Innovation in product and services in the shipping retrofit industry: A case study of ballast water treatment systems

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Abstract

Eco-innovation research pays increasing attention to business models and their contribution to the diffusion of environmental technology into socio-technological systems. The extent to which a business model hampers or promotes certain types of eco-innovations remains an open question. In order to shed light on this issue, the authors develop a conceptual framework to show how a specific type of business model (Product-Service Systems) could be applied to the context of the maritime industry. With a focus on the Danish maritime industry, the case study addresses two questions: *Which business models are being used to develop, install and service the ballast water treatment technology*? And, *How can these business models add value to the ballast water treatment systems in the market?* The case shows that different business models are applied depending on whether the installation is on new or retrofitted vessels. Both installation and operation stages of ballast water treatment systems provide opportunities for collaboration among stakeholders. Based on the Eco-costs/Value Ratio model, the authors perform an analysis of on-board and port-based ballast water treatment systems with the aim to propose a possible product-service system. These results suggest that port-based systems have the highest potential for eco-efficient value creation and a possible product-service system can be designed for this kind of technology. The article highlights the point that authorities need to improve regulations to stimulate port-based ballast water treatment systems rather than on-board ballast management systems.

Keywords
Ballast water, shipping, product-service systems, eco-innovation, eco-efficient value creation

Highlights

- Environmental regulations drive the development of ballast water treatment systems (BWTS).
- Different business models operate in the various stages of the BWTS life cycle.
- A qualitative Eco-costs/Value Ratio (EVR) analysis was performed on port-based BWTS.
- A possible Product-Service System with port-based BWTS was presented.
- Port-based BWTS have a higher eco-efficient value creation potential.

1. Introduction

Ballast water is essential for ship operations. Unladed ships require ballast water to keep stability and trim; fully-laden ships need it to keep an appropriate trim during rough seas (Goncalves and Gagnon, 2012). More than 150 000 metric tons of fresh/sea water can be pumped in or out of ballast tanks in one operation and that water may include living organisms (Dunstan and Bax, 2008; Ruiz et al., 1997). Due to these large volumes of water being transported from place to place, there is a risk that many different species are transported and are viable at the destination waters (Ruiz et al., 1997). These species are usually called invasive, non-indigenous or alien species and the broad definition "includes any species reported to have become established outside its native range" (Molnar et al., 2008). Ballast water on ships is considered as the most important vector in dispersing these invasive species throughout the world, although the dispersion risk highly depends on the vessel's type and route (Seebens et al., 2013). Alien invasive species may have economic, ecological and health impacts on marine and estuarine ecosystems. Ruiz et al (1997) provide the example of the zebra mussel's invasion in the Great Lakes, which beyond being an ecological problem led to costs of between 1,8 – 3,4 billion US dollars by the year 2000. Cholera is an example of a disease indirectly caused by ballast water, as the *Vibrio cholera* pathogen can travel in ballast water (Ruiz et al., 1997).

To control the spread of invasive species, the Ballast Water Convention was approved by the International Maritime Organization- Marine Environment Protection Committee (IMO-MEPC) in 2004. By April 2014, the convention is pending ratification by some countries – it will enter into force twelve months after the ratification of countries representing 35% of the world's merchant shipping tonnage. Meanwhile, individual countries, ports or regions have put in place local rules to prevent invasive species distribution from ballast water discharge. A significant event took place on March 23, 2012, when the United States Coast Guard (USCG) published stricter rules to prevent untreated ballast water discharge in U.S. coasts. These international and national regulations generally focus on three strategies to manage ballast water, namely, ballast water exchange, installing ballast water treatment systems (BWTS) or a combination of both. Ballast water exchange implies flushing the ballast water tanks and refilling them with saltwater in mid-ocean (i.e., more than 200 nautical miles from the shore). This water exchange reduces the number of viable fresh water organisms in the ballast tanks due to the salinity (Briski et al., 2013). Ballast water exchange is not always possible; the major constraints being geographical (i.e., some shipping routes do not operate in mid-ocean). Therefore, BWTS represent a second alternative to reduce the number of organisms to low risk levels for the ecosystem and human health. The requirement is that ships need to install a technology that is able to clean all ballast water before it is released into the harbour. Some prototypes of port-based systems receive the ballast water from the vessel instead of having to install a treatment unit on board (King and Hagan, 2013). Existing on-board or port-based treatment technologies combine mechanical (filtration, separation) and biological steps (sterilization through UV, Ozone) (Goncalves and Gagnon, 2012; Veldhuis et al., 2006).

Currently, twenty-eight on-board systems have received the final approval by the IMO and are ready to be commercialized (IMO, October, 2012). This legislation will create a significant market for new BWTS. According to King et al. (2012), the market size includes 68,000 vessels whose owners require the installation of on-board BWTS before 2020. King et al. (2010) estimated a market value in the range of US $50 to $74 billion between 2011 and 2016.

Environmental technology such as BWTS is perceived to be a key sector for future economic growth at the EU level. The possibility of positioning the member states as world leaders in key areas of green technology development is explicitly stated in the EU 2020 green growth strategy (European Commission, 2010). Some member states, such as Denmark, consider the maritime industry as a key sector for growth and have taken action to try and enter the BWTS market. Environmental technology for the maritime industry is mentioned in the national eco-innovation strategy (MST, 2010). The Danish Partnership for Ballast Water Technologies was formed with the participation of public and private actors to find cost-effective opportunities of compliance once the convention is put into force (Danish Shipowners' Association, 2013). The Danish maritime industry recognised this market opportunity and set up companies such as DESMI Ocean Guard A/S, to develop BWTS (Filtration industry analyst, 2009).

However, the maritime industry is globalised, and any market for BWTS will also be globalised (Köhler, 2014). Current data on orders for new ships shows that Europe as a whole only has 6% of the global orders (Clarkson Research Services, 2013). However, BWTS may also be installed as a retrofit during a docking period. In this case, the decision about where to retrofit will be partly determined by the location of the ship at the time being, with the implication that ships on EU trade routes could be cheapest to refit in EU shipyards. This would give, e.g., Danish ship-repair yards and equipment suppliers a competitive advantage for part of the retrofit market. Since on-board BWTS are specialized equipment, the provision of maintenance services to ship operators could also be a significant market.

An important question for the Danish ship-repair yards and equipment suppliers is which business model will lead to profitable involvement in the BWTS markets. There is, however, only a limited selection of literature on business dynamics in the marine industry. Hameri and Paatela (2005) consider the dynamics of supply networks including the case of shipbuilding as a case of an industry where the structure of supply networks has changed. They find that from the end of the 1970s, shipyards changed from producing all the systems at the shipyard to a multi-layered supply network, where the specialist firms in, e.g., industrial kitchens or computer services also have other customers and are less dependent on the vagaries of the shipbuilding market. 90% of the end product value is now produced by the supplier network (Hameri and Paatela, 2005). For a country such as Denmark, with a small shipyard sector but a strong reputation in ship technologies, the provision of services around BWTS installation and operation might provide the best market prospects.

