policy and Management*, vol 26, pp. 249-255.

Strauss, A & Corbin, J 1990, *Basics of qualitative research*, Sage Publications, London.

Stremitzer, A 2005, *Agency theory: Methodology, analysis; A structured approach to writing contracts.*, Peter Lang AG, Bern.

Sustainable Shipping News 2011a, 'APL lowers fuel surcharge on slow steaming gains', 24th June 2011, Petromedia Ltd, London.

Sustainable Shipping News 2011b, 'Maersk Line: Speed cuts have reached their limit', 11th March 2011, Petromedia Ltd, London.

Sustainable Shipping News 2011c, 'Study of CO2 abatement cost shows 'amazing results'', 22nd July 2011, Petromedia Ltd, London.

Sustainable Shipping News 2012a, 'Engine room 'revolution' pays off at DFDS: DFDS encourages crew to help achieve bunker fuel savings', 17th August 2012, Petromedia Ltd, London.

Sustainable Shipping News 2012b, 'Maersk to impose bunker surcharges in tanker sector', 7th June 2012, Petromedia Ltd, London.

Sutherland, R 1991, 'Market barriers to energy efficiency investments', *The Energy Journal*, vol 12, no. 3, pp. 15- 34.

Sweeney, J 1993, 'Comments on Energy Efficiency and Human Activity: lessons from the past, importance for the future', vol unpublished draft.

Tamvakis, M 1995, 'An investigation into the existence of a two-tier spot freight market for crude oil carriers', *Maritime Policy and Management*, vol 22, pp. 81-90.

Tamvakis, M & Thanopoulou, H 2000, 'Does quality pay? The case of the dry bulk market', *Transportation Research Part E*, vol 36, pp. 297-307.

Tashakkori, A & Teddlie, C 1998, *Mixed methodology: Combining qualitative and quantitative approaches*, Sage, California.

Tashakkori, A, Teddlie, C (eds.) 2003, *Handbook of mixed methods in social and behavioural research*, Thousand Oaks, California.

Thollander, P & Ottosson, M 2008, 'An energy-efficient Swedish pulp and paper industry - exploring barriers to and driving forces for cost-effective energy efficiency investments', *Energy Efficiency*, vol 1, no. 1, pp. 21-34.

Thollander, P & Palm, J 2013, *Improving energy efficiency in industrial energy systems*, Springer, London.

Thollander, P, Palm, J & Rohdin, P 2010, *Categorizing barriers to energy efficiency: An interdisciplinary perspective. Chapter in Energy Efficiency by Palm, J.*, Sciyo Publications.

Trianni, A, Cagno, E, Worrell, E & Pugliese, G 2012, 'Empirical investigation of energy efficiency barriers in Italian manufacturing SMEs', vol Online first, pp. 1-15.

UNCTAD 1990, *Charterparties: A comparative analysis*, viewed 05 March 2012, <http://unctad.org/en/PublicationsLibrary/c4isl55_ar.pdf>.

UNEP 2006, *Barriers to Energy Efficiency in Industry in Asia*, United Nations Environment Program, viewed 12 September 2011, <http://www.energyefficiencyasia.org/docs/Barriers%20to%20Energy%20Efficiency%20review%20and%20policy%20guidance.pdf>.

UNEP 2011, *Bridging the emissions gap*, United Nations Environment Program, viewed 16 March 2012, <http://www.unep.org/pdf/unep_bridging_gap.pdf>.

Veenstra, A & Dalen, J 2011, 'Ship Speed and Fuel Consumption Quotation in Ocean Shipping Time Charter Contracts', *Journal of Transport Economics and Policy*, vol 45, no. 1, pp. 41–61.

Veenstra, A & Ludema, M 2006, 'The relationship between design and economic performance of ships', *Maritime Policy & Managment*, vol 33, no. 2, pp. 159-171.

Vehovar, V, Lozar, M & Batagelj, Z 1999, 'Web surveys: Can the weighting solve the problem?', *Proceedings of the section on survey research methods*, pp. 962-967.

Velthuijsen, J 1993, 'Incentives for investment in energy efficiency: and econometric evaluation and policy implications', *Environmental and Resource Economics*, vol 3, pp. 153-169.

Vernon, D & Meier, A 2012, 'Identification and quantification of principal–agent problems affecting energy efficiency investments and use decisions in the trucking industry', *Energy Policy*, vol 49, pp. 266-273.

Walker, G & Weber, D 1984, 'A transaction cost approach to make-or-buy decisions', *Administrative Sciency Quarterly*, vol 29, pp. 373-391.

Walking, R & Long, M 1984, 'Agency theory, managerial welfare and takeover bid resistance', *The Rand Journal of Economics*, vol 15, pp. 54-68.

Walther, J 2002, 'Research ethics in internet-enabled research: Human subjects issues and methodological myopia', *Ethics and Information Technology*, vol 4, no. 3, pp. 205-216.

Wang, H, Faber, J, Nelissen, D, Russel, B & St Amand, D 2010, 'Marginal abatement costs and cost-effectiveness of energy efficiency measures', Submitted to IMO MEPC, 61st Session, 23rd July 2010..

Wärtsilä 2008, *Boosting energy efficiency*, viewed 17 April 2011, <http://www.wartsila.com/file/Wartsila/en/1270037230672a1267106724867-wartsila-sp-b-wartsila-boosting-enegy.pdf>.

Watt, J 1999, 'Internet systems for evaluation research', in G Gay, T Bennington (eds.), *Information technologies in evaluation: Social, moral, epistemological, and practical implications*, Jossey-Bass, San Francisco.

Weber, L 1997, 'Some reflections on barriers to the efficient use of energy', *Energy Policy*, vol 25, no. 10, pp. 833-835.

Williamson, O 1979, 'Transaction-cost economics: The governance of contractual relations', *Journal of Law and Economics*, vol 22, no. 2, pp. 233-261.

Williamson, O 1985, *The Economic Institutions of Capitalism*, The Free Press, New York.

Williamson, B 2012, *Understanding performance claims*, viewed 13 October 2012, <http://www.lmaa.org.uk/uploads/documents/Performance%20Claims%20by%20Brian%20Williamson.pdf>.

Wilson, J 2010, *Carriage of Goods by Sea*, 7th edn, Longman, London.

Witmer, D, Colman, R & Katzman, S 1999, 'From paper-and-pencil to screen-and-keyboard: Toward a methodology for survey research on the internet', in S Jones (ed.), *Doing internet research: Critical issues and methods for examining the net*, Sage, Thousand Oaks, California.

Witte, J 2009, 'Introduction to the special issue on web surveys', *Sociological Methods & Research*, vol 37, no. 3, pp. 283-290.

Wolfson, M 1985, 'Empirical evidence of incentive problems and their mitigation in oil and gas shelter programs', in J Pratt, R Zechhauser (eds.), *Principals and agents: The structure of business*, Harvard Business School Press, Boston.

Wright, P, Mukherji, A & Kroll, M 2001, 'A reexamination of agency theory assumptions: extensions and extrapolations', *Journal of Socio-Economics*, vol 30, pp. 413-429.

Yin, R 1994, *Case Study Research: Design and Method, Applied Social Research Methods, vol. 5.*, Sage, London.

Yin, R 2003, *Case study research: Design and methods*, Sage, California.

York, C, Blumstein, C, Krieg, B & Schipper, L 1978, 'Bibliography on institutional barriers to energy conservation', no. Lawrence Berkeley National Laboratory LBNL-7885.

Yun, G & Trumbo, C 2000, 'Comparative response to a survey executed by post, e-mail, & web form', *Journal of Computer-Mediated Communication*, vol 6, no. 1, p. Online.

Zerman, P 2011, *Deviation: Justified or allowed and implications for the P&I cover: Slow steaming*, Skuld, Copenhagen, viewed 22 January 2012 , <http://www.skuld.com/topics/legal/legal-news/deviation--justified-or-allowed-and-implications-for-the-pi-cover--slow-steaming/>.

Zhang, Y & Wildemuth, B 2006, *Qualitative analysis of content*, viewed 12 March 2013, <http://7702-f13.design4complexity.com/qualitative-research/content-analysis.pdf>.

Zilahy, G 2004, 'Organizational factors determining the implementation of cleaner production measures in the corporate sector', *Journal of Cleaner Production*, vol 12, no. 4, pp. 311-319.

Zimmermann, J, Evans, M, Griggs, J, King, N, Harding, L, Roberts, P & Evans, C 2012, *Household electricity survey: A study of domestic electrical product usage*, viewed 05 July 2013, <https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/208097/10043_R66141HouseholdElectricitySurveyFinalReportissue4.pdf>.

Appendix

to

MARKET FAILURES AND BARRIERS AFFECTING ENERGY EFFICIENT OPERATIONS IN SHIPPING

By

Nishatabbas Rehmatulla

UCL Energy Institute

Supervised by:

Dr. Tristan Smith

Prof. Paul Wrobel

A dissertation submitted for the degree of Doctor of Philosophy

Appendix A – Methods

Research strategy

	Quantitative	Qualitative
Role of theory in relation to research	Deductive, theory testing	Inductive, theory construction
Epistemological orientation (what should be regarded as acceptable knowledge)	Positivism (advocates methods of the natural sciences to the study of social reality)	Interpretivism (constrasting positivism views, people and their institutions are different)
Ontological orientation (concerned with the nature of social entities)	Objectivism (ontological position that social phenomena and their meaning have an existence that is independent of social actors)	Constructionism (ontological position that asserts that social phenomena and their meaning are continually being accomplished by social actors)

Table A1: Difference between quantitative and qualitative research strategy
Source: Bryman (2008)

	Quantitative	Qualitative	Mixed methods
Strengths	• Can generalize results if correct sampling is followed • Allows to more credibly assess cause and effect relationships • Relatively quicker to obtain and analyse data compared to qualitative • Useful for studying large populations	• Can understand a limited number of cases or phenomena in depth • Data is generally collected in more naturalistic contexts • Can shift focus of the research as more inductive	• Can use strengths of additional methods to counter weaknesses of other methods • Can provide stronger evidence for a conclusion through corroborated findings • Can add complementary views to each methods findings • Can increase generalizability of results

Weaknesses	• Difficult to create indicators for what is being measured • More prone to confirmation bias • Generally results in abstract knowledge to specific situations	• Knowledge produced may not be generalizable • More difficult to test the hypothesis • Takes relatively longer to collect and analyse data compared to quantitative • Results can have researcher bias	• Difficult for a single researcher to conduct, unless phased approach is used. • Mixing methods requires additional training • More time consuming than just a single method

Table A2: Advantages and disadvantages of qualitative, quantitative and mixed methods strategy
Source: Mostly from Johnson & Onwuegbuzie (2004) and Creswel (2009)

Mixed methods strategy

Strength	**Explanation**
Completeness	Refers to the notion that the researcher can bring together a more comprehensive account of the area of enquiry in which he or she is interested if both quantitative and qualitative research are employed.
Different research questions	This is the argument that quantitative and qualitative research can each answer different research questions.
Explanation	One method is used to help explain findings generated by the other method.
Context	Refers to cases in which the combination is rationalized in terms of qualitative research providing contextual understanding coupled with either generalizable, externally valid findings or broad relationships among variables uncovered through a survey.
Illustration	Refers to the use of qualitative data to illustrate quantitative findings, often referred to as putting 'meat on the bones' of 'dry' quantitative findings.
Confirm and discover	This entails using qualitative data to generate hypotheses and using quantitative research to test them within a single project.
Enhancement	Augmenting either quantitative or qualitative findings by gathering data using a qualitative or quantitative research approach.

Table A3: Strengths of mixed methods
Source: Bryman (2006)

Typological questions	This research
1) Are the quantitative and qualitative data collected simultaneously or sequentially? (Morgan 1998; Morse 1991).	Quantitative data is collected first, followed by qualitative data collection
2) Which has priority – the quantitative or the qualitative data? (Morgan 1998; Morse 1991).	Quantitative data has priority over qualitative data (Following Creswell (2009) sequential explanatory design)
3) What is the function of the integration – for example, triangulation, explanation, or exploration? (Creswell 2002); Greene, Caracelli & Graham 1989).	Function of integration is: completeness, explanation, different research questions, illustration, confirming and discovering and enhancement.
4) At what stage(s) in the research process does mixed methods research occur? (Tashakkori & Teddlie 1998). It may be at stages of research question formulation, data collection, data analysis, or data interpretation.	Mixed methods research occurs after research questions have been formulated and follow through from data collection to interpretation.
5) Is there more than one data strand? (Tashakkori & Teddlie (eds.) 2003). With a multi-strand study, there is more than one research method and hence source of data.	There are different data strands/sources as a result of different methods.

Table A4: Typological questions in mixed methods research
Source: adapted from Bryman (2008)

Research designs

Research Design	**Description**
Longitudinal (Panel & Cohort)	The collection of data is more than once. There are two types of longitudinal design; panel and cohort. Panel studies survey a random sample at one point in time and then survey the exact same respondents a later point in time. Cohort study surveys a sample of respondents selected based on a specific criteria and then surveys based on the same criteria (Bryman 2008)
Cross-sectional	Collection of data from more than one case at single point in time i.e. a snapshot of all the variables to detect patterns of association. Examples of this are generally found in research employing surveys.
Case study	The collection of data from one or more groups at a time. "Entails studying two contrasting cases using more or less identical methods" (Bryman 2008, p.58). It involves investigation of a phenomenon within its real life context using multiple sources of evidence (Saunders, Lewis & Thornhill 2007).
Experimental	Collection of data is based on a control group which is exposed to a treatment and another control group which is not (Bryman 2008). Examples of these are generally found in clinical or laboratory experiments.

Table A5: Main types of research design

	Longitudinal	Experimental	Cross-sectional	Case study
Strengths	• Can examine changes in variable of interest over time • Data on many variables from a large number of sample • Generates hypotheses for future research • External validity is strong with use of random sampling	• Can draw valid conclusions about causality • Maximises internal validity • Results are more generalizable • Used as a gold standard or yardstick against all non-experimental designs • Highly replicable	• Conducted when there are constraints of time or resources (Collis & Hussey, 2003) • Are generally inexpensive (Collis & Hussey, 2003) • Brings stability to the research (Barrington, 2012) • Data on many variables from large number of sample • Generates hypotheses for future research • External validity is strong with use of random sampling	• Provides in depth data in a specific context • Attempts to investigate the real life context of a phenomenon • Advocates use of multiple sources of evidence for validity. • Useful for exploratory and explanatory questions • Multiple case strategy enable some generalization
Weaknesses	• Requires relatively more resources (Time and cost) • Respondents may drop out from panel studies • Eco-logical validity may be jeopardised (Bryman, 2008)	• May not represent the real context or environment which is a threat to external validity • Difficult to control for variety of variables	• Eco-logical validity may be jeopardised (Bryman, 2008) due to the instruments used • No control of independent variable • Increased chances of error as	• Single case strategy may not be representative, making generalization difficult. • External validity is generally weak

	due to the instruments used • No control of independent variable • Increased chances of error as internal validity is typically weak	• Can result in 'Hawthorne effect' (subject bias) if not conducted properly. • Does not lend itself to some types of research, i.e. requires good control over a subject or manipulation • Not feasible for many business and management and social research questions	internal validity is typically weak	

Table A6: Strengths and weaknesses of research designs
Source: Bryman (2008), Saunders, Lewis & Thornhill (2007), Hussey & Hussey (1997)

Research methods

Interviews

Interviews are a systematic way of talking and listening to people in order to collect data as well as to gain knowledge from individuals. Gray (2004) gives the following as reasons to conduct an interview over other research methods: there is a need to attain highly personalized data, there are opportunities required for probing, a good return rate is important, respondents are not fluent in the native language of the country, or where they have difficulties with written language.

Quantitative interview or structured interviews use questionnaires (administred by an interviewer) based on a predetermined and standerdised or identical set of questions (Saunders, Lewis & Thornhill 2007), in order to maximise reliability and validity of measurement of key concepts (Bryman 2008). Corbetta (2003) adds that the questions are also in the same sequence. The questions are directly drawn from research questions or used to answer research questions (Bryman, 2008). Structured interviews involves the use of closed, closed ended, pre coded or fixed choice of questions but can inlcude some open ended questions (Bryman 2008).

Qualitative interviews or semi structured interviews refer to a context in which the interviewer has a series of questions that are in a form of an interview schedule but the interviewer is able to vary the sequence of questions (Bryman, 2008). Unstructured interviews are based on topics or issues called an interview guide (Bryman, 2008). There is emphasis on greater generality in order to formulate initial research ideas and there is much greater interest of respondents point of view (Bryman, 2008). They often inlvolve use of open ended questions, that can be later coded.

Content analysis

Quantitative content analysis (NCA) is an approach to the analysis of documents that seeks to quantify content in terms of predetermined categories and in a systematic and replicable manner (Bryman 2008). Research questions guide the selection of content to be analysed and the coding schedule (Bryman 2008). Quantitative content analysis can be applied mainly to cross-sectional designs but may also be useful in longitudinal and comparative designs (Nuendorf 2002).

Qualitative content (LCA) analysis is comprised of searching underlying themes in the materials being analysed, illustrated with examples and quotations (Bryman 2008). Qualitative content analysis aims to be systematic and analytic but not rigid (Altheide 1996). Categories and variables initially guide the study, but others are allowed and expected to emerge during the study as the researcher is in a state of constant discovery, comparison of situations, settings, styles etc (Altheide 1996).

Focus groups

The focus group method is a form of group interview in which there are several participants (including a moderator) and questioning is on a particular fairly tightly defined topic (Bryman 2008). The emphasis is on interaction within the group and joint construction of meaning (Bryman 2008). It has also been called the focussed interview, in which interviewees are selected because they are known to have been involved in a particular situation (Bryman 2008) therefore the 'information rich' (Krueger & Casey 2000; cited by Saunders, Lewis & Thornhill 2007) participants are usually chosen on a non-probability sampling method (Saunders, Lewis & Thornhill 2007). Focus groups may be conducted several times with similar participants to enable trends and patterns to be identified (Saunders, Lewis & Thornhill 2007). This research method is primarily used for collection of qualitative data, however it can produce quantitative data (Stewart & Shamdasani 1990)

Observation

Structured observation entails the direct observation of behaviour and the recording of that behaviour in terms of categories that have been devised prior to the start of data collection (observation schedule) (Bryman 2008). It aims to ensure systematic recording of behaviour in order to aggregate the behaviour of all those in the sample and the resulting data resembles of that obtained from a questionnaire and is underpinned by a cross-sectional design generally (Bryman 2008). There is a continuous degree of involvement by the observer, from complete observers (detached) to complete participants (involved) (Gold 1958; cited by Bryman 2008). Structured observation tends to fall in the detached category, whereas ethnographic observation falls in the involved category (Gold 1958; cited by Bryman 2008).

Ethnographic observation is the involvement of the researcher in the social life of those he or she studies, observing behaviour, listening and asking questions. This method typically involves gaining further data through interviews and content analysis or collection of documents (Bryman 2008). Much of the sampling in this method is based on a combination of convenience sampling and snowball sampling (Bryman 2008)

Self-completion questionnaire

Self-completion questionnaires include all modes (postal/mail, web/internet, mixed modes, etc) of data collection in which each person is asked to respond to the same set of questions (usually closed) in a pre-determined order (de Vaus 2002) by themselves (Bryman 2008). This method of data collection is by far the most used research method under the cross-sectional research design (Saunders, Lewis & Thornhill 2007). Self-completion questionnaires tend to have closed questions, easy to follow designs and are shorter in contrast to other research methods such as structured interviews etc. Self-completion questionnaires can be used for descriptive or explanatory research and are used to answer pre-formulated research questions (Saunders, Lewis & Thornhill 2007) and therefore conform to the deductive theory testing research, which generally implies a quantitative strategy.

