Influences on general dry cargo vessels' operation using ventifoils

Master of Science Thesis in the Maritime Management Program

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Cover: MV Ankie vessel with retrofitted ventifoils (published with approval of Van Dam Shipping)

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Μαμά, Μπαμπά και Πέτρο σας ευχαριστώ πολύ για την υποστήριξη!

Cám ơn gia đình và bạn bè đã luôn bên cạnh trong suốt thời gian qua!

Abstract

As the world faces various environmental questions, the International Maritime Organization (IMO) has set a new target for all merchant ships to decrease their greenhouse gas emissions by 50% until 2050 compared to 2008. This is the reason why experts in the maritime industry have started to look for solutions to reduce the emissions from vessels. One of the available ideas is not new but an innovative revival of the old concepts of wind assisted-based propulsion.

This thesis aims to investigate the expected, perceived, and potential impact of wind propulsion technologies, particularly of ventifoils (also known as suction wings), on vessel operations. Additionally, the importance of crew members in working with ventifoils will be examined.

To address the objective of this thesis, a qualitative research approach based on interviews was adopted in order to get an understanding of the market and operational changes from the perspective of an experienced and of a potential user of ventifoils, and a ventifoils' provider.

The results show that the installation of retrofitted ventifoils and containerized (flatrack) units, assisting traditional propulsion systems on board general dry cargo vessels, has an influence on the operations on board. In terms of crew's workload, it increases mostly in the loading and discharging process, adding more responsibilities to crew members. Additionally, in order to operate the units properly, crew members are required to have good knowledge about the ventifoils on how they can use them properly and acquire motivation and awareness to work with the systems.

Keywords: Wind ship propulsion; ventifoils; retrofitted ventifoils; containerized units; flatrack units; human factors; human element; operational changes; crew.

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1. Introduction

In this section, the background of the topic will be provided together with the objectives, research questions and the scope of the study.

1.1. Background

The maritime domain plays an important role in transporting people and exporting and importing products/goods around the globe, being responsible for more than 90% of world freight (International Chamber of Shipping, 2020). Because of the increasing demand of world seaborne trade, the maritime industry has a growing impact on the environment. According to the final report of the third International Maritime Organization (IMO) GHG Study 2014, with results from 2007 to 2012, it was estimated that international shipping was annually responsible for around 3.1% of global CO_2 emissions and 2.8% of Greenhouse Gases (GHGs) on average based on a CO_2 equivalent basis (Smith, et al., 2014). In addition, in order to make the scenarios for shipping emissions and demand, the Representative Concentration Pathways (RCPs) for coal and oil demand and the Shared Socioeconomic Pathways (SSPs) for economic growth in the future are combined to create a scenario. The name of these scenarios is "Business as Usual" (BAU) scenarios (ibid., 32). These scenarios forecast that the shipping industry could witness a growth of emissions from 50% to 250% in the period from 2012 to 2050 due to an increase of seaborn trade (ibid., 17).

In order to move towards long-term sustainability goals, the shipping industry is now under a strong pressure to reduce GHG emissions. In 2011, the IMO's Marine Environment Protection Committee (MEPC) introduced and adopted two primary measures in order to manage GHG emissions from international shipping. They are the Energy Efficiency Design Index (EEDI), which set up minimum compulsory requirements for energy efficiency performance for new ships, and the Ship Energy Efficiency Plan (SEEMP), which provides a system for ship owners to enhance the energy efficiency of all ships by conducting operational measures including speed optimization, weather routing, etc. (International Maritime Organization, 2020a). In 2018, the IMO adopted a strategy with visions of reducing annual GHG emissions from ships by at least 50% by 2050 compared to 2008 (International Maritime Organization, 2020b). In order to reach the target, a combination of different design, operation and economic solutions is required. For example, in terms of operational measures, voyage optimization could potentially reduce 1-10%

GHG emissions. Regarding technical measures, designing hull structures accordingly could reduce the energy demand, resulting in 2-20% potential reduction of GHG emissions. Furthermore, improving the power and propulsion system could decrease the amount of GHG emissions by 5-15% (International Maritime Organization, 2020b). Among different innovation technologies, wind propulsion systems could be a promising technology to achieve decarbonization (Gilber, et al., 2014).

In fact, the use of wind had been applied in sailing merchant ships in the 1840s, which was better in terms of efficiency, speed and space than steamships (Lloyd's Register Marine, 2015). However, with advanced technologies such as the triple expansion engine and the diesel engine, and the higher demand for merchant shipping, sailing merchant ships were no longer in use. Due to the oil crisis of the 1970s, wind propulsion solutions became an interest in the 1980s again, but its development and adoption was stalled because of the stabilization of fuel prices. In 2015, wind propulsion technologies would face the same challenges due to the decrease in fuel prices (Lloyd's Register Marine, 2015). Today, the development of wind propulsion technologies is being reconsidered as promising since organizations are not only paying attention to operational costs but also to the reduction of CO2 emissions.

In the perspective of environmentalists, wind energy is preferred as an alternative energy source to fossil fuels because it is “free”, renewable, abundant, clean and does not generate GHGs (Shukla & Ghosh, 2009). In the shipping industry, wind energy growingly attracts interests because it brings benefits in cost, energy security and it is predictable (International Windship Association, 2020a). According to the International Windship Association (IWSA), investing in ships requires a long-term capital. Therefore, using wind energy could promote a considerable part of operational costs to be fixed during its lifetime. Furthermore, ship operators are more independent of erratic fuel prices and can take advantage of plentiful renewable energy supply. Wind energy can be deployed efficiently since wind speeds and direction are predictable, being forecasted based on historical data (International Windship Association, 2020a).

Currently, wind propulsion technologies can be categorized into seven main types with automated operation to ensure safety and efficiency in use. They are ventifoils, soft sails, hard sails, flettner rotors or rotor sails, kites, turbines and hull form (International Windship Association, 2020b) (see section *2.1. Wind-assisted propulsion technologies* for a short description on the main ones). Each type of wind propulsion technology has its own technical performance and potential in power saving. Among different wind propulsion technologies, ventifoils could be promising and suitable for cargo ship operations (CRAIN, 2020).

Expectedly, the deployment of this new technology – ventifoils – on vessels, as with other types of ship propulsion, will have an influence on on-board operations and activities of crew members. Therefore, it is crucial to understand how the operations will be affected. Also, it is important to examine if the operational changes will result in any new requirements on the crew members to work with the new system on the ship.

1.2. Objectives

The objectives of this thesis are to explore the impacts of ventifoil technology on cargo vessels' operation and crew from the viewpoints of ventifoils manufacturers, ship owners and crew. Their expectations and experiences are valuable to develop wind propulsion technologies further as well as to prepare for the associated operations more appropriately. Lastly, the authors examined the pre-requisites that crew members need to meet in order to be able to work with the ventifoil units on board.

1.3. Research questions

This thesis addresses the following research questions:

1. How does the use of ventifoils impact general dry cargo vessels' on-board operations?
2. What are the pre-requisites crews need to fulfil to be able to work with ventifoils?

1.4. Scope

This thesis focuses on ventifoils – and hence on the current existing manufacturer of ventifoils, as they are currently one innovative wind propulsion technology manufacturer in the maritime industry, and ventifoils are one of the technologies in focus in the WASP project.

As ventifoils have only been applied on one vessel so far, the authors of this thesis were limited to absorb most of the information from the owner, crew members of that vessel, as well as the ventifoil manufacturer, and their upcoming customers. The scope of this thesis only includes, as a result, general dry cargo vessels.

2. Literature Review

In this section, a review of existing literature will be presented for a better understanding of wind propulsion concepts, of on-board operations on general dry cargo vessels and of aspects related to the human element in shipping.

2.1. Wind-assisted propulsion technologies

Currently, there are seven types of wind-assisted propulsion technologies as mentioned in section *1.1. Background*. However, only four types, specifically Ventifoils, Flettner rotors, DynaRigs and Kites are introduced below in order to provide examples on how wind propulsion works and how they can influence operations in general.

2.1.1. Ventifoils

Ventifoils, also known as suction wings or turbosails, are one of the existing wind-assisted prolusion technologies for ships. Today's ventifoils originated from the turbosail concept initiated by the Cousteau Foundation in the 1980s (Höllbacher, 2012). In 1984, Captain Cousteau and Monsieur Jean-Pierre Ergas decided to make an agreement to install a turbosail as auxiliary propulsion on ships. The first industrial exploitation of turbosails was done on 3000 DWT chemical vessels and it was operated alongside the main engines. The installation of the turbosails was expected to save fuel consumption from 15% to 35% (Charrier, et al., 1985).

In 1984, Captain Cousteau built a new ship with two turbosails called Alcyone. Each turbosail had a surface of 21 m^2 and a height of around 10 meters. With the reduction of the height, it could reduce wind power which was crucial to manoeuvre at port or under bad weather (Charrier, et al., 1985). Due to the use of turbosails, the transatlantic crossing voyage of Alcyone saved up to 35% of consumption. However, because of the oil crisis in the 1980s, turbosails became unachievable and delayed until 1988. It could be said that, at that time, turbosails were proven to be an effective technology but it required more economic incentives to be fulfilled (Höllbacher, 2012).

In terms of structure, the turbosail contains the wing sail, a pneumatic pump, the revolving mechanism, a computer system, and sensors. The wing sail includes a thick profile, two suction areas and a flap as shown in Figure 1. The fan is located on the top and inside the wing, which is supplied with energy by the pneumatic pump (Höllbacher, 2012). The function of the fan is to create low pressure inside the wing (ibid.,10) to increase the flow around the wing-masts, consequently accelerating the lift which generates the driving force (Alza, 2012). Low pressure inside the wing turns into airflow going through porous suction areas. The aim of the boundary layer is to prevent flow separation at the rear of the wing. This allows the sail to reach the lift coefficients. In addition to the wing sail, sensors and a computer system enable adjustments to the sail and engine so that the use of wind power can be optimized. Thus, the turbosail is a relatively simple and autonomous system to assist ship propulsion with wind power (Höllbacher, 2012).

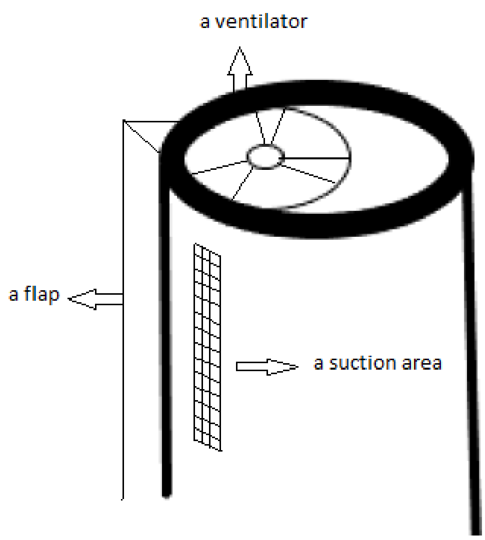

Figure 1. The structure of the wing sail (Malavard, 1984) (the sketch was modified by the authors)

The basic working principle of ventifoils is using boundary layer suction with ventilators placed inside the wing sail to generate thrust for the ship. Hence, the use of the propeller can be reduced in order to remain the same speed, saving fuel and energy consumption (Conoship International, 2020). Principally, there are two main types of ventifoils which have been researched and exploited in commercial application: they are the retrofitted ventifoils and the containerized ones.

Regarding retrofitted ventifoils, the unit is installed and is non-removable on the vessel's deck as shown in Figure 2. It can rotate around its axis and be folded in order not to become a hinder while loading or discharging cargo, enabling easy access to the cargo holds. The retrofitted type is not limited in size to be fitted in a container; thus, it is possible to make a big foil for this kind of ventifoils. As a result, the larger foils should generate more thrust force forward and great propelling force, saving fuel consumption for the ship (eConowind, 2020).

Figure 2. Retrofitted ventifoils on MV Ankie, with supporting frames (Source: Van Dam Shipping).