This suggests that the Danish shipyard sector as a highly integrated and specialized network of suppliers has the potential to use the so-called Product-Service System (PSS) as a basis of its business models. The accepted definition of a PSS is: *"A system of products, services, supporting networks and infrastructure that is designed to be: competitive, satisfy customer needs and have a lower environmental impact than traditional business models"*, e.g., Mont (2001) and ELIMA (2005).

BWTS developments' overall intention is to reduce environmental impacts by drastically reducing the risk of invasive species spreading due to shipping. The required integrated offering delivered by a complex multi-stakeholder network mean that BWT technology is fully compatible with the application of Product-Service Systems (PSS). Therefore, the authors applied the PSS literature to the case of eco-innovation in the shipbuilding industry and expanded the PSS concept to explicitly consider supply networks in an industry where these relationships are complex. The results of Hameri and Paatela (2005) described above show that the shipbuilding industry already has a complex supplier network, which is therefore capable of applying a PSS approach. The results also show that the shipbuilding industry has changed its balance between OEMs and suppliers, which indicates that the industry is also capable of further changing its structure to adopt a PSS approach.

In this article, the authors address two research questions:

- Which business models are being used to develop, install and service the BWTS?
- How can these business models add value to the BWTS market?

Section 2 summarizes the analytical framework as well as the hypothesis. Section 3presents the methods. Section 4 presents the case study. A discussion is presented in Section 5. Conclusions and suggestions for further research are presented in Section 6.

2. Product-service systems and the maritime industry

An emphasis on service provision rather than equipment manufacture suggests that the PSS concept could provide a suitable conceptual approach to this study. PSS has received attention as a suitable model for sustainable innovation (Boons and Lüdeke-Freund, 2013). On argument is that the division between manufacturing industries and service providers has become blurred (Baines et al., 2007; Pawar et al., 2009). In particular, many firms now view services as a source of added value and it has come to dominate the operations of firms which were traditionally considered as manufacturers. Baines et al. (2007) argue that product manufacturers and service providers have moved closer together in their structures to generate added value, a trend also identified by Wong (2004). The concept is that what is sold is not the product, but the use value which the customer derives from a product and its associated services. This involves a continuing relationship with the customer and provides a continuing source of added value for the PSS provider. An important feature is that the asset ownership is not transferred to the user, but the PSS provider contracts the asset to provide a service. In general, this involves selecting the equipment, monitoring performance and providing servicing. An example of such an arrangement could be the provision of transport services. A manufacturer could traditionally build and sell e.g. a diesel engine, but in a PSS, a (network of) firm(s) could build the engine, install it in a ship but also monitor and maintain it while the ship is operating.

Tukker (2004) identifies at least eight different PSS types in three categories:

1. Product-oriented PSS, where the product is sold but also with an after-sales service contract,
2. Use-oriented PSS where the product is rented or leased to the user together with after-sales services,
3. Result-oriented PSS where a performance or capability is sold (functionality/function/result) (e.g., a level of power provision instead of “an engine” or “a comfortable climate” instead of “air-conditioning” and a specified availability over a specified length of time). Here, the PSS provider offers a customised mix of products and services and the user pays the amount of delivered functionality.

Ceschin (2013) shows how firms have successfully introduced PSS into markets for eco-innovations. It is found that factors for success could be clustered into four groups: the implementation of experiments in a niche, the establishment of a broad network of actors, the development of a shared PSS vision, and the implementation of learning processes. In a market such as BWTS where a demand is already being established, it is the last three factors that form the major challenges to successful market development.

When engaging in innovation towards PSS business models, new producer-customer relationships are required. Pawar et al. (2009) describe a case in which an aero-engine manufacturer sells power. Their service guarantees a certain number of flying hours and minimises maintenance (Johnstone et al., 2009). They conclude that a PSS provider must create value through the combined design of a product, the service provided and the organisation to provide the service. They identify three stages: defining value, designing value, and delivering value. They argue that this will require that the gap between production and marketing is removed and that resources and capabilities which are not internal to a manufacturer are present. Thus, the collaboration with other partners may be necessary.

2.1. Service and product provision in the international maritime industry

The maritime industry system connects a complex network of subsidiaries, suppliers and customers (Hameri and Paatela (2005). Figure 1 adapts Dicken’s (2011) production circuit to illustrate connections between inputs, service provision, distribution, and consumption in the maritime industry. Shipping lines are responsible for providing transport services, while shipowners may be sub-suppliers to these shipping lines or can sell transport services themselves. Both own or lease different kinds of vessels, which are subsequently used for transport purposes. Vessels are the main assets that are upgraded - either by maintenance or by new additions to the fleet (Lun et al., 2010).

Shipping lines require new equipment to improve the performance of their fleet. Maritime equipment manufacturers and shipyards provide ship owners or shipping lines with a variety of maintenance and installation services. These “conventional” services may range from retrofitting—upgrading existing vessels with new or improved equipment—to new builds (Hall et al., 2011). Alliances among maritime system actors are common: equipment manufacturers become suppliers to shipyards, while at the same time shipyards are suppliers to shipping lines or shipowners. Geographical proximity may influence these alliances, i.e., maritime clusters (Viederyte, 2013). However, in globalized industries, such as shipping, equipment suppliers can be located anywhere in the world (Dicken, 2011).

Distribution agents are intermediaries between customers requiring freight transport and service providers. Examples of distribution agents are freight forwarders, inland transport providers or logistics providers. Shipping firms are also moving into this part of the market (Fremont, 2009). Companies requiring transport services may be users in different ways. Figure 1 groups them into passenger and ferry transport (including cruise ships), bulk, cargo, off-shore services, and oil and gas industry.

The shipping system is complemented by a second tier of actors which provide competences or service inputs directly needed by the industry. This second tier is represented by the boxes located above and beneath the central square in Figure 1: Technology inputs, competence development, and energy provision. Similarly, other advanced services can be placed here such as insurance, legal advice, and advertising (Hall et al., 2011).

In a third tier, Figure 1 presents the financial system and the regulatory framework. In industry, financing is characterized by an important circulation of capital, which in turn is required for investments in equipment and fleet (De Monie et al., 2011). Regulation sets the standards for the different activities taking place within the system. At an international level, this is done through the IMO or the EU (for European waters). These international agencies approve conventions and directives that each nation state must translate into national legislation. It is the task of the port authorities to enforce the different conventions. Similarly, classification societies certify that all vessels comply with safety standards (Mensah, 2007).

