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Title: **Drivers for Innovation and Development of cleaner technologies in Shipping: A study of ballast water treatment systems**

Author: **Ogungbemi Toluwalope Benjamen**

Master programme: **Environmental Management & Sustainability Sciences**

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Supervisor: **Soren Kerndrup**

Preface

This study research is a master thesis that was carried out at as a master program of Environmental Management and Sustainability Sciences at Aalborg University, Denmark. The thesis topic was the drivers for Innovation and development of Cleaner technologies; A study of ballast water treatment systems. The research focus was selected to inform key maritime actors, researchers, academic institutions and maritime authorities the drivers which could influence the attractiveness of ballast water treatment systems in shipping. The student chose to conduct the study using a case study to explore the key drivers influencing innovation and development of ballast water treatment systems. With a thorough supervision from my supervisor Soren Kerndrup, the student chose the thesis topic.

The author would like to appreciate Soren Kerdrup for the continuous support, critical remarks and most importantly for believing in me during the research period. Thank you very much for the supervision. Thanks to Roberto Rivas Hermann for the support and knowledge in shipping.

My sincere gratitude goes to my family, Late Elder M.T Ogungbemi, Mrs G.O. Ogungbemi, Mr and Mrs Aina, Titilope, Temitope, Olamide. I also want to thank my fellow JEMES colleagues Felix Kwabena Donkor, Esther Nyanzi, Adeiga Adedayo and Samuel Kweku Yamoah for the positive contributions.

Finally I want to say thank you Lord for the gift of life to successfully complete my studies.

Abstract

This thesis examined the drivers and barriers of cleaner technologies in shipping. Considering the complexity, the size, and numerous actors involved in the industry. The study chose to make a relevant case study on ballast water treatment systems focusing on the key drivers and barriers affecting the attractiveness of the technology. With this aim in mind, the study explored the drivers responsible for the development and implementation of ballast water treatment systems. Recognising the need for the development of cost- effective and environmentally friendly technologies which are viable to address environmental issues of ballast water activities, ballast water management regulation was adopted in 2004. Resolutions of the convention provided a benchmark for the development of ballast water treatment systems (BWTS), and as well requiring all new and existing vessels to install this equipment on board. The results of the study indicated that the attractiveness of ballast water treatment systems can be improved if higher priority is given to cleaner technology (eco-innovation) drivers. Theories on innovation and cleaner technology drivers formed the guiding conceptual framework of the study. The study presented some key drivers of cleaner technologies such as regulatory push, market pull, firm strategies and technological drivers. The barriers were also identified as lack of a universal legislation, high cost of equipment development, uncertainty as regards the efficacy of system produced, and low demand of technology from ship-owners. Empirical data was collected for the study through in-depth interviews, document review, websites review and email interviews.

Keywords: Ballast water treatment systems, Eco-innovation, Cleaner technologies drivers, Shipping.

The image used on the cover page of the thesis is taken from; Ballast Water Management Regulations and Challenges;
Sources: Institute of Marine Science & Engineering. (IMAREST 2012)

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ABBREVIATIONS AND TERMS

BWPS	Ballast Water Performance Standard
BWMS	Ballast Water Management Systems
BWTS	Ballast Water Treatment Systems
DNV	Det Norske Veritas
GESAMP-BWWG	Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection – Ballast Water Working Group
ICS	International Chamber of Shipping
IMO	International Maritime Organization
MARCOD	Maritime Center for Optimization and Operation
MEPC	Marine Environment Protection Committee
OECD	Organization for Economic Co-operation and Development
UNEP	United Nations Environment Program
UNCTAD	United Nations Conference on Trade and Development
UNIDO	United Nations Industrial Development Organization
U.S	United States
USCG	United States Coast Guard
UV	Ultraviolet Irradiation

CHAPTER ONE

1.1. Introduction: Problem Analysis

The increasing socio-political awareness of the consequences associated with environmental problems, and the recognition of innovation as an instrument for driving the growth of an economy calls for emphasis on environmental innovation (Pereira 2012). This is a core approach that will drive firms to engender parallel, socio-economic development compatible with environmental targets to a large extent (Pereira 2012). Innovation tends to lead to the transformation of the growth of an existing economy towards an advance and more sustainable direction (Hekkert and Negro, 2009). Innovation is an important process which helps firms to meet up with its goals and at the same time survive in a competitive market.

Several studies have investigated the drivers which determines eco-innovation (Horbach 2008; Demirel and Kesidou, 2011). The studies have shown that cleaner technologies concept brings about close competition among population, thereby resulting into immense environmental benefits to the immediate industry (Editorial 2008). Cleaner technologies tend to limit emissions and waste and most importantly reduce cost in treatment pollution and waste management processes (Editorial 2008). However, despite all the positive contributions of cleaner technology in most industry, some key issues still limit its introduction and development. In this regard, this study attempts to investigate the drivers influencing the cleaner technologies (ballast water treatment systems) in shipping

From shipping perspective, the complexity involved in the innovation and widespread use of cleaner technology process in the maritime industry requires an effective functioning of different multi-levels and stake-holders to achieve the desired output. Kemp and Volpi (2008) categorize processes of this kind as endogenous and exogenous mechanisms. The endogenous process includes socio- economic factors such as costs, research and design activities, learning and increment in the invention of new technologies. While exogenous process involves legislative activities (regulation) and market structure (Kemp and Volpi 2008). Ballast water treatment technology is a special and complex type of technology which has experienced difficulties in introducing it to the industry. Studies suggest different barriers such as the non-existence of a binding international regulation and technical standards to effectively develop BWTS; uncertainty about the reliability and efficiency of the equipment; high cost of developing and installing technologies; and inadequate technical expertise in developing and supervising the installation processes (King et. al. 2012). Based on these challenges, this study attempts to identify the drivers influencing the attractiveness of ballast water treatment technologies in shipping.

1.1.1. Trade and Shipping

International shipping plays a vital role in the world trade. According to the International chamber of shipping (ICS), marine transportation sector accounts for the movement of over 90% of global trade and commodities (UNFCCC, 2009). Shipping is used to transport of goods, raw materials to end users or a target market. Shipping is a global business which accounts for one third of total shipping operations. (Stopford, 2009). Example of trades and commodities shipped from one region to another can be categorized into different trades (Stopford, 2009).

- Energy: as crude oil, coal, renewable energy.
- Agricultural goods: sugar, grains,
- Metal: steel, iron aluminium.
- Industrial goods

The transportation of trade volume by shipping has contributed positively by increasing the growth of the economy of both developed and developing countries (UNCTAD, 2012). The world seaborne trade statistics shows that the volume of total commodities transported by ships from 1970's to the year 2011 is approximately 8.7 billion tons (UNCTAD, 2012). The trade for each of the three container cargos (oil and gas, main bulks and other dry cargo) specify an increase in trade volume of 6143 millions of loaded tons between 1970 and 2011.

Table 1- Development of seaborne transportation for selected years (millions of tons loaded).

Year	*Oil and gas*	*Main bulks*[a]	*Other dry cargo*	*Total (all cargoes)*
1970	1440	448	717	2605
1980	**1871**	**608**	**1225**	**3705**
1990	**1755**	**988**	**1265**	**4008**
2000	**2163**	**1295**	**2526**	**5984**
2005	**2422**	**1709**	**2978**	**7109**
2006	**2698**	**1814**	**3188**	**7700**
2007	**2747**	**1953**	**3334**	**8034**
2008	**2742**	**2065**	**3422**	**8229**
2009	**2642**	**2085**	**3131**	**7858**
2010	**2772**	**2335**	**3302**	**8409**
2011	**2796**	**2477**	**3475**	**8748**

Sources: Compiled by the UNCTAD secretariat on the basis of data supplied by reporting countries and published on the relevant government and port industry website by specialist sources. The data for 2006 onwards have been revised and updated to reflect improved reporting, including more recent figures and better information regarding the breakdown by cargo type. Figures for 2011 are estimated based on preliminary data or on the last year for which data were available. Iron ore, grain, coal, bauxite/alumina and phosphate. The data for 2006 onwards are based on various issues of the Dry Bulk Trade Outlook, produced by Clarkson Research Services:

Table 1; Shows the development of seaborne transportation for selected years (millions of tons loaded). **Source:** UNCTAD (2012, Table 1.3).

Both developed and developing nations have in one way or the other contributed positively to the growth of the global economy through their export and import activities. For instances, through shipping transportation, developing nations such as Japan, India and selected African countries have all contributed to the world seaborne trade with 57 percent share of imports and exports of raw materials like coal, crude oil and iron ore (UNCTAD, 2012). While developed countries like the European Union nations, United States and some other have also contributed positively to the world seaborne with 41 percent import share and 34 percent export share (UNCTAD, 2012). Meanwhile, the incremental growth achieved in international shipping over the years can be traced to the role played by different economic actors involved in shipping activities (MIF 2011; UNCTAD, 2012).

1.1.2. Environmental Impact of Shipping

As ships travel from one region to another, about 3 to 5 billion tonnes of ballast water is transferred globally (Tsolaki and Diamadopoulos, 2010). Ballast water is indispensable for bulky ocean-going vessels transporting goods and services in international shipping. This water is often used when ships are empty; not carrying cargo nor hauling heavy cargoes. Ships require ballast water to gain stability, structural strength and to maintain manoeuvrability on the water during voyage operation. However, various researches has made emphasis on ballast water as a primary source responsible for the global spread of various non-native species and pollutants into a new geographical environment (Tamburri et al. 2002; Endresen et al. 2004; Jeng et. al. 2012). The transfer of marine invasive species is a major problem which accounts for several adverse ecological and socio-economic effects globally. Studies indicate that, over ten thousand marine species are transported in ballast water tanks of ships across the sea (Buck 2010).

These species, which are carried along to the last destination of the journey are released into the environment posing a threat to the biodiversity of the marine environment. This form of invasion results in economic, human health risk and ecological impacts (Murphy et al 2008). The adverse effect of invasive species on the economy is not favourable. The introduction of the zebra mussels for example alters the ecosystem and food chain. The presence of the zebra mussel results in fouling on infrastructures and ships. It also causes severe clogging on water pipes and irrigation equipments. The United States has incurred an economic cost of about US$750 million to $1 billion from 1989 to 2000 (EMEC 2010). The breakdown of the costs incurred includes the cost of preventing, eliminating, and monitoring the problems caused by these species. Besides, marine invasive species could also have an economic impact by causing severe damages on properties and discard of yields accumulated from fishing activities (Carlton 2001; CSL 2013).

The invasion of non-native species into a new environment may have adverse effects on the functioning of the ecological system by altering available resources, as well as causing disruption in the organization of the ecosystem (Richardson et. al 2000; Pyšek, & Richardson, 2010). The introduced invasive species interact with the existing native species such that they dominate the habitat and cause massive death of local native species. According to Tamburri et.al.(2002) studies, the invasion of non-native species may lead to the reduction of food sources due to the strict or tough competition for survival that may exist in a particular habitat invaded by invasive species. Ballast water containing pathogens and other microorganisms could result in a global spread of epidemics such as water borne disease and cholera. These outbreaks have been reported to have inflicted negative infections on the life of humans, plants and animals (Glo-Ballast 2002; Ruiz et al. 2000; Takahashi et al. 2008; Jeng et. al. 2012).

1.1.3. Ballast Water Treatment Technology

Presently, significant efforts are beeing made by various maritime sectors and suppliers to propose and develop different ballast water treatment technologies. Some of these technologies which exist in the market have been approved, and some are still awaiting approval. Studies indicate that these treatment technologies can be grouped into primary and secondary separation methods (Tsolaki and Diamadopoulos, 2010). The primary method also known as the solid- liquid separation technique consists of physical processes including filtration and hydocyclones (Tsolaki & Diamadopoulos, 2010; MICA (P) 039/02/2012). While the secondary separation method consists of both physical and chemical disinfection technologies,(ultraviolet, cavitation, ozonation and coagulation MICA (P) 039/02/2012).

1.1.3.1. Solid-Liquid Separation

This type of treatment process makes use of separation technique method. In this case, large particles and microorganisms (>40-50 μm) are separated from ballast water through the use of mechanical systems such as filtration, hydrocyclone and flocculation (MICA (P) 039/02/2012; Bureau Veritas 2011).

1.1.3.1.1. Filtration system

This is a common method adopted for treating ballast water during uptake (Tsolaki & Diamadopoulos, 2010). This method is often carried out during ballasting; it makes use of discs or screen filters as well as automatic filter systems with sizes ranging from 20 - 40 μm to effectively capture particles and organism. The filter technology operates through a back-washing cycle by removing organisms and particles which are captured by the filters to be discharged adequately at the port (CSL 2013). In general, since the filtration system involves specialized equipment for removing smaller particles and sediment from ballast water, it is projected to be expensive to acquire and install on ships (Corrina et al. 2002). Another major set-back of this system indicates that the filters used are susceptible to clogging and needs to be replaced with new filters and back flushing frequently (Germanischer 2010).

1.1.3.1.2. Hydrocyclone

Hydrocyclone is another option that can be used to separate larger solid particles from the ballast water through centrifugal forces and gravity (Hofer et.al 2012). When ballast water is pumped into the tank with high velocity of centrifugal rotational motion, the velocity of the particles contained in the water is increased to allow the particles to be separated from the water. Studies shows that the hydroclone separation technique is seen to be cost-effective compared to the filtration method (Taylor and Rigby, 2001; Rajoo Balaji et. al (2011). A major drawback of the hydrocyclone system is that aquatic organisms with small sizes are difficult to separate since they have almost the same density with the seawater (CSL 2013).

1.1.3.1.3. Flocculation system

This technique involves the use of an electro-mechanical separation. It helps to enhance the efficiency of the treatment system (Bureau Veritas 2011). During the treatment process, coagulant is introduced to the existing particles in the water to generate more particles that are of large density. In order to ensure an effective removal of flocculated particles, the filtration separation technique is applied. The effectiveness of the electro-mechanical separation method is reliant on time residence (Bureau Veritas 2011). The flocculation system is known for its high removal efficiencies during treatment of large flows of ballast water. In the same way, this technique tends to limits the volume of coagulant used in the process. Limitations for this separation method indicate that the process employed in removing the desired pollutants is time consuming.

1.1.3.2. Disinfection

This type of treatment process is used to remove or inactivate smaller organisms existing in the ballast water (MICA (P) 039/02/2012). It consists of two main kinds of treatment process such as the physical and chemical disinfection technique. The physical treatment technology requires the use of non-chemical method to eliminate organisms existing in ballast water (CSL 2013). Technologies used in this process consist of ultraviolet irradiation, cavitation and de-oxygenation methods.