In terms of containerized units, the wings are designed to be fitted in a 40ft-container as shown in Figure 3. This would bring flexibility to different types of sea vessels including general cargo vessels or tankers as long as there is space on the deck to store one or two 40ft-container units. In order to get the most favourable angles in accordance with the apparent wind, the ventifoils can be rotated by themselves. This produces a force for the propulsion of the ships, maintaining speed for the ship and meanwhile reducing the engine power. All equipment including hydraulic parts, automation and ventilators are merged into the unit. The ship has to provide the unit a power connection of 400-460 voltage, 3 phases and 50-60 Hertz (eConowind, 2020).

Figure 3. Illustration of a containerized unit (Conoship, 2020)

A special type of containerized unit is the flatrack ventifoil, which has similar characteristics to the normal containerized unit, but it is customized to be more suitable for ships with a hatch cover crane as shown in Figure 4. With this version, the hatch crane can move the folded ventifoil to different places on the ship horizontally.

Figure 4. Illustration of containerized (flatrack) units expected to be installed on the Frisian Sea vessel owned by Boomsma Shipping this year (Boomsma Shipping, 2020).

There are advantages to using ventifoils on board ships. The system of ventifoils can achieve energy efficiency and aerodynamic performances on a large scale of operation (CRAIN, 2020). Furthermore, they have a reasonable size to create a great propulsion force for ships. Ventifoils can potentially reduce fuel consumption and GHG emissions, however, weather conditions, the ship's route and operating speed shall be taken into consideration when measuring the potential saving of this technology (ibid.).

2.1.2. Flettner rotors

Flettner rotors, as illustrated in Figure 5, are a different type of wind propulsion design used on vessels to create thrust and help the vessel to move with the help of the wind. Flettner rotors are designed to be moved with the Magnus effect, which essentially means that the wind hits the rotor sail and the air accelerates on the one of the sides of the rotor sail and decelerates on the opposite side of the rotor (Norsepower, 2020). The shift of the speed makes the wind flow result in a pressure difference from which a lift force that is vertical to the wind flow direction is created. This wind propulsion technology consists in a spinning cylinder (see Figure 5) which generates thrust and pure propulsion energy for the vessel, by spinning around on its own axis with the air force, which in turn causes a push to the vessel and makes it move towards the wind direction (Pollux, 2018).

Figure 5. Ship using flettner rotors (Schuler, 2016)

Flettner rotors stand vertically on a vessel in order to spin with the airflow. It is an innovative way of propulsion with a number of advantages, e.g. reducing the speed and at the same time saving fuel without changing the ship's route or the voyage time (Norsepower, 2020). On the other hand, this system carries some disadvantages, e.g. flettner rotors are big units that require a lot of space on deck. Moreover, the units are fixed and cannot be moved, for example, to make the crew's operations while loading and unloading easier (Norsepower, 2020).

2.1.3. DynaRigs

Another concept of wind assisted technology is the "DynaRig" as shown in Figure 6. It is suitable for big yachts. The big rigs are installed horizontally. As the sails are deployed, the thrust of the boat is optimized by rotating the shafts. DynaRig is an updated version of "square rigger" with sails where the only difference is that the sail does not swing around the fixed masts but are instead attached permanently (Yaughts, 2010).

Figure 6. Super-yacht with DynaRig called Maltese Falcon (Yaughts, 2010).

This wind-assisted technology allows to receive the wind to an optimal angle on the sails through rotation of the shafts and the navigation is guaranteed by the wind flow direction (Magma, 2020).

One of the advantages of DynaRig is that it is possible for the vessel to sail efficiently without the need for much crew. Another benefit is that due to the sails, DynaRig can navigate without the need of the engine, taking full advantage of the wind and making the navigation and manoeuvring easy to handle. Lastly, by sailing off the wind, one does not require any additional costs, specialized crews or any handling system in order for the vessel to operate efficiently (Magma, 2020).

On the other hand, the materials that are needed for construction of DynaRig (e.g., the free standing rotating masts) are consider more expensive than the traditional materials that are used in traditional sailing boats (Spilman, 2012). Furthermore, as DynaRig requires expensive materials, it also requires expensive maintenance or applying new materials in case of destruction of this innovative technology. Also, the masts of DynaRig could stand in the way of cargo operations making the whole procedure difficult for crew members and increasing the risk of the ship being damaged in the loading and discharging of cargo (Spilman, 2012).

2.1.4. Kites

Another wind-assisted propulsion system on vessels is the kite technology, as shown in Figure 7, in which ships are connected to a kite by a thin rope and pulled by the kite creating thrust from the wind flow. The towing rope is fixed to the deck and is controllable to the desired direction by a motorized module that is attached on deck (SkySails, 2007).

Figure 7. Kite technology installed on the ship (Hanley, 2018)

As per SkySails, a company that manufactures automated kite systems for all kinds of ships, ship's crew can operate the system from the bridge using an automated system, such as for the launch and recovery of the kite done by the simple push of a bottom from the application (SkySails, 2007).

The advantages of kite technology are various. One of them is that the kite is efficient as the system is operating in a big altitude between 100 to 300 metres where the wind is stronger and more constant. As a result, it gives more thrust to the ship. Another advantage is that the kite is easily stowed when not needed and does not require much space on board the ship (SkySails, 2007).

On the other hand, the structure of this approach may bring difficulties to merchant ships during the loading or discharging of cargo at port or even during navigation passing under bridges as the kite has large dimensions.

2.1.5. Influences of wind-assisted propulsion on operations

According to Bergeson and Greenwald (1985), there are some aspects of ship operation and crew tasks that could be affected by the installation of new wind propulsion systems. Some aspects are related to economic performance such as operating cost, weight of the unit, available area for the system on the ship. In terms of cargo handling, the system may collide with the cargo gear not only on the ship but also on shore. In addition, the installation of the unit might potentially obstruct visibility from the bridge (Bergeson & Greenwald, 1985).

All wind-assisted systems have been built for commercial ships in a way that they enable favourable operation at sea, not requiring more manpower. Technically, the hydraulic operation has been utilized to operate the wind propulsion unit such as adjusting the angle of the sail, unfolding, and folding the wings, etc. These tasks are conducted and managed from the bridge with the button control system. Automation has been utilized to ease operation. Furthermore, the system should also not require intensive effort in maintenance at sea (Bergeson & Greenwald, 1985).

2.2. Ship management structure

In shipping companies, ships are units that make a profit by transporting goods and carrying passengers by waterway (Bistričić & Kuzman, 2011). In order to operate the ship, it is indispensable today to have competent crew (Institute of Chartered Shipbrokers, 2013). Ship management is responsible for the operational activities of the ship (Bistričić & Kuzman, 2011).

The management responsibility level is based on the rank of the ship Captain, Chief Mate, Chief Engineer and Second Engineer. The management and organizational structure on a ship is different from the land-based organization. On board, only mechanics and functional structures are employed (Bistričić & Kuzman, 2011).

The ship management structure is divided into two components: deck and engine. Regarding the deck department, the Master/ship Captain is the top manager on the ship and the representative of the shipping company (Bistričić & Kuzman, 2011). The Captain is in charge of overall operation on the ship (Institute of Chartered Shipbrokers, 2013) and has the right to give permission on the type of cargo and quantity of cargo to be loaded on the ship as well as assign the route (Bistričić & Kuzman, 2011).

Being in the middle management level and assistant to the Master is the Chief Deck Officer/Chief Officer/Chief Mate who has responsibility for the cargo operations and maintenance (Bistričić & Kuzman, 2011). The Chief Officer needs to decide the amount of cargo to be loaded into each compartment, and in what order it shall be loaded and unloaded in order to avoid unnecessary overwork for the ship (Institute of Chartered Shipbrokers, 2013).

The Chief Officer is a senior to the second, third and fourth mates. The number of mates depends on the size of the ship as long as there is at least one competent navigation officer in charge of the watchkeeping activity at a time (Institute of Chartered Shipbrokers, 2013).

In terms of the engine department, the middle manager is the Chief Engineer who oversees maintaining and managing the main and auxiliary machinery and all equipment. The Chief Engineer is responsible for the remaining engine department crew (second engineer, electrician, mechanic, oilers, cleaners, and engine assistants). In case the Chief Engineer is not able to perform his tasks, the second engineer who is also a middle manager will take over the management duty (Bistričić & Kuzman, 2011).

The Chief Officer, Chief Engineer and Second Engineer have the right and duty to organize and make a plan for the upcoming voyage, consisting of arranging and handling cargo, calculating amount of needed fuel and grease, etc. (Bistričić & Kuzman, 2011).

There are factors determining the number of crew working on a ship: the size of the ship, the flag of registration, the expected health and safety conditions on board as well as correspondence with trade unions. On small-sized ships, the role of the Master and the Chief Engineer could be integrated. In that case, four or five members would suffice (Institute of Chartered Shipbrokers, 2013).

2.3. The human element

The Human Element, as defined by the IMO, refers to the field of human actions implemented by seafarers, on-shore management and regulatory authorities which influence maritime safety, security and the environment (International Maritime Organization, 2020c).

Historically, the human element was considered in the IMO's STCW (International Convention on Standard of Training, Certification and Watchkeeping) Convention in 1978, when the first amendment was established to address the qualifications that seafarers need to acquire before working on board (International Maritime Organization, 2020d). The concept was later considered in the 1995 STCW amendment as well, which demanded the technical training of seafarers (engine departments, radiocommunication operations etc). And lastly, in the 2012 amendment, standards of training for ships' crew were enhanced and came into force (International Maritime Organization, 2020c).

In terms of human element, the ISM (International Safety Management) code was established to enhance the safety and the reduction of pollution from ships. As a result, the human element concept helps to minimize the issues regarding safety and environmental impacts that might be caused by crew members' activities (International Maritime Organization, 2020d).

Also, the IMO's convention on Safety of Life at Sea (SOLAS) established that shipping companies follow safety standards on the ship's structure, equipment and on on-board operations. The effective implementation of the conventions from the IMO should ensure increased safety and decreased risk for ship accidents (International Maritime Organization, 2020d).

2.3.1. Crew training and education

In crew management operation, training and education of seafarers are vital. According to research, human error has contributed to the rate of 75-96% of marine casualties which are in the form of collisions, fires, explosions, grounding and allisions (Hanzu-Pazara, et al., 2008). There have been major catastrophes in maritime history, resulting in serious consequences purportedly associated with human error. For example, the Exxon Valdez oil spill in 1989 was reportedly caused by the absence of the Captain since he did not show up on the bridge to navigate the ship through the course during the transit of Valdez Narrows, and the Third Mate was in charge in this situation and did not make an in-time steering to avoid the ice. As a consequence, the ship crashed into the shore and spilled oil in a large area, leading to tremendous harmful effects on wildlife, fisheries and tourism in Alaska's Prince William Sound area (Amadeo, 2018). There are various contributing factors to human errors, including insufficient knowledge and experience, fatigue, inadequate communication, negative emotions and overconfidence, among others (Goulielmos, 1997).

Consequently, in order to enhance seafarers' education and training standards, a variety of international and mandatory requirements have been established. Personal safety and social responsibility are compulsory training in the STCW (Anastasiou, 2017). The STCW aims to enhance the human factor and diminish poor decisions. The fast development of advanced technology in ship operations is an area in maritime training which the STCW needs to pay attention to in order to enable shipping companies to comply with international regulations and maintain safe on-board operations. Therefore, shipping companies need to ensure that their seafarers are trained adequately in accordance with the technological development (Wang & Zhang, 2000). It is necessary for crew to understand clearly how the system works as well as competent knowledge to maintain and monitor the system properly in order to get an optimal result (International Windship Association, 2020).

2.3.2. Multinational crew

It could be seen that cultural diversity is common in the shipping industry, influencing not only training but also communication on board ships (Wang & Zhang, 2000). According to Progoulaki (2009), communication problems derived from a multicultural environment can impact overall performance due to the co-existence of multiple backgrounds and languages (Progoulaki, 2009). In order to have effective communication on board, crew management needs to ensure that international sailors speak a common language (English). This will enable them to understand each other and operate ships appropriately, including in emergency cases (Wang & Zhang, 2000).