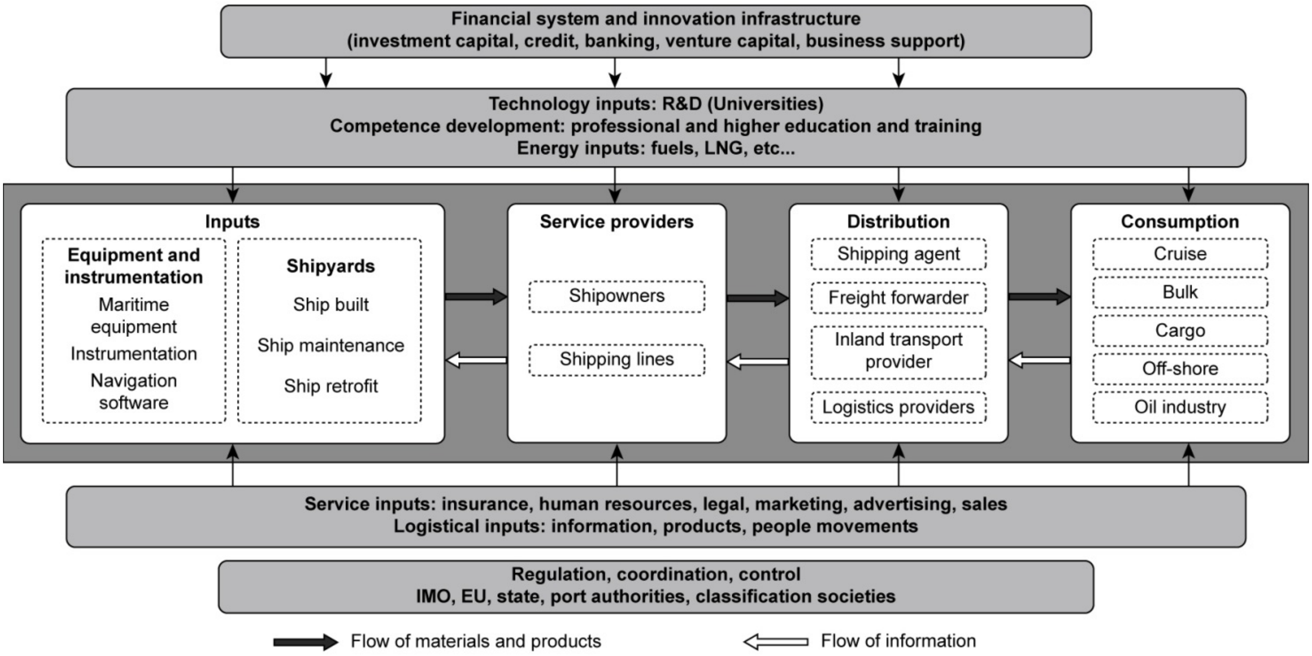

Figure 1: A proposed model of circuits of materials, products and information in the Danish shipping industry. Different actors are involved in supply and demand aspects of environmental maritime technology. *Adapted from*: (Dicken, 2011, DMA, 2006, Fremont, 2009)

As shown by Figure 1, the maritime industry is characterised by a highly complex market structure, which has traditionally used a variety of contractual relationships between shipbuilders, shipowners and charterers who buy the transport use value of a ship, and hence can be placed in the use-oriented PSS category. An example of such a PSS is the use of bareboat charters, where a shipbuilder builds a ship and then leases it to a charterer, who then operates the ship. Another arrangement is time chartering, where a shipowner leases a vessel to a charterer for a fixed time period. The operation of the vessel may be undertaken by the shipowner or the charterer, and in current markets, firms also exist which specialise in ship management only. Hence, contractual arrangements in two directions can be identified: the application of PSS structures with elements of combined production and on-going services and in contrast, the division of shipping into specialist single activities.

These arrangements apply to a complete ship and the transport service that it provides. Modern ships have a wide range of specialist machinery, which the crew cannot repair on board. Therefore, specialist firms are contracted to maintain and repair equipment in addition to production and installation. This is already the case of engines, where specialist manufacturers are not only contracted to service and repair engines, but also provide consultancy services in the design of machinery arrangements for ships. Another example is lifeboats, where a specialist firm builds the lifeboat and is also contracted to inspect and maintain the lifeboat during the operational life of a ship. Other examples in ships are ramps, lifts and also cranes, where the manufacturer builds and installs a relatively complex piece of equipment and is then contracted to maintain the equipment throughout the life cycle of the ship. A PSS can also be applied to electronic equipment such as radar or electronic control systems.

Therefore, the maritime industry is one in which PSS offerings are already well-known and institutional arrangements between shipbuilders, subcontractors, shipowners, and charterers are already developed. This means that new specialist firms who wish to enter the market for ballast water treatment equipment and services do not have to face major institutional and organizational barriers to providing ballast water treatment PSS.

2.2. Hypothesis and proposed analytical framework

The analytical framework in Figure 2 illustrates the authors' hypothesis: "Current business models contain elements of PSS in the market niche of BWTS and these elements could be a basis for increasing value in the offering of integrated services and products to the market". The framework, divided in four quadrants, describes the product life cycle in four stages (Scheepens et al., Forthcoming): production, installation, operation and end-of-life (it is interesting to note that the case study did not reveal attention to the end-of-life stage of BWTS). The main actors in this hypothetical Danish BWTS PSS are represented in circles (technology and manufacturing firms) and triangles (service companies) at four different systems levels which are derived from the Multilevel Design Model (Joore, 2010). The customer is placed centrally in the framework. In accordance with the PSS theory, the potential relation between these actors is included: The white arrows represent the value added to the product during its life cycle (black arrows). A linear representation of the BWTS life cycle in Denmark is depicted in Figure 3 in Section 4.

In accordance with the case study, the environmental issues associated with untreated ballast water discharge, placed within the societal system level, are the incentive for policymakers such as the IMO at the socio-technical system level to develop regulations addressing these issues. These regulations have spurred the development of mainly on-board BWTS technology and products, placed at the product-technology system level. Based on the case study presented in Section 4, marine consultants and shipyards (represented by two triangles in the installation phase), flying squads and other contractors (represented by two triangles in the operation phase) are the BWTS service providers at the Product-Service System level. "Flying squads" are specialized staff from external maritime service firms that could travel around the world to service vessels. The End-of-life phase has not been mentioned by the stakeholders in BWTS, therefore it is assumed that this phase in the product life cycle is not taken into account during current developments of BWTS.

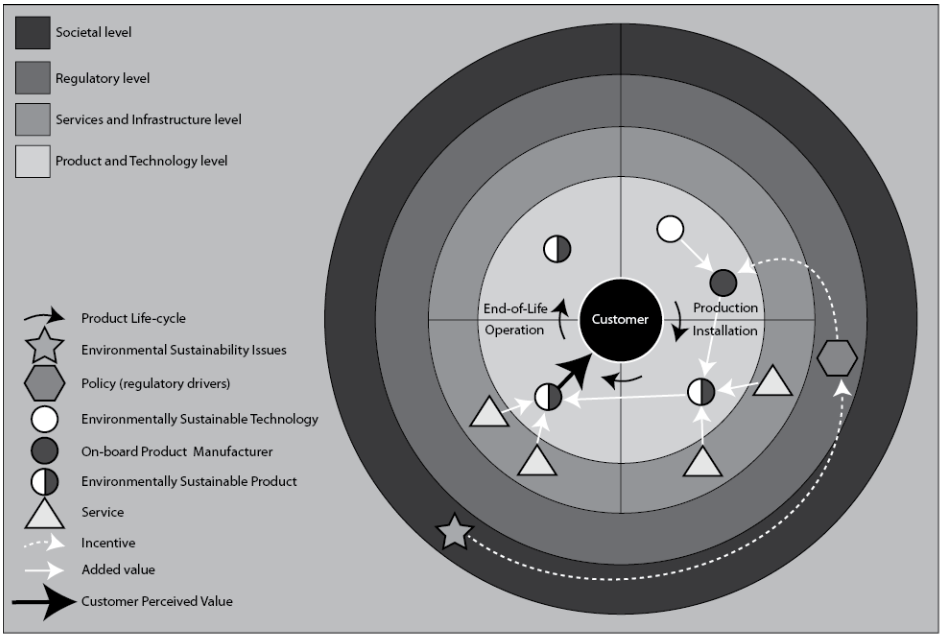

Figure 2- A conceptual framework of PSS for ballast water treatment systems within the multi-level design model