	Interviews (Structured and unstructured)	**Content analysis (Quantitative and qualitative)**	**Focus groups**	**Structured Observation and ethnographic observation**	**Self-administered Questionnaire**
Strengths	• Structured interviews maximise reliabilty and validity of measurement of key concepts • Provides much more detailed information than what is available through other data collection methods • Results in generally good response rates • Allows for probing and prompting for other peripheral issues • Requires relatively more training compared to other methods	• Coding scheme makes the research method transparent and replicable • Longitudinal analysis can be performed with ease • Unobtrusive and non-reactive • Widely applicable to unstructured information • Allows convenient access to data that is difficult to gain from other methods • Represents data which is thoughtful	• Emphasize a specific theme or topic of relevance to the participants • Saves time and money compared to interviews • Emphasises the social context, participant as member of the group and participant ownership • Results in more realistic accounts compared to the interview due to group settings and less artificial settings	• There is generally no problem of access • Unobtrusive way of analysing a real life situation • No problem of reactivity • Useful in investigating issues that may be uncomfortable for participants to discuss	• Stronger external validity • Cheaper and quicker to implement and administer • Absence of social desirability bias • No interviewer variability • Provides convenience to respondents

Weaknesses	• Structured interview is less flexible and highly standerdised • Resource constraints (time, money & people) • Interviewees behaviour, attitudes, norms, beleifs and values can result in errors and raise concerns • Susceptible to social desirablity bias and acquiescence (acceptance) • Weak external validity due to small sample sizes and non random sample of in-depth interviews	• Highly dependent on documented data, therefore can only get as good as the document • Coding manuals require coder interpretation • Some difficulty in answering exploratory questions • Difficult to connect with theory	• Less control over proceedings of the group • Data is difficult to organise and analyse • Susceptible to group effects and expressing culturally expected views	• Difficult to take notes on the observations • Difficult to combine with other methods • Ethical problems with covert research • Researcher may be seen as intrusive • Difficulty in differentiating private and public research	• Weak internal validity • Inability to prompt and probe • Questionnaire can be read as a whole • Do not know who actually responds to answers • Not appropriate for some types of respondents • Difficult to establish causality (internal validity) • Difficult to get meaningful aspect of social action • Difficult to create indicators or measurements

Table A7: Strengths and weaknesses of research methods. Source: Bryman (2008), Saunders, Lewis & Thornhill (2007), Creswell (2009)

Content analysis forms

Types of qualitative content analysis	Description
Discourse analysis	Focuses on how particular phenomena are represented or their manifestations in various matters. Discourse is defined as text above the level of sentences.
Social constructivist analysis	Focuses on discourse analysis in order to understand how reality comes to be constituted in human interactions
Rhetorical analysis	Focuses on how messages are delivered and with what effects
Ethnographic content analysis	Advocated by Altheide (1987) does not avoid quantification but encourages accounts to emerge from reading of texts.
Conversation analysis	Researcher recodes verbal interactions in natural settings aiming to create collaborative construction of conversations.

Table A8: Various forms of qualitative content analysis
Source: Krippendorff (2004)

	Quantitative content analysis	Ethnographic content analysis
Research goal	Verification	Discovery, verification
Reflexive research design	Seldom	Always
Emphasis	Reliability	Validity
Process	Serial	Reflexive, circular
Researcher involvement	Data analysis, interpretation	All phases (as shown above)
Sample	Random or stratified	Purposive and theoretical
Pre-structured categories	All	Some
Type of data	Numbers	Numbers, narrative
Data entry points	Once	Multiple
Narrative description/comment	Seldom	Always
Emerging concepts	Seldom	Always
Data analysis	Statistical	Textual, statistical
Data presentation	Tables	Tables and text

Table A9: Comparison of quantitative and ethnographic content analysis
Source: Altheide (1987)

Questionnaire design and implementation

The TDM guidelines for survey implementation are as follows (Dillman 2009):

1. To the extent possible, personalize all contacts to respondents
2. Send a token of appreciation with the survey request
3. Use multiple contacts and vary the message across them
4. Carefully and strategically time all contacts with the population in mind
5. Consider contacting by another mode when possible
6. Keep email contacts short and to the point
7. Take steps to ensure that emails are not flagged as spam
8. Carefully select the sender name and address and the subject line for email communication
9. Provide clear instructions for how to access the survey
10. Make obvious connections between the opening screen and other implementation features
11. Assign each sample member a unique ID number
12. Know and respect the capabilities of the web servers
13. Establish a procedure for dealing with bounced emails
14. Establish procedures for returned incentives
15. Establish procedures for dealing with respondent inquiries
16. Implement a system for monitoring progress and evaluating early completes

Dillman's (2009) advice on design is as follows:

1. Decide whether an electronic alternative to a web survey is more appropriate (e.g. fillable PDF or email survey)
2. Choose how the survey will be programmed and hosted commensurate with the needs, skills, and sponsorship of each survey
3. Evaluate the technological capabilities of the survey population
4. Take steps to ensure that questions display similarly across different platforms, browsers and user settings
5. Decide how many questions will be presented on each web page and questions will be arranged
6. Create interesting and informative welcome and closing screens that will have a wide appeal to the respondents
7. Develop a screen format that emphasises the respondent rather than the sponsor
8. Use a consistent page layout across the screens and visually emphasize question information that respondents will need to complete the survey while deemphasizing information that is not essential to the task

9. Do not require responses to questions unless absolutely necessary for the survey
10. Design survey-specific and item-specific error messages to help respondents troubleshoot any issues they may encounter
11. Evaluate carefully the use of interactive features, balancing improvements in measurement with the impact on respondent burden and the implications for mixed mode survey
12. Use audiovisual capabilities of the web survey sparingly and evaluate the different effect they may have on respondents
13. Allow respondents to stop the survey and finish completing it at another time
14. Whenever possible, collect paradata that provide feedback on how the respondent interacts with the questionnaire
15. Test the survey using a variety of platforms, connection speeds, browsers and user controlled settings and test the database to ensure that items are collected and coded correctly
16. Take screenshots of each page of the final questionnaire for testing and documentation

Literature on incentives

Birnholtz et al. (2004) examined the effects of a cash incentive ($5 USD) in postal survey and ($5 USD) in Amazon gift vouchers via both postal delivery and e-mail and found that Amazon gift vouchers (online incentive) resulted in significantly lower response rates than cash-based incentive delivered in the post. The literature on the use of incentives for web surveys is not so clear and Couper (2000) cautions on the little experimental literature on strategies that may work or that may not work. Goritz (2006) considers different types of incentives used in web surveys e.g. lottery based, monetory, non-monetory, prepaid or on-return incentives and conclude that incentives motivate people to start a web survey and have better retention rates when an incentive is offered. However, the study excludes mixed mode follow up surveys (i.e. if potential respondents were solicited on the phone to take a web survey), which is the case in this research. Millar and Dillman (2001) examine the response rates to web and mixed mode surveys on highly internet-literature population with full internet access. They find that a combination of both postal and email contacts and delivering a token cash incentive in advance are useful methods for improving web response rates. There are also several pitfalls in using monetary or lottery incentives as they could directly affect external validity, by creating a bias by attracting a particular type of respondent (Goritz 2006). None of the studies that investigated barriers to energy efficiency discussed in chapter two make use of incentives including those that were concluded to be methodologically rigorous (e.g. Rohdin, Thollander & Solding 2007;Thollander & Ottosson 2008; Sorrell et al. 2000 & 2004).

Pretesting

Pretesting questions:

1. Was there a particular question that took longer to fill out?
2. Do you have any comments on wording of the questions and choices, was there anything you did not understand
3. Did you become bored at any point? If so which question/where?
4. Are there any obvious spelling or other mistakes?
5. Are there any other comments that would help improve the questionnaire?

Some of the comments from pretesting are shown in table A1.1, including comments from one expert in the subject of surveys and social research. Below is another comment by another expert.

" p. 1 - Introduction page:
I think this would be better presented directly as part of the Low Carbon Shipping consortium project in the first instance - with reference to the funders and consortium stakeholders - this will make it come across as more official and will increase the chances of people responding.
Make sure that if you say it will take 5 minutes that it will take that - if it actually takes 15 minutes then it's better to say that.

'Please select FIVE operational energy efficiency measures from the list below that you believe have the highest potential for fuel savings and CO_2 reductions'
- Is there difference between fuel savings and CO_2 savings in the context of these measures? If yes then this potentially ambiguous, if no then CO_2 savings is a redundant term and can be deleted.
- Are the options provided subject to different forms of interpretation (need someone with expertise in these methods to know this). E.g. are there different ways to enact Trim/draft optimisation with different results? If there are then you may need some kind of a comments box to allow people to express which form they are thinking of.
- Add 'Don't know' option or be mindful in interpretation that people may not tick boxes - but that doesn't mean these measures are not being implemented because the respondent simply is not aware of them.

'From your choices to [Q1] could you indicate whether you are implementing them or not'
- Are you interested if people are implementing choices they did not select in Q1? If so where is this data captured? If not, you need to be careful not to interpret their non-selection in Q1 as not meaning they are not doing them.

'When thinking about your response to [Q2] implementation, you selected you are beginning to consider GENERAL SPEED REDUCTION, could you indicate what has/have been the MAIN DRIVERS for this?'
- Change this to: When thinking about your response to [Q2] on implementation, you selected you are beginning to consider GENERAL SPEED REDUCTION, could you indicate what has/have been the MAIN DRIVERS for this?
- The wording of this question suggests you are assuming that measures selected in Q1 are those being implemented - this is not entailed by the question wording (see above).
- Add 'Don't know' option or be mindful in interpretation that people may not tick boxes - but that doesn't mean these measures are not being implemented because the respondent simply is not aware of them.

'When thinking about your response to [Q2] implementation,you selected considering and still deciding on implementation for TRIM/DRAFT OPTIMIZATION, could you indicate what have been the MAIN REASONS forthis?'
- Sort out word spacing on screen.
- You've got a 'don't know' options for this but not previous screens - it's best to be consistent.

'When thinking about your response to [Q2] implementation, you selected considered but decided against for SPEED REDUCTION DUE TO PORT EFFICIENCY, could you indicate what have been the MAIN REASONS for this?'
- No comments

'When thinking about your response to [Q2] you have indicated that you have already implemented EFFICIENT VOYAGE EXECUTION, how important do you think the following are in influencing your decision to implement this measure?'
- Changed wording structure of question ('implementation') missing - change to be consistent with previous.

'Thinking about a VOYAGE/VOYAGE charter, how important are the following factors when fixing a ship?'
- Consider changing to: Thinking about a VOYAGE/VOYAGE charter, how important are EACH of the following factors when fixing a ship?

'Thinking about a PERIOD/TIME charter, how important are the following factors when fixing a ship?'
- Consider changing to: Thinking about a PERIOD/TIME charter, how important are EACH of the following factors when fixing a ship?

'As an informational tool, how important do you think the Energy Efficiency Design Index (EEDI) will be for comparison of ships during the selection process?'
- No comments

'The International Maritime Organzation (IMO) considers speed optimization to be one of the best practice measures that should be incorporated in the Ship Energy Efficiency Management Plan (SEEMP), do you think this is achievable under the following:'
- No comments

'How important do you think are the following in their potential to reduce CO_2 emissions achievable from speed reduction?'
- Confusing ambiguous question. Do you mean 'How important do you think are the following in their potential to reduce CO_2 emissions achievable from speed reduction?' or 'How important do you think are the following reducing CO_2 emissions through speed reduction?' The first wording suggests that the things listed have the potential to undermine our attempts to save carbon from speed reduction. The second is a neutrally worded question which requests an assessment of the impact of these things on savings.
- This question needs clarification

'Thank you for taking the time to complete this questionnaire. Your assistance in providing the information is very much appreciated. I will endeavour to send you a full report containing the summarized results and analysis of this study.'
- consider rebranding this along the lines of what is suggested at the top to make it seem more part of the `low carbon shipping' consortium work, etc. Generally the survey looks good to me Nish”

Respondent	Q1	Q2	Q3	Q4	Q5
1	All of those that listed lots of answers took longer, but maybe easier for those who actually know about shipping to answer	Energy efficient operational measures is a bit of a mouthful and I didn't understand most of the techy questions, but again I'm sure those you have selected to send the q'aire to will. A pilot with those who have a better understanding of the shipping sector than me, may help with that.	A little bit with the long list of possible measures, but again if I understood more about what each of those measures actually meant and took the time to consider them, then it would presumably be more interesting.		I don't think so. My only comment would be that in your last page you say that you will 'endeavour' to get the results back to them, which makes it sound like a really strain/ hassle for you to do so. Might you say that you will send those who are interested (asking them to opt out if they're not) a summary of your findings? That way they definitely get something out of their participation.
2	The multi column multi row take quite a while	I'm not a shipping expert so have no idea if the terminology (of which there is a fair bit) is usual in the field. Need to pre-test on your target sample. Mostly the questions are pretty clear.	Yes.	None that I voyageted but I've printed out the questionnaire to have a look.	Don't tell people it will take 5 minutes if it will actually take 15! / I'll get back to you with comments on the print out if need be
3	What would be considered Q3, as it added in elements that I did not tick in Q2 so I had to go back and figure out what I had ticked and not ticked	Implementing -- you are asking about considering AND implementing, so I would word the question "considering or implementing yet." / / Answer categories: Need to add 'did not consider' and 'not applicable' into the question on considering / implementing. You could also get rid of extra words, to increase readability -- i.e. delete 'on implementation' and 'against implementation' and delete 'considered and' in the answer category 'considered and plan to implement'. / / You refer to Q1 and Q2, but they are never labelled as such. According to Dillman and de Vaus, it is very important to number each question, so it would be good to add these into the survey, if you can. / /. / / I would suggest possibly separating the one long sentence (in the why?	Not bored, but have to bear in mind that the repetitive nature of the questions might lose some people's interest -- but this is just something that happens in surveys. Only way to avoid it is to break up sections, and you've done that quite nicely.	There were some typos -- 2 question marks at the end of one sentence; space left out between "thatyou have considered and plan to ..."	On the first page, I would probably put a very introductory sentence to say "I am Nish. I am a PhD student at UCL Energy Institute" and then continue with the rest of it. Only saying this because it starts with things about 'my research' and I am just wondering if they know who you are? / / Also, as far as a pre-test, you might want to ask people at the beginning to take notes -- otherwise, they will probably not remember details to be able to feedback at the end of the questionnaire. This type of pre-test might work well for print questionnaires, but I think on-line might be a bit different. Might even be a good idea to sit down with people as they go through it (though I know that is pretty much impossible!).

		questions) into 2 sentences and putting them on separate lines, so that the second line starts "Could you indicate ...[why]?" This would increase readability. / / You most often spoke of MAIN REASONS but once changed the language to MAIN DRIVERS. I would try to stay consistent (and stick with the former). / / I would re-word this sentence: "How important do you think are the following in their potential to reduce CO_2..." to "How important do you think the following are in their potential to reduce CO_2 ....”			
4	No	no, but it would be good to have question / page number.	(a) good questionnaire design, in particular the breadcrumb at the beginning / (b) toward the end, it seams that I answer the same question twice?	No	To include page or question number and [p of p] page number of page count? / or To include % of completion as the bar shading seams a little inaccurate
5	No	Questionaire looks really good. Here's a couple of things that may help if i were to nitpick: / / - Q1 and Q2 seem to be aimed at shipowner and charterer respectively. Therefore, it may help to give an option of not applicable on each or be explicit on who it's aimed at. / - Q3 and a couple of others might be good if you allowed the user to give a reason why. I'm not sure how that fits with your analysis framework though. / - The question on potential to reduce CO_2 emissions from speed reduction. i thought the option of trade/route was a bit unclear. Did you mean potential changes in trade demand or were you referring to specific trade/route	No problem in terms of length - in fact you could probably squeeze in a few more questions.	No	

		combinations. / - Question numbers would help especially since you ask later on were any questions unclear. It may be useful to say at the start that there are only x number of questions - becuase it is very short, which is a great thing and people are more likely to fill it out if it's shorter. / / Hope these are some help. Looking good though - great work!			
6	don't think so	I've put some comments in an email that I'll send now	yes, but that's just my attention span and because its 4pm in the afternoon.	not that I voyageted	Just wondering if "opimization of ballast voyages" needs further explanation? do you mean minimisation of their duration or optimisation of speed on the ballast voyage? In your list of drivers, I think some of them are drivers but are some of them just absent barriers (e.g. high savings potential is clearly a driver, but is "allowed under charterparty" a driver, or just the absence of a charterparty barrier? Maybe just use the words "influences to the consideration" instead of drivers? or separate out to distinguish between the two? In your question "how important do you think are the following in their potential to reduce CO2 emissions achievable from speed reduction"? doesn't it depend on the charterparty? I didn't get a question asking me for the profile of my organisation - is that because its just a sample survey? Otherwise, think its looking really good - have you figured out anything about hosting and do you want CWR involved?
7	No	I found the 'importance of EEDI' question odd, maybe 'will you use' or 'do you think the EEDI will be a good information tool?'. A couple of the choices	Didn't become bored.	repetition of somewhat unimportant in the choices of the question: 'How	Clever survey, I like how it knew the responses from Q2 and used those throughout.

		options may have been differently worded, for example, 'somewhat not achievable' could be 'somewhat unachievable'. On the 'how important do you think are the following in their potential to reduce CO2', somewhat unimportant was given as an option twice. The 'considering implementing' choices were quite long, maybe shorter, like: 'might implement', 'won't implement', 'planning implementation', 'already implemented'. / Also, giving people a 'don't know' gives them the option not to give a useful answer, and there is already a central 'neither important nor unimportant' option for these people. What is the difference between don't know and neither important nor unimportant? /		important do you think are the following in their potential to reduce CO2 emissions achievable from speed reduction?'	

Table A1.1: Comments from seven participants to the survey pretest

Emails to participants

First contact email

Dear ……………,

Further to our recent telephone conversation, I attach the survey link, which is for an important piece of research that I am carrying out as part of my PhD at University College London (UCL), Energy Institute.

This survey is the first one of its kind and to appreciate your participation, you will receive an anonymous summary results report of the operational energy efficiency measures being applied in the sector and what issues are affecting their uptake, enabling you to be better informed of the opportunities and challenges in energy efficiency.

The survey is brief and will only take about 10 minutes to complete. The information will be treated as strictly confidential and handled in accordance with the provisions of the UK Data Protection Act 1998. Data Protection Ref for this survey: Z6364106 /2011/09/43.

Please click the link below to go to the survey web site:
https://qtrial.qualtrics.com/SE/?SID=SV_6m09Afw8hc6KNms

Should you have any comments or questions, please feel free to contact me at nishatabbas.rehmatulla.09@ucl.ac.uk

I look forward to your response and thank you in advance for your time and cooperation. It is only with the generous help of industry participants like you that my research can be successful.

Sincerely,

Nishat Rehmatulla

Doctoral Researcher
UCL Energy Institute
Central House
14 Upper Woburn Place
WC1H 0NN
London, UK
+ (44) 7540051942
http://www.lowcarbonshipping.co.uk/

Second reminder email

Dear ……………,

Further to our telephone conversation two weeks ago, I would like to remind you about the above mentioned survey, which is for an important piece of research that I am carrying out as part of my PhD at University College London (UCL), Energy Institute.

Your company has a sizeable number of ships operating in the container sector. The response rate to the survey has been very low from this sector and your responses will be invaluable in making my research findings more generalizable.

This survey is the first one of its kind and I would really appreciate your participation. For your participation you will receive a FREE anonymous summary results report of the operational energy efficiency measures being applied in the sector and what issues are affecting their uptake, enabling you to be better informed of the opportunities and challenges in energy efficiency.

The survey is brief and will only take about 10 minutes to complete. The information will be treated as strictly confidential and handled in accordance with the provisions of the UK Data Protection Act 1998. Data Protection Ref for this survey: Z6364106 /2011/09/43.

Please click the link below to go to the survey web site:

https://qtrial.qualtrics.com/SE/?SID=SV_6m09Afw8hc6KNms

Should you have any comments/questions, please feel free to contact me at nishatabbas.rehmatulla.09@ucl.ac.uk

I look forward to your response and thank you in advance for your time and cooperation. It is only with the generous help of industry participants like you that my research can be successful.

Sincerely,

Nishat Rehmatulla

Doctoral Researcher
UCL Energy Institute
Central House
14 Upper Woburn Place
WC1H 0NN
London, UK
+ (44) 7540051942
http://www.lowcarbonshipping.co.uk/

Further contact for item non response

Dear ……………,

I would like to humbly thank you for your participation in the survey.

Your inputs are invaluable to my PhD/research.

I looked at your response on the chartering ratio question and didn't quite get the answer, apologies if this was a confusing one. I would like to simplify it as:

- How much of your fleet is 'owned' and chartered in on 'time' or 'bareboat' basis? (Total must equal 100%)

- How much of your fleet is traded out on 'voyage', 'time', 'COA' or 'bareboat' basis? (Total must equal 100%)

I attach a draft survey report and I shall update this in the next couple of months as soon as I get statistically significant responses.