2.3.3. Influences of technology on the crew

Technology is designed in a way mean to allow the sailors to accomplish their tasks more efficiently (Squire, 2013). However, seafarers may face problems that emerge when using a new system. Seafarers tend to rely on technology that is there to help them make decisions (ibid.,18). For example, according to accident reports, a junior bridge officer relies mostly on the information displayed on the screen to gain awareness of the situation rather than looking out from the bridge to see outside to evaluate the situation (ibid.,18). Thus, it can be necessary to make seafarers aware of the need to process the information and data provided by computerized systems based on their knowledge and experience, especially if something unexpected occurs with the information source or technical failure (ibid.,18). Today, automation has been increasingly applied in technologies. As a result, when any failures occur, it is likely that the chance of human error increases (Norman, 1990). In the initial phase of implementation and development, there is a tendency for people to have less awareness of potential issues/failures in the system which could lead to unexpected negative impacts (Rumawas & Asbjørnslett, 2012). Additionally, the failures of an interaction between crew and the propulsion systems may emerge due to poor design (Grech & Lutzhoft, 2016). Poor design results in inefficient operation performance since the equipment or machinery does not support the crew (Kataria, et al., 2015).

Even though all specifications of the system are approved by the IMO, manufacturers tend to add their distinctive specificities/features to make their products more competitive in the market. However, due to the multi- cultural environment on the ship, it is necessary to have common standards for the system control such as switches, symbols, etc. Additionally, seafarers need to be trained on a fundamental level to work with the new system before they go aboard the ship rather than being instructed on the job by other crew that are not certified in the new systems. There is also the issue of diverse equipment and systems on board different vessels. Standardization of equipment becomes thus a topic of relevance that would facilitate that a general training program for new systems can be conducted (Squire, 2013).

2.4. Operations on general dry cargo vessels

Dry cargo vessels were first used after the end of World War II in order to transport general cargo, bulk cargo, etc. Normally, these vessels have a small size between 5 000- and 25 000-ton deadweight (dwt). Today, general cargo ships are more referred to as multi-purpose vessels (OpenSea, 2020). According to DNV-GL, there are five main types: coasters, general dry cargo vessels, multi-purpose vessels, multi-purpose project carriers and open-hatch general dry cargo vessels (Bergmann, 2018).

According to Bergmann (2018), coasters are small carriers that usually travel on short sea voyages, carrying bulk and general cargo. A small number of coasters are equipped with cranes. General dry cargo vessels are designed with more than 5000 dwt and without crane. General dry cargo vessels transport non-containerized cargo, non-packaged and packaged bulk cargo. They are built with two decks (i.e. "tweendeckers") and double hull. Multi-purpose vessels are equipped with cranes and carry break, dry bulk, and containers. Multi-purpose project carriers are used to transport project cargo and are built with box-shaped cargo holds and cranes. Open-hatch general dry cargo vessels are large carriers, featuring cargo holds in a U-shape and carrying wood, paper, general cargo and project cargo (Bergmann, 2018).

2.4.1. Loading and unloading

The main duty of the Chief Officer during loading and unloading process is to supervise cargo handling and make the stowage plan of all cargoes that will be loaded. The first responsibility is to handle cargo which includes collecting cargoes, ensuring that cargo holds are clean and monitoring all conditions such as bilge bays, rose boxes, hatch covers, etc. Secondly, the Chief Officer needs to establish a cargo plan to make sure that cargoes are reached and identified easily, and that there will be no harm to cargo during the voyage. It is also important to have a right sequence of loading and a competence of cargo unloading (House, 2011).

Meanwhile, according to House (2011), on dry cargo vessels, the Junior Officer is responsible for handling cargo operation and making sure that the operation is following the stowage plan. He/she has various tasks in each phase of cargo operation. Before cargo operation, the Junior Officer needs to check whether assigned compartments are clean. Besides, he/she also has to examine the condition of cargo battens, the drainage and bilge suctions, the rigging of cranes or derricks, etc., and relevant hatch covers are opened and stored securely. During moving cargoes, the Junior Officer has to take note of the start and end times of loading and discharging events in the logbook and also of the transfer of cargo into corresponding compartments in the stowage plan. After cargo operation, hatch covers are closed and lifting equipment is secured. The engineering department is informed to close power which provided energy for deck winches. Lastly, the Junior Officer informs the Chief Officer that the deck is secured after completion of loading or discharging (House, 2011).

Among different activities, hatch work is one the most crucial parts in cargo operation. There are four main types of hatch covers that can be utilized on general cargo ships, including folding hatch covers, lift-away hatch covers, piggyback covers and stacking hatch covers (MacGreror, 2016). Each of them has a different system and procedure to operate. The folding hatch covers are operated by using hydraulic pumps. Panels can be folded into different pairs, could be single, double or triple (House, 2011). The folding hatch covers are illustrated in Figure 8.

Figure 8. Folding hatch covers (MacGregor, u.d.)

Lift-away hatch covers are shown in Figure 9. With this type of hatch covers, each hatch opening is covered by covers of multiple panels. They feature not only partial opening but also do not have to follow a specific sequence. They can be opened by an on-board crane or an onshore crane. Then the panels can be stacked on the next covers which are stored on the deck or on the quay (Wärtsilä, 2020).

Figure 9. Lift-away hatch cover (TTS Group ASA, u.d.)

Piggy-back hatches are applied in case there is not enough space for covers to be placed on deck. The system contains two panels in which one can be lifted by hydraulic cylinders so that the other one can be rolled under it as shown in Figure 10 (MacGreror, 2016).

Figure 10. Piggy-back hatch cover (TTS Group ASA, u.d.)

Stacking units are shown in Figure 11. These hatch covers are stacked and closed in a specific order, connected to a towing device that drives a continuous chain to adjust the position of the panels (MacGreror, 2016).

Figure 11. Stacking hatch covers (MacGregor, u.d.)

2.4.2. Navigation

Vessel navigation consists in the supervision and management of how the ship moves and runs between origin and destination. Before executing the voyage, the most favourable route is planned. There are numerous tools aiding ship navigation, including radars, gyro and magnetic compasses, GPS, etc. They enable the sailors to have precise data for the voyage as long as they are kept in good condition and are used by well-trained seafarers (Maritime Knowledge, 2018a).

In case of restricted visibility caused either by fog, dusty storm, or heavy rain, the deployment of appropriate equipment and action by the ship's Officer of the Watch (OOW) needs to be taken (Maritime Knowledge, 2018b) and the ship's route must be prepared accordingly (Chopra, 2020). The Master needs to be informed about the situation by the OOW and to be present on the bridge. It is required to increase manpower on the bridge in such cases (Maritime Knowledge, 2018b) so that they can better monitor and have a better watch of the ship's course (Chopra, 2020). Meanwhile, the engine room should also be informed, maintaining the engine so that immediate manoeuvring can be conducted at any time. In addition, watertight access, ventilation fans and engine room ports should be closed (Maritime Knowledge, 2018b). Especially under a sandstorm circumstance, they must be shut down in order to prevent sand particles penetrating the accommodation. Moreover, all navigation equipment must be confirmed by the OOW to be ready to work appropriately to support navigation. Ship speed also needs to be reduced based on visibility. In challenging conditions, secondary tasks must be postponed, even with more manpower on the bridge and in the engine room in order to avoid collisions (Chopra, 2020).

Narrow channels or narrow fairways can occur either with shallow waters on both sides or due to the characteristics of the ship, for example length or draft. In such areas, ship navigation could be more vulnerable since the movement of the ship is restricted by limited space. According to Bhattacharjee (2020), there are some important points that crew needs to take into account when navigating in these conditions. It is important to have clear communication with the Vessel Traffic Services (VTS) to be guided to avoid collisions. Navigation aids such as radars can facilitate the clear communication between bridge members and VTS so that they know what they intend to do in relation to surrounding vessels. Furthermore, the engine room should also be communicated appropriately to make them ready for any changes in speed and direction. In the meantime, the ship needs to be operated at average speed which gives room for vessels to increase speed at appropriate time. The most difficult factor when transiting a narrow fairway is turning points. This task requires clear communication between the pilot who understands the local waters well and the Master so that they can decide the right time to make the turn (Bhattacharjee, 2020).

Manoeuvring

Manoeuvring is the process in which a ship enters or leaves coastal waters or a port and passes through channels and traffic-dense areas. This operation demands a sufficient number of personnel and all systems need to be controlled manually to fully monitor the ship. From a crew's perspective, manoeuvring operation is the most important time of the voyage and could pose danger to the ship (Chapro, 2019).

Generally, before manoeuvring, all aspects such as the condition of wind, tide, the ship's trim and draft, the navigation equipment aids should be fully understood by the Master along with the help of the pilot and tugs. The Master and the pilot stand side by side to keep good communication and navigate the ship safely (Chapro, 2019).

2.4.3. Maintenance

Maintenance could be considered as one of the most important activities on board a vessel since it can extend the life cycle of machineries and small or big equipment. On vessels, crews are responsible for the maintenance to ensure that the vessel runs without disturbance (Mohit, 2019). Moreover, all ships are following a Planned Maintenance System that reminds the crew members of what kind of reparation tasks they need to perform on board (Mohit, 2019). The different kind of responsibilities of different crew members about the maintenance is implemented on board are presented below.

Deck crew

A Deck Officer will inspect the deck to uncover defects on the deck equipment so that they can be added to the crew's maintenance plan list. If the Deck Officer finds a vessel deformity or condition which has to be added to the maintenance plan for the staff to fix, he/she must set up an imperfection report and repair proposal for the ship owners. These repair proposals will be sent by the Master to the ship owner's repair department where they will be assessed and booked for repair in port, performed by a crew member allotted to the ship. As a result, the ship owner's repair department will have an understanding of what the vessel's issues are and then have to maintain the damaged equipment or machinery (Rudley, et al., 1994).

Deck crews, like Able Seaman (AB) and boatswain, are responsible for the maintenance or repairs on deck. Some of the repairing that is performed by deck crew is the cleaning of holds before and after the loading or discharging of cargo on a vessel. Some of the mechanical assignments of deck crew are shared with the engine room crew, such as removing rust from the vessel's steel covers, accommodation, and the operational areas where all members must make sure the vessel is working efficiently (Rudley, 1994).

Engine crew

The engine room is where a big number of machines are located. Also, this is the department where the most maintenance efforts are required for a safer operation on board (Mohit, 2019).

Nowadays, the number of on-board crew in different segments of operation is sizeable and crews could perform their maintenance procedures relatively quickly and comfortably. Yet, the number of crew on board has changed as ship owners choose to hire only the needed engine crew members. Ships now carry only 3-4 engineers that have to carry out all the workload of maintenance and repairs that might be needed for the engine (Mohit, 2019).

Engine crew members also have to follow a planned maintenance system regarding machinery that is put in the engine room. One of the existing systems for maintenance is the Plan Maintenance System, where all the needed repairs and maintenance or replacement of different kinds of equipment in the engine room are logged, resulting in more efficient planning. Alternatively, there is the breakdown maintenance approach, carried out only when the system breaks down. As has been proven, this way is not that efficient as machinery breaking down can cause emergency situations (Mohit, 2019). On the other hand, this type of maintenance has the advantage of allowing for the machinery to be used until the end of its life, resulting in less waste(ibid.).

Another maintenance system is the condition maintenance system, where different kinds of machinery and equipment are checked frequently, and the maintenance is done properly. This process requires expert crew (Mohit, 2019).

3. Methodology

This chapter presents the methodology of this thesis and how it has been used in relation to this research. Firstly, the research paradigm will be analysed in the sections of Ontology and Epistemology (based on the map seen in Figure 12). Furthermore, the authors of this thesis will proceed to the Data Collection section where the chosen research methods will be presented (literature review and interviews). The last section presents the data analysis method chosen to analyse the data gathered from the interviews.

3.1. Research approach

In this section, the research approach in which the authors examined their data will be described. It is divided into the parts of Ontology and Epistemology.