Since it is assumed that the equipment and installations for BWTS currently in development will last the full life cycle of the ship - e.g. 26 years in average for container ships (World Shipping Council, 2014) - the environmental impacts of the end-of-life phase are likely to be insignificant compared to the production - and use - phases of the BWTS. This is mainly due to the BWTS energy use over a lifespan of 26 years. In Europe, it is likely that a large share of the BWTS (as part of the ship) waste materials are recycled (Ahuja et al., 2011), assuming that most of the components are manufactured using (high grade) metals and plastics. This is also the case in the automobile sector, where due to regulatory drivers up to 95% of the materials in cars are to be recycled in 2015 in Europe (Dalmijn and Jong, 2007). When regulatory drivers such as the IMO guidelines on ship recycling are applied to BWTS, the environmental impact over the full BWTS life cycle is reduced. Recycling has reduced environmental impacts compared to raw materials mining and processing; in LCA, the recycling of, e.g., metals yields environmental impact credits, where, e.g., landfill adds to the environmental impacts of the system (Vogtländer, 2012). However, performing a LCA of the BWTS is outside the scope of this paper.

What is more important in the context of this paper is that, during current design and development processes of BWTS, the end-of-life stage of the products/PSS appears not to be considered at all. Assuming that this is confirmed in future LCA studies on BWTS, this should not result in massive environmental sustainability issues. Nonetheless, considering the end-of-life stage during design and development is an important recommendation from an LCA perspective to current and future BWTS designers, developers, installers, maintenance providers, manufacturers, and above all, policy makers.

3. Methods

The authors have considered a single-case study design to structure the results. To select the case study, the authors followed an information-oriented strategy, which is one category of selection described by Flyvbjerg (2006). In an information-oriented strategy, "cases are selected on the basis of expectations about their information content". The authors expected to present a critical case, which according to Flyvbjerg (2006) allows "deductions of the type 'if it is (not) valid for this case, then it applies to all (no) cases". The authors agree with Flyvbjerg (2006) that "context dependent case studies" –e.g., generalizable under certain conditions – are also valid means of achieving knowledge. The selection of a critical case had the purpose to increase the possibilities of generalization from a single case.

3.1. Case study and selection criteria

In Section 2.1, the authors explained that the ship repair market is globalized and therefore it is challenging to set national boundaries when analysing business models. In addition, collaboration and trust building among firms have been highlighted as important factors in generating business models leading to PSS (Mougaard et al., 2013). This endeavour of collaboration and trust building is facilitated by interaction and networking (Mougaard et al., 2013). The authors have considered business models leading to the retrofitting and building of new ships with BWTS by Danish firms as a critical case of study. The first reason is that Denmark counts with an active shipping cluster with the representation of all actors presented in Figure 1 (DMA, 2006). Second, in Demark there is a political commitment to support the shipping industry as a key area of economic growth at the national level and in some regions (Danish Government, 2012; Region Nordjylland, 2014). An important element in these strategies is to support cluster collaboration between national maritime equipment manufacturers and suppliers (Sornn-Friese, 2007). Third, some of the most important actors in the shipping/ maritime innovation system have started collaborative network initiatives to develop and prototype environmental technologies, but also network initiatives to consider alternative business models which involve the combination of products and services (Hsuan et al., 2012; Schack, 2009).

Following the research questions and the analytical framework presented in Section 2.2, the authors have considered the case study as the business models for the production/ development, installation and maintenance/operation of BWTS within Denmark. In the analysis, focus was on three units: BWTS manufacturers (suppliers of equipment and instrumentation), maritime service companies (shipyards and consultants) and shipping companies (demand). The authors did not limit the case study to a specific BWTS technology and manufacturer despite the more than 26 systems already approved by IMO (and many more being developed). There were practical reasons for this. First, it appeared that the shipyards and maritime service companies are able to work with different providers of BWTS. Second, shipowners are free to install any of the systems currently in the market if approved by IMO. Thus, the case study focused on a general rather than a specific business model of BWTS. However, since it was not possible to interview all Danish BWTS manufacturers, shipyards, and shipping companies, the authors developed a set of criteria for selecting these interviewees and ensuring representativeness. These selection criteria are expanded on Section 3.2.

3.2. Data collection

Empirical evidence was collected between February 2012 and February 2013 through in-depth interviews, document review and participant observation. The authors carried out seven in-depth interviews as shown in Appendix A. Judgement sampling was performed to select these interviewees (Marshall and Rossman, 2006). An initial overview of the actors involved in the Danish BWTS innovation system was performed at the outset (as explained in Section 2.1 and illustrated in Figure 1). As shown in Appendix A, the authors selected key representatives from different types of stakeholders involved in this innovation system to include in the sample. The sample of interviewees included one global shipping company and the shipowners' association, two BWTS manufacturers, one shipyard, one maritime equipment branch organisation, and a maritime service firm (135 employees). These interviewees were acquainted with business models involved in BWTS and were active participants in several networks of business development in the shipping industry. Although two other Scandinavian BWTS manufacturers were contacted, they did not accept to participate in the study. A summary presents the interviewees' positions within the organisation, see Appendix A. A semi-structured interview guide was prepared before the meetings. The purpose of this data collection method was to guide the conversation while leaving the interviewee free to provide longer answers (Rubin and Rubin, 2012). Appendix B shows a general template of the interview guide.

A document review complemented the interviews. This document review differed from the literature review presented in Section 2. The main difference was the kind of documentation and the sources. As Table 1 summarizes, the documents were of different categories (i.e., commercial brochures, websites and international law). To select the document source, the authors first mapped actors in the innovation system of BWTS as presented in Section 2.2. From this map of actors, the authors considered important documentation which was collected from key organizations as shown in Table 1. A first criterion of selection was to triangulate the information arising from the interviews, for example, to complement specific data about the technology, dates, regulations, etc. A second criterion was that some stakeholders were not interviewed; either they did not give permission to include the interviews in the article or they had no time for interviews. Through a document review, it was possible to include information about their roles in the BWTS business models.