1.1.3.2.1. Ultra-violet irradiation (UV)

The U.V method operates by generating photons in form of active substance to breakdown the cell walls of organisms which are present in water (ABS 2010; Bureau Veritas 2011). This technique functions by surrounding a quart sleeve with combined lamps to generate UV light at various wavelengths to kill micro-organisms such as viruses and cysts (Lloyds Register 2010). Studies indicates that the ultraviolet irradiation technique may not be effective if suspended matter is present in ballast water, for this reason it is necessary to filter off the water prior to treatment (Germanischer 2010). Also, UV treatment systems may efficiently perform better during treatment of ballast water if paired with mechanical separation methods, but the limitation attached to this pairing is that more space and financial cost will be incurred (EPA-SAB 2011).

1.1.3.2.2. Cavitation system

This is another physical treatment method which makes use of venturi pipes to generate bubbles for destroying the cell walls of organism contained in the ballast water (Bureau Veritas 2011). Studies indicates that the cavitation system sometimes displays an inconsistent result during treatment process (ICS 2011), similarly as the venturi pipe create bubbles for the breakdown of the cell walls of the organisms, high energy is produced in the process, however a challenge as regards creating a control mechanism for the energy generated is experienced (ICS 2011).

1.1.3.2.3. De-oxygenation technology

De-oxygenation technology is used to get rid of oxygen present in the ballast water, and with subsequent substitution with inert gas such as nitrogen to produce a condition not conducive for existing aquatic organisms (Lloyds' Register, 2010; Bureau Veritas 2011). A major weakness of this technological process is that it requires enough time between one to four days to effectively get the ballast water treated from organisms (Rajoo Balaji et. al 2011).

1.1.3.2.4. Chemical disinfection

This technique could be used to treat ballast water onboard vessels. It involves the use of chemical disinfectants such as oxidizing and non-oxidizing biocides (bromine, chlorine and ozone) to attack and kill the cell membranes of different organisms existing in the ballast water (Tsolaki & Diamadopoulos, 2010; CSL 2013). While ozonation process generates hydrogen and chlorine gas when ozone is added into the ballast water. Decomposition of chlorine gas in the presence of chlorine ions leads to oxidization of the existing organisms (Bureau Veritas 2011). Depending on the temperature, PH level and the kind of organism present in the water different types of disinfectant such as chlorine, bromine and ozone can be used to treat ballast water. However, studies shows that the use these disinfectants to treat water has several associated limitations. For instance, the use of ozone in a particular treatment process may have a negative impact which can lead to corrosion of vessel equipment (Rajoo Balaji et. al 2011).

1.1.3.3. Combination of Treatment Technological Process

The combination of different shipboard treatment technologies (physical, mechanical, and chemical) can be implemented to achieve more effective results (CSL 2013). Depending on the type of system, each treatment technology varies in terms of advantages and drawbacks. Studies suggest the mechanical and physical method is mostly combined during uptake and discharge to eliminate both large and small organisms. For instance, Albert et. al. (2010) suggest the filtration system and the UV irradiation could be combined together to treat ballast water. These systems can be used at both ballasting (uptake) and deballasting (discharge). During the uptake of ballast water, back-flushed solids or sediments is retained by the filter, and in the discharge process UV irradiation is used on the ballast water to kill organisms that may exist (Albert et. al. 2010). Electro-chlorination and ozonation can also be paired together to complement each other. For example, electro- chlorination may not be appropriate for treating sea and fresh water because it has potential of generating explosive gas (H_2) and radioactive substance, hence ozonation can be used to get rid of this problem by employing sodium bisulfite (Na_2HSO_3) to regulate the value of Total Residual Oxidants (TRO) that may exist in the ballast water (MICA (P) 039/02/2012).

Summary

The research study shows that different forms of technologies have been developed for the treatment of ballast water in the shipping industry. The existing types of technologies are categorized into solid-liquid separation and disinfection technologies. The methods classified under solid-liquid separation are filtration, hydrocyclone, and flocculaton technologies, while the disinfection technologies are ultra-violet irradiation, cavitation, de-oxygenation, and chemical disinfection technologies. The study also presented the strengths and weakness attributed to the various technologies discussed. Finally , I also learnt that these methods can be combined in a way to get the best technique in terms of treatment efficiency.

1.2. Shipping Industry

The shipping industry can be considered as a complex system which involves a network of technology providers, ship builders, ship owners and logistic agents (Hermann R., 2013). Technology manufacturers play a crucial role in the innovation, development and distribution of various technological inputs to service providers. Ship owners may serve as sub-suppliers or in some cases sell haulage services themselves, while shipping companies act as service providers of containerized shipping services and marine transportation in the industry. Both possess or outsource several kinds of vessels for transport. Vessels are thus the key assets regularly upgraded in the industry. Ship-yards are responsible for the provision of various kinds of services to shipping companies. Services including the development of new builds, retrofitting, maintenance and recycling of existing ship (MARAD 2013).

Figure.1. illustrates the various actors in the supply and demand aspects of environmental maritime technology.

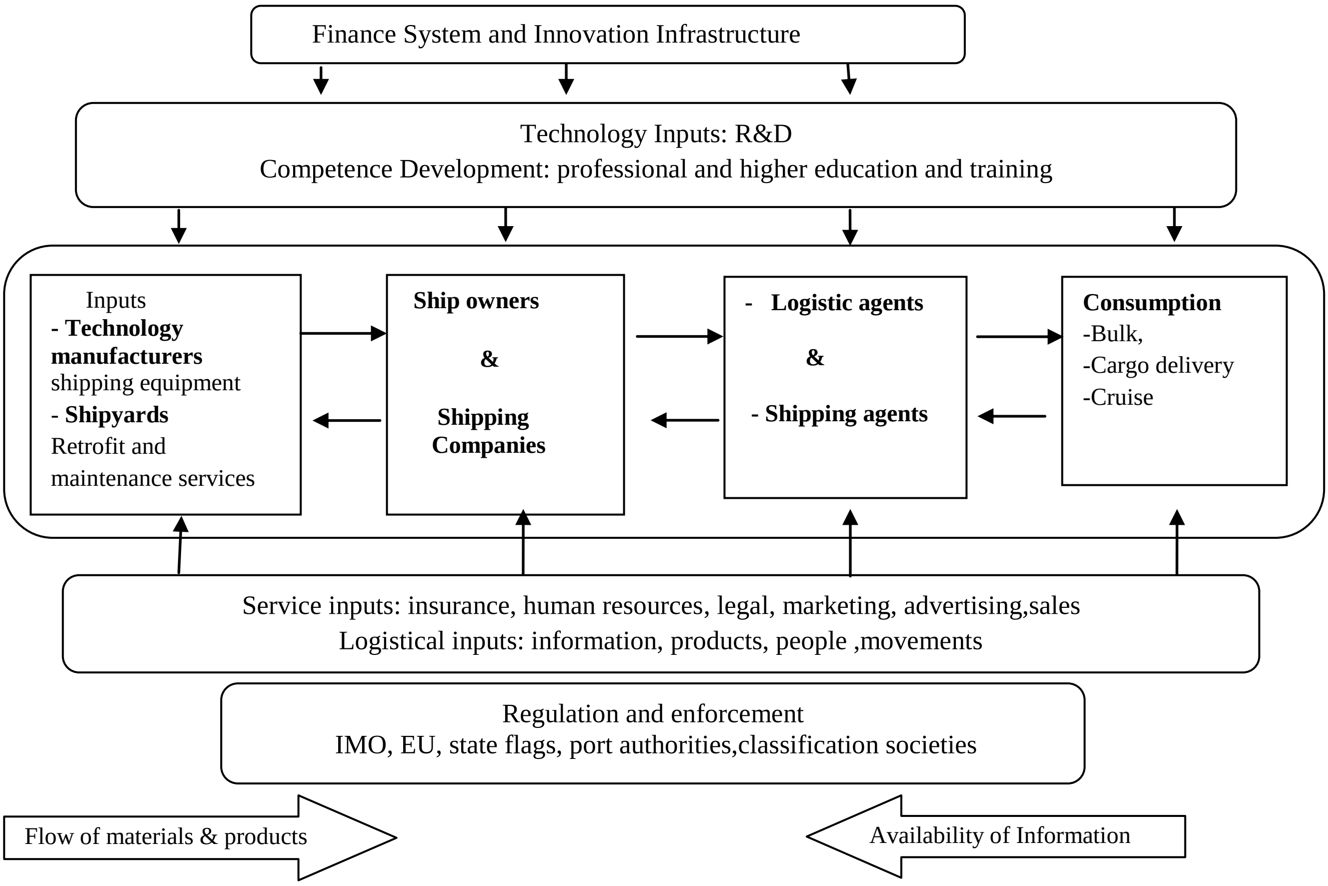

Figure 1. A production network of Shipping Industry. Source: Adapted from Herman, R. (2013)

Shipping companies need to constantly upgrade to keep pace with industry competition. Technology manufacturers of ships component (DESMI Ocean water guard) and ship yards offer numerous maintenance and equipment services, such as retrofitting or constructing entirely new models.The mutual dependence of the several actors leads to the nurturing of important alliances amongst the various actors (Hermann R ,2013). Logistic agents serve as the link between clients in need of freight haulage services and shipping companies. The dynamic nature of the industry is such that there is a constant demand for state of the art technology. This demand is satisfied through research and development offered by professional and advanced educational institutions (Hermann R., 2013).

A number of standards and regulations mediate activities in the industry to ensure adherence to standards. Thus an international organization such as the IMO is a key source of conventions and directives that are adapted at the national level of member states. Port authorities implement the various conventions whilst classification societies confirm that vessels adhere to safety benchmarks (Hermann R., 2013). Classification societies such as Det Norske Veritas (DNV) and Lloyd's Registers ensure safe reduction of environmental impacts and smooth operations of key players such as the ship-owners, shipyards and port state authorities (IACS 2013). They establish guidelines or standards in conformity to international regulations for verification of ships design, operations, maintenance and insurance purposes (IACS 2013). As depicted by the figure 1, the shipping industry can be seen as a complex production network of actors, relations and institutions. The interaction among these production networks can be seen as one which contributes positively by providing valuable services to consumers and the global economies of different countries.

1.3. Drivers for adopting cleaner technology in shipping

Considering the increasing environmental impact of international shipping, the maritime industry has set in motion measures to encourage environmentally friendly shipping (Höfer et. al. 2012). In this regard, the international shipping community has made significant progress by adopting environmental regulations (e.g. the IMO ballast water management convention) to tackle environmental challenges (Höfer et. al. 2012). Similarly, maritime stakeholders (e.g. equipment suppliers) have also intensified various efforts by taking up voluntary innovative measures to develop environmentally friendly products aimed at reducing environmental impacts, as well as meeting the demands of ship-owners (GSF 2010). The implementation of these environmentally innovative measures presents a case for green shipping initiatives in the shipping sector. The green shipping initiative aims at influencing maritime companies to develop and adopt cost-effective cleaner technologies for the mitigation of environmental impacts (Lai et. al., 2011).

Cleaner technologies are regarded as environmental innovation adopted to transform a production (technological) process to limit pollution or waste generated (Del Río, 2005; Markusson 2011). Cleaner technology is an abatement techniques used during a cleaner production process; it seeks to minimize pollution at the source (Markusson 2011). Studies show that industrial firms prefer to make financial investment on cleaner technologies because of their perception that the demand for their products may reduce due to consumers increasing level of awareness and reactions to environmental pollution (Gil-Moltó and Varvarigos 2013).

End-of-pipe technology is another type of an environmental innovation which reduces pollution at the end of a production process, without altering the result of the process (Frondel et al. 2007). Nevertheless, the application of end-of-pipe technologies incurs additional cost to the process (Horbach et.al. 2011). From the perspective of shipping, environmental innovation (or eco-innovation) is an important concept which promotes technological innovations and contributes towards achieving environmental goals (OECD 2010). It encompasses both technological and non-technological approaches to achieve reduction of environmental impact of shipping.

Eco-innovation is defined as, '*the implementation of new or significantly improved, products (goods and services), processes, marketing methods, organizational units and institutional structures which reduce environmental impact with or without intention in comparison to relevant alternatives* '(OECD 2010). Rennings (2000) also describes eco-innovation as a *'concept which offers environmental gains and ensures environmental sustainability'*. According to other literatures, four major drivers are solely responsible for achieving eco-innovations and these includes; *regulation, technology, market forces and organizational strategies* (Rennings, 2000; Horbach et.al. 2011*; Kesidou & Demirel, 2012)***.**

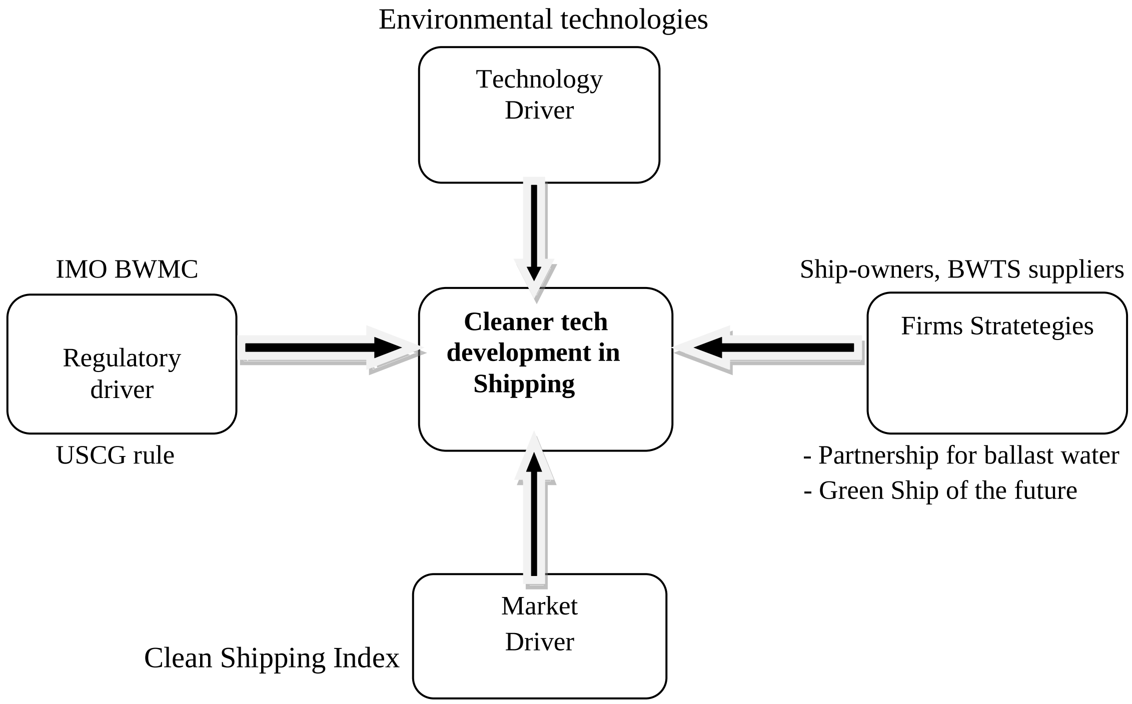

Figure 2 - Drivers of Eco-innovation. Source: Horbach et.al (2011) and Hermann et. al. (2012)

Regulation is an important driver exemplified by empirical studies demonstrating it to be a fundamental factor that influences eco-innovation (Rennings and Zwick, 2002; Brunnermeier & Cohen, 2003; Horbach et. al. 2011). Other studies also illustrate the role of regulation on eco-innovation could have a positive or negative impact depending on the approach (Kivimaa and Mickwitz, 2006). Ashford & Hal's (2011) analysis on Porters hypothesis shows that environmental regulation can potentially stimulate remarkable innovations (Ashford and Hall 2011). The role of induced regulation on innovation explains that weak regulation could stimulate reactions from companies and industry to implement process and product innovations. While strong regulations with strict enforcement can displace existing technologies by inducing the entrance of new producers to create innovative products and processes (Ashford and Hall, 2011).