3.1.1. Ontology

Ontology is defined as the study of how people view reality (O'Gorman & MacIntosh, 2014). As the map in Figure 12 suggests, ontology can follow the subjective approach. In more detail, according to O'Gorman and Maclntosh (2014), "a subjective perspective examines the reality that is made up of the interactions of living subject" (ibid.,56). Furthermore, a subjective ontology assumes that the only thing that shapes reality is people's perceptions, and this is used in social sciences (O'Gorman & MacIntosh, 2014).

The authors of this thesis examined this study under the light of a subjective ontology, gathering the perceptions of interviewees on a new technology and how to interact with it.

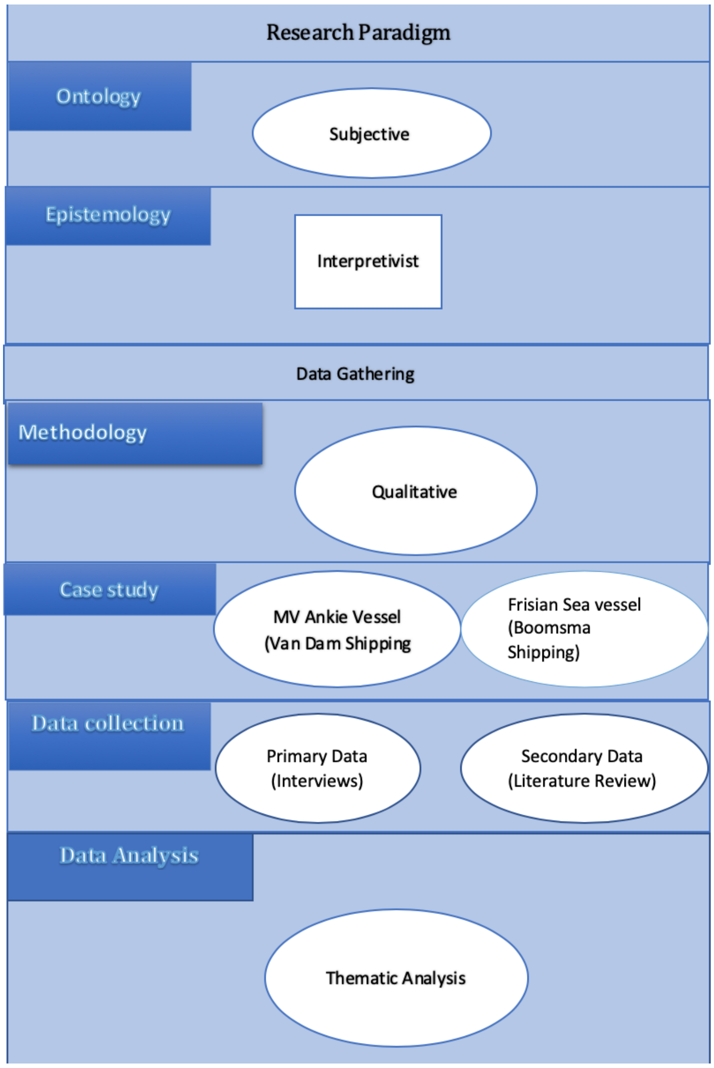

Figure 12. Method Map

3.1.2. Epistemology

Epistemology is defined as the way of acquiring knowledge in studies (Wenning, 2009). Epistemology, as it is shown in Figure 12, includes the interpretivist approach, which recognizes, as per O'Gorman and Maclntosh (2014), "the differences between natural and human sciences in which these distinctions stemmed from different aims and explanations versus understanding" (ibid.,64).

According to Weber (1924), social science seeks to understand social phenomena in terms of meaningful categories of human experiences and therefore the causal-functional approach of natural sciences is not applicable in social inquiry. Also, while examining people, physical frameworks cannot respond to expectations made about them, and social frameworks can. Weber (1924) called attention to the 'self-consciousness of people and the 'freedom of choice', which infers that a spectator can never acquire a forward-thinking record of the subject's perspective, which would be right for the spectator to acknowledge (Weber, 1924; O'Gorman & MacIntosh, 2014).

This thesis follows a subjective ontology, as was added above, with an interpretivist approach. Those two characteristics have as an outcome to follow a qualitative methodological approach to data collection and analysis.

3.2. Data gathering

In this section, the authors described the data collection approach, in which two case studies of two different shipping companies have been added where one has already installed retrofitted ventifoils and the second one is expected to install flatrack units. Moreover, the authors analysed the process of collecting the data.

3.2.1. Qualitative research

This thesis follows a qualitative research approach. According to Blumberg, Cooper, and Schindler (2011), different empirical methods can be used to accomplish this research approach, such as interviews, observations, questionnaires, audio-visual material, and documents. In this thesis, the authors performed a set of interviews in order to conduct the qualitative data collection (Blumberg, 2011).

3.2.2. Case Study

Considering that the scope of this thesis is focused on ventifoils, specially a vessel that has applied retrofitted ventifoil technology on board and another vessel that is planning to do so with different ventifoil technology which is the containerized (flatrack) units, this thesis introduces them as case studies. The first general dry cargo, MV Ankie, is owned by the Van Dam Shipping company and has operated with two eConowind retrofitted ventifoils since January 2020. Moreover, the authors were also investigating the case of the Frisian Sea vessel, a general dry cargo vessel owned by Boomsma Shipping, for which the on-board installation of two eConowind containerized units with one ventifoil in each container (flatrack version) is planned. They are to be located on the deck. As this company has not installed the eConowind units yet, the authors aimed to interview them in order to probe about their expectations and plans for their operations. Finally, this thesis focuses on the case of one ventifoil manufacturer, as ventifoils are a new concept and no other manufacturers of this exist outside of this one and researchers that examine if this phenomenon will be successful for the maritime world. Hence, this thesis focuses on these examples, represented as case studies.

3.2.3. Data collection methods

This thesis uses secondary data from a literature review and from attending a conference to gather existing information about wind propulsion, particularly ventifoils, as well as about existing relevant theories and methods.

Furthermore, primary data was gathered by the authors to address the research objective and answer the research questions through interviews with relevant actors in the ventifoil propulsion market.

Secondary data

A literature review through books, peer-reviewed articles, scientific journals, and referencing materials was performed to create the frame of reference. Literature was searched on databases such as Science Direct, Elsevier Business Source Premier, Chalmers library.

The authors attended the International Wind Propulsion for Shipping Forum 2020, that took place in Copenhagen, Denmark, where information on different kinds of wind propulsion technologies was introduced by experts resulting in a clearer perspective and understanding of wind propulsion systems for the authors. Moreover, the authors had the opportunity for conversations with the experts in order to ask for more clarifications on the subject that they presented. After the conference, relevant materials like PowerPoints were gathered.

Other materials were collected from the crew members of the MV Ankie vessel, such as pictures from the installation of the ventifoils.

Primary data

The primary data was collected from interviews from which each stage is described below.

Interviews

Interviews were employed to collect the interviewees' own perspectives and identify patterns. Qualitative interviews are normally performed by one or two researchers that seek to find an answer to a research question through a group of people that might help to solve a problem (Lochrie, 2014). It was necessary for the authors to contact some of the participants more than one time in order to clarify some data.

In order to perform and examine the interviews, three stages were followed: (1) pre-interview considerations and formulation of interview questions or objectives; (2) interview is conducted using different kinds of approaches, for example via video or face-to-face; and (3) post-interview activities, such as making transcriptions of the interviews (Lochrie, 2014).

Pre-interview considerations: Design and access

In this stage the authors started to formulate ideas on what kind of questions the interviewees should be asked to gather specific information and answer the research questions. The next step was to select a suitable type of interview that, according to O'Gorman and MacIntosh (2014), can range from unstructured to structured, with semi-structured having a middle approach of the other two (O'Gorman & MacIntosh, 2014).

A structured interview is one where pre-prepared questions are strictly conducted as planned in a straightforward format. An unstructured interview is an approach where interviewers ask questions freely in order to turn the interview into a conversation. Furthermore, pre-prepared questions could be adapted or annulled, based on the interviewees' responses. Also, the set of questions were open-ended allowing the interviewee to start a discussion and feeling flexible and free to express their views.

After choosing the range of the interview, authors had to select the way of implementation, as the face-to-face option was not possible due to the Corona Virus pandemic. Video interviews were then the chosen alternative during this period.

During the interview

The interviewees were verbally informed that the data used in this thesis would be anonymized. The interviewees were listened to carefully to receive the input required for the author's research.

Sample

The process of gaining valuable data started with contacting the members of the WASP project, project within which the authors performed this research study. Then, it became a snowball process of finding other relevant participants such as crew members that were chosen depending on their role on board and their availability.

The first interview was with the manufacturer and application expert/trainer of ventifoils who were asked to describe how they came up with the idea of producing this kind of wind propulsion for ships and how ventifoils work on board.

The trainer expressed his ideas on training the crew and what he expects from them. The authors had two interviews with the application expert/trainer. The first one together with the ship owner to answer some questions before he went on board to first provide the training programme to a crew, so expectations were collected. The second one when the application expert/trainer had finished the on-board training on the first vessel where ventifoils were installed, in which he answered about experiences that he faced on board.

The interviewers were focused on asking what the changes were after implementing ventifoils, what the added workload for the crew was, and how crew members understood the procedure of training and if they could implement the theory in reality.

After the interviews about the manufacturer's side, the authors approached the ship owner of MV Ankie where the retrofitted ventifoils were installed. He expressed their ambitions and future savings that this type of technology could bring to his vessel.

After completing the interview with the ship owner, the authors had interviews with the on-board crew members of the MV Ankie vessel. So, the next step was to get in contact with crew members to find out what has changed in their workload, what their expectations were and what challenges they think they could face in the port and during the loading and discharging of cargo. The Chief Officer, Engine Officer and deck crews described the current workload and how much workload was added after the installation of ventifoils.

In order to find out more expectations on the installation of ventifoils on board ships, the authors also approached Boomsma Shipping, who plan the installation of the two flatrack units this year. The questions were mostly on expectations and apprehensions.

The Table 1 shows the list of interviewees in three companies, namely eConowind, Van Dam Shipping and Boomsma Shipping. Moreover, the codes of each of the interviewees are being shown in the Table 1 in order to keep anonymity in the section of Results. Besides, the times of interviews and exchanging information with each person are also counted and listed in the table.

Table 1. Interviewees

Company Name	Type of Companies	Title of the interviewee	Interviewee code	Numbers of data collected from	
				Interviews	E-mail exchanges
eConowind (Technology providers)	*Ventifoil provider*	*Co-owner/ Manufacturer*	*EC*	*1*	*3*
-	-	*Application expert/Trainer*	*EC1*	*1*	*1*
Van Dam Shipping (Shipping company - Technology user)	*Shipping Company currently operating an eConowind retrofitted ventifoil onboard MV Ankie since January 2020*	*Owner/Ship owner*	*VD*	*1*	*1*
-	-	*Chief Officer*	*VD1*	*1*	*5 (via telecommunication application)*
-	-	*Chief Engineer*	*VD2*	*1*	*0*
-	-	*Deck crew (deck seaman)*	*VD3*	*1*	*0*
Boomsma Shipping (Shipping company - Potential user)	*Shipping Company currently planning to install an eConowind containerized ventifoil (flatrack) onboard the Frisian Sea dry cargo vessel*	*Co-owner/ship-owner*	*BO*	*1*	*5*
-	-	*Captain*	*BO1*	*1*	*0*

Post-interview

Post-interview, the authors transcribed the audio-recordings taken during the interviews, organized all the data in order to have a clear overview, and prepared the files for analysis. The transcribing and coding of the data were performed in the qualitative data analysis software NVivo which helped to make the process more efficient. Moreover, after completing the interviews, the authors needed some more clarifications in order to make the data more complete. The added data was gathered again from the interviewees by e-mail to fill in some gaps identified during the transcription of interviews.

3.3. Data analysis

In order to analyse qualitative data, the authors chose the Thematic analysis method considering it the most suitable for the existing data.

3.3.1. Thematic analysis

Among different data analysis methods, thematic analysis is popular in qualitative data analysis approaches (Braun & Clarke, 2006). Thematic analysis is a method to find, analyse and reveal themes within existing data. Normally, there are six main steps to conducting this approach (ibid.,16).