I thank you once again for your participation.

Kind regards,

Nishat

Email upon completion

Dear ………….,

I would like to humbly thank you for your participation in the survey.

Your inputs are invaluable to my PhD/research. As a respondent, the results and summary analysis report will be sent to you as soon as I gather statistically significant responses.

I thank you once again for your participation.

Kind regards,

Nishat

Survey questions

Assessing the potential of energy efficient operational measures in reducing shipping CO_2 emissions

I am Nishat Rehmatulla a PhD candidate at University College London (UCL), Energy Institute. As part of my PhD research I am conducting a survey to identify which energy efficient operational measures are currently being implemented in the shipping industry. My research is part of the UK wide 'Low Carbon Shipping – A Systems Approach' project.

I would very much appreciate it if you took ten minutes of your time to fill out the following questionnaire. The questionnaire consists of twelve questions.

To appreciate your participation in this survey I hope to share the summary results with you, which will be entirely anonymous.

Confidentiality
By completing and returning this online survey, you are giving me your consent that the personal information you provide will only be used for the purposes of this project and not transferred to an organisation outside of UCL. The information will be treated as strictly confidential and handled in accordance with the provisions of the Data Protection Act 1998.

Data Protection Ref: Z6364106 /2011/09/43

Should you have any queries or difficulties in responding please do not hesitate to contact me:
Email - nishatabbas.rehmatulla.09@ucl.ac.uk
Tel - +44 7540051942

Thank you for your participation.

0% 100%

Survey Powered By Qualtrics

>>

Figure A1: Opening page

Assessing the potential of energy efficient operational measures in reducing shipping CO_2 emissions

Which operational energy efficiency measures do you believe have the highest potential for fuel savings.

Please select FIVE from the list below.

- [ ] Weather routing
- [ ] Autopilot adjustment
- [ ] General speed reduction
- [ ] Fuel consumption monitoring
- [ ] Trim/draft optimisation
- [ ] Speed reduction due to port efficiency - Just In Time Arrivals
- [ ] Raising crew awareness & energy efficiency training
- [ ] Efficient voyage execution – voyage planning & DWT utilisation
- [ ] Optimization of ballast voyages – speed optimization & reducing ballast voyages
- [ ] Other (please specify)

0% 100%

Survey Powered By Qualtrics

<< >>

Figure A2: Question 1

Assessing the potential of energy efficient operational measures in reducing shipping CO_2 emissions

You selected the following measures have the highest fuel saving potential. Could you indicate whether you are considering/implementing them yet?

	considering and/or trialling	considered and decided against	plan to implement	already implemented	did not consider	not applicable
Weather routing	○	○	○	○	○	○
Autopilot adjustment	○	○	○	○	○	○
General speed reduction	○	○	○	○	○	○
Fuel consumption monitoring	○	○	○	○	○	○
Trim/draft optimisation	○	○	○	○	○	○

0% 100%

UCL

Survey Powered By Qualtrics

<< >>

Figure A3: Question 2

Assessing the potential of energy efficient operational measures in reducing shipping CO_2 emissions

From your response to Q1, the following measures may not have a high fuel saving potential. Could you indicate the top THREE (3) factors that make the investment unattractive?

Please select up to three responses for each measure.

	Speed reduction JIT arrivals	Raising crew awareness & training	Efficient voyage execution	Optimisation of ballast voyages
Lack of reliable information on cost & savings	☐	☐	☐	☐
Savings cannot be fully recouped from the investment	☐	☐	☐	☐
Difficult to implement under some types of charter	☐	☐	☐	☐
Lack of access to capital	☐	☐	☐	☐
Additional costs e.g. transactional, contractual	☐	☐	☐	☐
Uncertain/long payback	☐	☐	☐	☐
Not allowed due to charterparty clauses	☐	☐	☐	☐
Lack of direct control over operations	☐	☐	☐	☐
Other (Please specify)	☐	☐	☐	☐

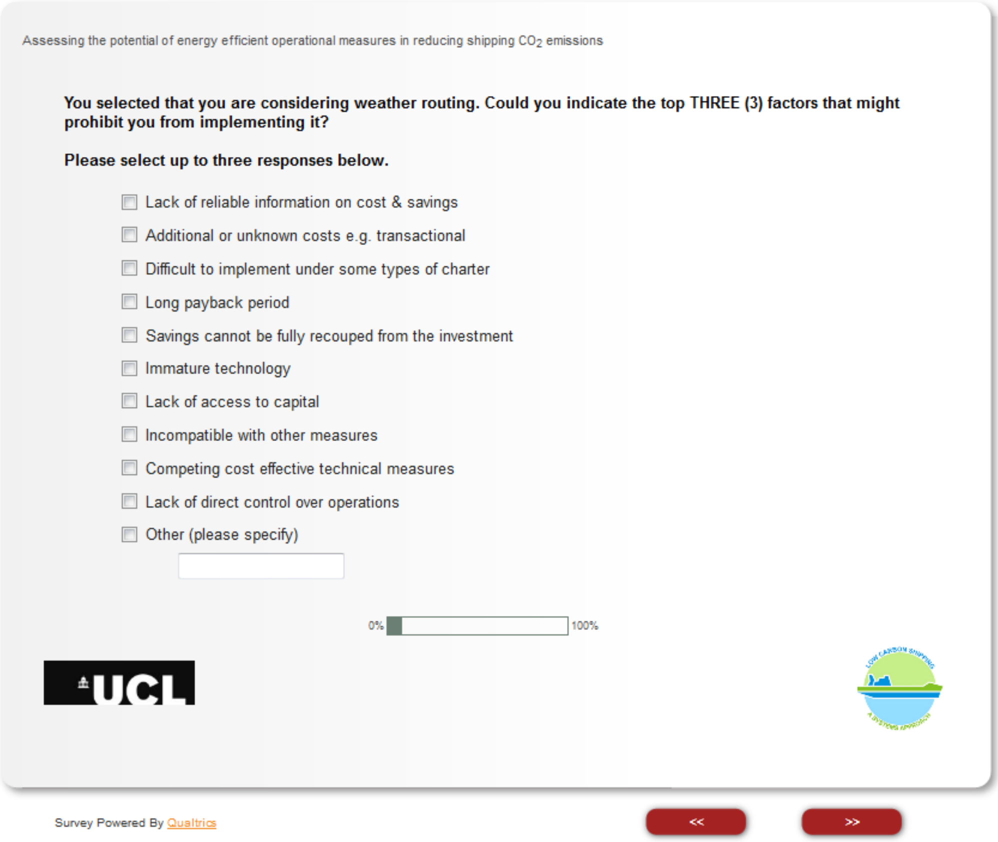
0% 100%

UCL

Survey Powered By Qualtrics

<< >>

Figure A4: Question 3


Assessing the potential of energy efficient operational measures in reducing shipping CO_2 emissions

You selected that you are considering weather routing. Could you indicate the top THREE (3) factors that might prohibit you from implementing it?

Please select up to three responses below.

- ☐ Lack of reliable information on cost & savings
- ☐ Additional or unknown costs e.g. transactional
- ☐ Difficult to implement under some types of charter
- ☐ Long payback period
- ☐ Savings cannot be fully recouped from the investment
- ☐ Immature technology
- ☐ Lack of access to capital
- ☐ Incompatible with other measures
- ☐ Competing cost effective technical measures
- ☐ Lack of direct control over operations
- ☐ Other (please specify)

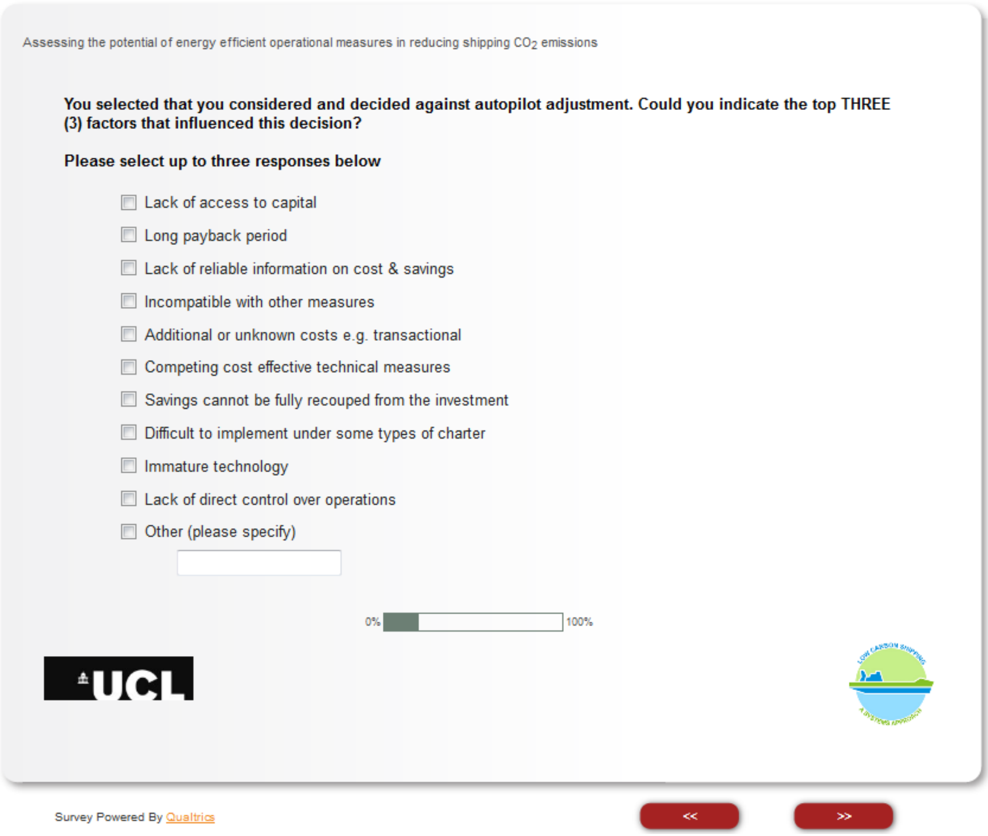
0% 100%

UCL

Survey Powered By Qualtrics

<< >>

Figure A5: An example of question 4


Assessing the potential of energy efficient operational measures in reducing shipping CO_2 emissions

You selected that you considered and decided against autopilot adjustment. Could you indicate the top THREE (3) factors that influenced this decision?

Please select up to three responses below

- ☐ Lack of access to capital
- ☐ Long payback period
- ☐ Lack of reliable information on cost & savings
- ☐ Incompatible with other measures
- ☐ Additional or unknown costs e.g. transactional
- ☐ Competing cost effective technical measures
- ☐ Savings cannot be fully recouped from the investment
- ☐ Difficult to implement under some types of charter
- ☐ Immature technology
- ☐ Lack of direct control over operations
- ☐ Other (please specify)

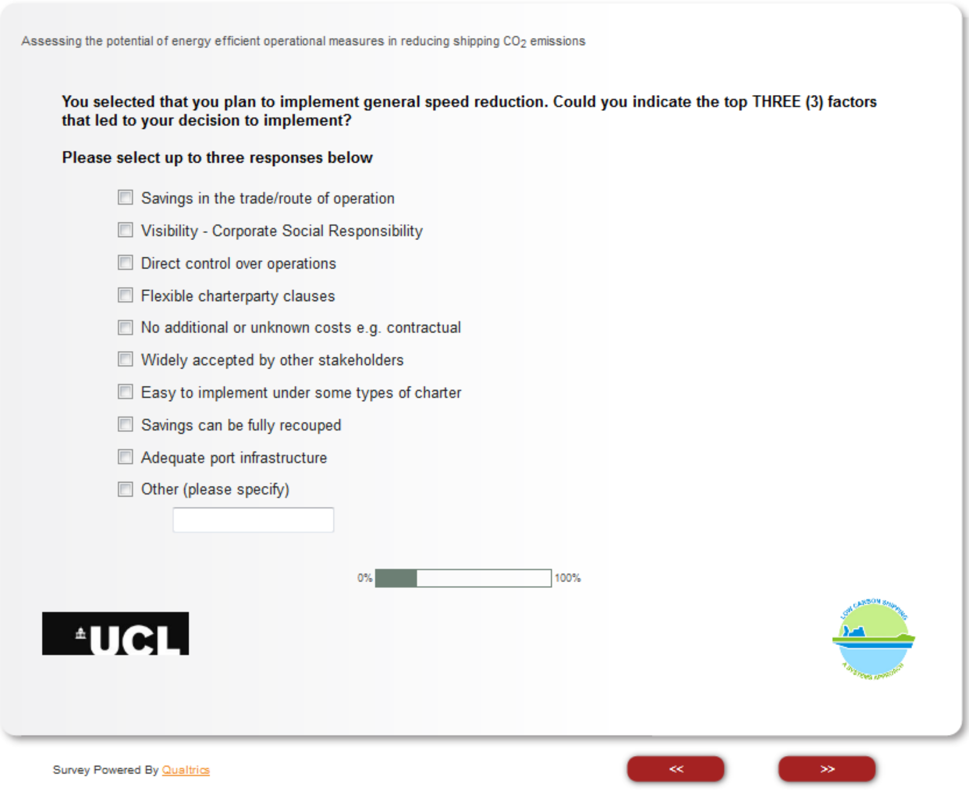
0% 100%

UCL

Survey Powered By Qualtrics

<< >>

Figure A6: An example of question 5



Assessing the potential of energy efficient operational measures in reducing shipping CO_2 emissions

You selected that you plan to implement general speed reduction. Could you indicate the top THREE (3) factors that led to your decision to implement?

Please select up to three responses below

- ☐ Savings in the trade/route of operation
- ☐ Visibility - Corporate Social Responsibility
- ☐ Direct control over operations
- ☐ Flexible charterparty clauses
- ☐ No additional or unknown costs e.g. contractual
- ☐ Widely accepted by other stakeholders
- ☐ Easy to implement under some types of charter
- ☐ Savings can be fully recouped
- ☐ Adequate port infrastructure
- ☐ Other (please specify)

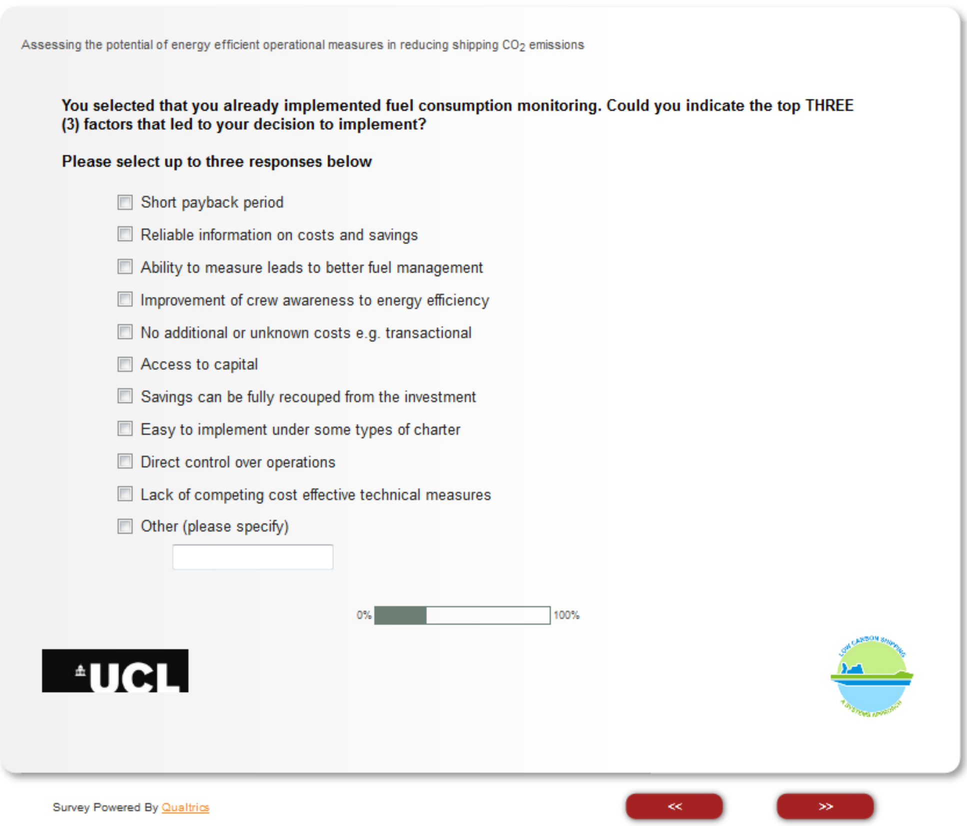
0% 100%

UCL

Survey Powered By Qualtrics

<< >>

Figure A7: An example of question 6



Assessing the potential of energy efficient operational measures in reducing shipping CO_2 emissions

You selected that you already implemented fuel consumption monitoring. Could you indicate the top THREE (3) factors that led to your decision to implement?

Please select up to three responses below

- ☐ Short payback period
- ☐ Reliable information on costs and savings
- ☐ Ability to measure leads to better fuel management
- ☐ Improvement of crew awareness to energy efficiency
- ☐ No additional or unknown costs e.g. transactional
- ☐ Access to capital
- ☐ Savings can be fully recouped from the investment
- ☐ Easy to implement under some types of charter
- ☐ Direct control over operations
- ☐ Lack of competing cost effective technical measures
- ☐ Other (please specify)

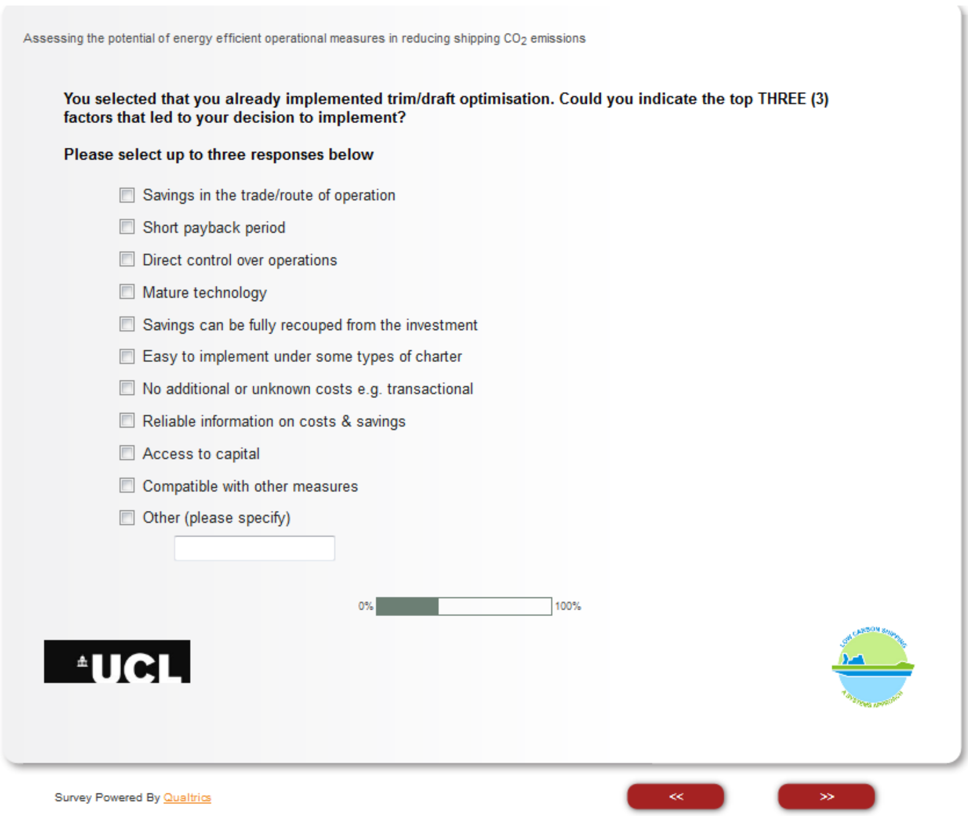
0% 100%

UCL

Survey Powered By Qualtrics

<< >>

Figure A8: An example of question 7



Assessing the potential of energy efficient operational measures in reducing shipping CO_2 emissions

You selected that you already implemented trim/draft optimisation. Could you indicate the top THREE (3) factors that led to your decision to implement?