Technology is another main driver of eco-innovation. It aims to reduce pollution and to cut cost of a production process. According to Kemp & Pearson (2007), green energy technologies are perceived to be part of environmental technologies employed for controlling pollution. In this case, most companies adopt environmental technologies to ensure improvement of product and services and to reduce environmental impact as waste management and energy saving technologies.

Market forces are drivers which play a significant role in eco-innovation. Demand and pressure from consumers can be a reason for companies to adopt. According to studies, the potential for consumers to enjoy benefits such as added value after the delivery of a product is a driver for environmental innovation (Kammerer, 2009). Besides, firms which introduce new products that are environmentally friendly or create innovation on existing product have the possibility of improving their production process. This approach helps the firm to save cost in the production process and to diminish damage on the environment (Triebswetter and Wackerbauer, 2008). Finally, ***firm's strategy*** *is* the fourth driver of eco-innovation. In this case, companies who engage in networking and knowledge transfer strategies tend to stimulate innovation decisions (Wagner 2009). Innovation requires companies to remain committed in making investment on research and design work so as to meet up with strict environmental regulations. Several factors have also been pointed out to be responsible for motivating firms to adopt cleaner technologies. For instance,, The level of awareness on the part of the society as regards global environmental issues as given room for increasing pressure on firms to adopt eco-innovative practices in their business activities (Montalvo 2008). In order words, consumer demands for use environmentally friendly products, technological and organizational capabilities are among factors responsible for firm's decision to adopt cleaner technologies (Montalvo 2008).

1.4. Emerging regulation of BWTS

In response to the increasing problems caused by the introduction of marine invasive species. The International Maritime Organization (IMO) was set up as an international organization under the United Nations responsible for ensuring safety in shipping, minimizing pollution from ocean going ships, as well as fostering collaboration among its member states (IMO, 2013). The IMO initiated a discussion in July 1991 to adopt guidelines for ballast water management (IMO 2004). According to the IMO report, the adoption of these international guidelines would prevent, reduce and put an end to the threat or negative impacts of ballast water discharge in the environment (IMO 2004). Following many years of negotiations, the IMO's Marine Environmental Protection Committee (MEPC) adopted an International convention for the control and management of ships ballast water and sediment (Convention) on February 13 2004 at a conference in London (IMO Resolution on BWM/CONF/36/Annex). Among the important requirements of IMO's Resolution on the BWMC are the D1 and D-2 ballast water performance standards (BWPS). Both standards require ship owners to satisfy the requirement for the discharge of ballast water (Annex 2, Resolution MEPC.124 (53), 2005**;** Annex 4, Resolution MEPC.174 (58), 2008).

The D1 - Ballast Water Exchange Standard represents a provisional approach for ships with ballast tank until pending full compliance of D2 standards is enforced. In fulfilment of this regulation, it is mandatory for ships to carry out a ballast water exchange of no less than 95 percent of volume of water contained in the ballast tank. For ships employing the pumping- through approach, it is required to perform a ballast exchange of at least 95 percent of the ballast water three times the volume of the ballast tank (IMO BWM/CONF/36/, 2004). In the case of the D-2 ballast water performance standard, conditions for this standard requires full compliance of the regulations from ships carrying out ballast water discharge. Ocean-going ships are obliged to carry out ballast water discharge operation within a range less than 10 viable organisms per cubic metre greater or equal to 50 micrometres in minimum dimension and less than 10 viable organisms per milliliter less than 50 micrometres in minimum dimension and greater than or equal to 10 micrometres in minimum dimension; and discharge of the indicator microbes should not surpass the exact concentrations (Liang et. al. 2006; Annex 4, Resolution MEPC.174(58), 2008).

In addition to the resolution of the ballast water convention, every ships are obligated to have a ballast water management book on-board at all times with various treatment records. This book is in form of a paper or electronic system highlighting discharge operation documented, duly signed and authenticated by both the officer in charge of the operation and the manager of the ship when a discharge is successfully performed, or in a case of accident and exceptional cases of discharge (Glo-ballast, 2013).

1.4.1. Implementation of new regulation

The conditions attached to the enforcement of the IMO ballast water management convention indicates that thirty member states consisting of thirty five percent of the world's merchant shipping tonnage must ratify the treaty. This resolution can only become effective after the period of 12 months (Tsolaki & Diamadopoulos, 2010). Until December 2013, 38 countries which represent 30.38% of world's merchant shipping tonnage have ratified the ballast water convention (ClassNK, 2013). This demonstrates that the stated number of representatives so far is still below requirement for the convention to come effective.

Parties to the Convention	Current Status
Albania, Antigua & Barbuda, Barbados, Brazil, Canada, Cook Islands, Croatia, Denmark, Egypt, France, Germany, Iran, Kiribati, Lebanon,, Liberia, Malaysia, Maldives, Marhall Islands, Mexico, Mongolia, Montenegro, Netherlands, Nigeria, Niue, Norway, Palau, Republic of Korea, Russian Federation, Saintkitts, and Nevis, Sierra Leone, South Africa, Spain, Sweden, Switzerland, Syrian Arab republic, Trinidad and Tobago, Tuvalu.	**38** States (representing **30.38%** of merchant Tonnage)

Table 2: Current status of countries ratifying the BWMC. Source: Adapted from (Watson et.al. 2013; ClassNK, 2013)

1.4.2. United States Ballast Water Management Regulations

The United States has made effort to establish a regulation to help manage ballast water operations and minimize the spread of invasive species for ocean-going ships travelling towards the Great Lakes region. The United States Coast Guard (USCG) and the United States Environmental Protection Agency (EPA) are the two federal agencies responsible for managing ballast water discharge operations (CSLC 2013). Recently, both agencies worked together to establish a new regulation for the management of ballast water in the United State's waters. The regulation which became effective on 21 June 2012 for ocean going ships operating within U.S. waters and ships entering from outside the country has specific requirement. It requires ships that are newly designed before or after December 2013, as well as existing ships as of 2014 to carry out an implementation program which includes an exchange or a treatment process and type approved system (DNV 2012). This rule provides a flexible option which gives more time for both ship owners and operators to act in compliance with the final rule (Federal Register, 2012). The enforcement of the USCG regulation has helped in a way to close the technology gap affecting the ballast water treatment technology market, such that every existing vessels intending to navigate into US ports must conform to the rule (NOAA, 2013).

1.4.3. State of the ballast water treatment systems market

The global Ballast Water Treatment System (BWTS) market has attracted immense interest has the full ratification of the 2004 Ballast Water Management Convention gradually approaches (King et. al. 2012). The international resolution which demands the installation of BWTS from every qualified vessel to treat ballast water, thereby leading to the reduction of negative environmental impact on marine habitat. A recent study on ballast water treatment systems indicate that the implementation of the IMO ballast convention in the nearest future would cause a growth of the ballast water systems market to increase by 32.9 percent within the next five years (Shipping Watch, 2013).

The market was estimated around USD 1.4 billion in the year 2012, and with the ratification of the IMO ballast water convention set to be implemented soon, the market which has been estimated to around USD 2.1 billion in 2013 and would experience a significant increase in the region of USD 8.5 billion in 2018 (Shipping Watch, 2013). Though, the delay in the ratification of the convention has been a major set-back affecting the growth of the global market.
As a result of this delay, the retrofit industry has experienced a slow development of treatment technologies by manufacturers, as well as a slow adoption of the various systems by ship-owners.
In this case, IMO member nations are perceived to be trying to delay the enforcement of the convention until they are sure that sufficient systems have been fully developed and supplied into the market (King et. al. 2012). As this level of uncertainty continues to prevail in the market, potential investors and manufacturers (vendors) are all waiting for the green light or assurances from the regulators before committing their resources in investing on the ballast water treatment systems.

Meanwhile, studies made on ballast water treatment systems shows that several factors such as the installation and development cost of BWTS, size of the market, flag of ships, vessel types and age of vessels all determines the ballast water treatment systems market (King et. al. 2012). According to the cost analysis made on the global market for BWTS, the market value in terms of acquisition and installation for BWTS could be estimated around US$50-74 billion between 2011 and 2016 (King, Riggio & Hagan 2010; King et. al. 2012). The purchasing cost of each system varies with respect to the system type and vessels type system. Some suppliers present quotations indicates that a unit of systems is estimated around US D640 000 to US D 947 000 (King et. al. 2012).

The breakdown of this estimate shows that about thirty units of systems could be installed in a day, while ten thousand units of the system would be installed annually from now till 2016. However, considering the fact that over 68000 vessels would be required to be equipped with BWTS before 2017, and then it implies that the rate of development and installation of BWTS would need to be intensified in order to meet up with IMO D2 timetable and the demand of the growing market. Also, if the IMO convention is to be enforced by 2017 as planned, then virtually all ships would have conformed to the required time-table. This event will result in a situation whereby only newly built ships would need to install the technology, and the demand for the installation of BWTS will reduce drastically to 2000 units per year. In this case, BWTS vendors may experience a surge in demand for their products.

Summary

This chapter looks at the state of art for the shipping industry in relation to the environment. The basis for this highlights the importance of the industry accountable for the movement of over 90% of the total global trade. As presented, I critically look at the various environmental impact caused as a result of shipping activities which calls for improved environmental technologies. Detailed description is given to describe functions and types of these technologies such as ballast water treatment systems which exist. More so, an overview of the interaction that exists among network of actors and institution is given. This interaction can be seen as a network which provides valuable services to the industry and consumers. Further work of this report gives an insight on the specific directives and standards in existences that are used for the control and management of Ships' Ballast Water and Sediments. (IMO ballast water management convention). The study also examines the United State ballast water management regulation that present specific requirements for every ships intending to navigate via US waters to carry-out ballast water treatment in an effective manner.

The chapter also touches the current and future market projection for BWTS to understand the rate at which BWTS market grows. The following factors were found as key determinants for the development of ballast water treatment systems; the size of the market, flags of ships, cost of equipment, age and types of vessels.

Focuses is also laid on other factors presented by different researchers in relation to the drivers which determines the which determine firms decision on the implementation of eco-innovation and cleaner technologies (Horbach et. al 2012; Kesidou and Demirel 2012). The study then linked the concept of cleaner technology drivers to the shipping industry, and to examine how these drivers could have a dynamic interaction between each other to influence the attractiveness of ballast water treatment systems in shipping.

1.5. Aim and Objective of the study

The main aim of this study research is to explore the drivers and barriers influencing the implementation of ballast water treatment technologies in the shipping industry.

1.5.1. Research Questions

This study thus attempts to address this challenge by answering the following research questions:

1. What are the drivers and barriers of innovation and development of ballast water treatment systems in shipping?
2. How do drivers influence the implementation of ballast water treatment technologies and is it possible to make the technology more attractive for the shipping industry?

1.6. Justification of the Study

In recognition of the significance of innovation as a tool that influences environmental protection (Pereira, 2012), cleaner technology has emerged as an approach which offers various benefits to the environment (reduction in resource use, environmental pollution, and less waste) (Montalvo and Kemp, 2008).

Several efforts have been made in the shipping industry to encourage the implementation of the such type of technology like ballast water treatment systems. However, the introduction of this technology still faces a number of challenges, which are affecting its advancement and usage. For example, absence of a definite performance standards for ballast water treatment systems development, lack of guidelines for assessing performance of equipment, low demand rate, uncertainty about the reliability and efficiency of the technology, and high installation costs. Based on these challenges, this thesis is set to explore the drivers and barriers of innovation and development of ballast water treatment systems in the shipping industry. It aims to inform the shipping industry specially the regulatory institutions, technology manufacturers and ship-owners who are the buyers of the technology about the existing gaps so that they devise better measures for quality and environmental control.

1.7. Study Delimitation

The study has focused entirely on the shipping industry which incorporates ship-owners, technology manufacturers, and classification societies as a network of actors. Initially, the study focal point was laid on the roles played by technology manufacturers to improve the implementation of ballast water treatment systems. But due to the limited access and empirical materials on the stakeholder, the scope of the study was changed. Thus, this study has been supported more with desktop research analysis as a major source of information, which has helped to present more empirical fact to back up the study.

The next chapter sheds light on the methods used in conducting the research study and the steps taken in answering the research questions.

CHAPTER TWO.

2.0. Methodology

This methodology chapter presents and describes the approach used to carry out the research study. The first part of the chapter presents an introduction on the case study design and also clarifies the importance of using case study approach. The second part highlights the methods used including a brief explanation on how the selected methods were used in collecting the required information for the research work.

2.1. Research Design

This study research started with the analysis of the project problem (see figure 3). The study was initiated by the following; concepts of innovations (eco-innovation), environmental impacts of shipping, state of art of ballast water treatment systems and the drivers influencing cleaner technology adoption. The researcher deemed it necessary to have an understanding of the drivers of cleaner technologies, and how they could be applied to improve the implementation of ballast water treatment technologies in the shipping industry. In this regard, it took on a qualitative approach with a case study design, so as to study these concepts in detail to gain more insight of real-life, and explore understanding of the environmental technologies as the subject under investigation (Yin 2009).

2.2. Case Study Selection

Yin (2009) describes a case study *as ''an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident*. The ballast water treatment system was selected as a case study to explore how these environmental technologies could be implemented in shipping industry. Ballast water treatment systems are a special type of technology that is complex and difficult for maritime service companies to introduce into business operations. In view of this, this subject topic seemed an interesting case for study that would guide the study of different units within the selected case (Flyvberg 2011). For instance, units like ship-owners, technology providers, IMO, USCG and the classification society. More so, it also contributes to a researcher's learning process and skills (ibid)

Theoretical concept

The background of this study focused on the ballast water treatment systems as a case study of how to implement environmental technologies in the shipping industry. Thus the researcher made use of a theoretical framework based on the theories of innovation and cleaner technology drivers. The theories on the drivers of eco- innovation explain key drivers significant for the implementation of environmental technologies, and in a way some of these drivers are related to the problems presently being experienced in the shipping industry. These theories were most appropriate and best fit for analysing the research questions and as well important for setting up the analytical structure.