1. The first step is to become familiar with the data by transcribing it manually. The authors listened to the audio material in order to transcribe it word by word. Then the authors read the material together and wrote down some initial ideas for the analysis.
2. Secondly, in order to make coding more efficiently, the authors used the computer-assisted qualitative data analysis software NVivo to produce initial codes in each transcript. In this phase, the authors coded the data into different nodes and some interviews would share the same nodes based on its content. Some contents in different interviews revealed the same aspect, for example, the influence of ventifoils on loading and unloading process, advantages of using ventifoils, etc. There would be some information not relevant to any codes, while others were highlighted in different codes. Some nodes were not consistent with each other, but this should be noted because it would be helpful for discussion afterwards (Sang & Sitko, 2014).
3. After that, the analysis would be refined and defined at the broader extent (Sang & Sitko, 2014). The authors had to look back at the node sets in order to identify potential themes

that would emerge from the data. Nodes were classified in different themes and some nodes formed a subtheme.

4. The fourth phase of thematic analysis is to review themes in which researchers had to examine extracted codes to see the connection between them (Sang & Sitko, 2014). In this phase, some codes were broken down into different parts so that they would fit better in the theme. For example, a code defined as "Operational Changes" was divided into two sub-codes referring to the findings on the retrofitted and the flatrack ventifoils. After a comprehensive revision, a thematic map should be formed to illustrate the analysis as shown in Figure 13. The map shows that in order to investigate in "Influences on operations' vessels using ventifoils", the authors have identified two main themes including "Influences on operations" and "Pre-requisites regarding crew members". The former is analysed based on two types of ventifoils, retrofitted and flatrack ones, to see how these ventifoils affect deck room operation, engine room operation and workload on the ship. The latter is analysed based on opinions of crew members and trainers who worked with retrofitted ventifoils and plan to work with flatrack version.

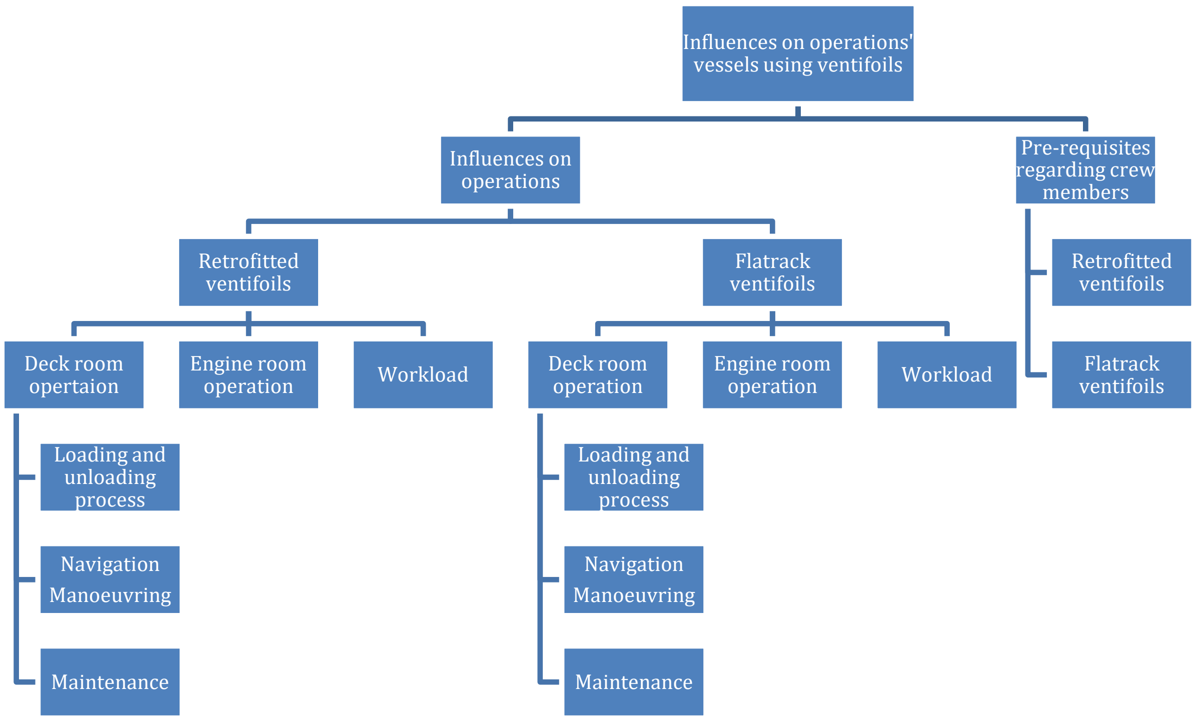

Figure 13. A thematic map

5. The next step is to further define the identified themes to see how they were relevant to the overall analysis. The purpose of this step is to interpret the data rather than to summarise interview transcripts so that the hidden story will be revealed (Sang & Sitko, 2014).
6. Finally, after thoroughly identifying themes, the authors wrote up the analysis results to tell the reader the story hidden behind the data. The authors used examples/quotes from the interviewees from extracted data to support the arguments.

4. Results

In this chapter, the results of the interviews will be presented in order to answer this thesis' research questions. There are two main themes which have been extracted from the data, including influences of ventifoil's implementation on on-board operation and pre-requisites regarding crew members' preparedness to use the ventifoils. The first part of this chapter (corresponding to the first theme) consists of the expected and experienced impacts on operation on board caused by two different kinds of ventifoils, the retrofitted and the containerized (flatrack) ones. The second part (corresponding to the second theme) refers to the pre-requisites. Table 2 reminds the reader of the list of interviewees and respective text code, in order to facilitate the reading and interpretation of the Results section.

Table 2. Codes of interviewees

Title of Interviewee	Interviewee Code
Co-owner of eConowind (Ventifoils provider)	EC
eConowind application expert/ Trainer	EC1
Ship Owner of Van Dam Shipping	VD
Chief Officer on MV Ankie (Van Dam Shipping	VD1
Chief Engineer on MV Ankie (Van Dam Shipping)	VD2
Deck Crew on MV Ankie (Van Dam Shipping)	VD3
Co- owner of Boomsma	BO
Captain on Frisian Sea (Boomsma Shipping)	BO1

4.1. Influences on vessel operation

The installation of ventifoils on board influences vessel operations. More specifically, the implementation of retrofitted ventifoils, which are the only ventifoil technology that has been installed at this point, have influenced the workload of crew members. Further, the implementation of the containerized (flatrack) version of ventifoils is planned for later this year and expected impacts on vessel operations are studied.

4.1.1. Retrofitted ventifoils

The operational changes that were experienced on the MV Ankie vessel in relation to deck operations, engine room operations and workload are described as below.

Deck operations

Loading and unloading process

Loading and unloading was one of the operations on MV Ankie that was affected by the installation of ventifoils in the sense that new tasks were added. The new task was that crew members needed to free the space of the hatches by folding down the ventifoils, which ensured an efficient cargo operation. At the port, the retrofitted ventifoils needed to be folded towards the nose of the ship, as crew members described. This way, they were able to open the hatch covers easily (see Figure 15). The folding of the ventifoils was done manually with a manual controller (see Figure 14) in order to minimize the possibility to damage the units which took about ten (10) minutes according to EC1.

> *We [Chief Officer and deck crew] just open hatches. But now, we have to put ventifoils system forward. When we are in port, we have to put it forward again, because otherwise, we cannot open the hatches for discharging and loading cargo. We are just all the time open hatches. But now, before opening hatches, we have to put the ventifoils forward. Otherwise, we cannot open the hatch. (VD1)*

Figure 14. Manual controller of retrofitted ventifoils on MV Ankie vessel (Source: Van Dam Shipping)

Figure 15. Ventifoils were folded forward when the ship is at port (Source: Van Dam Shipping)

Another task that crew members were required to carry out when the vessel was ready to sail again was that they needed to place two supporting frames on top of the hatches in order to hold the ventifoils while they were folded during the voyage. The two supporting frames are stored on the hatches as shown in the Figure 16 with the red circle.

Figure 16. Two supporting frames marked with red circle (Source: Van Dam Shipping)

As claimed by EC, the loading and discharging operations were done as usual since the ventifoils were folded at the bow of the ship (nose of the ship) and did not harm the operation. As can be seen in Figure 15, when the retrofitted ventifoils were stored in this way, it did not cause any major issues to load and unload cargo.

> *If we put them totally to the forward and in this way, there is no difficulties while discharging. (VD3)*

Regarding concerns during the cargo operation, the first aspect was the weight of the units. EC1 stated that the Chief Officer had to take into account the weight of the unit when loading cargo which was seven (7) tonnes of retrofitted ventifoils. According to him, there was a loading computer which showed how many tons of cargo the ship can load. Therefore, the Chief Officer needed to pay more attention in the loading of cargo because of the retrofitted ventifoils on the ship, which had to be calculated and added to the total weight.

Besides, the Chief Officer also had to take care of the cargo capacity on the deck if it was necessary to store cargo on the deck. The reason is that, according to EC1, when the ventifoils were folded down (on the supporting frames as shown in Figure 16) during the voyage, the units would occupy the deck space. Taking this situation into consideration, in order to avoid any damage to cargo and the ventifoils during the voyage, the Chief Officer should keep in mind that they could only load cargo for one and a half meters under the ventifoils.

Another concern from VD1 was that the ventifoils could be damaged during loading and unloading cargo; the big crane could be a problem because, when moving it, it could hit the ventifoils. However, in fact, no situation of this kind had been reported so far.

Maintenance

The installation of the ventifoils also requires maintenance involving the deck crew. According to VD3, the only maintenance needed on the units was lubricating the ventifoils in order to protect it from rust. Regarding the frequency of maintenance, the procedure of greasing was supposed to be done a few times a month according to the manufacturer's side (EC1) but sometimes it depended on the Chief Officer of the vessel, depending on the workload and when it was actually needed. The crew members on MV Ankie mentioned an experience of performing the greasing every second week. It could be said that crew members have done an appropriate frequency to maintain the system.

In terms of the person who performs the greasing, EC1 stated that the maintenance was mostly the responsibility of ratings, especially AB, who are responsible to accomplish duties like operations on board, mooring the ship etc. According to VD3's experience on the ship, he claimed that the task was done by different members. This is considered as small maintenance for the system; thus, it depends on the Chief Officer to assign who will perform the task.

On the other hand, if there is a serious damage to the ventifoils, the manufacturer is responsible to fix and maintain the system. Crew members do not have an obligation to do an advanced maintenance.

> *If there is something broken inside, we have to call a technician from eConowind. Normally on board [we] only do small maintenance and for more advanced maintenance will be done by eConowind. They watch it and look at it to do the job. (VD1)*

Manoeuvring

Manoeuvring refers to navigation in tight port areas. As per VD1, ventifoils did not have any effect when the ship started its manoeuvring operation. The units would be folded on the two supporting frames, causing no impacts on manoeuvring (see Figure 17). Also, VD1 added that the process of manoeuvring did not influence the crew members. The only thing they had to do was folding the retrofitted ventifoils down and then the existing workload should be handled.

Figure 17. MV Ankie vessel during manoeuvring process with folded retrofitted ventifoils towards bridge (Source: Van Dam Shipping)

Navigation

Navigation refers to operating in open waters. As per EC1, the system was autonomous during navigation and manoeuvring. The Chief Officer only needed to press the green button (see Figure

18) and there was also a software in the bridge where the crews could control to fold and unfold the ventifoils during the voyage (see Figure 19). Additionally, if the air flow is within limits, the ventifoils can operate efficiently, as there is a limit system that informs the crews where they should fold the ventifoils down.