Table A Stakeholder and document type used as source for empirical material

Document source	Document type
International Maritime Organization (IMO)	Ballast water convention Environmental protection committee documentation (e.g. minutes from meetings, available through the IMODOCs website) BWTS technologies approval requirements and status
BWTS Manufacturers interviewed	Technical documentation and websites
Danish Maritime magazines International green technology maritime magazines	Newsletters
Danish Branch organizations	Position papers, technical studies
Consultants	Product catalogue Commercial presentations
Specialized conferences and seminars on ballast water treatment technology and regulation	Presentations

A third method was participant observation. The authors formed an insider/outsider team (Louis and Bartunek, 1992). This method claims that a better analysis of an organization's affair can be achieved when combining the experience of insiders with the critical eyes of outsiders (Bartunek, 2007). One of the authors was a researcher in the Maritime Centre for Operations and Development (MARCOD). This centre provides support to SMEs willing to start new ventures with environmental service and technologies. As an insider, this author co-organized a seminar on "Business opportunities with ballast water treatment technologies" in March 2013. During the event, around 50 practitioners from BWTS manufacturing firms, shipyards or maritime consultants[1] shared their experiences on business models involving ballast water systems. A consultant also facilitated a brainstorm on possible services that could be associated with these business models. As a researcher in MARCOD, the author also attended two practitioner events in November 2013: the second Copenhagen international ballast water conference; and the Danish seminar on marine product service systems organized by the PROTEUS consortium (Hsuan et al., 2012). Both these events were an opportunity to understand different perspectives from the business models involved in the current ballast water treatment technologies and to identify interviewees. The authors have included some of the reflexions from these seminars as part of the case study.

[1] The presentations of MARCOD's events are available at http://www.marcod.dk/arrangementer/konferencemateriale/38-materiale-fra-konference-om-forretningsmuligheder-inden-for-ballastvand

4. Ballast Water Treatment Systems business models in Denmark

The findings from the case study are grouped into the following three categories (Figure 3):

- Market context and system development
- Installation new build/ retrofit
- Operation

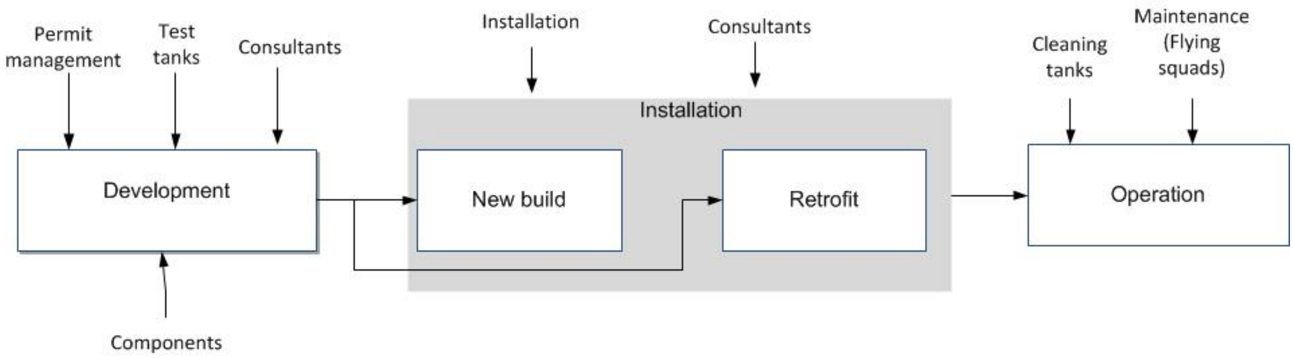

Figure 3 A linear model of BWTS production and service flows. The model comprises three main parts: development, installation and operation. The different products and services that can be provided are listed as arrows in the model.

4.1. Market context and system development

For maritime service firms, the current context will determine the future growth in the market of ballast water treatment technologies. The installation of ballast water treatment systems has begun, even though the ballast water convention is not ratified by the minimum number of IMO member states required. However, the installation of systems is proceeding at a very low rate and the market growth is small. This is the result of shipowners' interest in avoiding large investments before January 1, 2014. The IMO convention does not require the retrofitting of ships before that date. For this reason, most systems are currently installed on new builds, and few are installed on retrofitted vessels:

> *"I think we haven't really started the retrofitting yet, because we don't have the Convention in place. The convention was agreed in IMO in 2004, but we still need 30% of the world fleet to sign on, before it is entered into force. It will be enforced twelve months after the ratification. So, that's why we still, I mean, our members will not go and retrofit before they are totally sure about the future regulation. Despite the fact that the convention was agreed upon in 2004, we are still discussing amendments to the convention, so as part of that discussion we are actually working on changing the implementation dates for the existing ships. If you have a big tanker or bunker, you will first have to install equipment in 2019 or 2020. Then you are not going to do anything. We have a lot of members who will be in that situation. We see installations on new buildings (as I see it), but we don't see many retrofits" (Interview 3).*

Despite this apparent inertia from a shipowner's perspective, while the negotiations are going on at the IMO, shipowners are very active in their networks. There are on-going assessments of different technologies and service partnerships with suppliers. An example is the Danish partnership for ballast water. The partnership organizes match-making meetings and specialised seminars to seek cost-efficient ways to comply with the regulations:

> *"No, we are more into meetings and conferences at the moment. We had a meeting about land-based solutions last time, we made together with MAERSK, DFDS and Danish Ports, and then there have been other projects as well. The projects may be supported by the [Environmental Ministry], and they*

> *have a call right now. We wait to see which projects they will support and then people will start discussions. So far, no technology development or demonstration projects"* (Interview 3)

Manufacturers react to this situation in three ways: manufacturing a few units with local resources and suppliers, getting the permits to commercialize BWTS ahead of the competition, and looking into innovative systems. Until the convention is enforced, most activities are centred on securing the right system permits (IMO and USCG). Similarly, the production of the systems is at very low rates, mostly with local manufacturing (e.g. in Denmark) with most suppliers of components among local firms (e.g. UV lamps or steel components). The manufacturers have, however, acknowledged that this may not be sustainable when the demand increases considerably.

The Danish maritime branch organization (Danish Maritime) considers it to be preferable to support Danish R&D companies to look into second generation ballast treatment systems. The main reason is the large offer of first generation systems already in the market looking for permits (e.g., currently 26 with Type I approval at the IMO). Many of these systems are developed by South Korean and Japanese firms with strong connections with shipyards in Southeast Asia. A couple of Danish companies are developing "second generation BWTS". These second generation systems will be developed for direct use on vessels and not as land-based technologies adapted to the vessels (Interview 4). An example of such land-based systems is port-based ballast water treatment. In a first principle of operation, "ballast water is treated at the port of departure and discharged at the destination without further treatment". A second option is when "ballast water is taken in without treatment and treated immediately before discharge at the destination" (COWI, 2012). An advantage of port-based systems is that shipowners will not have to invest in installation, maintenance or retrofitting (COWI, 2012).