Please select up to three responses below

- [ ] Savings in the trade/route of operation
- [ ] Short payback period
- [ ] Direct control over operations
- [ ] Mature technology
- [ ] Savings can be fully recouped from the investment
- [ ] Easy to implement under some types of charter
- [ ] No additional or unknown costs e.g. transactional
- [ ] Reliable information on costs & savings
- [ ] Access to capital
- [ ] Compatible with other measures
- [ ] Other (please specify)

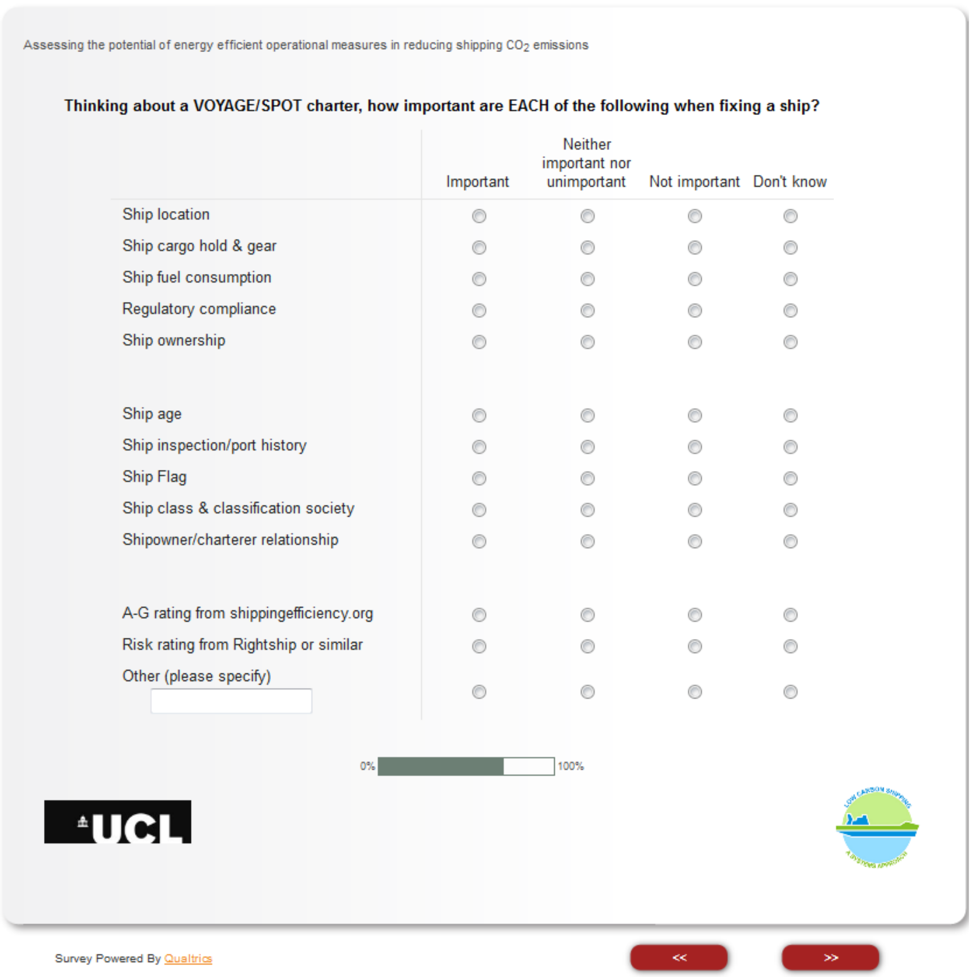
0% 100%

UCL

Survey Powered By Qualtrics

<< >>

Figure A9: An example of question 8



Assessing the potential of energy efficient operational measures in reducing shipping CO_2 emissions

Thinking about a VOYAGE/SPOT charter, how important are EACH of the following when fixing a ship?

	Important	Neither important nor unimportant	Not important	Don't know
Ship location	○	○	○	○
Ship cargo hold & gear	○	○	○	○
Ship fuel consumption	○	○	○	○
Regulatory compliance	○	○	○	○
Ship ownership	○	○	○	○
Ship age	○	○	○	○
Ship inspection/port history	○	○	○	○
Ship Flag	○	○	○	○
Ship class & classification society	○	○	○	○
Shipowner/charterer relationship	○	○	○	○
A-G rating from shippingefficiency.org	○	○	○	○
Risk rating from Rightship or similar	○	○	○	○
Other (please specify)	○	○	○	○

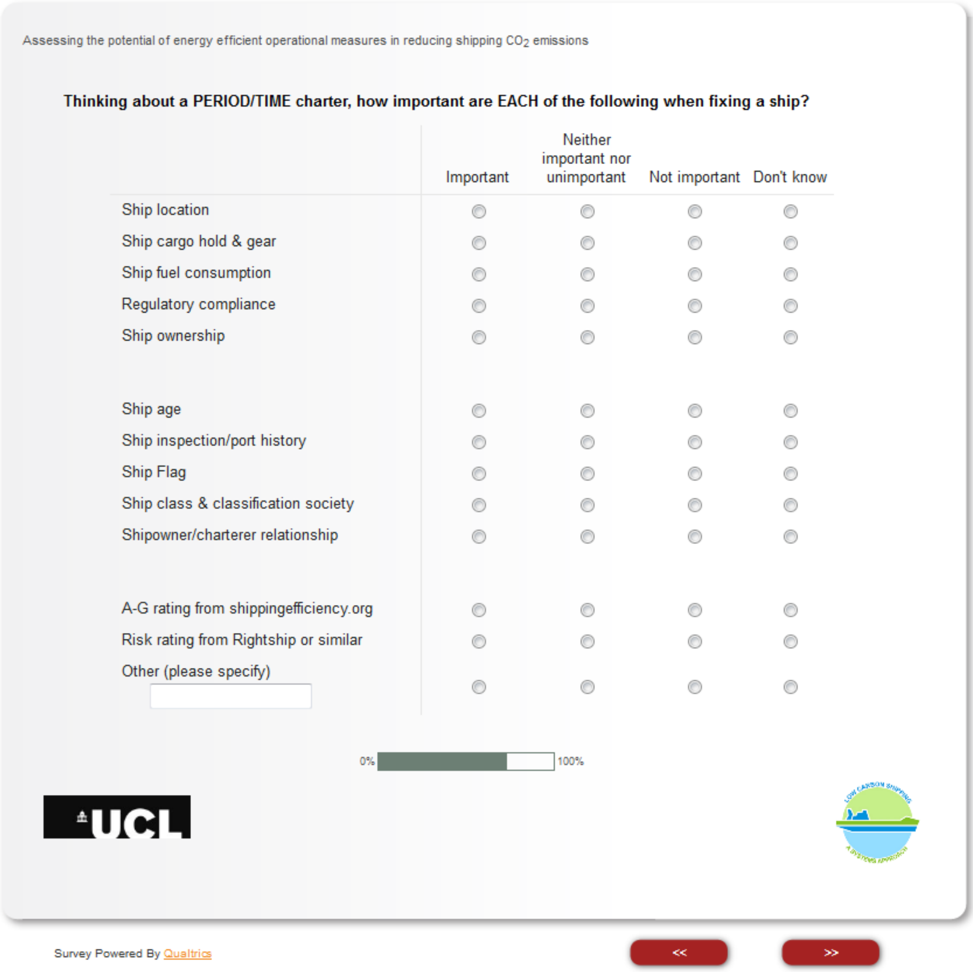
0% 100%

UCL

Survey Powered By Qualtrics

<< >>

Figure A10: Question 9



Assessing the potential of energy efficient operational measures in reducing shipping CO_2 emissions

Thinking about a PERIOD/TIME charter, how important are EACH of the following when fixing a ship?

	Important	Neither important nor unimportant	Not important	Don't know
Ship location	○	○	○	○
Ship cargo hold & gear	○	○	○	○
Ship fuel consumption	○	○	○	○
Regulatory compliance	○	○	○	○
Ship ownership	○	○	○	○
Ship age	○	○	○	○
Ship inspection/port history	○	○	○	○
Ship Flag	○	○	○	○
Ship class & classification society	○	○	○	○
Shipowner/charterer relationship	○	○	○	○
A-G rating from shippingefficiency.org	○	○	○	○
Risk rating from Rightship or similar	○	○	○	○
Other (please specify)	○	○	○	○

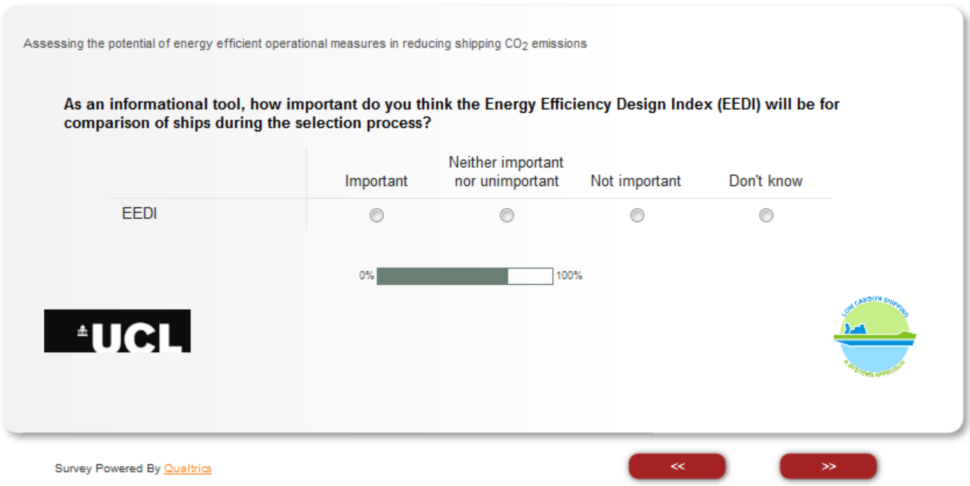
0% 100%

UCL

Survey Powered By Qualtrics

<< >>

Figure A11: Question 10



Assessing the potential of energy efficient operational measures in reducing shipping CO_2 emissions

As an informational tool, how important do you think the Energy Efficiency Design Index (EEDI) will be for comparison of ships during the selection process?

	Important	Neither important nor unimportant	Not important	Don't know
EEDI	○	○	○	○

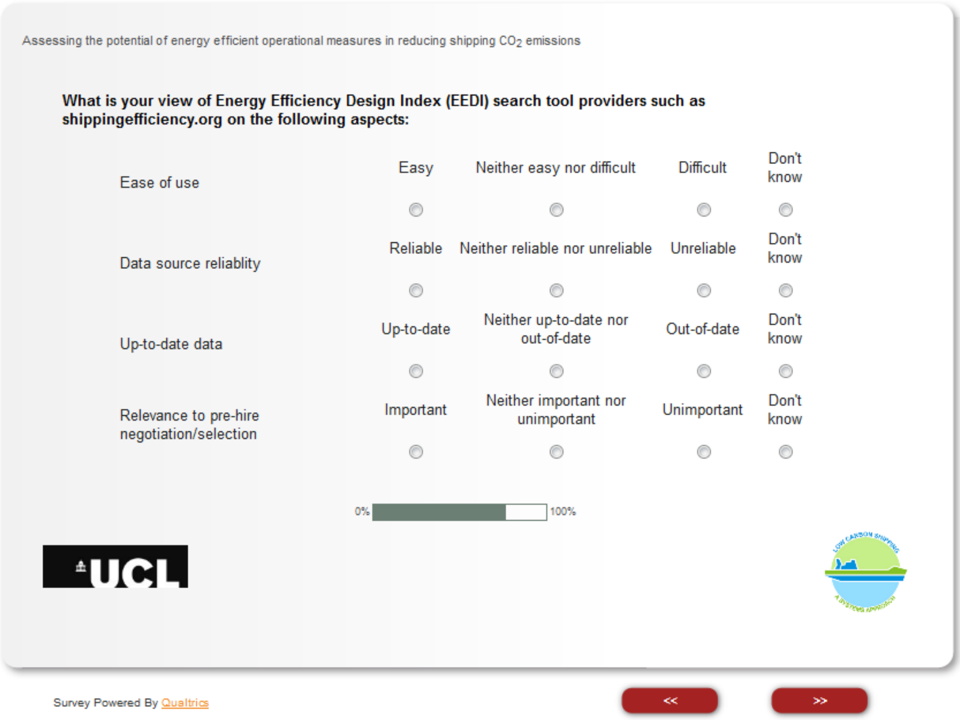
0% 100%

UCL

Survey Powered By Qualtrics

<< >>

Figure A12: Question 11



Assessing the potential of energy efficient operational measures in reducing shipping CO_2 emissions

What is your view of Energy Efficiency Design Index (EEDI) search tool providers such as shippingefficiency.org on the following aspects:

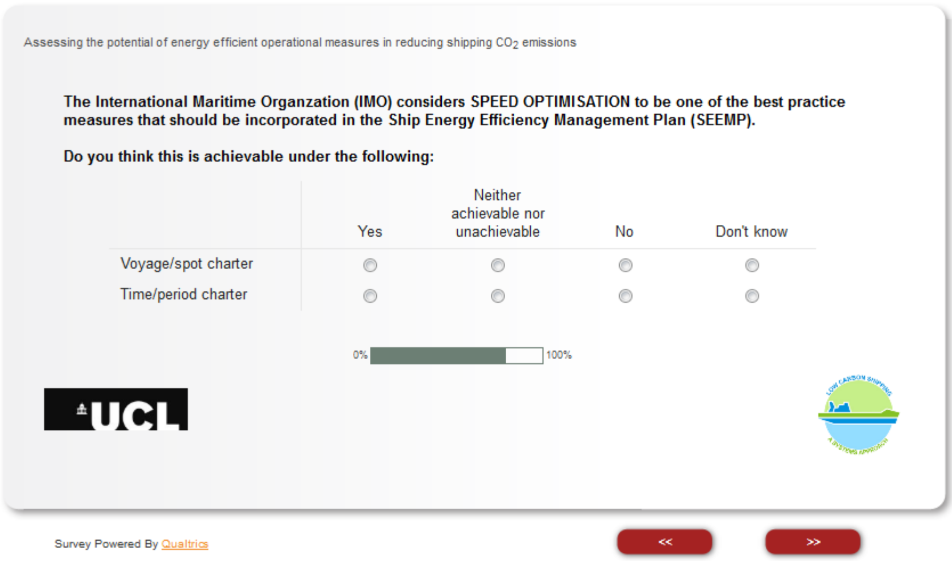
Ease of use	Easy	Neither easy nor difficult	Difficult	Don't know
Data source reliablity	Reliable	Neither reliable nor unreliable	Unreliable	Don't know
Up-to-date data	Up-to-date	Neither up-to-date nor out-of-date	Out-of-date	Don't know
Relevance to pre-hire negotiation/selection	Important	Neither important nor unimportant	Unimportant	Don't know

0% 100%

Survey Powered By Qualtrics

<< >>

Figure A13: Question 12



Assessing the potential of energy efficient operational measures in reducing shipping CO_2 emissions

The International Maritime Organzation (IMO) considers SPEED OPTIMISATION to be one of the best practice measures that should be incorporated in the Ship Energy Efficiency Management Plan (SEEMP).

Do you think this is achievable under the following:

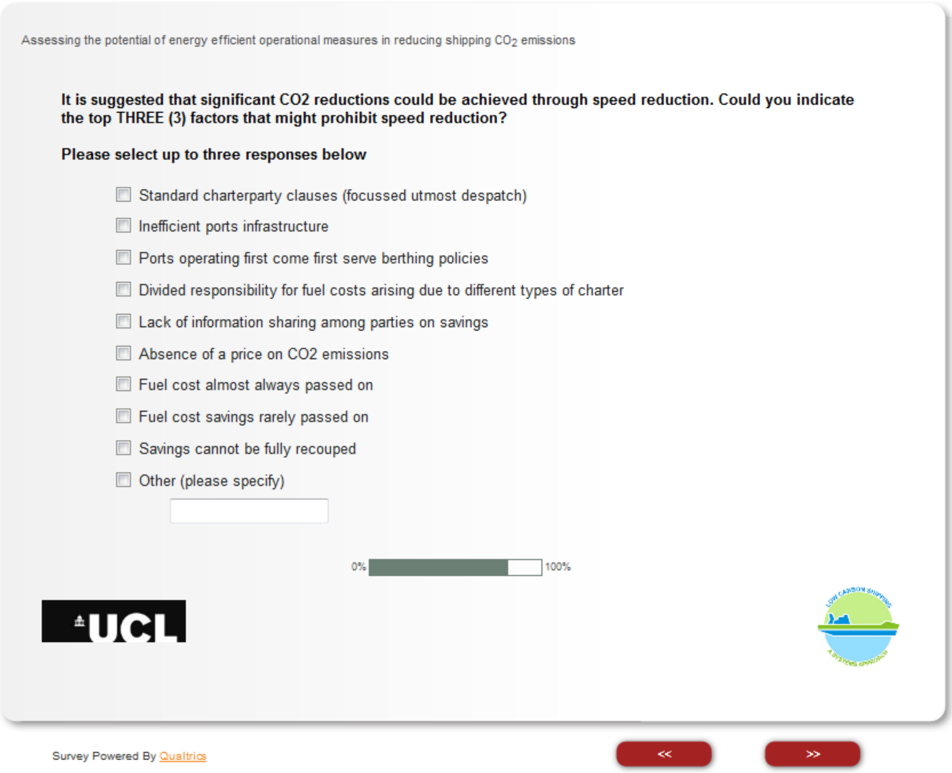
	Yes	Neither achievable nor unachievable	No	Don't know
Voyage/spot charter				
Time/period charter				

0% 100%

Survey Powered By Qualtrics

<< >>

Figure A14: Question 13



Assessing the potential of energy efficient operational measures in reducing shipping CO_2 emissions

It is suggested that significant CO2 reductions could be achieved through speed reduction. Could you indicate the top THREE (3) factors that might prohibit speed reduction?

Please select up to three responses below

- [ ] Standard charterparty clauses (focussed utmost despatch)
- [ ] Inefficient ports infrastructure
- [ ] Ports operating first come first serve berthing policies
- [ ] Divided responsibility for fuel costs arising due to different types of charter
- [ ] Lack of information sharing among parties on savings
- [ ] Absence of a price on CO2 emissions
- [ ] Fuel cost almost always passed on
- [ ] Fuel cost savings rarely passed on
- [ ] Savings cannot be fully recouped
- [ ] Other (please specify)

0% 100%

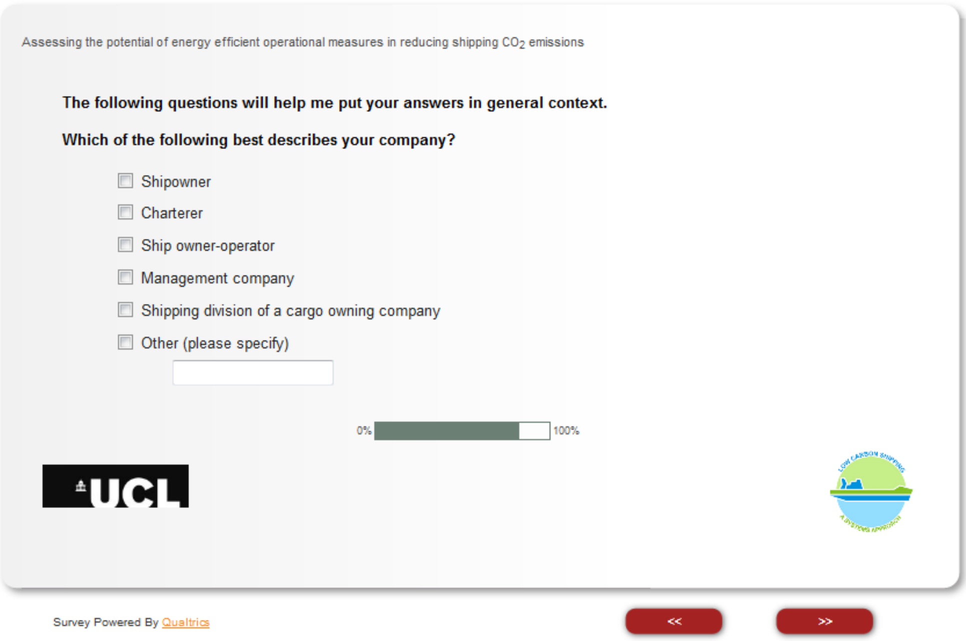
UCL

Survey Powered By Qualtrics

<< >>

Figure A15: Question 14

Respondent profiling questions



Assessing the potential of energy efficient operational measures in reducing shipping CO_2 emissions

The following questions will help me put your answers in general context.

Which of the following best describes your company?