2.3. Methods

Methods are an integral part of a study used for collecting information for the purpose of a research study. For this thesis, different methods were used to build up the investigation of the research study. These methods includes; literature review (documents analysis, website reviews), Interviews and use of email all of which are applicable for a qualitative research (Bryman,2012; Kvale &

Brinkmaan,2009). The selection of these methods allowed the researcher to get information and knowledge about the shipping industry, actors involved and their roles. For instance, reports put together by consultants in relation to BWTS, classification societies (DNV, Lloyd's Register, Marine link, Shipping News) were read with relevant information extracted in relation to BWTS.
All in all, a qualitative research strategy was also adopted as an approach which makes emphasis on words and text rather than using a strategy which quantifies and analyse set of data's (Bryman, 2012).

2.4. Data Collection

2.4.1. Literature Review

The main method used to gather information for the research study was literature review which involves review of various documents, websites and reports. Documents review as a method is an important aspect of research work.
According to Rubin et, al (2009), this method combines summary and synthesis to analyse state of the art knowledge on a topic under investigation for a given time frame. A review of available literature on the shipping industry related to BWTS was conducted. Systematic searches were made on specific scientific databases to find the needed information:
(1) the Google Scholar http://scholar.google.dk/
(2) Science direct http://www.sciencedirect.com/
(3) Aalborg University Library http://www.en.aub.aau.dk/

These scientific databases had a wide array of current information papers. To find the vital papers and specific keywords utilised such as: *"Ballast Water Treatment Technologies", "Cleaner Technologies", "Eco-innovation"*, etc. This method enhanced the researcher's understanding as well as complementing other data collection methods. Numerous articles and web based documents were also analysed to understand ballast water treatment systems and the key drivers to improve the implementation of the technology within the industry. These sources made the study process easier in finding journals, articles, web- based reports and books which are relevant for the analysing literature in relation to ballast water treatment technologies study.
The literature review method also enabled the researcher to gather background information on the research study, identifying a sampling frame from which key informant samples were drawn with discovering right theories to use which are relevant to the shipping and ballast water treatment systems were applicable for the study. The limitations associated to the document review method was partial judgement from researchers, difficulty in the choosing the right documents and document retrieval (Yin 2009). The researcher made use of various sources which are reliable to avoid relying too much on a particular document.

2.4.2. Interviews

To cover comprehensive views from different actors in relation to the ballast water treatment systems, diverse approaches in soliciting information were employed; namely electronic mail (e-mail) and phone interviews. In support of the telephone interview, a set of open-ended questionnaires that enabled the respondents to formulate their own responses were sent via their emails as requested by informants. The answered questionnaires were returned to the researcher by the respondents at a convenient date within the study period. However not all informants responded due to the busy work schedule. These methods were used as feasible alternatives to face-to-face interviewing in this case (Meho, 2006).

More so, interview method proved to be cheaper in terms of time and for respondents who were not physically accessible as at the time of the carrying out the study. Due to the busy schedules and unavailability of key respondents, only two telephone interviews were carried lasting between 20-30 minutes. Before hand, a brief introduction of the research study focus and questionnaires were sent ahead through e-mails to various respondents. Also, a specific date and time was arranged for an interview based on the respondents' convenience.

However, during the telephone interview, recordings were done with direct permission from the respondents to allow the researcher avoid missing out on vital information while taking notes (See attached list of resource persons interviewed). In addition to support the telephone interviews, the email method was also used. Open ended questions (approximately 11) were formulated by the researcher based on the study context to ensure consistency and sent through mails. In case of any clarification, follow up calls were made to understand different themes from these varied respondents.

Interview selection

Through document analysis, key informants within the field related to ballast water treatment systems and the shipping industry were chosen to allow the researcher have different perception on the study context.

These respondents include key actors in relation to the technology.

a. BWTS Consultant: Frost & Sullivan. (Frederick Royan- Global Research Director)
b. Classification society: Det Norske Veritas AS. (Andreas Cappelen -Technical Engineer)
c. BWTS manufacturer: DESMI Ocean water Guard. (Christian Invorgsen - Technical Director).
d. BWTS manufacturer: Bawat A/S. (Jan S. Hummer- representative)

2.5. Quality of the Methods

In an attempt to validate the data used in the research study, document review, primary data generated from telephone and email interviews as well as websites were used as sources of evidences. This approach is in line with Yin (2009) explanation that recommends use of a combination of different methods of data as a chain of evidence to support data collection. It's through such approach that validity and reliability of the study can be achieved (ibid). Therefore, in order to establish validity of the study, data collection embedded use of; email, telephone interviews and document along with website reviews which were helpful in gathering information from various actors associated to the ballast water treatment systems.

Summary and Research design

In general, figure 3 summarises the problem formulation, research design , methodology and the theoretical review of the study, providing a platform that has formulated the research questions of the for the study topic.

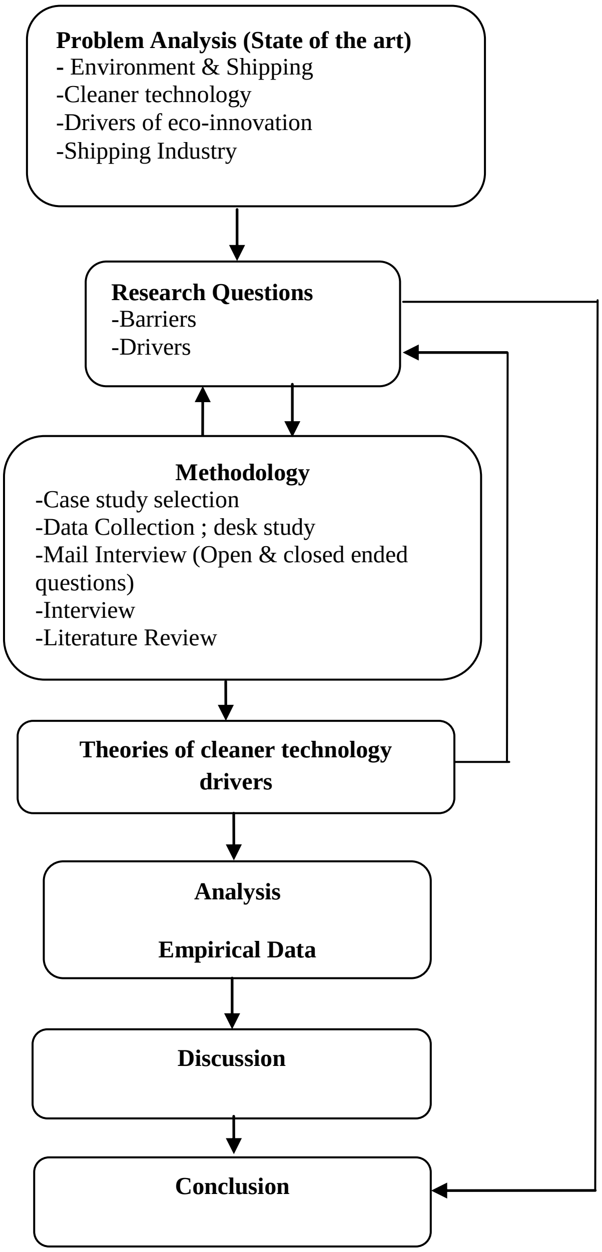

Figure 3: Research Structure of the Project (own elaboration)

This research structure is categorized into different steps. It consists of information derived from various chapters of the study. That is; the problem analysis (state of the art), methodology, theories of cleaner technology drivers, analysis, discussion and conclusion. The aim of the model was to assist the researcher in defining the key goals and problems of the study. It also helped to clearly present the research questions and methods used in the study.

The first section starts with the introductory chapter which incorporates the problem analysis. It presents the state of art of shipping in relation to environment, and gives an overview of the different types of ballast water treatment technologies available in the market, eco-innovation and cleaner technology drivers and the guiding research questions of the study. The methodology section (Chapter 2) then explains the research design as well as the various methods employed in carrying out the research objectives. The research design which is the qualitative approach to research is highlighted in this section together with the selected case study design. Chapter three subsequently outlines the theoretical bases of the study; innovation, eco-innovation, cleaner technologies and ballast water treatment technology in the context of the shipping industry.

This is followed by the theoretical chapter that formulated the analytical framework used to analyse the dynamic process for implementing cleaner technologies, It employs the theory of cleaner technology. The ensuing chapter four helps spells out the study outcomes (regulations technology, market and firm strategies). It presents empirical information for the research study achieved through investigating the drivers and barriers influencing the implementation of ballast water treatment technologies in shipping. Chapter five (discussion) continues with a thorough assessment of the study (empirical) findings which are then addressed. The conclusion chapter finally presents the conclusion of the study, by giving a sum up of the research study and consequently answers the two research question posed originally.

CHAPTER THREE

3.0. Theoretical framework

This chapter describes the theories on the drivers of eco-innovation and cleaner technologies.
For the purpose of this study, the core theoretical concepts underpinning this study are innovation, eco-innovation, cleaner technologies and ballast water treatment technology. These concepts were approached from the shipping industry perspective. This chapter attempt to outline the conceptual model for the research study.

3.1. Innovation.

The concept of innovation as defined by OECD is *"the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations"* (OECD 2005). Similarly, Boslaugh (2012) also defines innovation as a way of creating or doing something new, either by developing a new product or establishing new ways of solving problems theoretically.
Based on the OECD (2005) description of innovation, this concept consist of four major types of processes including product innovation, process innovation, organizational innovation and marketing innovation.

Innovation has become a must in today's fierce competitive business environment. Innovation is also a boost for economic growth and development and hence the need for firms to be innovative. These firms however need a favourable environment and the support of appropriate institutions to succeed. Firms are thus motivated to innovate to satisfy market demands, by introducing superior methods of operations or superior products to stay ahead of competition.

3.2. Eco-innovation

A key concept underpinning sustainable development is satisfying humanity's present needs without compromising the ability of future generations in meeting their (UN.ORG,2012). Technology has a crucial role to play in this regard. Hence superior innovations and technologies with limited environmental impacts or carbon footprints by way of *eco-innovations* are worth considering (Kemp,2009). The term eco-innovation is used in this study context to analyse the drivers which influences firms to undertake environmentally friendly products.

Rennings (2000) describes eco-innovation as techniques for developing novel products, processes or ideas as well as enhancing environmental sustainability. Kemp & Pearson (2008) also explain that "*eco-innovation is the production, assimilation or exploitation of a product, production process, service or management or business methods that is novel to the firm and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives"*. This implies that the firms which embrace eco-innovations stand to gain from reduced cost of doing business and limited environmental footprint (OECD, 2009). Kemp (2009) indicates that eco-innovation can be categorized as environmental technologies, product and process innovation, green system innovation and organizational innovation. Environmental technologies are described as new pollution control technologies or cleaner technologies introduced into a production process to reduce negative environmental impact on the ecosystem (Kemp, 2009).

3.3. Cleaner technology

The concept of eco-innovation consists of various innovative pollution control measures or technologies such as waste reduction techniques, green technologies, cleaner technologies and transport technologies (Kemp and Pearson 2007).

Cleaner technologies are used as a means of reducing pollution or harmful environmental impacts at the main source (Frondel et. al 2007). These technologies are regarded as preventive techniques used by firms for reducing environmental problems such as emission reduction at source (Del Rio,2009). Cleaner technologies tend to limit emissions and waste and most importantly reduce cost in treatment pollution and waste management processes (Editorial 2008). However, despite all the positive sides of the cleaner technology in the global industry, there are major setback affecting its rate of development and adoption.

In shipping perspective, ballast water treatment technologies can be seen to have similar features or functions to that of cleaner technologies. The introduction of BWTS by the international maritime community in 2004 became necessary since there was no sufficient technological solution to treat ballast water operations at that time. The convention which requires all vessels to carry out a ballast water technique (either ballast water exchange or ballast water treatment systems that fulfil the D2 ballast water Discharge Standard Requirements.

Given the strict requirement of the ballast water performance standard, ballast water treatment systems are perceived as environmental technologies which could possibly reduce the risk of marine invasive species to a minimal level through the elimination of existing organisms in ballast water (IMO-WMU, 2010). Although, BWTS is considered as reliable equipment that can efficiently remove invasive species, but maritime service actors like the ship owners and technology manufacturer still have difficulty in introducing the technology in shipping. In terms of efficiency and reliability, the technology has been designed to operate through different methods. Ship-owners can determine the effectiveness of BWTS only if they install on their vessels and put into use.

3.4. The Framework of Cleaner Technologies

This section begins by introducing the framework that is required for eco-innovations, the drivers and barriers of eco-innovations which relates to cleaner technologies and ballast water treatment technologies.

3.4.1. Drivers of cleaner technologies (eco-innovation)

There are several approaches to stimulating eco-innovation. Nevertheless, the study will focus on some of the key drivers which are vital for achieving eco-innovations. This drivers include *regulation, technology, market forces and organizational strategies* (Rennings, 2000; Horbach et.al. 2011*; Kesidou & Demirel, 2012)***.** Different authors used the word, cleaner technology, eco-innovation, environmental technologies are used inter-changeably. However, in this research study, cleaner technology and eco-innovation are used interchangeably.

3.4.1.1. Regulation Drivers

Several studies describe regulation as an important driver which drives firms to implement eco-innovation (Rennings and Zwick, 2002; Horbach et. al. 2012). But Rennings & Rammer (2010) explains environmental regulation has standards or directives established by the industry or government to facilitate the reduction of environmental burden and resource usage. They argued that regulation can trigger firms to implement innovation activities through various ways. Regulations stimulate firms to adopt processes which lead to the improvement of existing technologies and development of new ones if necessary (Rennings & Rammer 2010). Environmental regulation also pushes firms to invest on environmental technologies which act in compliance with standards (Rennings & Rammer 2010). According to Ashford and Hall (2011), firms can engage in eco-innovation activities only if they have the right attitude (willingness), knowledge, opportunity and capability to make the necessary changes. In most cases, regulations which are strictly enforced can influence firm's decision in the implementation of innovation. This implies that the stringency of a regulation implemented will determine the level at which firms operate. From shipping perspective, different regulatory bodies at international, national and local level have put in place rules on the discharge and treatment of ballast water. At the International level, ballast water operations are guided by the IMO ballast water convention, but there are challenges related to the enforcement of the regulation. As an interim measure, each member nations is saddled with the responsibility of establishing individual national standards to control and manage the activities relating to ballast water operations. Definitely, the stringency and enforcement of these standards differs across various IMO member nations due to different commitment, willingness, motivations and capabilities to enforce compliance.

3.4.1.2. Technology drivers

Technology plays a vital role in the reduction of various forms of environmental problems and helps industrial firms in the realization of their environmental goals (OECD 2001). According to studies, technologies are innovation drivers that are used to cause incremental changes or upgrading on existing products and processes (Horbach et. al. 2011). Similarly, technology responses are incremental innovation embarked upon to develop new products and processes (Kemp 2000; Machiba 2010). Firms who engage in incremental innovation do so to improve technologies and processes which currently exist to increase their efficiency output, without altering or changing the whole processes (OECD 2012).