4.2. Installation

Installations can take place in two ways: in new builds and by retrofitting older vessels with ballast water treatment technology. Different business models are involved in these markets. Shipowners decide that new builds are to be delivered with the BWTS because it is easier to install the system during the construction than it is in a later retrofit (Interview 3). The date when the convention will enter into force is still uncertain. However, from the manufacturers' perspective, the market share for installation of BWTS in new builds was small in 2012:

> *"What we are seeing is that 2012 has been a year with very low activity in the new building market. Very few new builds have been contracted. What you can say is that in the [BWTS] market is very weak for new buildings right now"* (Interview 6).

Most new builds are produced in Southeast Asian shipping yards (mainly China and South Korea), with a close relation between shipowners and shipyards in terms of related services and products. Therefore, there are fewer opportunities for external service firms. The BWTS manufacturers receive an order from the shipyard, and what the shipyard needs is the system delivered in components. The shipyard then installs it, and does all the pipe work, electrical installations, etc.:

> *"When it comes to new builds, strictly speaking, the customer is the shipyard. But of course, the shipowner has also something to say, on which system to put on their vessels" (interview 6)*

In the retrofit market, more opportunities exist for collaboration between manufacturers, shipyards and other maritime service firms. For BWTS manufacturers, these opportunities exist and they are continuously looking for options of collaboration with maritime equipment installing firms. Part of this collaboration is focused on the early stages of engineering assessments (calculations, detail drawings, etc.). Then, another firm can install the system on board. All these additional services should be reflected in the quotation handed to the shipowner:

"Sometimes the shipowner will ask you to make a complete retrofit. For example [the shipowner] will ask: "What is the price to equip my vessel with this system?" Design, installation and delivery will be a total price for that delivery. We can work with the business model that we take the responsibility of everything, but then we will need to carry joint projects in collaboration with some others. But we cannot take out the whole responsibility. In other cases, we will remain, we just send the components to the dock, and we have done our part. It depends on the shipowner, on the shipyard, what they agree" (interview 6)

This manufacturer-centred business model could change to a shipyard-centred model (similar to the new builds explained above). Depending on the complexity of the installation, the ship must be taken out of operation for some weeks and be serviced in a dry dock. Because this entails loss of revenue, it is an important business decision from the ship operator perspective. The shipowners may already have planned a refit at a given shipyard. In that case, the BWTS installation can be an extra task for the servicing shipyard on top of a normal service stop and the shipyard will only require the system and the technical details from the manufacturer. In Denmark, a shipyard has already installed four BWTS with this business model. The vessels had a Norwegian BWTS installed at the request of the shipowner.

Previous to the installation, calculations must be performed by an external naval architect. These calculations assess the exact location of the different modular components of the systems within the vessel. The owner approves, involving close communication with the BWTS manufacturer. Then, the installation follows as a normal part of a refit by the shipyard staff. This involves making the foundations, pipe work and electrical connections (interview 5). From a shipyard perspective, it is the shipowner who decides which system goes in the vessel, and there is no imperative to require a binding agreement with a specific BWTS supplier.

In any case, manufacturers and shipyards agree that the shipowner will have the last word on where the installation is to be undertaken. Some variables that come into play are where the vessel usually sails, what are the comparative prices of shipyards, etc. Manufacturers have considered this as problematic; they want to compete globally with other companies in Asia (for example).

Ways to tackle this are either by sending a specialist from the BWTS manufacturer to supervise the installation or by hiring other companies which have already installed the BWTS system that has been chosen. It is, however, important to have close supervision along the whole installation because "you can never teach a yard in total to do everything, that will be difficult and definitively not all yards [will be able to be trained as fast]. Maybe, some few yards will be trained on location or something like that" (Interview 6).

4.3. After sales and operation

The operation phase of BWTS provides some opportunities for the integration of product and services into one package. One reason is that shipowners focus their business on transport, and would welcome integrated solutions that will outsource the maintenance of ballast water treatment technology to the supplier (Interview 2). Although no formal PSS is already in place with this profile, the possibility is being considered by manufacturing and service firms:

"I think that the big players will do it themselves. But there may be opportunities in relation to the smaller companies if they could make a package so to speak. If they can say we can make sure that it can be installed and it will be working and perhaps there is a possibility" (Interview 3).

The possibility is already being considered by one of the Danish BWTS suppliers:

"We will do it ourselves with our network. Likewise with the automobile shop, they don't want to earn money with the new cars but with repairs" (Interview 6).

In practice, this could be translated into some partnerships in different harbours in the world, but also agreements with "flying squads". The idea is for the shipowner to purchase a "package" once the shipowner pays for the BWTS. Manufacturers consider the following requirements to set such service agreements:

> *"One thing which is important when you look at these… it has to be a company with certain size and experience within the industry and also very used to working globally, because we don't expect that the majority of our systems will fit in Danish repair yards or something like that. It will be global, because the shipowner will take their ships in docks where they have agreements or where it is already trading and so on. It is really global. You really need to team-up with companies that already have experience with this and are used to having people working in Asia, middle-East" (Interview 6).*

Shipyards, on the other hand, are less likely to get involved in these maintenance agreements on a long-term basis:

> *"The service is the responsibility of the [BWTS] manufacturer. They do that where the vessel is, we don't service the BWTS within the vessel because that is the manufacturer" (Interview 5).*

The reason is that, from a shipyard perspective, the tasks of the shipyard are best narrowed down to the installation. More technical and precise maintenance –not requiring a long stay in the shipyard – is a manufacturer's commitment:

> *"As a shipyard, we are not promoting a maker. But if someone comes to us tomorrow, an owner, they don't have an idea what to use. We will recommend this system. But one thing is what we know about installing it and another thing is working with it on the day-to-day basis. We don't know if it is easy. But we don't interfere with the choice" (Interview 5)*

5. Discussion

The research questions will be elaborated based on the results presented in Section 4.

In relation to the first question considering which business models are being used to develop, install and service the BWTS; it can be said that different business models also operate in segregated phases of the BWTS life cycle: manufacturing, installation and operation. Manufacturing is characterised by a relatively small demand of BWTS (since the convention is not yet entered into force). The business model is organized by manufacturers with mostly local manufacturing of a few demonstration units. Installation and operation also have differentiated business models. In the installation phase, the shipyards play a major role by coordinating what is installed on board of a new or retrofitted ship. Shipyards become hubs of collaboration between shipowners, manufacturers and contractors. The business model in the operation phase of BWTS is more relevant to manufacturers and service companies than to shipyards. Manufacturers avoid a strong fixed dependency on a single shipyard that may limit the manufacturers' ability to make extensive contacts worldwide. The capability of maritime service firms to provide prompt responses through, e.g., flying squads gains a large relevance here. Once the ballast water convention is put into force and the demand of BWTS and services increases dramatically, manufacturers may well lack the staff to service the industry.

The case study results did not show that the business models in these three phases can be defined as a result-oriented PSS. A characteristic result-oriented PSS will be that in which shipowners pay by the volume of water treated and not by the BWTS, with the actors (manufacturers, shipyards and contractors) selling the product-service system to the shipowners. In the case, however, BWTS are still considered as a product; shipowners pay separately by installation and for a possible aftersales service.