- [ ] Shipowner
- [ ] Charterer
- [ ] Ship owner-operator
- [ ] Management company
- [ ] Shipping division of a cargo owning company
- [ ] Other (please specify)

0% 100%

UCL

Survey Powered By Qualtrics

<< >>

Figure A16: Question 15

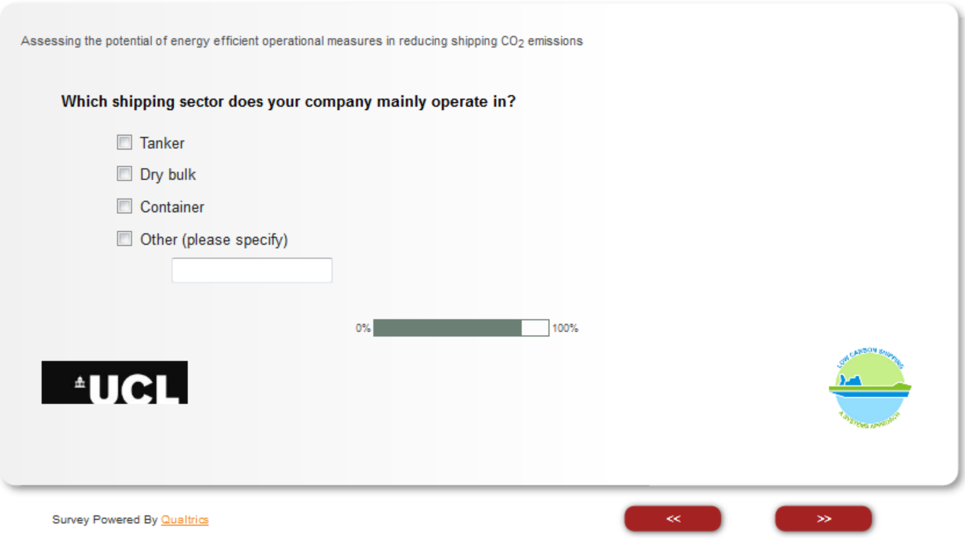


Figure A17: Question 16

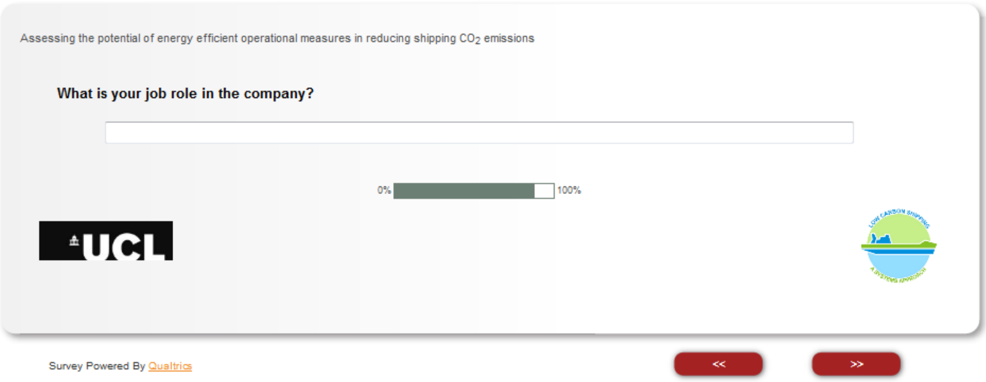


Figure A18: Question 17

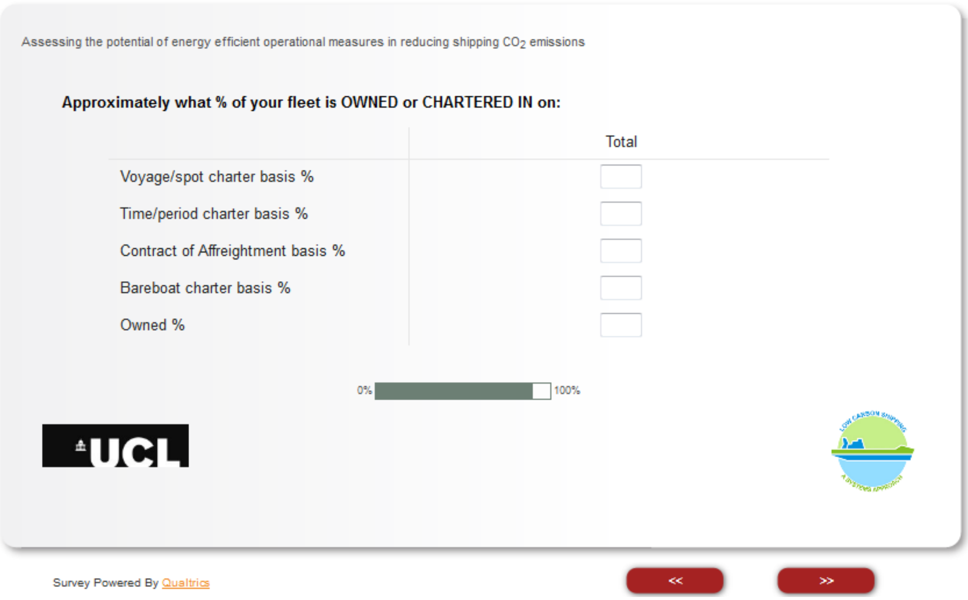
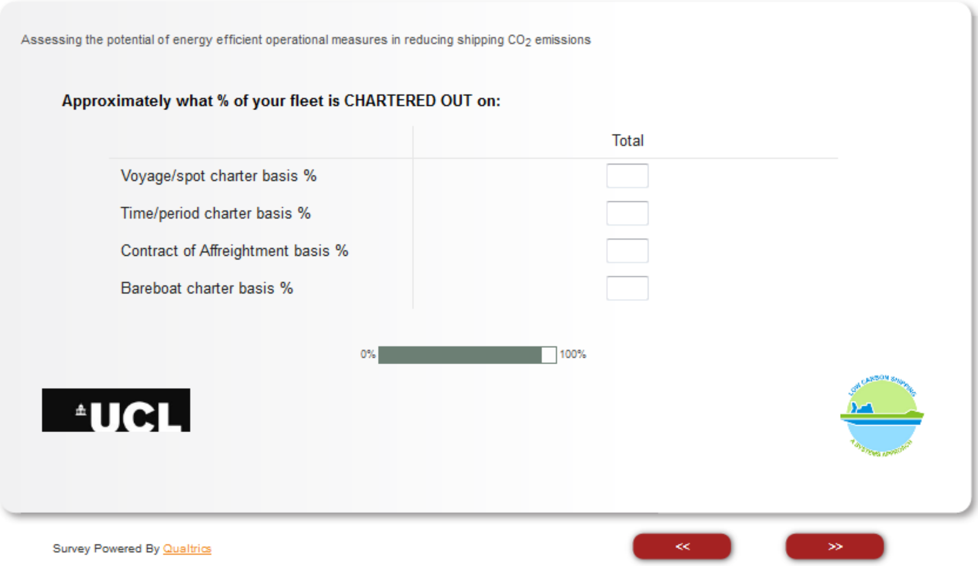


Figure A19: Question 18



Assessing the potential of energy efficient operational measures in reducing shipping CO_2 emissions

Approximately what % of your fleet is CHARTERED OUT on:

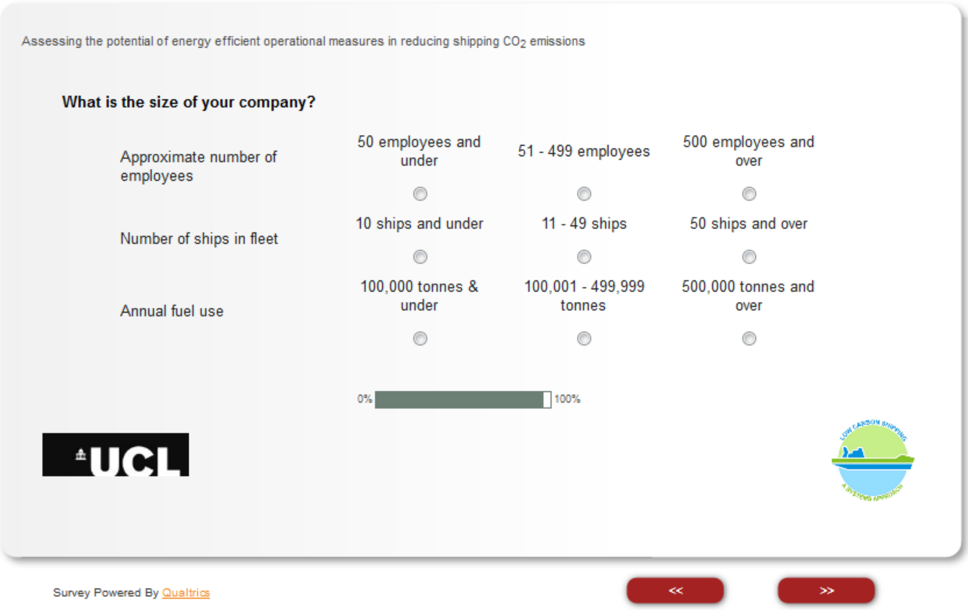
	Total
Voyage/spot charter basis %	
Time/period charter basis %	
Contract of Affreightment basis %	
Bareboat charter basis %	

0% 100%

Survey Powered By Qualtrics

<< >>

Figure A20: Question 19



Assessing the potential of energy efficient operational measures in reducing shipping CO_2 emissions

What is the size of your company?

Approximate number of employees	50 employees and under	51 - 499 employees	500 employees and over
Number of ships in fleet	10 ships and under	11 - 49 ships	50 ships and over
Annual fuel use	100,000 tonnes & under	100,001 - 499,999 tonnes	500,000 tonnes and over

0% 100%

Survey Powered By Qualtrics

<< >>

Figure A21: Question 20

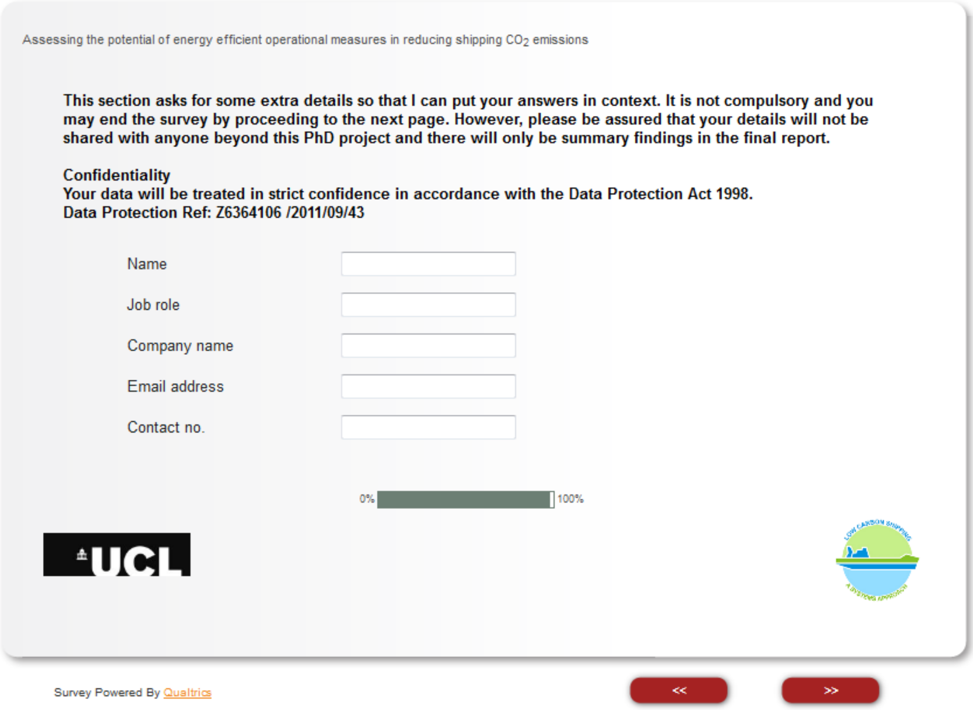


Figure A22: Question 21

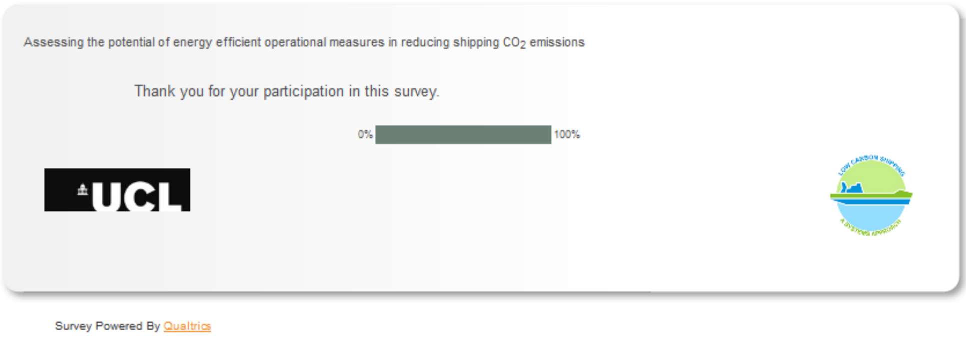


Figure A23: Closing page

Appendix B – Secondary data analysis

Analysis of principal agent problems in other operational measures

	Charterer can select weather routing measure	**Charterer cannot select weather routing measure**
Charterer pays energy bill (Direct energy payment),	No principal agent problem. Case 1 All time charters	Efficiency problem. Case 2
Charterer does not pay energy bill (indirect energy payment)	Usage and efficiency problem. Case 3 NA	Usage problem. Case 4 All voyage charters

Table B1: Weather routing and principal agent problems

	Charterer can select speed reduction measure	**Charterer cannot select speed reduction measure**
Charterer pays energy bill (Direct energy payment),	No principal agent problem. Case 1 All time charters	Efficiency problem. Case 2
Charterer does not pay energy bill (indirect energy payment)	Usage and efficiency problem. Case 3 Some voyage charters	Usage problem. Case 4 Most voyage charters

Table B2: Speed reduction and principal agent problems

	Charterer can select Just In Time arrival measure	**Charterer cannot select Just In Time arrival measure**
Charterer pays energy bill (Direct energy payment),	No principal agent problem. Case 1 All time charters	Efficiency problem. Case 2
Charterer does not pay energy bill (indirect energy payment)	Usage and efficiency problem. Case 3 Some voyage charters	Usage problem. Case 4 Most voyage charters

Table B3: Just In Time arrivals and principal agent problems

Estimating the proportion of the fleet affected by principal agent problems

	Fixtures on voyage	Fixtures on time
Wet VLCC	1698	18
Wet Suezmax	1616	15
Wet Afra	4069	20
Wet Panamax	1420	10
Wet Handy	5117	58
Total	**13920**	**121**
Dry Cape	1262	111
Dry Panamax	2653	394
Dry Handymax	1268	170
Dry Handysize	288	34
Total	**5471**	**709**
Cont Post Panamax		57
Cont Panamax		196
Cont Sub Panamax		380
Cont Handy		897
Cont Feedermax		509
Cont Feeder		12
Total		**2051**

Table B4: Number of fixtures on voyage and time charters for 2011

	Ships on Voyage	Ships on Time	Ships in fleet
Wet VLCC	450	18	
Wet Suezmax	393	14	
Wet Panamax	334	9	
Wet Afra	729	17	
Wet Handy	1171	47	
Total	**3077**	**105**	
Dry Cape	468	104	
Dry Panamax	1150	329	
Dry Handymax	800	159	
Dry Handysize	234	31	
Total	**2652**	**623**	

Table B5: Number of ships on voyage and time charters for 2011

	Ships on Voyage	Ships on Time
Wet VLCC	150	20
Wet Suezmax	127	13
Wet Afra	131	13
Wet Panamax	101	16
Wet Handy	269	49
Total	**778**	**111**
Dry Cape	110	90
Dry Panamax	184	322
Dry Handymax	53	132
Dry Handysize	10	23
Total	**357**	**567**

Table B6: Number of ships on voyage and time charters for 2011 adjusted for time.

Methodology for adjusting proportion of time chartered ships

For estimating number of ships on time charter:

A) Time charters before 2011 but long enough to fall in 2011:

1. Number of days difference between Laycan to beginning of 2011 (Days360)

2. Time charter length in days (Period*30)
3. If time charter days are long enough to fall in 2011, fixture considered (1), not considered (0)
4. If considered then how many days in 2011
5. Proportion of days in that year on TC
6. Sum of all proportions

B) Time charters during 2011:
1. Number of days difference between Laycan to end of 2011 (Days360)
2. Time charter length in days (Period*30)
3. Proportion of days in that year on TC
4. Sum of all proportions

Sum of proportions from A+B

For estimating number of ships on voyage charter:

1. Pivot table to get number of ships and number of fixtures per ship
2. Apply assumptions for each ship type E.g.

Average haul 5000 miles for oil & products (Stopford, 2009)
Average journey length at 12kn/hr = 5000/288 = 17.4 days
Ballast to loaded days ratio = 0.9. = 15.6 days
Total days = 33 days = 1.1 months per fixture

3. Number of fixtures * Days per fixture
4. Sum of all proportions

Per ship year basis	**Wetbulk**	**Drybulk**	**Container**
% of total merchant shipping CO_2 emissions	≈23%	≈18%	≈27%
% of ships on voyage charter in charter market	≈90%	≈40%	N.A
% of ships on time charter in charter market	≈10%	≈60%	100%
Average length of time charter in months	17	8	11
% of ships on fixtures less than 6 months	8%	39%	41%
% of ships on fixtures less than 1 year	32%	59%	76%
% of ships on fixtures less than 2 years	53%	84%	82%
% of ships on fixtures less than 3 years	81%	94%	87%
% of ships on fixtures less than 4 years	83%	96%	88%
% of ships on fixtures less than 5 years	94%	98%	91%
% of ships on fixtures more than 5 years	6%	2%	9%

Table B7: Summary of durations of fixtures for three main sectors (Data from Clarksons SIN)

SPSS outputs for comparison of means of cases

Group Statistics Wet VLCC

	Group	N	Mean	Std. Deviation	Std. Error Mean
DWT	Voyage	384	304686.03	9927.566	506.614
	Time	27	312275.93	27443.368	5281.479
NOE	Voyage	384	4.356589	1.1037005	.0563230
	Time	27	4.268556	.7791916	.1499555
Speed ratio	Voyage	384	.862013	.0719670	.0036725
	Time	27	.873963	.0790131	.0152061
TE	Voyage	384	2.294395	.3658314	.0186688
	Time	27	2.277951	.3405321	.0655354

Table B8: Summary statistics comparison between voyage and time chartered VLCC's

Independent Samples Test Wet VLCC

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
DWT	Equal variances assumed	12.449	.000	-3.220	409	.001	-7589.897	2357.209	-12223.654	-2956.141
	Equal variances not assumed			-1.431	26.481	.164	-7589.897	5305.721	-18486.339	3306.545
NOE	Equal variances assumed	3.036	.082	.407	409	.684	.0880334	.2162160	-.3370001	.5130668
	Equal variances not assumed			.550	33.808	.586	.0880334	.1601841	-.2375681	.4136348
ratio	Equal variances assumed	.221	.639	-.829	409	.408	-.0119493	.0144219	-.0402996	.0164011
	Equal variances not assumed			-.764	29.115	.451	-.0119493	.0156433	-.0439379	.0200394
TE	Equal variances assumed	.001	.972	.227	409	.821	.0164440	.0725276	-.1261294	.1590174
	Equal variances not assumed			.241	30.377	.811	.0164440	.0681426	-.1226493	.1555374

Table B9: Comparison of means analysis between voyage and time chartered VLCC's

Group Statistics Wet Suez

	Group	N	Mean	Std. Deviation	Std. Error Mean
DWT	Voyage	269	155812.62	6641.177	404.920
	Time	15	157606.40	6099.680	1574.931
NOE	Voyage	269	6.367521	1.1954972	.0728908
	Time	15	6.239600	1.1435330	.2952590
speed ratio	Voyage	269	.846130	.0626054	.0038171
	Time	15	.849202	.0612269	.0158087
TE	Voyage	269	3.339458	.4341512	.0264707
	Time	15	3.276887	.2665038	.0688110

Table B10: Summary statistics comparison between voyage and time chartered Suezmax's