Meanwhile, Kemp and Pearson (2007) argue that green technologies and environmental technologies can be considered to have the same functions. They point out that these technologies are used for minimizing pollution and managing resources in a more efficient manner (Kemp and Pearson, 2007). These technologies are further classified as cleaner technologies and end-of-pipe technologies. End of pipe are pollution control technologies used to transform a production process without making changes or altering the entire production process (Frondel et. al. 2007). While cleaner technologies require a total change in the production processes to achieve considerable reduction of pollution that may be generated from the process (Triguero et. al 2013).

Organisational capabilities are another important technological driver that induce eco-innovation among firms (Kesidou and Demirel 2012). These drivers are responsible for influencing firm's decision in the adoption of cleaner technologies. Montalvo (2007) describes organisational capabilities as a situation whereby firms are endowed with the required knowledge and expertise to implement innovation into their business operations (Montalvo 2007). In order words, to achieve a successful eco-innovation process, firm's needs to possess the required technological and organizational capabilities such as knowledge about the technology and the process involved (Baumol 2002; Horbach 2008; Triguero et. al. 2013). According to Montalvo (2007), efforts made by industrial regulators to induce pressure on firms in the integration of innovative strategies in their business operations may not be enough to achieve diffusion of cleaner technologies, unless firms are able to develop and incorporate organizational capabilities into their internal business strategies. For instance, firms who take the initiative to implement pollution prevention techniques and practices such as efficiency, and improvement in environmental performance in their production process are more likely to adopt cleaner technologies (Montalvo 2007; Kesidou and Demirel 2012).

3.4.1.3. Firm Strategies

When firms set environmental targets or embrace environmentally friendly policies; it serves as a motivation for them adopting cleaner technologies (Dangelico and Pujari 2010). Firms that are able to effectively integrate environmental sustainability concepts as well as reflect such ideas within the company could be well positioned in the deployment of environmentally sound products (Dangelico and Pujari 2010). The ability of firms to effectively communicate the relevance of environmental targets and policies to staff within the company is necessary to this end. This communication is carried out by way of developing company environmental ethical codes and benchmarks to the benefit of all staff (Dangelico and Pujari 2010).

Studies also stress the importance of organizational capabilities as a factor which influences firms' decision on eco-innovation of environmental friendly products. (Kesidou and Demirel, 2010; Jorbach et.al. 2012). Eco-innovative firms can develop their organizational capabilities by implementing Environmental Management Systems. Environmental management tools are vital for the successful introduction of environmental product innovations (Horbach et. al 2012). This policies supplies information for new product opportunities.

3.4.1.4. Market drivers

Market drivers which is otherwise known as demand side drivers has also been highlighted by various authors as a significant factor which determines eco-innovation (Horbach 2008; Doran & Ryan 2012). Consequently, firms which desire to generate more profit or revenue in their businesses need to embark on eco-innovative practices (Horbach, 2008; Kesidou & Demirel (2010). Kammerer (2009) also makes a strong case for market pull factors as an important driver which determines eco-innovation. In his study, he highlighted the idea of consumer benefit has a vital tool that influences firms decision in the implementation of eco-innovation. Thus apart from regulatory policies which push firms to adopt cleaner technologies, environmental pressures drives firms to adopt cleaner technologies (Montalvo 2008). Based on this, firms (e.g maritime companies) who find them-selves operating in a global market are influenced to invest in cleaner technologies to satisfy consumers' demands and also remain competitive in the market.

3.5 Analytical Framework

The research employs the concepts of innovation, eco-innovation and cleaner technology drivers as the key theories for the studying how *innovation and development of ballast water treatment technologies in Shipping* can be realised.

The framework, illustrates the procedure for analysis of my study data. To explain how the proposed theories are employed, analysis of these central topics are assessed to generate a complementary link that highlights the background challenges affecting the implementation of BWTS in the shipping industry, and the important drivers that can help to overcome these challenges in the shipping industry as indicated by the research questions.

This analytical frame thus employs applicable questions on the BWTS industry to produce a problem tree that addresses these factors in the proceeding sections. Why questions; suggest the main concept behind the research work to attain the empirical knowledge of the theme, where as the how and what; touches on areas of actions. These assist with the theme and study context of the thesis, the analysis is therefore premised on these core topics which lie within the theories outlined above.

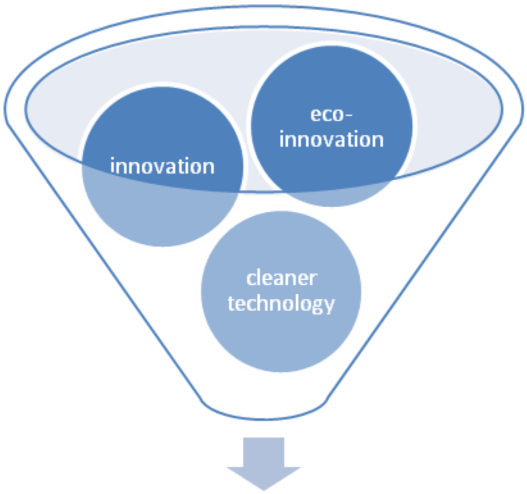

Figure 4. Analytical framework

The analytical framework can be considered as a funnel which is being used to filter some products. In this case a funnel is used to filter the various themes in the study to produce the results (filtrate) to be assessed / analysed in the discussion chapter. Innovation, eco-innovation and cleaner technology are the sieves in the funnel through which the themes are filtered.

Innovation: sustainable development has laid emphasis on the need to improve efficiency and effectiveness of organisations. In today's competitive shipping industry, firms need more than quality products to stay ahead of competition; firms need innovative processes and management that will improve cost efficiency and enhance productivity (OECD 2005; Horbach et. al 2012). The BWTS is one area in the shipping industry which demands such innovative processes as well as management to become successful.

Eco-innovation: sustainable development also indicates the need for the environment to play centre stage in technology development. This suggests that technology has to integrate environmental considerations or be environmentally friendly for the good of society (Kemp 2009; UNIDO, 2013). This is the focus of eco-innovations which is another aspect of the analytical framework.

Drivers of eco-innovation: to achieve the ideals of eco-innovation, there is the need to consider the critical determining factors which are needed for achieving the desired eco-innovation. The study consequently considers drivers of eco-innovation as part of the analytical framework (Rennings and Zwick, 2002; Kesidou and Demirel 2012; Horbach et. al 2012).

The environment is a key aspect of innovation. To enhance sustainability, firms have to balance financial, social and environmental performance (UNIDO, 2013). Eco- Innovation in the context of environmental management literature denotes an 'innovation that improves environmental performance‘(Carrillo, Río, & Könnölä, 2010). In relative terms, innovation is considered the most risky and full of uncertainties in the economic domain (Waarden, 2001).

Furthermore compared with general innovation, firms view eco-innovation to be even more riskier and more fraught with uncertainties. Numerous regulations, policies as well as institutions, have been created as stimulants for innovation. However the results of such measures indicate poor outcomes in reducing the uncertainty and risks of eco-innovation. To address these uncertainties and risks to produce success in eco innovation, requires that specific drivers be indentified (Ashford, 2011; Horbach et. al 2012). Thus identifying significant drivers of eco-innovation is necessary to achieve success of BWTS in the shipping industry. Consequently the drivers of eco-innovation form a major part of the analytical framework. The proceeding chapter gives an account of the outcomes of the study.

Summary

This chapter has presented the theoretical underpinnings of the study; touching on the necessity for innovation; determining factors and the technological approaches that can be employed. Theories of eco-innovation and cleaner technologies drivers have been presented and developed to analyse the structure of this research study. The chapter concludes with a guiding framework outline to be used for data analysis. The proceeding chapter gives an account of the outcomes of the study.
The proceeding chapter gives an account of the outcomes of the study.

CHAPTER FOUR

4.0. Results

This chapter explores the drivers and barriers influencing eco-innovation in the shipping industry. Drivers such as regulatory, technology and market pull for improving the attractiveness of ballast water treatment systems are presented in this section. Based on the findings of this research study, emphasis will be made to analyse cleaner technology drivers, with focus on Regulation, Technology and market drivers.

4.1. Regulation drivers

4.1.1. Ballast Water Management Convention: Ballast Water Treatment Systems

As earlier mentioned in the introductory section, the International Ballast Water Convention is regarded as the first significant legislation adopted to control and eliminate environment and health issues from the transfer of invasive species. This regulation includes specific requirement that demands every vessels depending on its ballast water capacity and construction date should treat it's ballast water with appropriate treatment systems having the right approval. Due to the increasing number of marine invasive species especially around the shores of the marine environment, over 60,000 ships globally will be required to install different ballast water treatment technologies on board during the 12 months of ratification. Concerning the condition of the IMO convention, entry into force can take place only when 12 months after 30 member nations consisting of 35% of world shipping tonnage have included their signatures to ratify the convention. Meanwhile, as at December 2013, only 38 countries representing 30.32% have included their signatories on the ratification of the convention (ClassNK 2013).

As an interim measure, the United State Coast Guard established a rule for every ship entering US ports. This regulation demands all ships coming to US ports to have ballast water treatment system on board. Depending on the ballast water capacity of the vessel, the standards must be strictly adhered to starting from 2014. The rule stipulates that newly constructed vessels on or after 1st of December, 2013 must act in accordance with the established ballast water discharge standard (NOAA, 2013). While ships built before 1st of December, 2013 having ballast water capacity that is less than 1,500 m3 or larger than 5000 m3 are required to act in compliance with the ballast water discharge standard on their first scheduled dry-docking from 1st of January, 2016 (NOAA, 2013).

The rule also requires that all vessels already built before 1st December, 2013 with a ballast water capacity within the range of 1500 - 5000m3 should comply on their first scheduled dry - docking after the 1st of January, 2014 (NOAA, 2013). The fact that December 1, 2013 deadline for ballast water treatment installation for existing vessels have just passed, beginning from the 1st of January 2014, all ships intending to enter the shipyard for dry-docking activity are required to conform to the USCG final rule by the time it departs the shipyard.

In general, the United State Coast Guard serve as an interim rule that could trigger the sales and installation of ballast water treatment technology in Europe, Asia- Pacific and North America if properly implemented (Frost & Sullivan, 2013).

	Vessel's ballast water capacity	Date constructed	Vessel's compliance date
New vessels	All	On or after 1 December 2013	On delivery
	Less than 1500 m3	Before 1 December 2013	First scheduled drydocking after 1 January 2016
Existing vessels	1500 - 5000 m3	Before 1 December 2013	First scheduled drydocking after 1 January 2014
	Greater than 5000 m3	Before 1 December 2013	First scheduled drydocking after 1 January 2016

Table 3- Implementation schedule for the enacted USCG ballast water treatment standard.

Source: Adapted from DNV.GL, (2013)

Summary

This section has shed light on the guiding regulation for the BWTS; the IMO´s BWTS Convention which triggered the wide interest in this particularly technology. It also touches on the United State Coast Guard ballast water discharge standard rule regarding the requirement and implementation of BWTS on new and existing vessels. It also considers the technical, financial and managerial demands of this new technology for ship-owners and technology providers in the shipping industry.

4.1.2. Institutional Rules

As discussed in the introductory chapter, the classification societies play a crucial role in the shipping industry by rendering technical services, verification exercises and issuance of certificate to maritime service firms (IACS 2013). They are authorised by flag state administration to perform verification procedure for marine equipments such as BWTS and scrubbers. They verify treatment technologies developed by technology providers and issue certificates. In order words, it is obligatory for technology providers to make their systems available to a third party body such as the classification societies for evaluation and certification purposes. The approval process which is performed according to the requirement of the IMO BWM convention (G8 and G9 Guidelines) aims to certify treatment for type approval and efficiency. In an interview conducted with a technical representative in Det Norske Veritas GL, Cappellen (2013) informs that as classification society they develop rules for safety in relation to ballast water treatment systems, and render consultation services to ship-owners to invest in ballast water treatment systems (Cappellen 2013). Classification societies are seen as key actors in the development process for treatment systems, because flag state administration has granted them the authority to issue type-approved certificates to systems which complies with standards.

4.1.3. Stakeholders Perspectives on regulation drivers

The recent enforcement of the United State Coast Guard rule is perceived to facilitate the development and supply of ballast water treatment technologies. According to a recent report from Frost & Sullivan;

> *"the interim the United States Coast Guard (USCG) requirement for vessels using the US waters to be equipped with ballast water treatment systems is set to enter into force from 2014. It has provided an interim measure in the form of the Alternate Management System (AMS) approval process which has been secured by about 25 ballast water treatment suppliers so far"* (Frost & Sullivan, 2013).

The report indicates that the USCG rule will have a significant impact on the European economy by facilitating the sales of equipment and as well dictate market proceeds from the year 2017 to 2019. For the technology provider, the recently established USCG rule is gradually providing a clearer view concerning the uncertainties facing the ballast water treatment systems market. Manufacturers with the required equipment, and a well structured sales and supply chain will tremendously benefit with the entry into force of the USCG rule (GWI, 2013).

4.2. Technology drivers for BWTS development

The aim of environmental technology is to reduce environmental pollution and cost, and in order to achieve this, findings from interview and review shows that it is an important driver that must be considered to improve the attractiveness of ballast water treatment systems. The worldwide market revenue for ballast water treatment system installation was estimated around $466.6 million in the year 2013 (Frost & Sullivan, 2013). Analysis on the retrofit market has further been projected to increase from $466.6 million to $3.14 billion by the year 2023 (Frost & Sullivan, 2013). With regards to this, the retrofit market has been predicted to make a larger contribution in terms of shares to the global ballast water treatment systems in the year 2018.

The business cycle of ballast water treatment technology revolves around three key stages: development, installation and operation. Both small and medium size companies can provide '*products and services to ship-owners, ballast treatment technology manufacturers and shipyards' (MARCOD, 2013)*. Hence, several opportunities exist for maritime service companies in various phases of the ballast water treatment technology business cycle. Development stage of the technology requires the implementation of different processes.

Technology manufacturers need various forms of support ranging from permit management, testing, ship architecture consultants, and supply of specialized instrumentation. In this stage, different treatment systems are designed. For instance, as explained in the first chapter, BWTS types were classified into mechanical, physical, and chemical treatments. Depending on the shipboard conditions, the combination of these types of technology can be filtration, hydo cyclones and disc or heat treatment, ultrasound and any other method (WWI, 2013).