> *During the sailing you have to operate the sail which works autonomous. So basically, when the Officer of the Watch feels that can use wind assisted propulsion, [he] pushes the green button. (EC1)*
>
> *I tell them to use the system as much as possible, but do not exceed the limit. We have some limit system that you cannot unfold the systems. When apparent wind is more than seventeen (17) metres per seconds or the angle is less than 20 degree, or when it is storm. (EC1)*

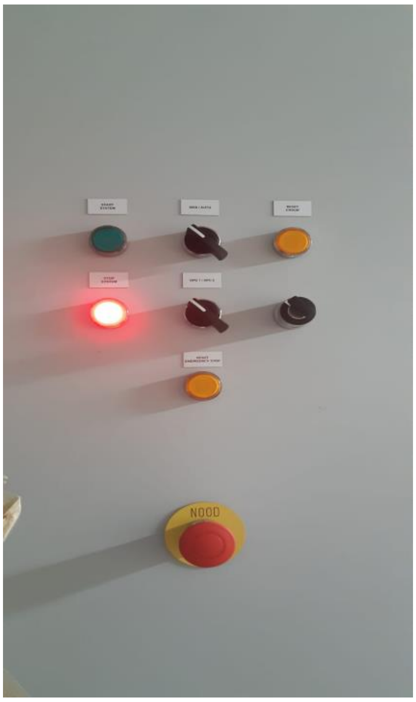

Figure 18. Next to hydraulic unit where crews choose to work manually or automatic (Source: Van Dam Shipping)

Figure 19. Software on bridge where crews put the units automatically up and down (Source: Van Dam Shipping)

Additionally, EC1 also added that was important for the crews to learn and understand the system and use the weather forecast wisely in order to take advantage of the wind and use the ventifoils in the sea.

> *We want them to understand the system and of course, it helps if they are interested in the system and willing to take in account this ventifoils when planning a route. Looking the weather forecast then of course that would optimize our performance of ventifoils. (..). That is a part of the training, how to sail with ventifoils. It is part of your propulsion now not only an engine anymore. (EC1)*

Meanwhile, VD3 added that the navigation was not affected or changed by the use of ventifoils. There were some circumstances that crews needed to pay attention when navigating. When navigating to narrow fairways, they needed to fold the units down so that they had a better visibility. Besides, they also acquired that under bad weather, they should not use the ventifoils. The most favourable condition to use the ventifoils was at open sea where crew members always unfolded the ventifoils to take advantage of the wind, except in bad weather.

> *It is really affected by ventifoils by difficult areas and we will put them down. And then it is okay again. For navigation, if we need to see good, then we put them down. But in the open sea they are always up. (VD3)*

Engine room operations

When it comes to engine room operations, according to VD2, activities at the engine room were not affected by the installation of the ventifoils. The unit needed energy to provide for the ventilators as EC1 stated. And the supply of energy to the units was taken from the engine room and connected with wires to transmit to the units. Other operations were performed as normally with no other changes.

Workload

In terms of workload, VD made it clear that the crew members did not have additional workload. Therefore, from his perspective, it was not necessary to have more crew members due to the installation of the ventifoils.

> *Of course, they have to look at the system. Check on what happens. But I do not think it will be extra workload, in my opinion. (VD)*

4.1.2. Containerized (flatrack) ventifoils

The flatrack units are planned to be implemented on the Frisian Sea vessel at Boomsma Shipping this year. Therefore, the operation changes in relation to deck and engine room operations and the workload are described according to the expectations and perspectives of the ship owner and the Captain.

Deck operations

Loading and unloading process

To begin with, in order to understand how the cargo operation is expected to change, the process of loading and unloading cargo with the placement of the flatrack unit on the top of the hatches was described by EC. According to him, in unloading processes, in order to open the hold to unload cargoes, the units should be moved to the front of the ships by the hatch crane. Afterwards, all hatches could be opened as usual by the hatch crane. Meanwhile, in loading processes, they need to close one hatch first in order to put the unit on top of it.

Regarding the advantage of using the flatrack units, both EC and BO shared the same opinion. Comparing between the regular containerized and the special flatrack version, EC preferred the flatrack version since it was more flexible than the regular containerized version and did not require more effort to move it during loading and unloading cargo. Similarly, BO also claimed that it would be flexible to open hatch covers and the device could be placed in different positions since they had a lift-away hatch covers on the Frisian Sea vessel. From his perspective, flexibility would be the most significant benefit of applying the flatrack units on vessels. The flexibility that the units would bring to the operations could be seen in the cargo operations. Furthermore, it was possible for the company to use the application of the units on different vessels that are owned by them. The retrofitted ventifoils would be less flexible as they cannot be moved to another ship and can also take more time from installation at the shipyard compared to flatrack units, according to BO.

Moreover, EC pinpointed that the flatrack units would be more efficient than the regular containerized units, as the containerized units' height cannot be moved by the hatch crane of the vessel. And, when the ship will be ready to load and unload, the help of a port crane would be necessary, resulting in more costs.

> *And the difference between container and flatrack is the normal container is high, 2.5 meters and they cannot move it with hatch crane. And the ships have hatch crane, the container is too high. (EC)*
>
> *So, you need the port crane to take that off and the port crane costs money. But in actual situation, we expect more from the flatrack because with the hatch crane, they can put first. (…) And then they do not have to unload the wings unit like you would have to do with the normal container. (EC)*

When it comes to the expected changes in cargo operation, according to BO, the operation at port could take extra time to move the ventifoil units. In addition, crew efforts might be also needed. The process of lifting the ventifoils was compared to moving the hatch covers.

> *It is being handled like a hatch cover. When you have the hatch cover, you have to lift out the hatch cover and move it over the vessel to store it on the top of another hatch cover. and the same can be done with the flatrack's installation and you just lift it by hatch cover crane you can move it everywhere you like. (BO)*

When BO1 was asked about how the installation of the ventifoils are expected to change the operation, he mentioned that at the port, holds on the dry cargo vessel are expected to be opened completely. However, due to the installation of ventifoils, he thought that 4 or 5 hatches would be closed and made not available for cargo operation. This means that compared to operation without ventifoils, more hatches will be closed when ventifoils are installed. As a result, the cargo operation would be slowed down. From his perspective, it would be more complicated for the loading and unloading process with ventifoils.

Additionally, he further explained and predicted how ventifoils could affect the way of stacking hatch covers in order to open the hold. He further explained that the ventifoils are higher than the hatch covers, and it will influence the way of stacking them as the hatch crane has a limited height. Normally, without ventifoils, the hatch crane can make a stack of five hatch covers. However, after the installation of ventifoils, the crane can only make a stack of three hatch covers together with the ventifoils. The reason is that according to his anticipation, the height of ventifoils is twice or thrice higher than one hatch.

Regarding the placement of the flatrack units during the loading and unloading process, BO mentioned that the units would be moved to the most convenient place on the ship. This place was expected to depend on the load of cargo and the Captain's decision. Normally, without the units, they are still not able to open hatches at once because hatches are needed to be stored somewhere; for example, half of the hatches are stacked on one side of the deck and another half are stacked on one hatch on another side. Therefore, if the flatrack units are installed, one more hatch will be closed to store the units on top of that hatch. In this way, BO said that it would be convenient and flexible for cargo operation.

Regarding the type of ships, according to BO1, containerized (flatrack) ventifoils are more suitable for tankers and RoRo vessels, as these types of ships are not required to move the units from the deck. As the cargo of this ships are not loaded from the open hatches, moreover, the interviewee added that the dry cargo ships are the least suitable as they are required to move the units every time the ships berth in a port.

Maintenance

In terms of maintenance, BO1 was concerned that the system would be uncovered and unprotected, leading to the penetration of saltwater into the units. Thus, it would be necessary to have extra maintenance of the ventifoils such as greasing of the moving parts, cosmetic maintenance like painting and greasing, and the maintenance of power connections and cables. If the ventifoils are not affected by the sea water, they can be maintained and used in the long term.

Manoeuvring

In terms of manoeuvring, both BO and BO1 shared the same perspective which was that manoeuvring would not be affected due to the installation of the flatrack units since they would be folded down and at the port. As BO added, during manoeuvring, the ventifoils have to be placed down in order to have a clear visibility and not interfere with cargo operations.

> *Manoeuvring will not be affected because the ventifoils will be folded during manoeuvring. At port, every pilot advises the Captain. And pilots do not know it. They will be reluctant to have the ventifoils while piloting the ship. During piloting the ship, it will be folded (…). (BO1)*

> *In manoeuvring, the wings will be down (…). When working then it will be up and, at the port, it will be down because [we] do not need them. It will be standing in the way; we just put it in a place that will not interfere the cargo operations. (BO)*

Navigation

Regarding the suitable area to use the ventifoils, EC1, with his expertise in ventifoils, described that he told crews to only raise the wings up at open sea. Meanwhile, in shallow areas, crews needed to fold the unit down so that it would not affect any on-board operations.

This is also what BO1 anticipated when using flatrack units. According to him, there would be different ways of deploying the flatrack unit in the narrow fairways and at the open sea as he stated that using the unit at the open sea is more effective compared to in the narrow areas.

> *I expect in the narrow fairways it would be quite difficult to use because if you have a lot of course changes after one another, the system has to adjust to the changed course and then we are changing of course. In the open sea it would be most effective. (BO1)*

Engine room operations

From BO1's point of view and as he understood the system, he knew that the ventilator inside the ventifoils needed power to run. Therefore, it would be necessary for the engine room to provide energy for the ventilator. However, it would not require intensive effort.

> *Engine room would be not so much I think, it would be only the power cable. And for the rest, somehow power from the engine room has to reach ventifoils. (BO1)*

> *There will be only one point ensuring power supply, because this ventilator need power; otherwise (it) is useless. (BO1)*

Workload

There was a same opinion between the ship owner and Captain regarding the workload and needed number of crew members to work on the ship after the installation of the ventifoils since it was a plan to install the units, they have not had an experience with the system before.

According to BO1, he was hesitant about the needed number of crew members to work on board when the ship would be equipped with the flatrack units. His main thoughts were regarding the workload and if the current number of crews could meet their responsibilities. In our second contact with BO1, he stated that he would not need extra crew members on board, as the workload would be handled by the current crews. When being asked about who will be responsible to work with the units, he expected that he would be the first one taking responsibility for operating the flatrack units, being together with crew members to get familiar with the system.

Also, BO claimed that they would not need more crew members because the total work after the installation of flatrack units would not be excessive.

> *I do not expect any crew member on board because the total work is not too much because is compared with its the same work open and close the hatch cover. (B0)*

4.1.3. Summary

After collecting and analysing data, Table 3 illustrates the influences of the installation of ventifoils on on-board operations. It could be seen that there are some differences and similarities between the two types of ventifoils.

Table 3. Summary of influences on on-board operations

		Retrofitted ventifoils (experienced)	Flatrack units (planned)
Deck operations	Loading and unloading process	• The retrofitted ventifoils need to be folded forward ➔ open the hatch covers easily • Potential collision between big crane and ventifoils.	• Extra work of moving ventifoils • Otherwise, more hatches will be closed ➔ slower cargo operation

	Manoeuvring	• Always fold them down during manoeuvring	• Always fold them down during manoeuvring
	Navigation	• No effect • Fold them up at open sea • Always fold them down in narrow fairways.	• No effect • Fold them up at open sea • Always fold them down in shallow areas.
	Maintenance	Extra lubrication	Prevent saltwater penetration into the units
Engine room operations		Same number of tasks	No intensive efforts
Workload		Same amount of workload	Same opinion from the ship owner and Captain

Regarding differences, firstly, the retrofitted ventifoils and the flatrack ones have different procedures during cargo operation due to their characteristics. The retrofitted ventifoils are placed at the foredeck and fixed; meanwhile, the flatrack version will be stored on the hatch covers and can be moved to different places on the deck.

Another aspect which is different between the two types of ventifoils is the maintenance of the units. According to interviewees at Van Dam Shipping, they experienced that they needed extra lubrication for the units. However, this work does not require extra effort, being able to work along with other maintenance. Meanwhile, the Captain at Boomsma Shipping was concerned more about the design of the ventifoils which are not covered and might be affected by the saltwater, requiring maintenance. Since the flatrack unit has not been installed yet, the work of maintenance will have more thorough plan to decide which tasks will be needed to maintain the system.