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
DWT	Equal variances assumed	.073	.787	-1.022	282	.308	-1793.775	1755.050	-5248.437	1660.886
	Equal variances not assumed			-1.103	15.908	.286	-1793.775	1626.151	-5242.675	1655.124
NOE	Equal variances assumed	.152	.697	.404	282	.686	.1279208	.3164953	-.4950722	.7509139
	Equal variances not assumed			.421	15.755	.680	.1279208	.3041232	-.5176059	.7734476
speed ratio	Equal variances assumed	.060	.806	-.185	282	.853	-.0030722	.0165913	-.0357306	.0295862
	Equal variances not assumed			-.189	15.677	.853	-.0030722	.0162630	-.0376060	.0314616
TE	Equal variances assumed	.240	.625	.552	282	.581	.0625712	.1133846	-.1606164	.2857588
	Equal variances not assumed			.849	18.429	.407	.0625712	.0737268	-.0920651	.2172074

Table B11: Comparison of means analysis between voyage and time chartered Suezmax's

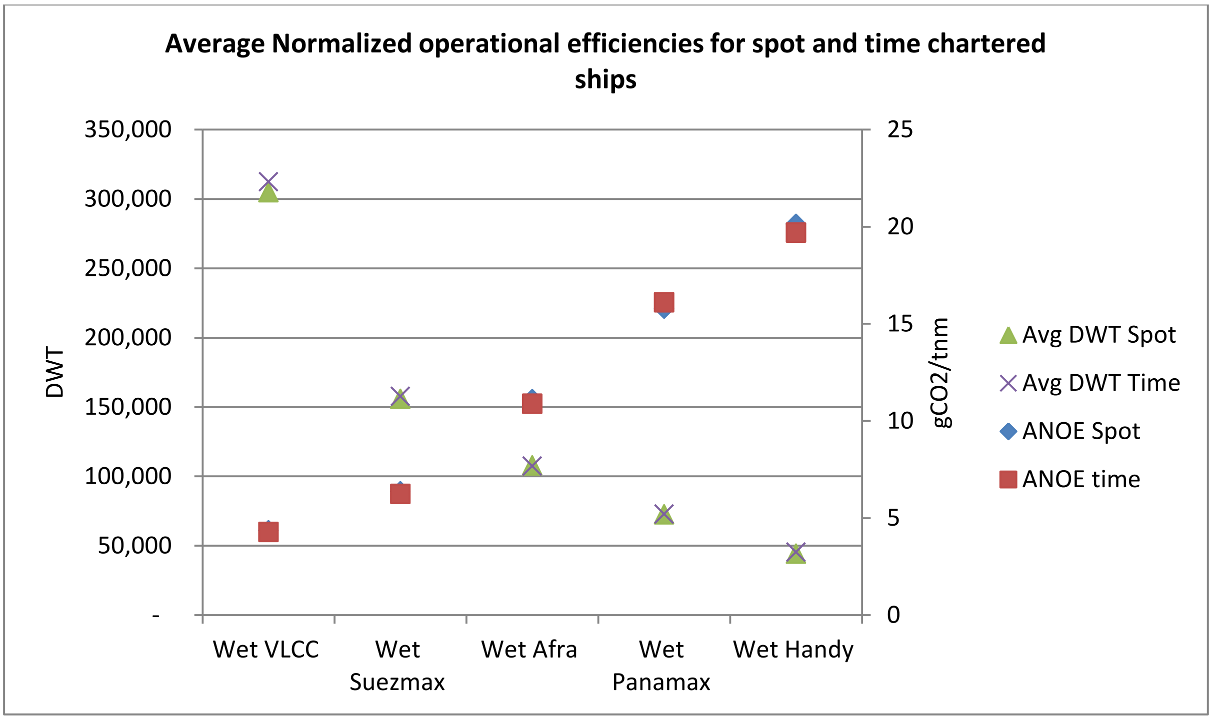


Figure B1: Comparison of Average Normalized operational efficiencies for voyage and time chartered ships

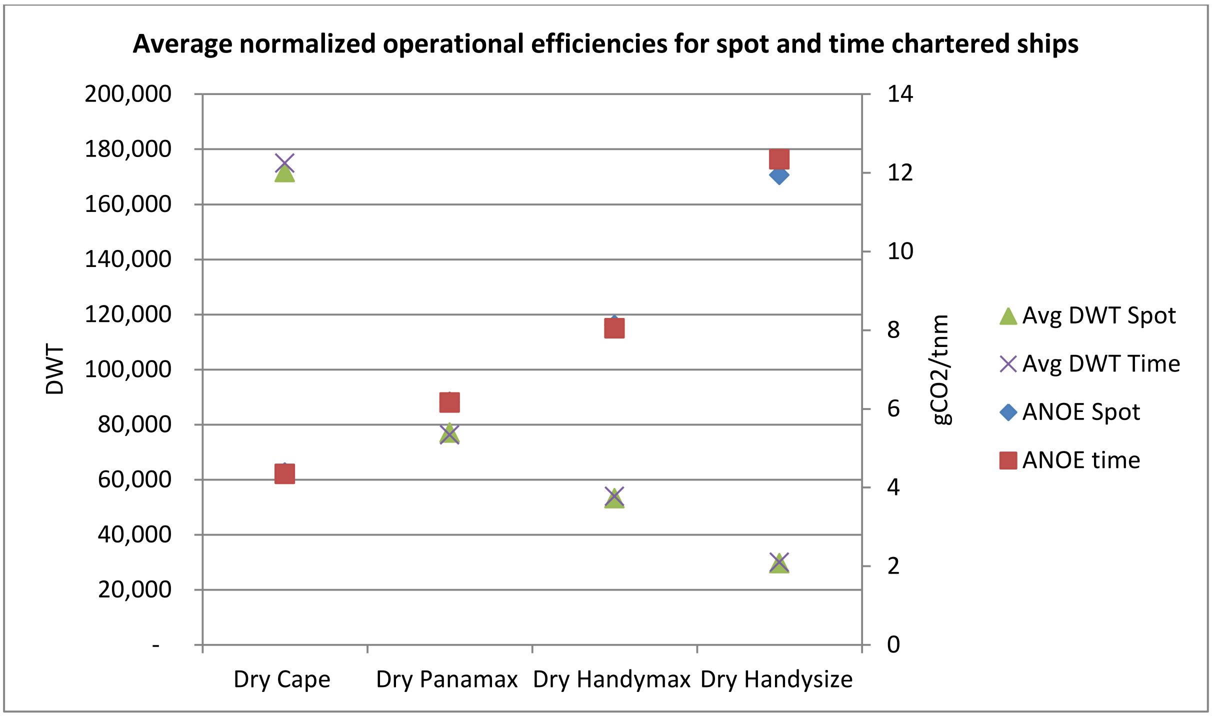


Figure B2: Average normalized operational efficiencies for voyage and time chartered ship

Subletting analysis

One of the key assumptions of the analysis in step two and step three is regarding the level of sub chartering that can take place in charters. For the analysis in step two and three, it was assumed that a ship remains in the state of the same charter throughout the period of fixture or charterparty. However, it is often suggested that a ship on time charter (or case two) may not remain solely under that charter. This is thought to be the case because charterparties allow for subletting the vessel. Brief review of the charterparties shows that subletting clauses not only are present in time charterparties, but are also present in voyage charterparties (e.g. Orevoy, Asbatankvoy) and can even include the same type of charter i.e. time head charterparty and time sublet charterparty. Thus subletting can occur in a variety of situations, however the subletting scenario that can affect the above results is when a ship on time charter is sublet under a voyage charter. When ships on time charter are filtered for subletting (based on the following method), the number of ships on time charter decreases to very low levels for any meaningful comparison.

The main assumptions for this analysis are:

- The fixture/charter period is assumed to be the maximum of the range given in the fixture reporting, the range difference is on average around two to three months and this type of reporting is mainly prevalent in dry bulk fixtures, e.g. six to nine months is assumed to be nine months.
- For fixtures where there are options for subsequent charters, the minimum option period is assumed, which is prevalent mainly in the wetbulk sector e.g. 1yr/6m/6m is assumed to be only one year.
- For the wetbulk sector the analysis excludes vessels chartered for storage purposes.
- The analysis only takes into account the recorded fixtures and calculates the estimated end date based on the length of charter added to the laycan date (when this is not available the contract date is used), thus does not take into account early redelivery of the vessel.
- Clarksons fixtures data is not comprehensive as “fixtures are provided only as reported” (Clarksons SIN website).
- Fixtures for the year 2011 are obtained for voyage charters and for time charters fixtures for 2009, 2010 and 2011 are used to check if any fixtures are still valid in 2011 as shown in Table 5.25.

A ship is said to be sublet when the laycan date (or contract date) for a single voyage charter or multiple voyage charters fall between the time charter beginning and end dates. The following plots show the level of subletting in each of the ship types and sectors followed by figure of mean results. As can be seen from the histograms in appendix B and figures B3 and B4, the level of subletting is higher in wetbulk sector than drybulk sector and higher for larger ships than smaller ship sizes. Furthermore, the correlation of subletting with the length of time charter (Table B12) shows that there is strong relationship between the number of times a ship is sublet and the length of the time charter. Figure 5.31 also shows the 95% confidence level (+/- 2 standard error of the mean) number of sublets per ship type. Due to the smaller sample sizes in wetbulk sector, the population mean range varies significantly, whereas for the drybulk sector, the sample means can be estimated to be very close to the population mean. These findings suggest that the number of ships that fall into case one and two (as shown in Table 5.21 and Table 5.23) in step two of the above methodology can be said to be high level estimates, since some of those ships are further sublet into voyage charters, changing the categorisation from case two to case four. So for example for the wetbulk sector, the 10% estimate of the charter fleet categorised as case two for technology and case one for operations may not be as high, because as shown in this analysis a ship in wetbulk sector on time charter would be sublet on average at least once in the time charter period or a majority of the fleet would be sublet once or more. In the drybulk sector, the 60% estimate of the charter fleet categorised as falling in case two for technology and case one for operations would remain as a high estimate but not decrease substantially compared to wetbulk because the average level of subletting is much lower or the majority of the fleet is not sublet. It can however also be said that the level of subletting (from time charter to voyage charter) may not really change the categorisation of ships because the entity paying for fuel in the end remains the same, i.e. a charterer in a head time charter who is the principal in the original contract (even though acting as agent for the sub-charterer/principal).

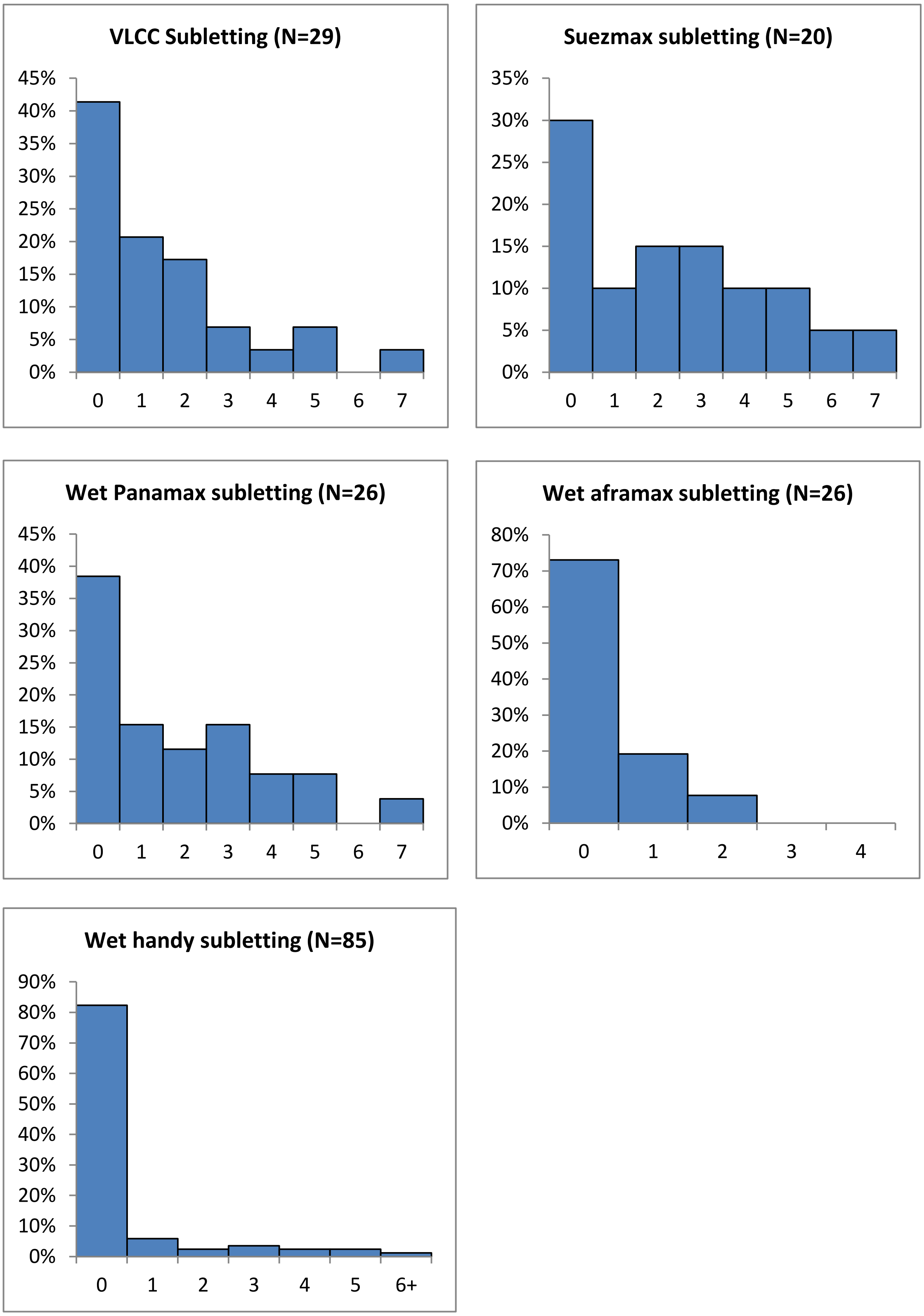


Figure B3: Distributions of number of subletting in wetbulk sectors

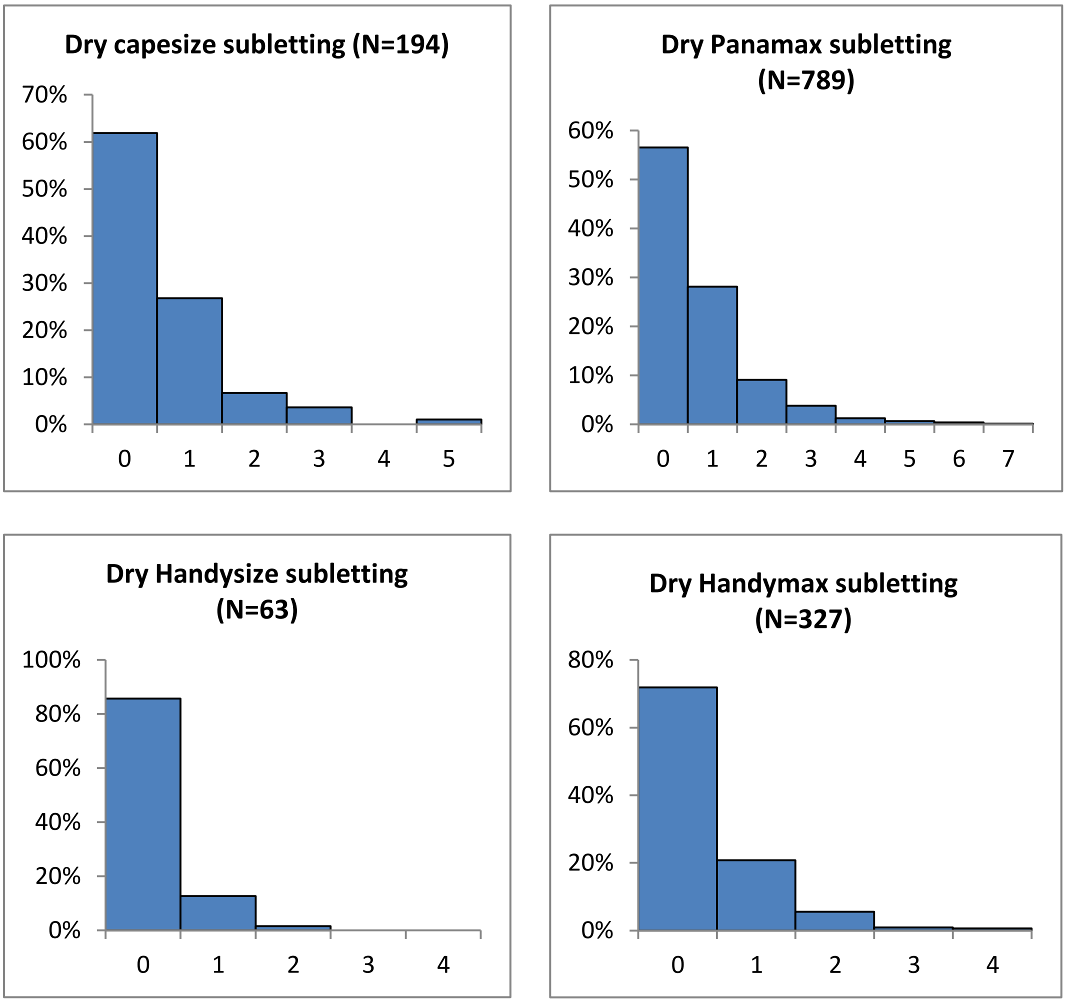


Figure B4: Distributions of number of subletting in wetbulk sectors

	Mean no. of sublets per TC	Mean duration of head TC in months	Correlation
Wet VLCC	1.48	17.66	
Wet Suez	2.4	18.7	
Wet Afra	0.35	14.44	
Wet Panamax	1.80	15.92	
Wet Handy	0.58	16	0.82
Dry Cape	0.56	10	
Dry Panamax	0.69	8.86	
Dry Handymax	0.39	7.67	
Dry Handysize	0.16	7.14	0.80

Table B12: Relationship between number of subletting and average length of time charter

Appendix C – Survey data and analysis

Grouping A

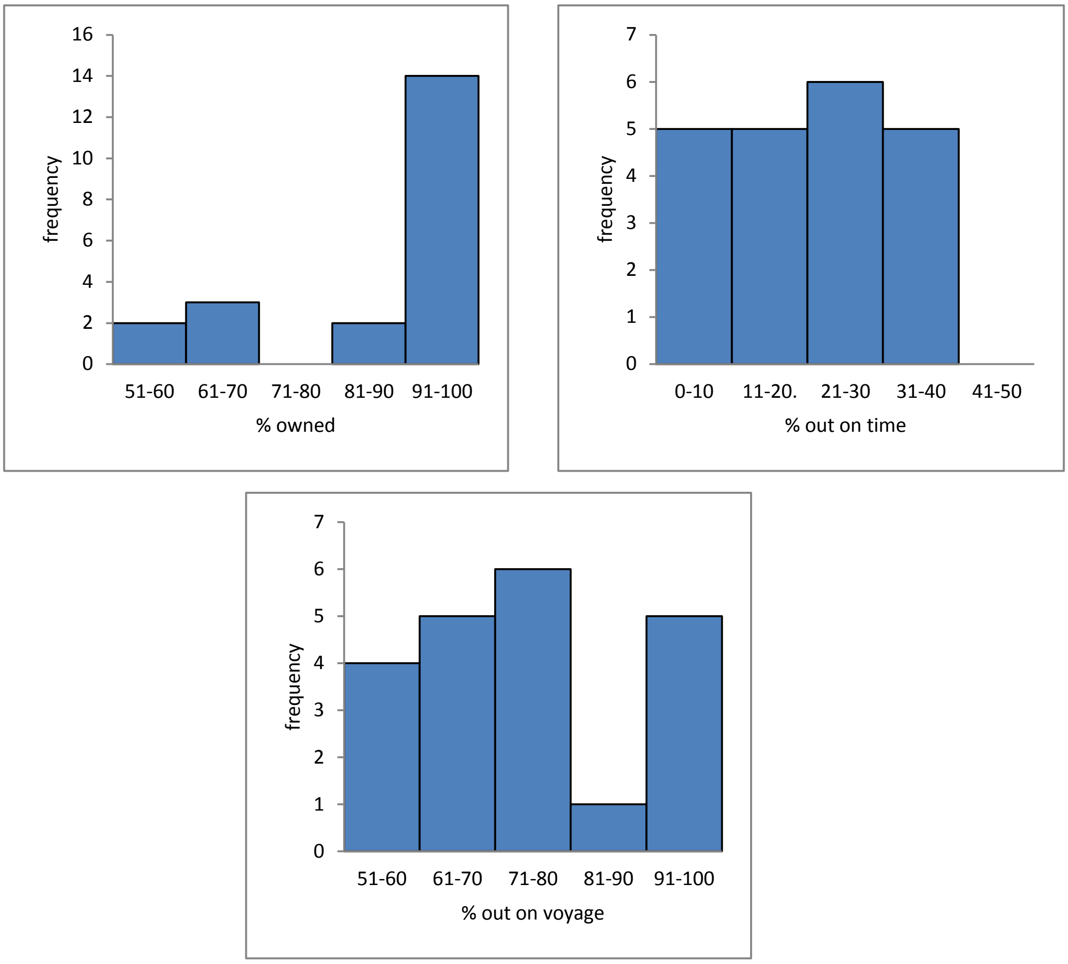


Figure C1: Distributions of group 1: Majority of the fleet is owned and voyage chartered out