Permit management addresses the demands of IMO ballast water resolution. The entire procedure involves obtaining authorization from classification societies and national authorities. In this case, equipment developed by technology providers are presented for evaluation and certification exercise to proof the efficiency and environmental requirement in line with performance standards. Coupled with this process, the classification societies carry out a land based and shipboard assessment on the systems. For the installation stage, the concentration of shipping yards in South-eastern Asia has nurtured a tight relation between ship owners and ship yards around associate services and products (MARCOD, 2013; Frost & Sullivan, 2013). Asia-pacific (South Korea, China and Japan) is the base for the design of ships, ship-owners and shipyards, and this is as a result of the retrofit opportunities that are being created in the region. (Frost & Sullivan, 2013).

This has led to a situation where very little prospects exist for external service firms particularly in Europe. Usually, a BWMS manufacturer obtains a request from the shipyard, and the shipyard requires the system delivered in parts. With regards to the retrofit market, there are several prospects for mutual collaboration amongst manufacturers, shipyards and other maritime service firms. BWMS producers regularly seek partnership with maritime equipment installing firms. Some of this partnership is concentrated on initial phases to carry out the engineering assessments (calculations, detail drawings, etc.). Also, a different company can install the system on board (MARCOD, 2013). Operation/ after sales service: this stage offers the prospect of combining product and services into one package. This can be attributed to the fact that ship-owners concentrate their business in transportation, and would embrace integrated solutions that will subcontract the maintenance of ballast water treatment technology to the supplier (MARCOD, 2013).

4.2.1. Technological Assessment for BWTS.

Ballast water treatment systems undergo series of assessment to evaluate its performance and efficiency before given an approval by an independent body (CSL 2013). The main objective of carrying out this process is to verify the degree at which equipment can eliminate or destroy invasive species present in the ballast water. Driven by this need, system providers are expected to develop their equipments in accordance to the IMO ballast water performance standards, while ship owners are also required to install systems which act in compliance to the IMO ballast water performance standards for ballast water discharge. Factors such as efficacy and availability of the technology in the market (Lyolds Register 2012; CSL 2013).

Efficacy of BWTS

Results indicate that efficacy is an important factor that needs careful consideration by systems providers when designing their equipment. It is described as a process whereby treatment technology should be a able to fulfil its obligations by effectively removing or eliminating micro-organisms contained in ballast water (CSL 2013). Studies indicates that the effectiveness and efficiency of treatment technologies developed is mostly evaluated based on the type of invasive species targeted, trade routes of ship, and ship's design (PWSRCAC, 2005). The process used in carrying out the efficacy of treatment systems tends to evaluate the effectiveness of systems for compliance purposes with existing performance standards. (Either the USCG or future IMO ballast water performance standards).

Availability of BWTS

Availability of equipment in the market depends on the demand made by the industry. And for a system to be commercially available, factors such as an estimate on number of vessels that would purchase the treatment systems, accessibility and sufficiency of treatment systems in meeting the demands of the industry, availability of resources that will facilitate the installation of treatment systems on new and existing ships (CSL 2013).

4.3. Market Drivers

Apart from regulation which act as a driver for the implementation of environmental friendly technologies in the maritime sector. In order words, market driver can influence maritime service firms to implement environmental technologies which act in compliance with regulations.
As explained in chapter one, Del Rio Gonzalez (2005) highlight corporate image as an important factor that could influence firms decision in the investment of cleaner technologies. From shipping perspective, It is significant for ship-owners to invest on ballast water controlling technology to help reduce their environmental impact. Investment of this kind could improve their company image and as well increase their customer base.

A typical example of a voluntary initiative established to provide an avenue for ship-owners to be environmentally conscious in their shipping operations is the Clean Shipping Project (Clean Shipping Project 2012). This projected was initiated by the Region Västra Götaland, Port of Gothenburg and the Göteborg Region Association of Local Authorities (Clean Shipping Index, 2011). The project group initiated an on-line tool for various actors like shipping companies, cargo owners and consumers of transport goods. For ship-owners, they are required to input at least 20% of their vessels in the index for evaluation of environmental performance of the vessels. In line with the information provided by the shipping companies, cargo owners evaluate, rank and select shipping companies based on their environmental performance. Cargo owners partake in this evaluation process by filling in 20 questions for different types of vessels in relation to ballast water treatment, CO_2 emissions, chemicals, NO_X and SOX emissions. The results of the evaluation are then made available to the transport purchasers and shipping companies.

From market perspective, online tool serves as a platform to influence the decision of ship-owners in the adoption of environmentally friendly technology to reduce their impacts. According to a Swedish shipping line (Transatlantic AB), the CSI initiative serves as a medium to evaluate their environmental performance, maintain a good image and most importantly increasing their customer base (Clean Shipping Index 2011). While Volvo Logistics an automotive producing company (Consumer) claimed to have identified with the CSI group to support sustainable development by evaluating the environmental performance of their transport suppliers (Clean Shipping Index, 2011). From environmental point of view, the Clean Shipping Project can be a medium to promote eco-innovation among maritime service companies. Also it encourages the use of environmental technologies to help in the reduction of negative environmental impact of shipping activities. This is as a result of the roles played by customers (e.g transport buyers, cargo owners) to push ship-owners to be eco-friendly or adopt environmentally friendly products.

4.3.1. Cost Analysis for Ballast water treatment systems

For the industry, one significant factor identified to be influencing the development of ballast water treatment systems is cost. The cost associated to BWTS depends on the equipment type, vessel type and size of the vessel. Various price ranges exist for different units of system, For instance, as shown in table 4, the combination of filtration and chemical treatment systems were estimated at an approximate value of $950,000, while the price range for the same system purchased at a bulk rate is required to be sold at a lesser price of $852,000 (King et. al. 2012). In the case of the combined electrolysis and electro-chlorination equipment, the estimated price were estimated around $670,000 and for a bulk purchase it cost 600,000 (King et. al. 2012). Also, the total cost of purchasing each of these systems will also depend on the size of the vessel. Bigger vessels may require the installation 2 units of systems, so that it would be able to cope with flow rate of ballast water volume contained in the ballast tank. The cost of acquiring these 2 units of systems will be higher in this case. An estimate made for a bulk purchase shows that these systems cost around $180000 (King et. al. 2012).

Unit Type (Systems)	Market price(US Dollars)	Bulk price (US Dollars)
Electrolysis & Electro-chlorination	666,667	600,000
De-oxygenation & Cavitation	640,000	600,000
Filtration & Ultra-violet Light	933333	840,000
Filtration & Chemical	946,667	852,000

Table 4: Purchasing Cost for Selected Ballast water Treatment Systems. Source: (King et. al. 2012)

The cost implication for buying and installing a system on a vessel were also calculated around $1 million. Consequently, analysis presented for the global installation of BWTS for both existing and new vessels from now till the time of entry into force of the IMO ballast water management convention were estimated around $70 billion annually (King and Hagan 2013). Also, the cost implication for compliance from all vessel owners is expected to be around $ 10 billion annually by the time of the convention is enforced (King and Hagan 2013).

4.4. Firm Strategies:

As analysed in the theoretical chapter, organizational capabilities of firms is an important factor that influence their engagement on eco-innovative activities (Kesidou and Demirel, 2010). The level of firm's innovativeness and capability to acquire skills and knowledge will largely have huge impact on firms decision on the implementation of environmental technologies. This is to say that, firms with organizational capabilities are more likely to have the potential to engage in eco-innovative activities.

The study also identified Environmental Management Systems as a key strategy for firm's eco-innovativeness on environmentally friendly products (Horbach 2011). This refers to *'a set of processes and practices that enable an organization to reduce its environmental impacts and increase its operating efficiency'* (US EPA, 2013). Firms implementing environmental management schemes are more likely to be motivated to embrace innovative activities which give room for development and use of environmental technologies. This suggests that environmentally active companies in the shipping industry have a higher probability of developing more novel environmentally related products. For instance, results shows that that some key actors are utilizing the delay period for the regulation to invest more on research and design activities. In the opinion of a technology provider, Kim Diederichsen who is the CEO at BAWAT explains that;

> The setback in the industry is perceived as an opportunity for them to increase their investment on designing new technologies, this is because of the company's believe that the

> ballast water convention will take off sooner or later, and by the time of enforcement they would be well positioned to meet the demands (Diederichsen, 2013).

This learning indicates that, service providers firms with the adequate organizational capability may not be deterred from carrying out eco-innovation.

In relation to cleaner technology drivers, a leading technology supplier was asked for his opinion on what drivers that could spur the development of BWTS. In his words;

> "*Having an idea, which the "manufacturer" think might offer a system more competitive than what is presently available".* (Hummer, 2013)

The response points out the firms capability to seek for knowledge and skills to improve existing technological product. This indicates that, technology suppliers can play a huge role in improving the implementation of BWTS if they commit more of their resources in seeking for knowledge or skills.

Also during the course of study, the researcher also identified that firm's can engage in network and partnerships with other key stakeholders to improve their innovativeness on the implementation of cleaner technologies. For instance, the case of Danish Partnership on Ballast water is a very good example which seeks to promote innovation. This partnership initiative is mainly funded and driven by the Ministry of the Environment to foster collaboration among the Danish Maritime Authority, the Danish Ship-owners' Association and maritime service companies such as equipment manufacturers, ship-owners and the classification societies (Ministry of the Environment, 2012). The main reason for initiating this partnership was to promote the development and use of eco-efficient technologies among Danish maritime actors. It seeks to foster knowledge improvement and formation of network among mentioned stakeholders, and to help prepare and position these actors to act in compliance to the future requirement of the Ballast Water Management Convention (Ministry of the Environment, 2012). With this kind of partnership in place technology providers will be pushed to develop and supply efficient equipment to have a good image in the market.

In relation to business strategies, another form of partnership initiated to encourage innovation in the Danish maritime sector is the Green Ship of the Future (GSM, 2010). In acknowledgement of the environmental responsibility promoted in shipping, Danish shipping companies came together to establish the Green Ship of the Future to promote the research, development and establishment of green technologies within the industry (GSM, 2010). At the moment, the partnership has been able to set up a network of partnership agreement with different Danish organizations such as Danish ship-owners Association, Danish maritime, Danish Marine Group and Danish Maritime Authority (Green Ship, 2009).

The idea is to support the reduction of environmental impact of ships operation. Current members of this group include shipping companies, maritime manufacturers, interest groups, and academic institutions (GSM, 2010). For the technology manufacturers, their objective for joining this group is develop environmentally friendly technologies that will reduce environmental impact of shipping operations. For instance, as a way of developing efficient technologies, DESMI Ocean Guard explained on its company's website that they associated with the Green Ship of the Future in 2009 to set up a network that stimulates research, innovation and development of environmentally friendly technologies for ships (DESMI, 2013). This learning implies that partnership could be seen as a medium for technology manufacturers to develop and test new technologies such as the BWTS. This process brings together different members in the group, and as a result encouraging research and design activities.

4.6. Barriers

4.6.1. Regulation

A major barrier identified with the implementation of ballast water treatment systems is the non existence of a binding international regulation to move the industry forward to the next level. Although the deadline for the enforcement of the IMO ballast water management convention has been projected to come into be enforced sooner, but the slow ratification has been highlighted as a major factor in the industry. The future IMO convention which is waiting for entry into force has been perceived to be a comprehensive regulatory framework for other regulations or guidelines in existence. Some of the respondent acknowledges the fact that regulation is a barrier affecting the retrofit industry.

> **T. Anderson, Optimarin BWTS:** *"The long running saga concerning the progress of the IMO's Ballast Water Convention adopted in 2004 looks to run on for some time. Yet, with 35 % of World shipping tonnage required, only 37 countries representing 30.32% of World's tonnage have ratified the convention to date"* (Andersen 2013).

> ***C. Invorgsen, DESMI Ocean Guard:*** *"It is for sure a problem that the IMO convention is still not ratified. USCG has ratified their legislation. However, the USCG legislation is still a little unclear and EPA part of the legislation may cause problems."* (Invorgsen (2013).

> **F. Royan, Frost & Sullivan:** *'The suppliers are witnessing a low demand in the purchase of BWTS because customers (shipping companies) are not willing to make financial commitment on the acquisition of technologies due to the uncertainties of the exact date for the enforcement of the IMO convention" Royan (2013).*

The future IMO convention which is waiting for entry into force has been perceived to be a comprehensive regulatory framework for other regulations or guidelines in existence. Some of the respondent acknowledges the fact that regulation is a barrier affecting the retrofit industry. As a result of the in-sufficient number of approved treatment technologies during the time of adoption, several deadlines have been considered to accommodate all ships constructed in 2009 with different sizes.

Another challenge highlighted in this study research study is the lack of a particular ballast water performance standard to facilitate the development of treatment systems.

> *"Without standards, investors were reluctant to devote financial resources towards conceptual or prototype systems because they had no indication that their investments might ultimately meet future regulations. Some shipping industry representatives, technology developers and investors considered the absence of a specific set of ballast water performance standards as a primary deterrent to progress"* (Debroski et. al (2009).

This statement suggests the need for industry benchmarks as regards ballast water performance.

> **A. Cappelen DNV**: *"The nature of the certification process of the treatment system with insufficient knowledge on using the systems is a disincentive affecting the attractiveness of ballast water treatment system technology"* (Cappelen 2013).

A comprehensive program that incorporates technical guidelines such as the ballast water performance standard, verification methods to test and evaluate the performance of treatment systems is therefore required for the development of ballast water treatment systems.

4.6.2. Market Barriers

The high cost implications involved in developing ballast water treatment technologies has also been identified as barrier for technology providers (King et. al. 2012). For instance, according to Dobroski et. al. 2009 studies, it was discussed that BWTS manufacturers are experiencing issues in relation to production cost of treatment technologies. The fact that ballast water treatment systems is still in its early phase of development, manufacturers tends to incur more cost in carrying out research activities and development of various technologies. According to a respondent;

> ***Christian Invorgsen:*** *"The cost for developing systems is definitely a barrier for existing manufacturers and potential new entrants. The cost for developing and testing a system is significant. Meaning that smaller companies may be limited in starting the development"* (Invorgsen, 2013).

Due to the uncertainty and the early phase of ballast water treatment market, the price of developing various treatment systems has been estimated to increase as the BWM convention gets closer for entry into force (WWI, 2013). This means that technology providers would absorb the expenses from developing a system and pass it on to the buyer. This leads to a situation where the prices of treatment systems becomes unstable (CSLC 2010; WWI, 2013). For instance, according to a UK based marine insurance firm,

> *"Ship-owners are urged to begin familiarizing themselves with the requirements of the convention. The cost of compliance will be high and likely require some financing, the insurer says. A ballast water treatment system can cost between $500,000 to $4 million, a figure that doesn't include the expense of dry-docking, installation and developing a water management plan."* (Environmental Leader 2013)

Based on this comment, it can be deduced that it will be to the advantage of the ship-owners to get to the requirement of the IMO ballast water convention earlier, This is necessary so that ship-owners can prepare to invest on the full cost implications of the technology.

From the perspective of a technology manufacturer, the CEO of Wartsila Corporation explained that any technology provider aiming to succeed or be a global leader in the retrofit industry supply of ballast water treatment system should maintain a flexible and considerate attitude on the cost structure of their equipment (Rosengren, 2011).