The second part of the hypothesis proposes that current business models have the potential to generate value through a possible PSS. The second research question deals with this issue in more detail by explaining how these business models can add value to the BWTS market. The case highlighted the importance of rethinking the concept of BWTS, which should be seen less as a product and more as a system of services that could be built around BWTS products. In particular during the operation stage, shipowners may be interested in paying per volume of treated ballast water, while concentrating their energies on their transport business. In this way, BWTS consortia could propose complete packages of installation, service and monitoring, enabling shipowners to outsource the entire process required to comply with the proposed regulation and its potential future follow-ups. This PSS concept should be designed by a consortium to deliver the required value for the shipowner whilst minimizing the environmental impacts associated with ballast water discharge in order to maintain and improve the competitiveness of the offering. The main question is thus how to design a PSS concept that achieves competitive value for customers of BWTS, whilst minimizing the environmental impacts. In the long term, the BWTS is also expected to yield competitive value for the PSS consortium, since future regulation compliance is ensured through continuous environmental impact reduction innovation. Tukker (2004) argues that when moving from product-oriented PSS towards result-oriented PSS (moving towards a service economy) the potential for environmental impact reduction and perceived value for the customer increase.

This coincides with the eco-efficient value creation (EVC) theory (Vogtländer et al., 2013) in which the Eco-costs/Value Ratio (EVR) model is suggested as having the potential to support eco-efficient value creation (EVC). The aim of EVC is to design solutions that increase the customer-perceived value whilst reducing the relative environmental impacts. . Simultaneously creating customer perceived value for environmentally sustainable offerings ensures market penetration. Therefore a qualitative EVR analysis is performed for designing a sustainable PSS concept for BWTS in terms of EVC.

In general, two types of BWTS can be discerned: on-board BWTS where the ballast water is treated on-board before discharge and port-based BWTS where the untreated water is discharged into BW processing facilities in a port. It appears that the main business focus is on on-board BWTS, since many ports do not have a BW discharge system and the treatment facilities required for a port-based system. However, a port-based treatment facility has several advantages in terms of eco-efficient value creation:

- The ships themselves do not need to be (re)fitted with complex BWTS, reducing the investment costs for shipowners.
- A lower relative energy consumption of the ship during operation: more goods can be transported since less room and weight are required for the BWTS.
- The BWTS is used much more frequently in a port-based system than on a ship: The BWTS processes ballast water of every ship coming into the dock, whereas an on-board system only processes its own ballast water. This should result in cost reduction for the shipowners, due to a more efficient operation of the BWTS.
- The measure is implemented at the place where the problem occurs: in the ports of destination.
- Expensive maintenance such as flying squads is no longer necessary for servicing the BWTS during operation.

These advantages both potentially increase the value perceived by the customer as well as the eco-efficiency of the operation of the service. Hence from an EVR design perspective, the port-based type BWTS PSS has the highest potential for EVC. Of course, there are several issues with such a PSS concept, as yet seemingly left unaddressed by individual companies or PSS consortia:

- No standards are set (yet) by the IMO regulation on the type of connection between ship BWTS and ports.
- Such a PSS would only work well if every port had such a system installed. PSS consortia should investigate whether it would be possible to install port-based BWTS in the necessary ports in order to be able to offer a BWTS service to shipowners wanting to comply with the IMO regulation.
- Substantial investments are required to fit ports with such systems, but on the other hand, this could provide a unique competitive edge compared to on-board BWTS offerings. Although indications have been found that port-based systems tend to be more expensive (COWI, 2012, King and Hagan, 2013), costs such as the so-called flying squads have not been taken into account in these analyses.

Therefore, it still remains questionable whether such port-based systems really turn out to be more expensive: *"The estimated cost of the on-board treatment seems somewhat lower than the calculated treatment cost of the best case; however, that needs to be investigated further, taking all conditions into account, to reach a more solid base for comparison between the concepts."* (COWI, 2012). In terms of customer perceived value (for shipowners) and eco-efficiency, port-based systems are preferred over on-board systems.

Therefore two possible venues can be defined for PSS consortia wanting to achieve EVC:

- Push the IMO regulation directed at shipowners to ports experiencing the problems of BW discharge
- Or invest heavily in port-based systems for ports experiencing BW discharge issues, potentially giving the consortium a competitive edge over on-board BWTS manufacturers and consortia.

Both venues should result in a more service-based economy, creating competitive value for customers of BWTS whilst minimizing the environmental impacts associated with BW discharge. The proposed framework for port-based systems as an alternative to on-board systems is depicted in Figure 4.

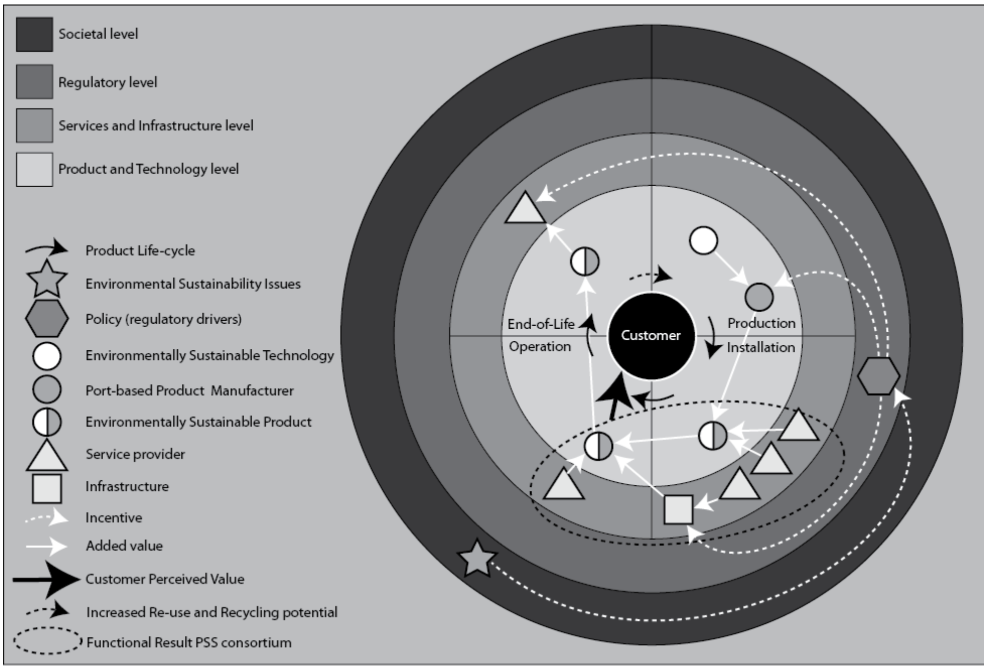

Figure 4- Proposed Functional Result PSS conceptual framework for port-based BWTS

The framework as presented in Figure 4 shows that the customer (shipowner) now also has the possibility to completely outsource the responsibility for compliance with, in this case, the IMO regulations. The consortium would be able to offer different configurations of products and services, payable by the amount of, in this case, ballast water treated. This means that there is no transfer of ownership of the products; therefore the responsibility of operation lies with the consortium. This has several benefits for the customer as well as the environment: End-of-life re-use, component re-use, remanufacturing and recycling are made easier, the product quality is enhanced, and less effort and risk are required of the customer to maintain operation. Port-based systems will also be beneficial to maritime service firms in the PSS consortia. These firms are usually hired by shipyards to carry out activities linked to the installation or maintenance of on-board systems. However, the operation of port-based systems can become an extra market for maritime service firms.