Voyage Out	
Mean	77.71429
Standard Error	3.083862
Median	75
Mode	100
Standard Deviation	14.13203
Sample Variance	199.7143
Kurtosis	-0.95057
Skewness	0.458146
Range	40
Minimum	60
Maximum	100
Count	21

Time Out	
Mean	22.28571
Standard Error	3.083862
Median	25
Mode	0
Standard Deviation	14.13203
Sample Variance	199.7143
Kurtosis	-0.95057
Skewness	-0.45815
Range	40
Minimum	0
Maximum	40
Count	21

Table C1: Summary statistics of group 1: Majority of the fleet is owned and voyage chartered out

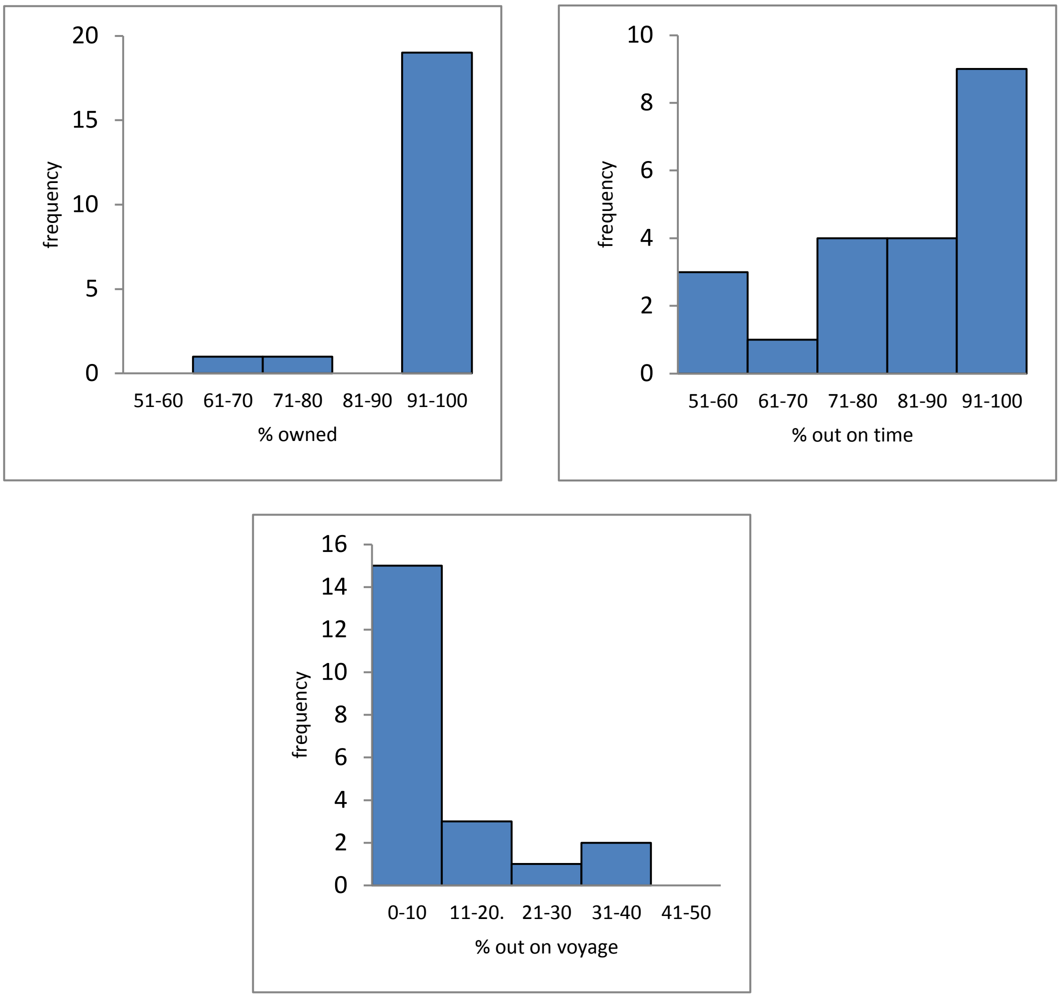
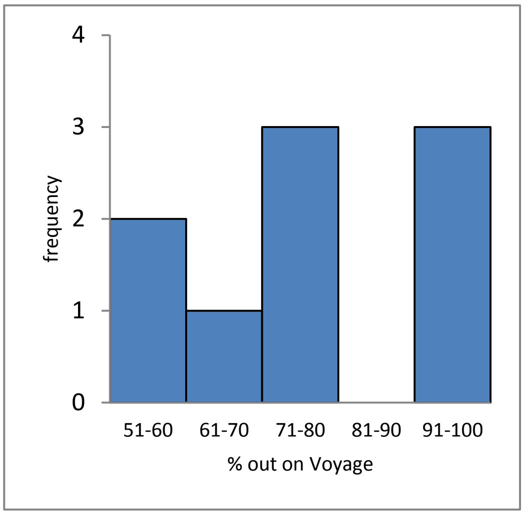


Figure C2: Distributions of group 2: Majority of the fleet is owned and time chartered out

Time Out	
Mean	85.14286
Standard Error	3.058389
Median	90
Mode	100
Standard Deviation	14.0153
Sample Variance	196.4286
Kurtosis	-0.78393
Skewness	-0.66377
Range	40
Minimum	60
Maximum	100
Count	21

Voyage Out	
Mean	10.2381
Standard Error	2.813153
Median	5
Mode	0
Standard Deviation	12.89149
Sample Variance	166.1905
Kurtosis	0.969684
Skewness	1.37357
Range	40
Minimum	0
Maximum	40
Count	21

Table C2: Summary statistics of group 2: Majority of the fleet is owned and time chartered out



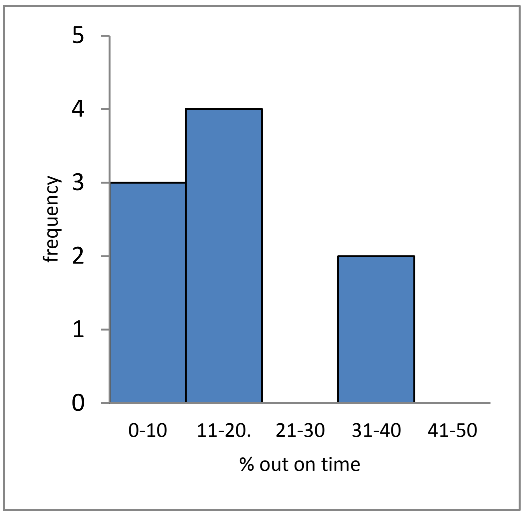
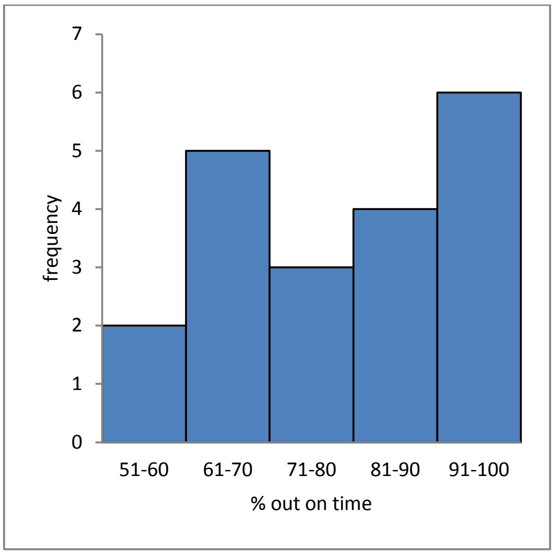


Figure C3: Distributions of group 3: Management company with majority fleet voyage chartered out

Voyage Out	
Mean	80.11111
Standard Error	5.297915
Median	80
Mode	80
Standard Deviation	15.89374
Sample Variance	252.6111
Kurtosis	-1.51177
Skewness	-0.00171
Range	40
Minimum	60
Maximum	100
Count	9

Time Out	
Mean	17.55556
Standard Error	4.625146
Median	20
Mode	20
Standard Deviation	13.87544
Sample Variance	192.5278
Kurtosis	-0.77307
Skewness	0.135267
Range	40
Minimum	0
Maximum	40
Count	9

Table C3: Summary statistics of group 3: Management company with majority fleet voyage chartered out



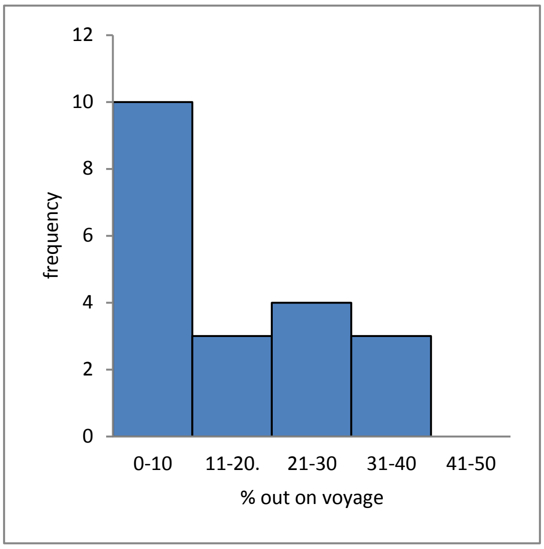


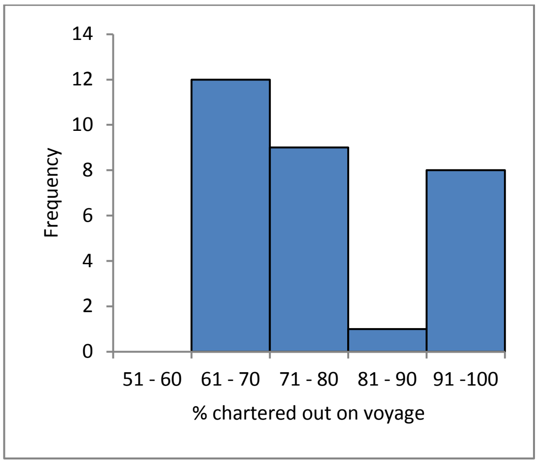
Figure C4: Distributions of group 4: Management company with majority fleet time chartered out

Time Out	
Mean	82.3
Standard Error	3.280805
Median	85
Mode	100
Standard Deviation	14.67221
Sample Variance	215.2737
Kurtosis	-1.57518
Skewness	-0.1196
Range	40
Minimum	60
Maximum	100
Count	20

Voyage Out	
Mean	16.55
Standard Error	3.045683
Median	15
Mode	0
Standard Deviation	13.62071
Sample Variance	185.5237
Kurtosis	-1.48144
Skewness	0.14634
Range	40
Minimum	0
Maximum	40
Count	20

Table C4: Summary statistics of group 4: Management company with majority fleet time chartered out

Grouping B



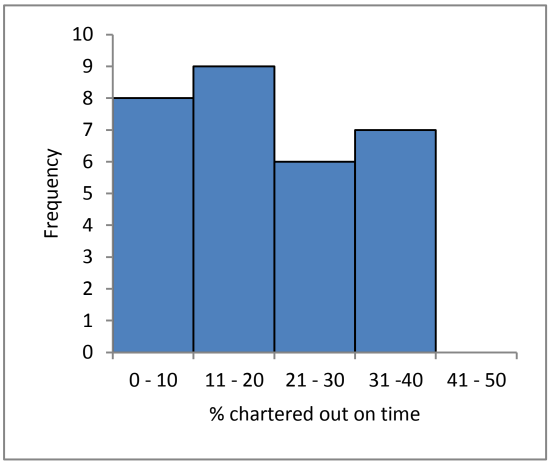
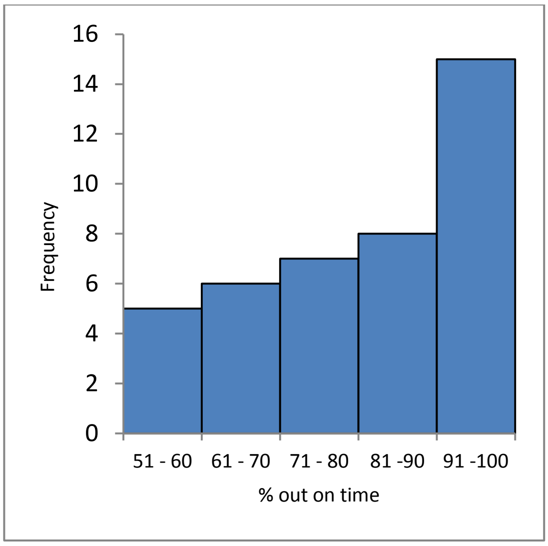


Figure C5: Distributions of group 1: Majority of the fleet chartered out on voyage charter

Voyage out	
Mean	78.43333
Standard Error	2.637346
Median	80
Mode	80
Standard Deviation	14.44534
Sample Variance	208.6678
Kurtosis	-1.17593
Skewness	0.305759
Range	40
Minimum	60
Maximum	100
Count	30

Time out	
Mean	20.86667
Standard Error	2.554119
Median	20
Mode	20
Standard Deviation	13.98949
Sample Variance	195.7057
Kurtosis	-1.09517
Skewness	-0.266
Range	40
Minimum	0
Maximum	40
Count	30

Table C5: Summary statistics of group 1: Majority of the fleet voyage chartered out



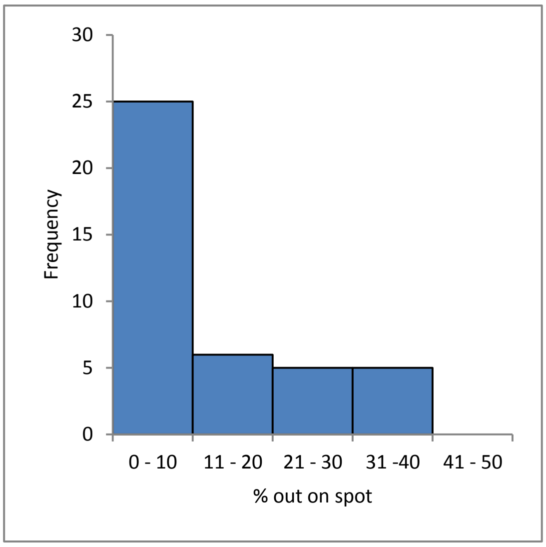


Figure C6: Distributions of group 2: Majority of the fleet time chartered out

Time out	
Mean	83.7561
Standard Error	2.222606
Median	90
Mode	100
Standard Deviation	14.23162
Sample Variance	202.539
Kurtosis	-1.27861
Skewness	-0.37434
Range	40
Minimum	60
Maximum	100
Count	41

Voyage out	
Mean	13.31707
Standard Error	2.103551
Median	10
Mode	0
Standard Deviation	13.4693
Sample Variance	181.422
Kurtosis	-0.89844
Skewness	0.678908
Range	40
Minimum	0
Maximum	40
Count	41

Table C6: Summary statistics of group 2: Majority of the fleet time chartered out

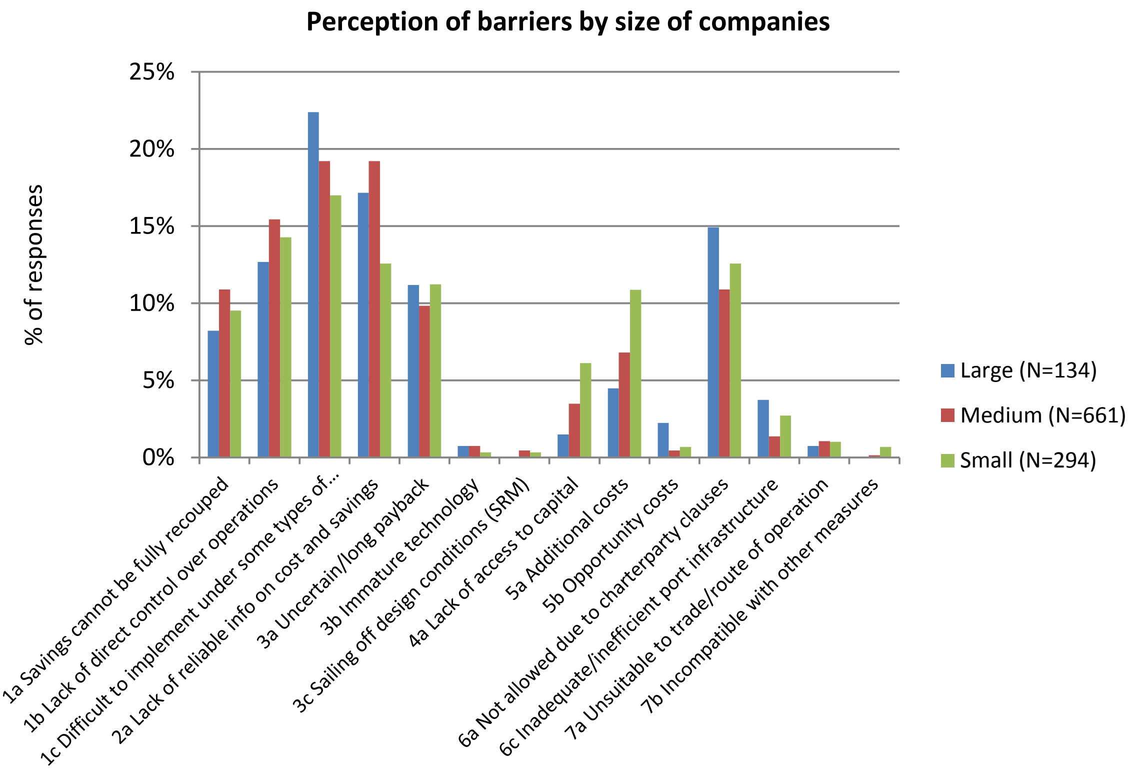


Figure C7: Perception of barriers cited by respondents across the survey disaggregated by size

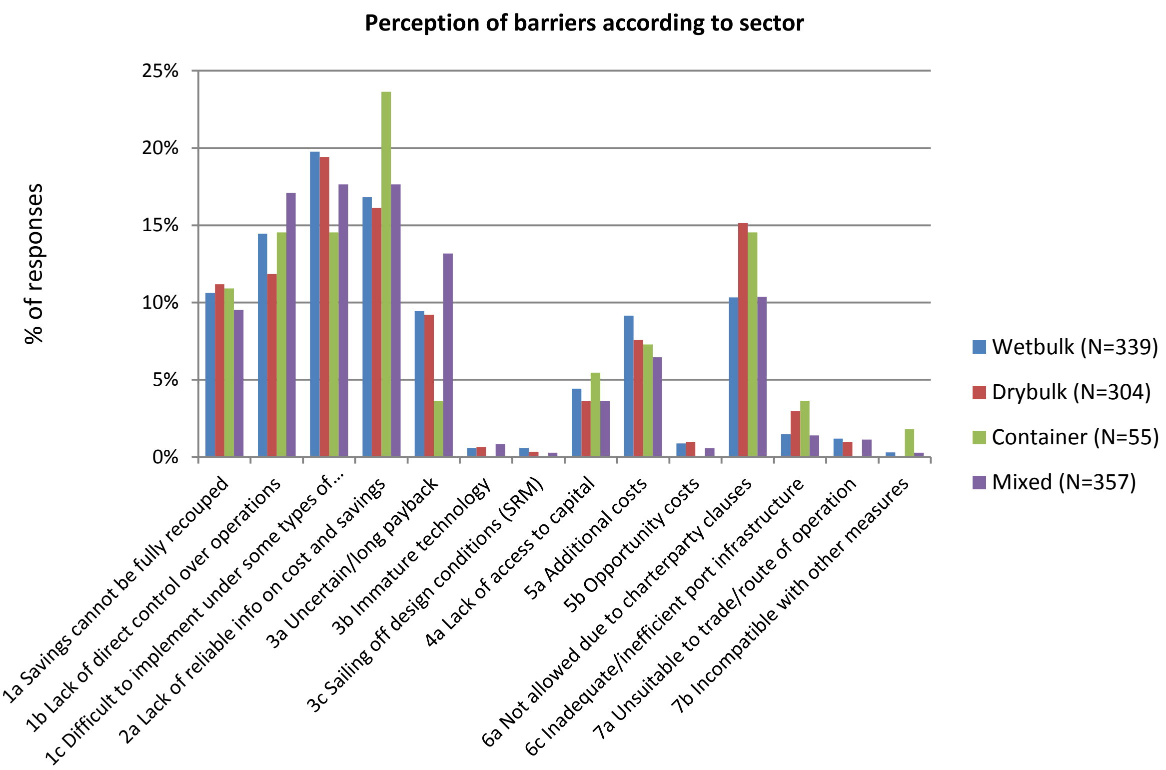


Figure C8: Perception of barriers cited by respondents across the survey disaggregated by sector