For the ship-owners, the high cost of buying and installing treatment systems is considered as a barrier affecting the advancement of ballast water treatment systems. Based on research findings, a leading marine insurance company gives explanation in relation to this issue. In the company's opinion;

> *"The cost of compliance to ship-owners will be very high. A ballast water treatment system can cost from half a million to four million dollars. There will be ancillary costs, including developing a ballast water management plan, dry docking and installation.* (UK P&I Club, 2013)" .

Considering this issue, ship-owners are not eager to carry out retrofit process on their vessels since the financial burden involved is huge and couple with the fact that it is not a requirement at the moment.

Also findings have shown that the low demand of equipments by the ship-owners is responsible for the advancement of ballast water treatment systems (CSL 2013). This slow response is also attributed to the recent MEPC 65 draft adopted by the Marine Environment Protection Committee. For instance, the researcher came across a press statement recently released by DESMI Ocean Guard to indicate their desire to limit their investment on the development of ballast water treatment systems due to the uncertainty concerning the convention.

> **R. Folsø, DESMI:** *"The market has not developed as expected, and Desmi Ocean Guard has opted to use the waiting period to explore possibilities and to position the company as well as possible for the expected boom in demand." (Folsø*, 2013)

> **R. Folsø, DESMI:** "*We expected a significantly higher sale of systems than what we were actually able to achieve. This was largely caused by the fact that the ballast water requirements haven't come into effect yet, now we're looking at a situation where the market is significantly different than what we expected, and in light of this we've decided to rethink our strategy." (Folsø*, 2013).

According to the draft, *" ships constructed before the entry into force of the Convention will not be required to comply with regulation D-2 until their first renewal survey following the date of entry into force of the Convention". (MEPC 65th, 2013).* The draft was put forward to relieve or give breathing space to ship-owners so that they can have enough time and resources to plan adequately for installations and retrofit of BWTS on their vessels. But findings shows that the draft is indirectly contributed to the low demand of BWTS

4.6.3. Firm strategies

One key challenge identified in this section is that system manufacturers are slow in investing on research and development of new systems because of the uncertainties surrounding the future of the market (King et. al. 2012). Dobroski et. al. (2009), explained that the lack of research and design effort is a challenge affecting the development of existing and new ballast water treatment systems. Research and design strategy is vital to evaluate and monitor systems performance, as well as making improvement on the existing systems to develop new ones.

For instance, during my findings one of the respondent attributed the inadequate research and design activities as a barrier to the inability of technology manufacturers to carry out intensive research and design activities on equipments. He mentioned that the motivation is poor for suppliers to invest in research and design due to the cost implication and the unclear status of the regulation (Invorgsen 2013).

Some of the key challenges arising from the interviews and document reviews are summarised in the table below.

Drivers	**Barriers**	**Suggested Approaches**
Regulation	-Delay in ratification and Non enforcement of the IMO Convention. - Non existence of a binding BWTS performance standards - No specific guidelines for testing and assessing BWTS performance.	-Full ratification by IMO countries and enforcement of IMO Convention. -Strengthening and enforcement of the USCG final rule
Technology	-Uncertainties about the effectiveness of the technologies. Insufficient approved equipment. -Unclear certification societies -Difficulty in carrying out retrofit on vessels -Time consuming and expensive certification process eg 1-2 yrs	-Partnerships to promote knowledge, network establishment and development within the areas covered by the convention. - Retrofit guidance by certification societies.
Market	-Low demand on equipment - Inability of suppliers in satisfying the peculiar needs of ship-owners demands. - Expensive BWTS	- Presence of more suppliers to increase competition and make cost of technologies more competitive. - Formation of networks and Partnerships among actors. - Educating the market on the implications of IMO approval
Firm strategies	Lack of technical expertise Lack of research and design High cost of equipment design	-Increased investment on research and design. - Technological and organizational capabilities.

Table 4: Purchasing Cost for Selected Ballast water Treatment Systems. Source: (King et. al. 2012)

Summary

This chapter has traced the legislative background of the BWTS industry staring from the International Ballast Water Convention which is regarded as the first significant legislation adopted to control and eliminate environment and health issues from the transfer of invasive species. It then touches on the United State Coast Guard rule with its demands for ships entering US ports to have ballast water treatment system on board. These two are some of the most significant legal backing for the adoption of BWTS as confirmed by literature review and the interview results. Instituions such as the classification societies play a vital role by rendering technical services, verification exercises and issuance of certificate to maritime service firms. The business cycle of ballast water treatment technology which centres on three key phases: development, installation and operation are explained to give an understanding on the BWTS market. The issue of efficacy and availability of BWTS is also discussed as important for the shipping industry. The chapter shows that market drivers are another important factor in addition to regulation that helps to influence maritime service firms to implement environmental technologies which act in compliance with regulations. The cost implication for buying and installing a system on a vessel is shown to be a significant factor in influencing the development of ballast water treatment systems as outlined in this section. A firm strategy which refers to the organizational capabilities of firms is an essential factor that influences their engagement on eco-innovative activities (Kesidou and Demirel, 2010). Hence the degree of firms innovativeness and capability to obtain the needed know-how is critical to their adoption and implementation of environmental technologies. This suggests firms with organizational capabilities have a higher probability to engage in eco-innovative. In addition Environmental Management System is highlighted by the chapter as a core strategy for firms' eco-innovativeness on environmentally friendly products (Horbach, 2011).

CHAPTER FIVE

5.0. Discussions

This chapter assesses the outcomes of the research, discussing the results obtained in light of the theoretical framework. The themes discussed have been filtered from the concept of innovation, eco-innovation and cleaner technologies drivers. Thus, the discussions revolves around the following; regulation, market drivers and firm strategies. The chapter begins by focus on the factors which influences innovation and development of cleaner technologies.

Regulation

With regards to the adoption of clean technologies, environmental regulation is a key factor which serves as a driver (Kemp and Volpi, 2007). This phenomenon is referred to as the "regulatory push/pull effect" (Horbach et.al2011). Regulations impact the evolution of *market structure* by facilitating the development of emerging technologies (Kemp and Volpi, 2007). This is to say, it can compel firms to develop and use cleaner technology (Ibid). In my interactions with respondents, Cappelin (2013) for example points to the absence of the IMO regulation as a major disincentive for the spread of BWTS. He affirms that until the IMO convention is enforced no serious commitment will be made by keys actors related to BWTS. This suggests that the IMO ballast water management convention can be an incentive for marine companies (suppliers and ship-owners) to develop and use efficient ballast water treatment systems.

Variations in regulation are the reasons why technology development is more rapid in some industries compared to others. although there could delays in the IMO regulatory enforcement, the new United State Coast Guard rule for ballast water management serve as a legislation acting tentatively to influences BWTS manufacturers in the development of their technology in accordance to the adopted IMO regulation. Hence new entrants and potential manufacturers of BWTS in the market see regulations as an opportunity to develop and design BWTS. They hope these are to aid their understanding and meeting routine demands of the market. Hummer (2013), also corroborates that the delayed IMO ratification is beneficial for some late comers in the industry.

Under present circumstances, Diederichsen (2013) believes that the delay in the ratification of IMO regulation, coupled with the on-going deliberations in the United States on the implementation of the USCG rule is not a distraction for them as a manufacturer. However, it serves as an opportunity that the company has capitalised on. This implies that even without regulations other factors can still drive the industry.

Technology Drivers

Technology is a key driver to realize incremental changes on existing products and process (Horbach et. al. 2011). Firms seeking to implement cleaner technologies are required to possess technological capability (Pereira 2012). In order words, the level at which firms possess the needed technological capability or competence can be a determinant factor for the implementation of cleaner technologies. For instance, technology manufacturers can improve their technological competence by investing more of their resources on research and design activities. Increased effort on research can create opportunity for the development of new and efficient technologies; this activity can put manufacturers in a position whereby they develop technology which would act in compliance to standards.

Market Drivers

In terms of BWTS, the study tells us that ship-owners are not certain of the efficiency of the new treatment systems and the possible implications of the *lost time*. To some ship owners, the task of installing systems on existing vessels is a challenging factor in terms of time and cost (Cappallen, 2013) indicates that awareness campaigns are needed to share more knowledge and feedback.

On the other hand for the technology manufacturers, the cost of designing ballast water treatment technologies is also a big challenge. The frequent price changes and market fluctuations involved in developing equipments for different types and sizes of vessels tends to affect the development of the of ballast water treatment systems (King et. al. 2012). In relation to this issue, estimate provided by different manufacturers shows that cost of buying treatment systems ranges between $640 000 to $947 000. And these prices varies according to the sizes and types of vessels built (King et. al. 2012) .

Besides cost, the study also discovered the challenges ship-owners are experiencing when choosing the right equipment. The issue of compatibility must be taken into account to effectively implement ballast water treatment systems (Shishkin, 2013). Due to the issue of compatibility, ship-owners are reluctant to invest in the equipment because the process involves in choosing the right equipment and demands series of evaluation. Some of the key considerations in opting for a particular BWTS includes; effectiveness of treatment method, power consumption, costs, and safety of crews.

Low demand in the sales of the technology was discovered as a challenge technology manufacturer are experiencing. Both Cappelin (2013) and Tan (2013) suggest that emerging ballast water treatment technologies are very expensive. Shipping companies are unwilling to make financial commitment on the acquisition of technologies due to the uncertainties of the enforcement of the IMO convention (Royan, 2013). This implies that when costs are high, there is a likelihood of technology manufacturers' to pass on added costs to their customers (ship-owners). Excessive costs associated with the new technology in terms of maintenance, developing technology, hiring of technicians limit a number of shipping-companies to engage in the business making it unattractiveness.

Firm Strategies

For firms, challenges related to '*market structure, demand, and the cost of the innovation activity'* are significant causes of withdrawal and '*failure without learning*' (D'Este et.al, 2012). This indicates that a competitive environment is a push for environmental innovation particularly when clients or consumers can switch from one Supplier Company to another due to their environmental performance. Similarly, new entrants (technology provider) aiming to stand competitive or undermine existing ones would need to invest in innovative activities such as research and design in improving existing technologies and also developing new ones. System manufacturers with higher priority for research and development programs are likely to experience vast improvement in the area of innovation and development of efficient technologies.

The formation of close partnerships between various actors in the shipping industry is important to facilitate exchange of knowledge and other vital resources. Examples of such networks could be a public-private partnerships, manufacturer-consumer partnerships and academic institution- industry relationships. When maritime companies participate in environmental policy making processes they are more likely to partake technologies which may eventually satisfy environmental regulation requirements. For instance, the Danish Ministry of Environment for example as a strategy formed to the Partnership for ballast water in 2009 as a platform for collaboration between the Nature Agency, Danish Maritime Authority and Danish Ship owners' Association, with the goal of implementing the

Ballast Water Convention and enhancing its dissemination (Danish Ministry of Environment,2013). This suggests that the involvement of maritime companies including manufacturers, small scale suppliers and ship-owners as active stakeholders in eco-innovation as a way prompts responsibility towards the environment and hence the development and implementation BWTS technologies.

Summary

This chapter shows that environmental regulation is a vital driver for the adoption of clean technologies (Kemp and Volpi, 2007). This is underscored by the impact of the United States Coast Guard rule on the use of BWTS technology which has compelled manufacturers and suppliers in the maritime industry to make investments in the innovation of environmental technologies like BWTS. Regulations can thus stimulate the evolution of the BWTS *market structure* as it facilitates the development of such emerging technologies (Kemp and Volpi, 2007). The delay in the ratification of IMO regulation on BWTS is therefore a hindrance to developing this market.

With reference to market drivers, the uncertainty and high costs associated with new treatment systems coupled with the possible impact of *lost time* are of concern to industry stakeholders especially ship-owners. Technology manufacturers, particularly regard the expensive nature of designing ballast water treatment technologies as a big challenge. This coupled with the frequent price changes and market fluctuations in producing new equipments for different vessels is a challenge to improving the attractiveness of ballast water treatment systems (King et. al. 2012).In addition, the role of consumers in pressurising ship-owners to embrace environmental friendly products or invest in innovative solutions that will limit their footprint on the natural environment has been emphasised in this section.

In terms of firm strategies, firms need to invest in innovative activities related to research and design so as to improve on existing technologies as well as develop new ones. Hence system manufacturers who give great importance to R&D will record immense results in the area of innovation and development of efficient technologies. Networks and partnerships amongst industry players (eg public-private partnerships) is crucial to the cross-pollination of ideas, information sharing and sharing of other resources which will help develop the BWTS market. The next chapter sums up the overall research.

6.0. Conclusion and Recommendation

Conclusions

This chapter addresses the research questions with emphasis laid on the study outcomes. The study research set out to investigate how the drivers of cleaner technologies can be used to facilitate innovation and development of BWTS in the shipping industry. Using this framework, the researcher explored the drivers and barriers which affect innovation and development of ballast water treatment systems. The research was consequently guided by two research questions which guided the research in addressing these research objectives namely:

1. What are the drivers and barriers that affect innovation and development of ballast water treatment systems in shipping?
2. How does drivers influence the implementation of ballast water treatment technologies and is it possible to make the technology more attractive for the shipping industry?

The result of this research study shed light on cleaner technology drivers in relation to the implementation of ballast water treatment systems in the shipping industry. The contribution of this study presents a new theoretical insight to cleaner technology field through the integration of innovation, eco-innovation, environmental sustainability and literatures on Regulation, market, technology, and firm strategies.

With reference to the first question; the study identified four major drivers of cleaner technologies as key factor that could be used in achieving eco-innovations and the implementation of BWTS. These includes; *regulation, technology, market forces and firm strategies* (Rennings, 2000; Horbach et.al. 2011; Kesidou & Demirel, 2012)**.** These factors also concurred with by the interview respondents. The study indicates that these drivers cannot work independently but rather have to be used collectively as they complement each other. Hence there has to be a dynamic interaction between the various individual drivers.

Regulation is considered a key factor that influences eco-innovation (Rennings and Zwick, 2002; Brunnermeier & Cohen, 2003; Horbach et. al. 2011). According to Ashford & Hall(2011) environmental regulation can potentially stimulate remarkable innovations . With the regulations, institutions guide the shipping industry actions and perspective by coercion or threats or legal sanctions to ensure environmental safety and quality controls. Actors agree to a set of rule or regulation as a result of fear preferring not to suffer the penalty for non compliance. For instance, findings indicate that a ballast water management operation in shipping industry is regulated internationally by IMO and nationally through USCG regulations. The IMO ballast water convention is a universal regulation which requires the implementation of a ballast water management technique. This legislation is responsible for compelling technology manufacturers and ship-owners to implement innovation and development of cleaner technologies like BWTS to minimize the introduction of marine invasive species.
The USCG rule which has been finalized and ready for enforcement in 2014 is a major driver in pushing ship-owners intending to enter US ports to install BWTS. Consequently, it will also provide a platform for technology providers to increase their effort in the development of the BWTS.