Despite these advantages of port-based systems, on-board systems are diffusing at higher rates in the international shipping industry. Since many ports do not have port-based and port-serviced BW facilities (infrastructure), and many ships will need to comply with IMO regulations, in the short term, on-board systems are the most applicable solution. Then the ships can sail to any port and discharge their BW after it has been treated on the ship. This underlines the importance of an adequate regulation development: in order to stimulate, e.g., port-based BWTS systems development and implementation, additional or different regulations are required, such as subsidizing port-based BWT facilities.

The case study material shows that Danish firms are actively engaged in developing their presence in the market for BWTS. They are dependent on relationships with operators and shipyards in Scandinavia and globally. They are applying the PSS concept for BWTS service provision to some extent, but have not yet fully developed the market potential through the PSS approach.

6. Conclusions and future research

This article has looked at business models for the case of BWTS in Denmark, using the PSS framework. This is a new market, created by international regulation from the IMO on ballast water management. Ballast water discharges have been recognised as an important environmental impact from shipping. This section first summarizes the main practical and theoretical implications, and then it provides suggestions for further research.

The article has three major practical implications: First, the case of Denmark shows that a western European maritime sector is entering into the market for BWTS. In spite of the East Asian domination of the shipbuilding industry, Western European specialist firms are still competing for equipment supply and service provision in a market which has been estimated to have a potential value of US $50 to $74 billion between 2011 and 2016 (King et al., 2010).

Second, the installation phase is driven by the shipowners' needs of installation and geographical service. The operational phase provides new opportunities for links between manufacturers and maritime service companies. Packages of products and services are especially welcomed by shipowners in this phase. While there are elements of a combined installation and service approach, the full potential of a PSS has not yet been exploited.

Finally, the EVR model has been found to be a valuable tool for developing future business strategies for eco-efficient value creation in BWTS. It provides direction for innovation on a product and PSS level, as well as for business strategies and regulation development. The model also indicates that the regulation could be refined towards stimulating port-based BWTS, instead of onboard BWTS.

The major theoretical contribution of the article has been to extend the PSS framework with the eco-efficient value creation (EVC) theory, using a qualitative Eco-costs/Value Ratio model approach. The case of BWTS in Denmark extends the literature on PSS through the consideration of the maritime industry, an example of a complex OEM-supplier structure with the business dynamics of a new market that is being created through environmental regulation. This extension of the PSS approach is generalizable to other industries with similarly complex OEM-supplier structures, where new eco-technologies are being developed for the product. Two examples of this are the development of fuel cells and batteries in the automobile industry (Köhler et al., 2013). The in-depth case study of BWTS shows that the ballast water regulation is certainly the main factor behind the development of BWTS. This is therefore an example supporting the perception that environmental regulation is often the cause of eco-innovation (Köhler et al., 2013; Walz and Köhler, 2014). However, the regulation itself explains little about the emerging service and product-service combinations in the industry. These were identified through the case study analysis as being based on current business structures in the shipbuilding industry. In the case study, current business structures provided more opportunities for new entrants (e.g., small and medium-sized maritime service enterprises). It is not possible to draw general conclusions about the most suitable product and service combinations in eco-innovations. A case specific analysis of the combination of industrial production structures and the particular environmental regulation is necessary to determine the potential for new production structures using PSS.

Future research could be, in the first place, firm-centred perspectives which explore, for example, which capabilities are necessary to implement or develop the links between manufacturers and maritime service companies. Another research avenue for future development could highlight the impact of the regulation in the implementation of sustainable business practices. Thereby, it is essential to further investigate the feasibility of port-based BWTS versus on-board BWTS. Finally, the current business models and regulatory drivers do not consider the end-of-life phase. It would be useful to explore how the end-of-life of BWTS is expected to be handled by manufacturers and service providers in a business-as-usual and a PSS model.

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Appendix A. Interviews to build evidence on the contextual conditions

Table A-1. List of interviews

#	Date	Type of organization / relevance to the case	Interviewee position within the organisation	Duration of the interview (minutes)	Purpose in the research	Where was the interview performed?
1	February 2012	Maritime service company/ The company provides contracting services in its yard but also through “flying squads”. Actively involved in local and national networks. Partnership with a BWTS manufacturer to carry BWTS installations.	Chief technical officer	60	Section 4.4	Company’s headquarters, Frederikshavn, Denmark
2	October 2012	Scandinavian-based global Shipping company/ Shipping company with 5700 employees worldwide Car-carrier and Roro vessels as main business area	Fleet manager responsible for a BWTS comparison assessment	*	Section 4.1	Aalborg
3	February 2013	Shipowners’ Association/ Industry branch for the Danish shipowners. Co-Coordinator of the partnership with ballast water (Along with the Nature Agency)	Consultant; Partnership spokesperson attached to Danish Shipowners’ Association	30	Section 4.1	Copenhagen

4	February 2013	Danish Maritime/ Branch organisation for maritime equipment suppliers Coordinator of Retrofit project/ member of the PROTEUS consortium/ MARCOD network and many other initiatives	Business consultant; project leader for retrofit project	58	Section 4.1	Copenhagen
5	February 2013	Shipyard Active shipyard with 230 employees; local hub for sub-contractors; have installed several BWTS to Scandinavian customers	CEO	30	Section 4.3	Frederikshavn
6	February 2013	BWTS manufacturer Danish manufacturer with IMO approval	CEO	52	Section 4.2	Nørresundby, Aalborg
7	March 2013	BWTS manufacturer American BWTS manufacturer but with business relations with Danish shipowners and shipyards	CTO/ Country representative	40	Section 4.2	Frederikshavn, subsidiary of American BWTS manufacturer

(*) Communication with this source was through email.

Appendix B. Template of semi-structured interview guide

Semi-structured interview guide with shipping liners/ shipowners

1) Firm's and IMO ballast water convention (Interviews with shipping liners/ shipowners)
    a. Firm's strategy for compliance
    b. Systems suiting firm's needs
    c. Collaboration with manufacturers and authorities
2) Pure-ballast water treatment system (interviews with equipment suppliers)
    a. Background of its development
    b. Relation with the Danish partnership for ballast water
3) Ballast water treatment systems
    a. Installation
    b. After sale service
    c. Consultants/ ship architecture design
    d. Spare parts
4) New services
    a. Retrofitting
    b. Collaboration with shipyards
    c. Opportunities for suppliers

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