In terms of similarities, there are some common aspects between the two types of ventifoils, retrofitted and flatrack units. Firstly, the most affected operation is the loading and unloading process. Both types of ventifoils need extra work before unloading cargoes and after loading cargoes on the ship. To be more specific, before unloading cargoes, ventifoils are required to be in a convenient position or place. After loading cargoes, crew members also need to do extra task, placing supporting frames in case of retrofitted units or storing flatrack units on the top of hatch covers.

Secondly, both types of ventifoils do not affect navigation of the ship since they are always opened up at open sea and folded down during manoeuvring. This is understandable because during navigation, open sea is the most favourable area to optimize the performance of ventifoils, taking advantage of wind to generate thrust force for the ship. Meanwhile, during manoeuvring, it is necessary for crew members to have a good visibility to navigate the ship via narrow areas or port areas. That is the reason why both types of ventifoils need to be folded down.

Another similarity is that there is no extra work in engine room operations since both versions only need to be provided energy for ventilators, not requiring extra tasks for crew members.

Lastly, concerning the workload after the implementation of ventifoils, the ship owner and the Captain of Boomsma Shipping has the same viewpoint as all interviewees at Van Dam Shipping which is that the workload is remained the same as usual. It could be seen that from an experienced user's perspective (Van Dam Shipping), the installation of ventifoils have not caused extra workload. However, at Boomsma Shipping – potential user of ventifoils, the needed number of crew members to work on the Frisian Sea vessel still needs more investigation to find out.

4.2. Pre-requisites to work with ventifoils

Regarding the pre-requisites which crew members need to fulfil to work with ventifoils, most of interviewees provided that crew members needed to acquire the basic knowledge of ventifoils including the working principle of ventifoils, how to control and operate the units, how to conduct maintenance and how to navigate and manoeuvre the ship, etc. In order to achieve this condition, a training program was provided. In the case of the MV Ankie vessel, a training program was provided by an application expert from the manufacturer of ventifoils. The trainer was responsible for conveying to on-board crew (at the moment crews on the MV Ankie vessel) theoretical and practical knowledge of the ventifoils. Regarding the reason why it was needed to provide a training program for crew members, EC1 confirmed that the first thing they wanted to achieve was to make crew understand the system functionally and make them more interested in the system. Furthermore, he added that a training program could help crew members to optimize the performance of ventifoils by planning a route or looking at the weather forecast.

In terms of a training program's procedure, EC1 shared that he went on-board and sailed with crews for a period of time. At that moment, since there were few customers where ventifoils had been applied, the manufacturer was able to provide this kind of on-board training program. An on-board training program included both theoretical and practical parts. This procedure was applied on the MV Ankie vessel already. The theoretical part was conducted as the beginning of the training in which the trainer made a presentation with a set of slides about the history of ventifoils and an introduction of mechanical system of ventifoils. The second phase of training is considered as the most important since EC1 needed to fulfil the training and made sure that the crew members are ready to apply all the information gathered from their trainer into practice.

> *First, I will go on board and will explain them how system works. So, I very often compare it to airplane wings. So, a little theory, not too much because when they sail it, they are not always interested in design about it. But first I want them to know how system works basically. After that, we go to operation, how to operate it. (EC1)*

After the first trial of training, EC1 may visit again the vessel in order to check if everything is working as was planned and if there are new crews on board, the trainer is required to train them too.

> *That is why I was sent to Ankie first to install it, and later on to train crews and now we have done one crew training with 3 officers on board and 3 officers at home. They are fixed crews so really know each other within 6 weeks, I think. Then I will go back to train other crews. (EC1)*

When being asked about concern during training, EC1 expected there could be a language barrier when providing the training program in English. However, it did not cause any difficulty on the MV Ankie vessel since most of them spoke the same language as EC1. VD1 also claimed that English was the international language used in the shipping industry; thus, it was not a problem for them.

> *I expect language barrier would be problem, but it was not the case on the Ankie because it was two (2) Dutch and one German guy. And if someone did not understand what I am talking about, I could explain it in Dutch to Dutch guy. (EC1)*

From the interviews, it is identified that crew members on the MV Ankie vessel had absorbed what the trainer conveyed. For example, EC1 claimed that safety was the most important aspect in the training program in which crew members needed to know that when apparent wind had angle of less than twenty (20) degrees or it was a storm, they could not unfold the system. This information had been acquired by VD1 as he stated that if the angle was twenty (20) degrees from the port side and 20 degrees from the starboard side, it was not efficient to use the wind. However, if it were more than twenty (20) degrees, they could use the system without problem. Furthermore, crew members on the MV Ankie vessel shared the common knowledge that they should unfold and use the ventifoils at open sea and fold down the system in shallow or narrow areas, which had been transmitted by the trainer.

Additional to this, after being trained on the vessel, according to VD3, it was an easy and understandable process by all the crew members as it was followed by a physical representation of ventifoils on board where all the theory was shown in reality as well. According to VD3, the materials that the trainer used were helpful and understandable, and that is the reason why they could implement it and started using the system directly.

> *First, he explains how it works, showing what ventifoils is really doing. We walk around and he let us. And, then he explains everything again. (VD3)*

It could be seen that the training program was effective to provide basic knowledge of how to work with the ventifoils to crew members, being the most important pre-requisites for crew members. However, an on-board training program could be enhanced if crew members have more time to be familiarized with the system before they join the vessel. As BO1 pointed out that crew members would need some time to be familiarized with the system since they had a limited time to know the ship and begin with the assigned tasks before they joined the vessel.

Additional to the training program, there are some other potential conditions that crews need to fulfil to work with ventifoils, including crews' motivation and awareness.

Regarding crews' motivation, EC1 stated that the important thing was not only to make the crews understand the system but also how they were interested in sailing with the system. Making crew interested in this new approach is the easiest way to make crews get along with it so that they will start using it properly. According to his experience, the most difficult part that he had faced was to convince crews to operate the unit in a proper way. Given the example of how the crew's motivation affects the performance of the system, EC1 stated that the result depended on whether the crew operates the system or not as he gained experience from the testing with the containerized version. During one month of testing, he witnessed that the crew did not operate the system at all since they did not trust the system. Thus, it impacted greatly on his results and the performance of the system. The reason could be that the ventifoil units were invested by ship owners because they wanted to use an alternative source of energy which was not the crews' desire. However, it really depended on the perception of different people.

> *They have to trust the system. They must not feel it like it is some compulsory things that the ship owner put on their ship and they do not want to operate it. (EC1)*

When being asked about experiences with the implementation of the ventifoils, crew members (deck crew, Chief Officer, Chief Engineer) of the MV Ankie vessel were quite interested when working with the system. The ship owner of MV Ankie also noticed that his crews had a positive response to the installation of the unit.

> *They (crew members) are optimistic, and they also really want to use it (the ventifoils). We like to follow what happens on board. (VD)*

On the other hand, as a flatrack unit is planned to be installed, BO was concerned that it could be a challenge to get crew members to be engaged in working with the system.

> *And the challenge is that to get the crew to use the device in a proper way. We all know and are aware how to use it, but also the crew needs to be aware how to use it and when to use it. (…) That can be one of the challenging, and demanding things for the crew to do it all the time. (BO)*

In addition, all crews on the vessel with retrofitted ventifoils shared the same opinion about advantage of this units. They said that due to the installation of these units, fuel consumption would be saved. Additionally, from the point of view of shipowner VD, the reasons he chose the ventifoils was because he gained some advantages, and one of the advantages was the fuel savings.

> *The main reason is that it saves fuel, approximately 10% per year. (VD)*

Furthermore, crews' awareness is also an important aspect to contribute to an effective use of ventifoils on the ship. From EC1's point of view, it was a tendency that younger crews accepted the concept of the ventifoils most. Also, he pinpointed that nationality was not a problem as from his training they all understood that something needed to be done in terms of pollution and marine destruction. From the extracted data, most crew members explained that using the ventifoils was to save fuel consumption which was mentioned many times in the interviews. Meanwhile, only VD1 and BO1 realized that the ventifoils were a solution to contribute to a green shipping industry, decarbonizing and reducing GHG emissions.

> *I must say that on the ship, generally with younger crews, they are more interested in the system. They accepted more. They have become a little more efficient. (…) Nationality does not matter. They understand that something needs to change. They are willing to get the chance. (…) The system can contribute to green shipping with the wind energy, why not use it. In the future, the system will be improved, and we will have better results. (EC1)*

5. Discussion

In this section, the results and the methodology will be discussed.

5.1. Result discussion

In this part, the results will be discussed corresponding to the findings in the literature review.

5.1.1. Influences on vessels' operation

In terms of deck department operations, from the results, it could be seen that the installation of ventifoils has had effects on on-board operations in terms of deck space, the weight of the unit, cargo handling and visibility. These results are in line with Bergeson and Greenwald (1985), who identified that the installation of wind propulsion systems could affect some aspects on the ship including the weight of the unit, deck space to store the system on the ship, cargo operation as well as visibility from the bridge.

Regarding the weight of the units, the Chief Officer needs to take this into consideration when loading cargo on the ship. As mentioned in the results, one of the interviewees stated that when they loaded cargo, they have to deduct the weight of the unit which was about seven tonnes for retrofitted units. However, the weight of the unit seems not to have significant effect on cargo capacity. From the perspective of ship owners, they may think about comparison between the earnings to transport this amount of cargo and the cost of saving fuel due to the installation of the ventifoils. If it is more worthy to save fuel, the weight of ventifoils is not the notable matter.

In terms of occupied area for the ventifoils on the deck, it depends on the type of ship as well as stakeholders' perspective. The ventifoil units are most suitable for the type of vessels that have space to store them on the deck and the unit may not interfere with the cargo handling process. One of the interviewees mentioned that tankers and Ro-Ro vessels could be most suitable to have the unit on the ship since these types of vessels have a space to store the unit without any movement. However, in order to install ventifoils on the ship, additionally to the cargo operation aspect, the perspective of involved stakeholders is also crucial to take into account since they have different points of view about the system. From the perspective of the manufacturer who designs the units and fully understands their function, they know that with the thrust force provided by ventifoils to the ship, it is the most suitable for short sea voyages and small ships. They have the same vision with ship owners to save fuel and energy; meanwhile, as technical providers, they have to find the most appropriate solution to meet the demand of their customers who are ship owners in this case. They made the autonomous unit which does not requires great effort of crew members while saving fuel and energy for the ship. From the results, regarding ship owners' point of view, the first thing they are aiming when installing the ventifoils is to save fuel and energy, eventually saving costs for them.

According to the next aspect, it can be seen that the installation of ventifoils affects cargo operation in some ways. The results show that the most of changes seems to happen in the loading and unloading process with both type of ventifoils, retrofitted unit and flatrack. In general, both types of ventifoils require small extra efforts of crew members and take about 10 minutes in cargo operations before starting to handle cargo. In order to achieve the good performance in cargo operations, according to House (2011), Chief Officers need to construct a good stowage plan in the way that it is convenient for moving cargoes from and to cargo compartments despite the installation of ventifoils. He/she should work together with the Captain to design the most feasible plan when handling cargo. Since there are two types of ventifoil units – retrofitted and flatrack, they have different required operation when loading and unloading cargo. It seems to be easier for the retrofitted units' ship since the Chief Officer does not have to modify the stowage plan. Meanwhile, because of moving the lift-away hatch covers to open the holds, the Chief Officer and the Captain on the ship using the flatrack units should arrange the work of moving hatches and ventifoil units accordingly.

According to Bergeson & Greenwald (1985), one concern that might emerge during cargo operation is that on-board or shore-based cargo handling equipment can cause any damage to ventifoils while they are moving to handle cargo. From the results gained from the retrofitted units' user, the equipment has not caused any damages to the ventifoils; but one of the interviewees was concerned about the collision between big cranes and the unit that could happen. Therefore, it is crucial to plan the most suitable place to store ventifoils when conducting loading and discharging cargoes. For the retrofitted ventifoils, crew members need to pay more attention when they unfold the wings forward to the nose of the ship in the way that it does not cause damage to both the unit and ship's construction.