Technology drivers: Cleaner technologies are another driver considered as environmental innovation which when adopted transform a production (technological) process to limit pollution or waste generated (Del Río, 2005; Markusson 2011). Technology is important for realising the goals of sustainable development as it plays an essential part in enabling industrial firms in the realization of their environmental goals (OECD 2001). Thus Kemp and Pearson (2007) emphasise that green technologies and environmental technologies can be regarded as having similar functions as they minimize pollution and help manage resources in a more efficient manner. Thus this is the idea behind eco-innovation.

Market forces are factors which promote eco-innovation and this rest on the demand and supply forces. Demand side drivers are shown in the study as an important factor which determines eco-innovation (Horbach 2008; Doran & Ryan 2012). Consequently, Kammerer (2009) also argues for market pull factors such as consumer benefit being a vital tool influences firm's decision in the implementation of eco-innovation. How Consumer pressure compel companies to improve their image with in the economic market by adhering to set performance standards in the industry. Thus firms (e.g maritime companies) who are subject the pressures of the global market are influenced to invest in cleaner technologies to satisfy consumers' demands and also remain competitive in the market.

Furthermore, the potential for consumers to enjoy benefits such as added value after the delivery of a product is a motivation for environmental innovation (Kammerer, 2009). Introducing novel products that are environmentally friendly or create innovation on existing product helps the firm to save cost in the production process and to diminish damage on the environment (Triebswetter and Wackerbauer, 2008).

Firm Strategies; Good Organisational strategies are conducive for firms' continued existence in a business market. Implying that, for different actors in the shipping industry to fair well, taking part in networking and knowledge transfer measures that promotes innovation decisions is essential (Wagner 2009). Innovation demands companies to actively pursue investment on research and design work so as to meet up with strict environmental regulations which calls for bench marking measures as well to learn new strategies.

The main aspects that would hinder further implementation of the technology can be as a result of the costs implications of BWTS, lack of specific performance standard, lack of capital and references on the part of the technology manufacturer, Inadequate qualified marine engineers to support in the design of equipments.

With reference to the second question (how do drivers influence the implementation of ballast water treatment technologies and is it possible to make the technology more attractive for the shipping industry?,

The studies showed that this could be done through;

Formation of partnerships: Collective efforts of all actors within the shipping industry can lead to sound decision making, risk sharing and protection of member's interest. Partnership could be a platform for introducing new skills and knowledge sharing, division of labour and responsibility. Well - coordinated network of actors at both national and regional level could cause lead to business opportunities and market development. For instance, the study found that the Danish Maritime Cluster uses collective efforts as a medium to encourage innovation and development of maritime cleaner technologies. Partnership such as the "Green Ship of the future" has created a platform for ship-owners, technology manufacturers and maritime authorities in Denmark to exchange ideas in relation to ballast water treatment technologies. My finding shows that the GSF partnership has been important in promoting the research and design of efficient technologies as well as safe-guarding the environment from pollution.

The use of the partnership approach could also encourage firms to enhance their organizational capabilities by employing **Environmental Management Systems** which are described as voluntary frameworks for improving the environmental performance. For instance, ship-owners and technology providers with clear environmental goals and policies may have the motivations to adopt and develop efficient technologies for improving their environmental performance. In order words, firms which subject themselves to environmental targets or adopt environmentally policies; are more receptive to the adopting cleaner technologies (Dangelico and Pujari, 2010).

The study also discovered that **research and design** is also important. Increased effort and investment of research and development activities can lead to the discovery of new solutions to guide the implementation measures. Technology manufacturers can achieve this measure by collaborating with academic and research institutions to provide technological solutions so as to improve the efficacy (efficiency) equipments, as well as contributing to the reduction of environmental footprint.

Additional support from the technology manufacturers: A cleaner technology such as ballast water treatment systems requires adequate maintenance support of its components and software operation for effective functionality of vessels. This calls for extensive manufacturer's responsibility. Technology manufacturers should be willing to support ship-owners in the operational maintenance of ballast water treatment systems.

The study also found out that **market pressure** can influence drivers by exerting pressure on shipping companies to implement environmentally friendly technologies. Through voluntary initiatives like the clean shipping project as explained in chapter four, this could serve as a platform for ship-owners to improve their image and increase business prospect. For instances, due to forces of market pressure, ship-owners can be influenced by customers (cargo owners) to adhere to set performance standards or directives and invest in innovative solutions to help limit their environmental footprint. This surmises that market pressure trigger firms to adopt processes which result in the improvement of existing technologies and development of new ones.

In conclusion, it is possible to make the BWTS technology more attractive for the shipping industry. However for this to happen, there needs to be a dynamic interaction between the drivers which rests on collective efforts of all actors within the industry.

The introduction of innovative channels (seminars, workshops) through which actors (ship-owners, technology manufacturers, research institutes, and regulators) can share knowledge on various organizational challenges to reinforce and support to the drivers in creating the demand of the cleaner technology.

When all stakeholders have higher priority for technological capability, innovation and development of cleaner technologies can be influenced. This is to say that increased priority for technological capability on the part of the actors can influence the attractiveness of BWTS in the shipping industry.

Future considerations

The attractiveness of ballast water treatment technologies can be improved if the IMO ballast water convention is ratified. Clauses in the BWTS regulation, that preserve the investments of ship-owners would go a long way to motivate them to adopt these cleaner technologies.

Furthermore, when regulations and standards become more exacting, it would help address the sense of uncertainty and motivate ship - owners to accept responsibility for their ballast water. The early preparation, engagement with expert partners will be the vital to timely compliance. The study results also suggests that partnerships in networks, investment on R& D activities, technological capabilities can assist BWTS manufacturers in improving the attractiveness of ballast water treatment systems.

The formation of partnerships such as the Danish Ballast Water Treatment Partnership and the Green Ship of the Future will help stakeholders to share knowledge on the systems, reduce uncertainties and improve the attractiveness of the ballast water treatment systems. More of this kind of initiatives should be encourage facilitating the exchange of ideas and knowledge regarding innovation and development of ballast water treatment systems. The involvement of stakeholders (suppliers and ship-owners) in environmental policy making will make them more responsible by engaging in the development and adoption of new and improved equipments. New entrants and small firms (system manufacturers) need the right assistance to keep up with the advancement or change in the retrofit market.

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Appendix I

NO	MANUFACTURER + SYSTEM NAME	TREATMENT PROCESS	APPROVAL TYPE	WEBSITE
1	21st Century Shipbuilding Co., Ltd. **Blue Ocean Guardian**	Filtration + Ultraviolet + Advanced Oxidation	Final	www.21csb.com
2	**Alfa Laval Tumba AB Pureballast (2.0 and 2.0EX)**	**Filtration + ultraviolet/TiO2 (AOT)**	**Final**	**www.alfalaval.com**
3	Aqua Eng. Co., Ltd. **AquaStarTM**	Filtration + UV + Ozonation	Final	www.aquaeng.kr
4	GEA Westfalia **BallastMaster EcoP**	Filtration+ Electro-Chlorination/Electrolysis + Residual Control	Basic	www.westfalia-seperator.com
5	RWO Marine **CleanBallast**	Filtration + Electro- Chlorination/ Electrolysis + Advanced Oxidation	Final	www.rwo.de
6	Hitachi **ClearBallast**	Filtration + Coagulation/Flocculation	Final	www.hitachi-pt.com
7	Dalian Maritime University **DMU ·OH**	Filtration + Advanced Oxidation	Basic	www.dlmu.edu.cn
8	**DESMI Ocean Guard A/S** **Ocean Guard Oxyclean**	**filtration + Ozonation + Ultra Violet Radiation**	**Final**	**www.desmioceanguard.com**
9	Hyundai Heavy Industries **EcoBallast**	Filtration + Ultraviolet	Final	www.hhi.co.kr
10	Techcross **Electro- CleanTM System**	Electro-Chlorination/Electrolysis	Final	www.techcross.com
11	Erma First Esk Engineering Solutions S.A **ERMA FIRST**	Filtration + Cyclonic Separation (Hydrocyclone) + Electro-Chlorination /Electrolysis	Final	www.ermafirst.com
12	Panasia Co.Ltd. **GloEn-PatrolTM**	Filtration + Ultraviolet	Final	www.pan-asia.co.kr
13	Hyundai Heavy Industries **HiBallastTM**	Filtration+Electro-Chlorination/Electrolysis +Residual Control (sulphite/bisulphate)	Final	www.hhl.co.kr

14	JFE Engineering Corporation **JFE BallastAce®**	Filtration +Residual Control (suplhite/bisulphate)	Final	www.jfe-eng.co.jp
15	Headway Technology Co. Ltd **Ocean GuardTM**	Filtration + Ozonation +Electro-Chlorination/Electrolysis +Ultrasound+ Advanced Oxidation	Final	www.headwaytech.com
16	HWASEUNG R& A Co, Ltd. **HS- BALLAST**	Electro-chlorination/Electrolysis	Basic	www.hsrna.com
17	Kuraray Co. Ltd. **MICROFADETM**	Filtration + Chlorination	Final	www.kuraray.co.jp
18	Nippon Yuka Kogyo Co., Ltd.2 Katayama Chemical, Inc. **SKY-SYSTEM®**	PARACLEAN OCEAN +Residual Control (Sulphite/bisulphate)	Basic	www.nipponyuka.jp
19	Mitsui Engineering & Shipbuilding **FineBallast® OZ**	CAVITATION +Ozonation	Final	www.mes.co.jp
20	NK Co. Ltd. **BlueBallast System**	Ozonation	Final	www.nkcf.com
21	Oceansaver AS **OceanSaver**	Filtration +Cavitation +Deoxygenation +Electro-Chorination/Electrolysis+Advanced Oxidation	Final	www.oceansaver.com
22	Samsung Heavy Industries **Purimar™**	Filtration + Electro-Chlorination /ELectrolysis +Residual Control(Sulphite/bisulphate)	Final	www.digitalvessel.com
23	Siemens **SiCURE™**	Filtration +Electrochlorination+ Demand-Regulated Control Logic	Final	www.siemens.com/sicure
24	STX Metals Co. Ltd. **Smart Ballast**	Electro- Chlorination /Electrolysis	Final	www.stxmetal.co.kr
25	SunRui Marine Environment Engineering Company **BalClorTM**	Filtration+Electro-Chlorination/Electrolysis	Final	www.sunriu.net

List of Resource Persons

Name of Person	Company and Contact
Christian Ole Ingvorsen	DESMI Ocean Guard A/S Technical representative
Yury Shishkin	Det Norske Veritas, Danmark A/S Yury.Shishkin@dnv.com
Andreas Cappelen Technical Engineer	Det Norske Veritas AS TNANO386 Environmental protection Phone: +47 928 40 206
Michael Prehn Deputy Director	Danish Maritime mip@amaliegade33.dk
Kim Diederichsen CEO at Bawat	http://shippingwatch.com/suppliers/article6182236.ece
Frederick Royan (Consultants)	Global Research Director, Environment (Water) Markets, Environment & Building Technologies Frost & Sullivan
Jan S. Hummer BAWAT	(Technical Repreentative) Mob.: + 45 22 23 86 11 E-mail: jsh@bawat.dk
Björn Rosengren	President and CEO at Wärtsilä Corporation**.**
UK P & I Protection and Indemnity insurance.	http://en.eshiptrading.com/news/d/222/5462/

Interview Guide II DESMI Ocean Guard A/S

1. In your opinion, what is your take on the current status of the global market for ballast water treatment technology in terms of regulation and treatment technology adoption in the industry?

2. In your opinion, what are the main challenges or barriers affecting the attractiveness of ballast water treatment systems globally?

3.In your opinion, what important factors or drivers are responsible for influencing the decision of system manufacturers to develop BWTS?

4. What are the barriers directly affecting suppliers or manufacturers in developing and supplying new technologies to the market?

5. Do you think there is enough technical knowledge or information about the different treatment technologies? Where are the knowledge gaps and how are key actors trying to fill these gaps?

6. How is the delayed IMO ballast water management Convention affecting manufacturers of BWTS in developing and supplying new technologies?

7. How can the suppliers minimize the barriers affecting the development and adoption of ballast water treatment technologies in the market?

8. In your view, what do you think ballast water treatment systems suppliers can do to improve their products to attract more customers in the adoption of different technologies?

9. What kind of partnerships do you see important for manufacturers or suppliers of BWTS to improve the attractiveness of the market and as well promote diffusion of different technologies?

10. What are some of the key incentives and opportunities that will motivate suppliers to develop these treatment technologies the more?

11. How can ballast water treatment systems suppliers position themselves to meet the anticipated high level of global demand for ballast water treatment systems (when the IMO regulation is finally ratified)?

11. Finally, what do you think should be the ideal relationship between the ship-owners, suppliers and manufacturer to improve the attractiveness of the market and the industry in general?

Interview guide for Frost and Sullivan consultant

Questions related to the global status of the market for BWTS

1. In your opinion, what is your take on the current status of the global market for ballast water treatment technology in terms of regulation and treatment technology adoption in the shipping industry?

2. How is the delayed IMO ballast water management Convention affecting ballast water treatment market? Also how is the delayed convention affecting the manufacturers of BWTS in developing and supplying new technologies?

3. Several studies and research as predicted a massive growth for the BWTS market, In your opinion what are the expectation or prediction for the future growth of the market?(i.e in terms of investments, development and installation of various technologies?)

Questions related to BWTS

3. In your opinion, what are the main challenges or barriers affecting the diffusion (spread) of ballast water treatment systems globally?

3a. Information from literature review indicates that some potential suppliers mentioned that the testing and certification process is costly and time-consuming. In order words, this can be a major barrier discouraging potential suppliers in investing in BWTS. In your opinion what do you think classification societies can do to solve these problems?

4. Do you think there is enough technical knowledge or information about the different treatment technologies? Where are the knowledge gaps and how are key actors trying to fill these gaps?

5. What are the barriers directly affecting suppliers or manufacturers in developing and supplying new technologies to the market?

6. How can the suppliers minimize the barriers affecting the development and adoption of ballast water treatment technologies in the market?

7. In your view, what do you think ballast water treatment systems suppliers can do to improve their products to attract more customers in the adoption of different technologies?

8. What kind of partnerships do you see important for manufacturers or suppliers of BWTS to improve the attractiveness of the market and as well promote diffusion of different technologies?

10. How can ballast water treatment systems suppliers position themselves to meet the anticipated high level of global demand for ballast water treatment systems (when the IMO regulation is finally ratified)?

11. What do you think should be the ideal relationship between the ship-owners, suppliers and manufacturer to improve the attractiveness of the market and the industry in general?

12. Finally, what are some of the key incentives and opportunities that will motivate suppliers to develop these treatment technologies the more?