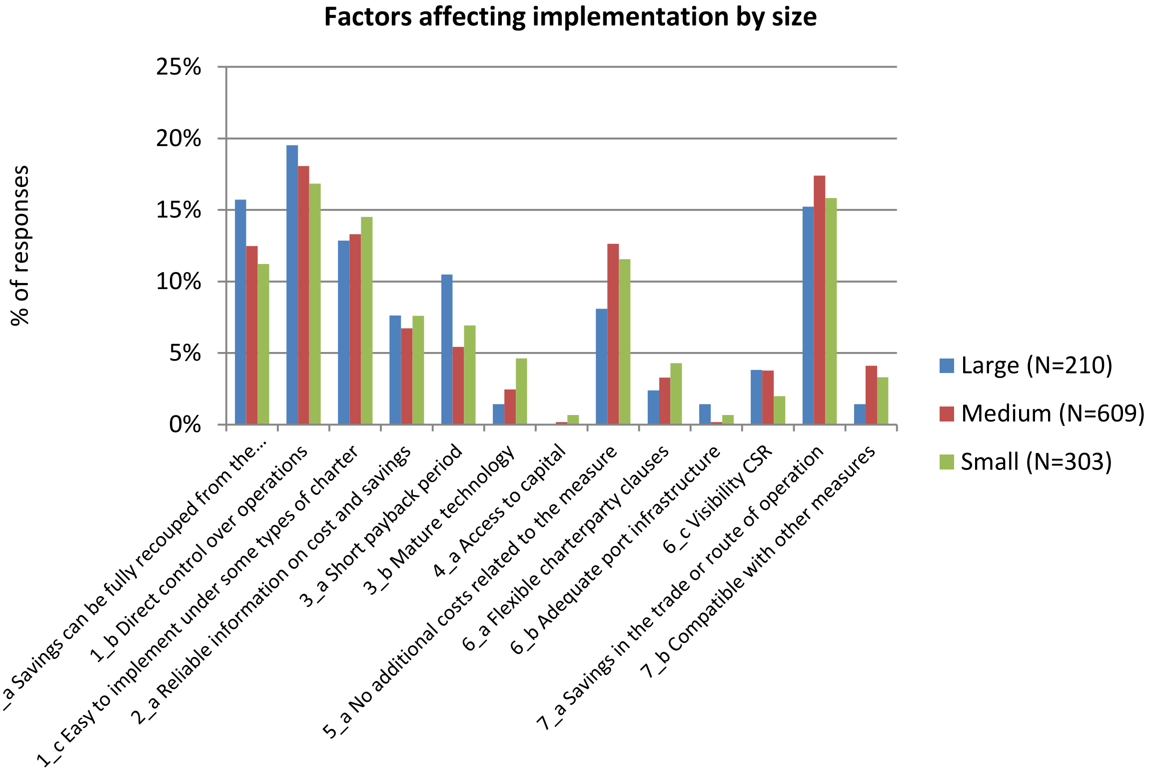


Figure C9: Factors affecting implementation by size

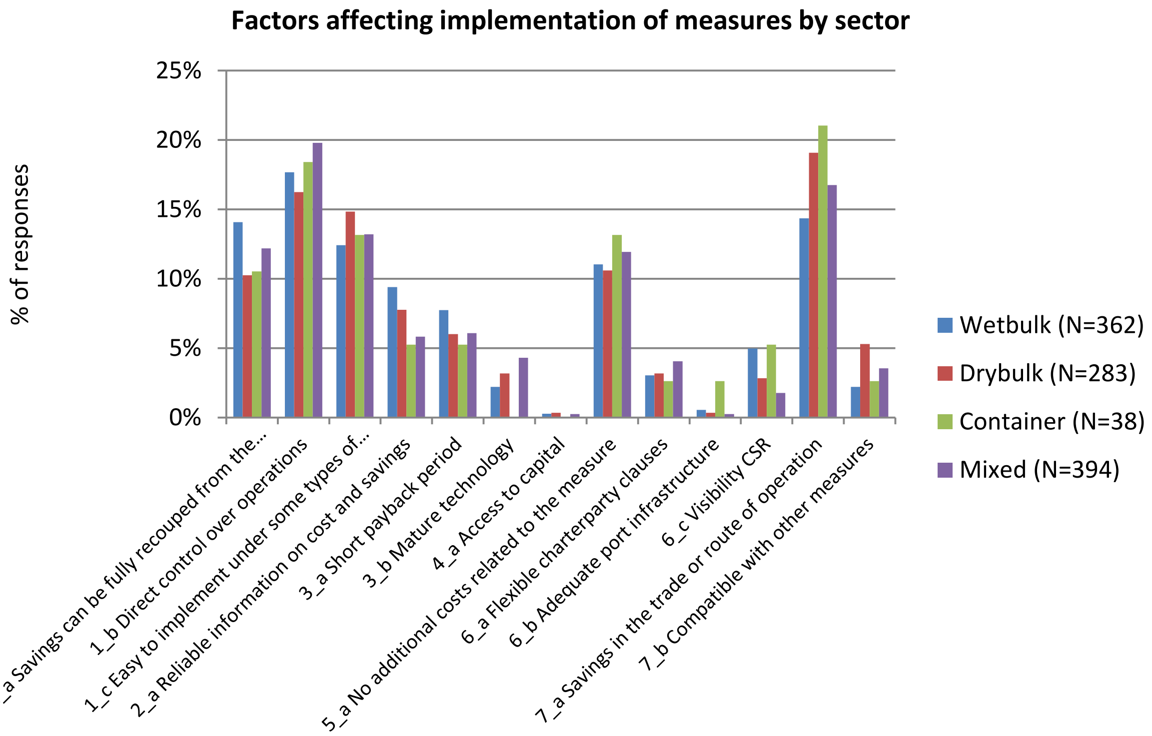


Figure C10: Factors affecting implementation of measures by sector

Appendix D – Charterparty content analysis

Voyage charterparty coding

Speed reduction measures

Coding category and questions	Definition	Example	Coding rule
Goal conflict Q: How does the outcome based contract address the principal agent speed goal conflict? Q: How does the goal conflict affect speed reduction measure implementation?	Conflicting interests between the charterer (principal) and shipowner (agent), which means use of: -Utmost despatch clauses in both voyage legs	"The said vessel being suitable for mechanical loading and grab discharge, shall with all convenient speed sail and proceed to the loading port. ...Being so loaded the vessel shall therewith proceed with all convenient speed to the discharging ports"	VSG1 = utmost despatch in ballast leg (load port) AND laden leg (discharge port)
	Conflicting interests between the charterer (principal) and shipowner (agent), which means use of: -Utmost despatch clauses only in laden leg	"The vessel shall proceed with due despatch to a safe port, berth, dock.... For loading the cargo, as ordered by charterers... And being so loaded proceed as ordered on signing of B/L ... As ordered by charterers"	VSG2 = utmost despatch in only laden leg
	Conflicting interests between the charterer (principal) and shipowner (agent), but no use of utmost despatch clauses.	"The said vessel shall proceed to the loading port....and being so loaded the vessel shall proceed to the discharging ports..."	VSG3 = No utmost despatch clause
	Conflicting interests between the charterer (principal) and shipowner (agent), which means use of: -Slow steaming clause	",,,However, unless 'no' is inserted in box 17 Part A, the owners may order the vessel to proceed at reduced speed solely to conserve fuel"	VSG4 = Slow steaming clause is present
Lack of Information Q: How does the outcome based contract address the principal agent information problem? Q: How does information problem affect speed reduction measure implementation?	Charterer (Principal) knows/agrees the speed at which the ship shall proceed through use of - Specific speed clause - Slow steaming clause	"..proceed at the speed stated in Section B.25 of PART 1 ("Charter Speed"), or at such her speed, not exceeding the speed stated in Section B.26 of PART 11 ("Maximum Speed"), as may be stated in Charterers' Voyage Orders. Charterers shall have the right at any time during the voyage to instruct Owners to adjust the Vessel's speed..."	VSI1 = Speed is stated
	Charterer (Principal) does not know/did not agree the speed at which the ship shall proceed i.e. use of utmost despatch clause. Only the shipowner (agent) knows the speed of the ship.		VSI2 = Speed is not stated
Outcome uncertainty Q: How does the outcome based contract address outcome	Contracting on specified outcomes of Shipowner (agent) by use of laycan & laytimes as well as: -Specific NOR times -Specific NOR locations -ETA/ERL	"NOR to load and discharge at the first or sole port shall be tendered in writing to the charterers between 0800 and 1700 hours Mondays to Friday and 0800 - 1200 on Saturday. Following tender of NOR, laytime shall commence 12 hours"	VSOU1 = Specific NOR times and locations

uncertainty? Q: How does outcome uncertainty affect speed reduction measure implementation?	Contracting on outcomes of Shipowner (agent) by use of laycan & laytimes as well as: -Non specific NOR times -Non specific NOR locations -No ETA/ERL	"Upon arrival at customary anchorage at each port of loading or discharge, the Master or his agent shall give the Charterer or his agent notice by letter, telegraph, wireless or telephone that the Vessel is ready to load or discharge cargo, berth or no berth"	VSOU2 = Non specific NOR times and locations

Weather routing & efficient voyage execution measure

Coding category and questions	Definition	Example	Coding rule
Goal conflict Q: How does the outcome based contract address the principal agent goal conflict? Q: How does focus on PA goal conflict affect weather routing & efficient voyage execution measure implementation?	Conflicting interests between the charterer (principal) and shipowner (agent), which means use of: -Strict deviation/charterer clauses	"The vessel shall be at the liberty to tow or be towed, to assist vessels in all positions of distress and to deviate for the purpose of saving life or property. On the laden leg the vessel shall not take on bunkers or deviate or stop, except as allowed in this clause, without prior permission of charterers, cargo insurers, and owners P&I club."	VWG1 = No geographical deviation allowed (liberty level 1)
	Conflicting interests between the charterer (principal) and shipowner (agent), however does not use strict deviation clauses, Liberty clause which allows for bunkering only	"The vessel shall have the liberty to sail with or without pilots, to tow or to the assistance of vessels in distress, to call at any ports for bunkers, and to deviate for the purpose of saving life or property or for any other reasonable purpose"	VWG2 = Geographical deviation allowed for bunkering only (liberty level 2)
	Conflicting interests between the charterer (principal) and shipowner (agent), however no use of strict deviation clauses, Liberty clause which allows for en route port calls, extra cargo etc.	"In the event that this CP is for part cargo, the owners shall have the liberty of loading/discharging other part cargo for the account of other charterers or shippers from/to port enroute or not enroute. B) when owners exercise this option this shall in no way constitute a deviation....The charterers shall procure that the owners option as provided for in this clause shall be duly incorporated in B/L issued under this charterparty"	VWG3 = Geographical deviation allowed for bunkering and extra cargo (liberty level 3)
Information Q: How does the outcome based contract address the principal agent information problem? Q: How does focus on information problem affect weather routing & efficient voyage execution measure implementation?	Charterer (Principal) knows/agrees the route on which the ship shall proceed through use of - specific route - Worldscale routes	"If owners or master unilaterally elect to proceed by a route that is different to that specified in Worldscale or different to that agreed between owners and charterers, freight shall be paid in accordance with the worldscale rate or in accordance with any special rate applicable for the agreed route"	VWI1 = Information on route
	Charterer (Principal) does not know the route on which the ship shall proceed due to use of -shipowner deviation/liberty clause	"The vessel has liberty to call at any port in any order, for any purpose, to sail without pilots, to tow and assist vessels in all situations and also to deviate for the purpose of saving life or property"	VWI2 = No information on route

Time Charterparties

General speed reduction

Category	**Definition**	**Example**	**Coding rule**
Goal conflict Q: How does the behaviour based contract address the principal agent goal conflict, if any? Q: If there is goal conflict, how does goal conflict affect speed reduction measure implementation?	Principal paying for fuel and determining speed. Shipowner does not have conflicting interest with this. This is through - use of guaranteed speed and consumption	"The average speed of the vessel shall not be less than "X" knots when loaded and "X" knots in ballast on an average daily consumption of no more than "X" metric tons of fuel oil..."	TSG1 = Speed and consumption specified
	Conflicting interest based on agents obligations to follow the principals' slow steaming instructions while taking into account the safety of the vessel, cargo obligations towards third parties, such as holders of bills of lading, manufacturers recommendations. - Use of slow steaming clause	"The charterers shall be entitled from time to time to instruct the Vessel to proceed at reduced speed for economic or other reasons subject to prior consultation with the owners concerning the peculiar characteristics of the Vessel and its machinery in this respect. The charterers shall indemnify the owners and hold them harmless against all consequences or liabilities towards third parties resulting from such instructions"	TSG2 = Built in slow steaming clause
	For several reasons (e.g. ballast legs, subletting) the time contracts also have - Use of utmost despatch clauses - Use of supercargo clauses	"The master shall perform the voyages with due despatch" "The charterer is entitled to appoint a supercargo, who shall accompany the vessel at the charterers risk and see that voyages are performed with due despatch"	TSG3 = Utmost despatch clause
	Conflict arises when prolonged periods of slow steaming or ultra slow steaming. Principal agent 'efficiency' problem. Extra investment is required for the measures implementation.	"...provided that such instructions will not result in the Vessel's engine(s) and/or equipment operating outside the manufacturers'/designers' recommendations as published from time to time. If the manufacturers'/designers' recommendations issued subsequent to the date of this Charter Party require additional physical modifications to the engine or related equipment or require the purchase of additional spares or equipment, the Master shall not be obliged to comply with these instructions.	TSG4 = Ultra slow steaming clause
Information problems How does the behaviour based contract make use of information systems required in a behaviour based contract? Q: How does focus on agent	Charterer (Principal) knows and agrees the speed at which the ship shall proceed through use of - Monitoring through weather routing company clauses	"Charterer may employ the services of an independent Weather Bureau Reporting such as Oceanroutes to route/monitor the vessel and master is to comply with the reporting procedure. The vessel shall be capable of at all times of performing at the agreed speed and consumption in the weather conditions as stated in Appendix A and in the event that this is not the case the charterer shall be compensated for slow speed or over consumption and shall have the right to deduct this amount from hire."	TSI1 = Use of weather routing company

monitoring affect speed reduction measure implementation?	Charterer (Principal) knows and agrees the speed at which the ship shall proceed through use of - Agents noon reporting - supercargo	“Evidence of weather conditions to be taken as reported daily on the noon position report to charterer” “The charterer is entitled to appoint a supercargo, who shall accompany the vessel at the charterers risk and see that voyages are performed with due despatch”	TSI2 = Use of noon reports and/or supercargo clauses
Outcome measurability	Outcome is based on ship under performance. If ship under performs then - Deduction for under performance (of speed) or over consumption (of fuel)	“...Charterers have the right to make deductions from hire in respect of any time lost and any additional bunkers consumed by reason of the vessel to maintain warranted capability”	TSO1 = Clause for deduction for any under performance
	Outcome is based on ship under and over performance - Compensates for over performance (of speed) or under consumption (of fuel)	“Increase or decrease in service speed leads to deduction or addition of hire paid and increase or decrease in bunkers consumed leads to additional bunkers consumed or saved shall be deducted or added to hire”	TSO2 = Clause for deduction or addition for any under or over performance
	In different weather condition - Wind speed minimum BF 4 as bad weather	“..Under normal working conditions and in moderate weather (which for the purpose of this clause shall exclude any periods of winds exceeding Force 4 on the Beaufort scale...”	TSO3 = Clause for weather conditions not exceeding Force 4.
	- Wind speed minimum BF 5 or above	“.. Good weather up till Force 8 on Beaufort scale...”	TSO4 = Clause for weather conditions not exceeding Force 5.

Email to survey respondents on charterparties

Dear ……….,

This is to inform you that the survey you participated has had over 100 responses so far. I hope to achieve 150 responses by April, in order to make broader generalizations about the industry and specific sectors.

Concurrently for the PhD, I am also analysing charterparties to examine how the specifics of each of the standard charterparties influence operational efficiency of a ship, e.g. what energy efficiency measures are incorporated within, what are the pertinent clauses that limit takeup of such measures, speed clauses etc.

I would really appreciate if you could help me by identifying which standard charterparties you most often use/come across in your sector AND whether you or the opposite party would tailor them to specific needs e.g. with rider clauses.

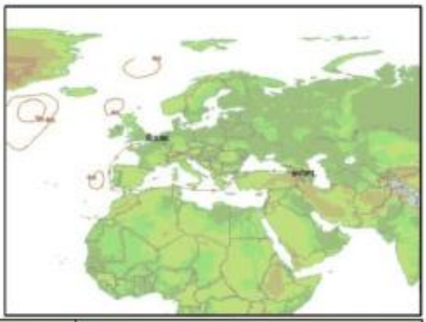
Sincerely,

Nishat Rehmatulla
Doctoral Researcher
UCL Energy Institute
Central House
14 Upper Woburn Place
WC1H 0NN
London, UK
+ (44) 7540051942
http://www.lowcarbonshipping.co.uk/

Wet bulk		**Dry bulk**		**General**	
Voyage		Voyage		Voyage	
BIMCHEMVOY		COALOREVOY		GENCON	
INTERTANKVOY		OREVOY		MULTIFORM	
ASBATANKVOY		NIPPONORE			
BEEPEEVOY 3		NIPPONCOAL		Time	
SHELLVOY 5/6		GRAINVOY		BOXTIME	
EXXONVOY90		BALTIMORE		LINERTIME	
MOBILVOY		NORGRAIN			
TEXACOVOY94		SYNACOMEX		OTHER (Please Specify)	
Time		Time			
INTERTANKTIME		BALTIME			
ASBATANKTIME		GENTIME			
BPTIME 3		NYPE 93			
SHELLTIME		NYPE 46			
BIMCHEMTIME		ASBATIME			
Other (Please specify)		Other (Please specify)			

Virtual Arrival Report
Post Voyage Analysis and Comparison

Vessel Name :
Departure : BATUMI — Sep 2, 2009 1900GMT
Arrival : SUNK — Sep 16, 2009 1000GMT
Reduction Point : 40.03N 26.15E (Sep 6, 2009 0048Z)
Voyage Number :2009083552



1. Voyage Analysis

From / To	BATUMI to Bosporus	Dardanelles to SUNK	
Ship Speed	 Full Speed	Reduced Speed	Simulation at full Speed
	Full Speed (actual)	Economical Speed (actual)	Full Speed (simulated)
Distance Sailed (nm)	557	3003	
Time En Route (hours)	40.3	249.2	222.0
Ordered Speed (knots)	14.0	12.0	14.0
Average Speed (knots)	13.8	12.1	13.5
Weather Factor	0.0	-0.3	-0.3
Current Factor	0.0	0.0	0.0
Entire Voyage Performance Speed (knots)	13.8	12.4	13.8
Average Daily Fuel Consumption (mt/day)	29.54	20.65	29.54
Entire Voyage Fuel Consumption (mt)	49.60 (a)	214.40 (b)	273.23 (c)

2. Slow Steaming Effect Analysis

Fuel saved	(c) - (b)	58.83 MT
CO2 decreased	(Fuel Consumption x 3.114)	183.2 MT
NOx decreased :	(Fuel Consumption x 0.07455	4.39 MT
SOx decreased :	(Fuel Consumption x 0.059)	3.49 MT

Figure D1: How virtual arrival savings are calculated
Source: OCIMF and INTERTANKO (2010)