The last aspect concerns the visibility from the bridge. According to the results, there is no difficulty to navigate the ship with the ventifoils at open sea, from perspective of both experienced and potential users. Meanwhile, manoeuvring at narrow channels or port access need more attention from crew members to fold the system down. After folding the system, they are able to manoeuvre as they usually do. According to Bergeson and Greenwald (1985), the wind propulsion system may hinder the visibility from the bridge. It is a reason why crew members need to fold the system during manoeuvring in order to have clear visibility. Furthermore, as mentioned in the literature review, according to Chopra (2020), manoeuvring also requires a moderate speed, a full control of the ship and changes all automated system to manual when navigating in narrow channels. Besides, folding ventifoils down also enables ship piloting to work more efficiently because the Captain and the pilot can still communicate and navigate the ship as when they work without the unit. According to the results, which are in line with the findings by Chopra (2020) and Maritime Knowledge (2018b), compared to normal operations without the ventifoils, navigation with ventifoils requires crew members to pay more attention mostly under restricted visibility areas, narrow fairways, port access and bad weather. They need to be able to fold the system down appropriately in these situations so that it does not cause any impacts on visibility from the bridge.

Regarding maintenance, in general, there is no significant change in maintaining the system on the vessel. An installation of ventifoils only requires deck crews to do additional greasing for the system. And this task does not take great effort of crew to do since they can maintain it along with other maintenance needed on board. The important thing is that the duty of the Chief Officer needs to ensure that this task is included in a maintenance plan.

In the engine room, for both types of ventifoils, engine crew have the same workload as before. However, they must work closely with other crew on the bridge in case of emergency. For example, according to Chopra (2020), when the ship navigates under restricted visibility circumstances, engine crew needs to be informed to be ready for immediate manoeuvring. In case of flatrack ventifoils, they also have to pay attention to turn off power during loading and unloading cargo so that the unit could be moved.

Regarding number of crew members needed to work with ventifoils, retrofitted ventifoils' ship owner still maintained the same number of sailors which is also what flatrack ventifoils' ship owner and the Captain at Boomsma Shipping expected. According to Institute of Chartered Shipbrokers (2013), the number of crew significantly depends on the size of the ship and other aspects. Thus, the ship owner planning to use flatrack unit needs to take into consideration number of crew that they need to have on the ship that is planned to install ventifoils in order to avoid unexpected excessive workload for crew members.

According to Bergeson & Greenwald (1985), wind-assisted propulsion has been designed in the way that it does not need a great manning requirement. The system has been operated by hydraulic operation and crew members can control the system from the bridge by pressing the button. Furthermore, the system does not require intensive maintenance. This is accurate in case of ventifoils because the system is autonomous and easy to operate and maintain. Therefore, in terms of on-board operation, compared to old operation when the ship is not equipped with ventifoils, there is no significant impact on operation regarding crew's tasks after installing ventifoils on board.

Taking all things into consideration, in order to see how vessels' operations are influenced by the installation of ventifoils, it depends on the type of the ship because different ships have different characteristics that could be suitable to store ventifoils. It also depends on the type of ventifoils because each type requires different techniques to store and move during cargo operation. Lastly, it also depends on the desire of the ship owners, how much fuel, energy, and cost they are able to save and how they evaluate the impacts of ventifoils on operations.

5.1.2. The importance of human element in operations

In order to operate the system and achieve the optimal results, the human element plays an important role. According to the Results section, the first pre-requisite for crew members to work with ventifoils is basic knowledge of the system including the working principle of ventifoils, how to control and operate them, how to conduct maintenance and how to navigate and manoeuvre the ship, etc. As ventifoils are a new wind-assisted technology on ships, it is important for crew members to understand it in order to operate it properly because knowledge of crew members is essential in a working ship. According to International Windship Association (2020), it might be a requirement for seafarers to have a specialist training to operate the wind propulsion system. An appropriate training not only enables the system to achieve expected results such as saving fuel and energy but also eliminate human error when working on ship, especially in the early phase of implementation and development of ventifoils when they are newly put into operation (Squire, 2013). In the results, the training program was provided by manufacturer's side, it was a good way to start to enable crew members to know more about the system and what they need to do. However, this training procedure is not compulsory when the units are applied on board. The authors believe that a training program should be a compulsory process for the crew members. According to Squire (2013), it would be better for crew members to take an amount of time to get familiarization with the new system before they join the vessels by providing training for them. In terms of specifications of the system, it can be seen that the controlling system of ventifoils is not complicated since there are basic switches and symbols. This basic standard allows seafarers to get familiar with the system quickly and avoids causing confusion to them. It is suggested that the companies should invest in pre-training program for the seafarers who have an important role in using the technology before joining the ship such as Captain, Chief Officer, etc. Afterwards, an on-board training program will be conducted for all crew members to enhance their knowledge and practice of using the ventifoils.

Another reason that supports why crew members need to have basic knowledge of ventifoils is that, regarding ship owners' side, the longer lifespan the units have, the more cost the ship owners can save. In order to achieve a longer lifespan, crews need to know how to maintain the units properly by obtaining knowledge from the training program and the right guidance from an expert. Furthermore, it is suggested the trainer to visit the vessel again after the first and second trial of training. That acquires more days on board ensuring that the crews are following the training processes. In the future, if the manufacturer has more customers, they also need to have more trainers or find the way to work with the ship owner in which to ensure crew members are able to acquire knowledge to work with the system.

In order to convey knowledge to crew members effectively, trainer and crew need to have clear communication with each other. According to Wang & Zhang (2000), due to multinational environment on the ship, English should be the common language to communicate between the crew and the trainer. In fact, as mentioned in the results, both the trainer and the crew on the MV Ankie vessel agreed that they do not find any difficulties in communication because the training program was given in English. Therefore, in the future, when conducting a training program on the Frisian Sea, English should still be the main language to use to deliver the knowledge. However, the trainer can consider being flexible in using language as he did on the MV Ankie vessel in case he/she and the crew share the same language. There should not be any misunderstanding in clarification which could lead to any inappropriate action to the system. And he should ensure that the crew acquires fully what he instructs them.

As indicated in the Results section, all experienced crew members were interested in the ventifoil system and there were no difficulties for them to operate the unit. Meanwhile, the Captain of the flatrack units' ship, he was concerned more about workload that could be increased for crew members after the installation of ventifoils. As seen in the literature review about roles and responsibilities of the Captain (Bistričić & Kuzman, 2011), the Captain has to monitor and control all aspects of the vessel; so, he/she has broader view than other crew on board. Deck crew and engine crew still mostly have the same number of tasks and same responsibilities after an installation of ventifoils. Therefore, as long as they accomplish their tasks as they did before, they do not have any pressure on their job, allowing to work efficiently.

It is important for crew members to be more willing to work with the ventifoils. They should not only accomplish their tasks as usual but also understand the purpose of using ventifoils on the ship which aims to save fuel and energy so that they can operate it effectively. They should not feel that it is a compulsory thing they have to do because this is what the ship owner wants, according to manufacturer's perspective. It is better for them to feel that they are interested in contributing to environment sustainability in shipping industry and IMO's vision. However, this is quite dependent on the perception of different crew members. On the vessel, there are multinational crew working together and they have different points of view and different background. Some sailors have more accepted the fact that wind-assisted propulsion could help to reduce negative impact on environment. They are paying more attention to environment than other ones. Therefore, it is important for all crew members to be aware of their key role in the sustainment of their work environment. The authors believe that it can be achieved by education. Since seafarers have diverse educational background from different countries, they perceive sustainability in different ways. For example, crew members on the MV Ankie vessel are from Philippines and Netherlands, they may have various courses in their education in which the sustainability concept is conveyed differently. Hence, the authors think that they might have different opinions and perception about sustainability. The role of crew's trainer, from manufacturer's side, should be enhanced so that he delivers knowledge in the way that it not only ensures how crew members understand and know how to operate the system but also raises their awareness how their proper work can contribute to the environment. Furthermore, the Captain and the Chief Officer should be motivated to work with the system because the Captain is the top manager on the ship, being able to encourage his juniors; meanwhile, the Chief Officer is the important person to operate the system.

5.2. *Methodological discussion*

In this part, the authors discuss the methodology that was used in this research. The currency-relevance-authority-accuracy-purpose (CRAAP) test will be discussed on how the authors performed their data collection, and the benefits and drawbacks of the selected methods and lastly the transferability of this research.

The data collection was mainly from interviews, recordings, and a literature review of academic websites and literature from the Chalmers library. Since qualitative research includes a variety of methods, the one that the authors chose was the Thematic analysis, which was the most suitable as the analysis applies to studies that contains interviews and then transcriptions of the interviews that have been applied in order to reach the needed results.

5.2.1. CRAAP Test

This section will scrutinize the currency, relevance, authority, accuracy, purpose (CRAAP) of the sources used in this academic work (Kurpiel, 2020). This established test is a unique tool that examines source reliability and credibility (Korber, 2020). Due to the big variety of information, it can be challenging for a researcher to gather reliable information that can be useful to his/her research.

In order to find out if the gathered data is trustworthy, currency needs to be examined (Korber, 2020). By currency, it is meant if the gathered data is up to date. In this research, some of the data were found in old documents as the concept of wind propulsion started 40 years ago.

In order for the authors to conduct this research, they needed to make it reliable and, to achieve this, the authors have used eight (8) interviews in total with different people that are using or will use the ventifoils technology. Moreover, the authors make this study reliable by choosing reliable sources, for example in the form of published academic books and articles. Furthermore, authors collect additional data from the manufacturers as academic information.

The sample data was gathered from professionals that use the systems, for example from the trainer, who shared with the authors his selected sources in order to teach crew members about the ventifoils concept. Also, from the Chief Officer, who is responsible for making a maintenance plan for the ventifoils in order to keep the systems efficient and for the deck crew, who are responsible for doing the maintenance needed to the ventifoils.

Moreover, the information gathered from the interviewees were pre-analysed and some clarifications were needed as the interviews were conducted using teleconferencing applications, resulting in bad quality of sound in some cases. The authors needed to clarify the information by contacting the interviewees again in order to make clear the data collected. The new added data were verified from the interviewees as the report was sent to them in order to confirm the results of this research. This study requires current information as the ships working with the wind is an old concept but, in this study, it examines an updated and an innovative idea of using the wind propulsion with ventifoils that was re-innovated from a manufacturer.

Relevance

The results gathered in this study were suitable to answer the authors' research questions. The authors set up different questions for each of the interviewees, for example, for the shipowners, engine/ deck crew etc. from the interviewees were professionals that have the knowledge of their own sector, and each crew member and each shipowner have different kind of information to share.

Furthermore, the intended audience of this thesis are people that are interested in new technology in the shipping market; ship owners that are interested in wind propulsion, particularly ventifoils, and want to enrich their knowledge on this matter; also, those who will be involved in crew training programmes and on-board crew members themselves, in order to check how the systems are working and be prepared to train crews and work with them. Furthermore, this study could be useful for researchers who wish to further study this innovative technology.

The variety of sources was limited due to no studies having been conducted yet, as ventifoils are new systems. On the other hand, the authors investigated the sources which were appropriate to absorb information and they were mostly provided directly from the people who have been working with the systems.

Authority

In writing this thesis, the authors made sure to cite all the used articles and studies with the authors' name(s) and publishing date in order to show what was extracted from literature. Furthermore, authority is gained via the contact of the authors with the manufacturers, where most of the information on how the systems are working was provided by them. Also, when describing results, the authors demonstrate direct quotes taken from the interviews.

Accuracy

Accuracy reveals the truthfulness of a content, for example, data gathered from reliable sources or even from personal knowledge that needs verification (Korber, 2020). Most of the information collected by the authors was gathered directly from the interviews with people working with – or interested in – ventifoils, crew members of the MV Ankie vessel, the manufacturer of ventifoils.

Additionally, all results are supported by evidence, such as the photograph collection from the systems on board in order for the reader to understand how the ventifoils are working and being used by the crew members. All the data were reviewed by the authors during the transcription exercises in order to be checked for and for the most relevant data to be selected for answering the research questions.

Purpose

The purpose of this research is to inform ship owners and seafarers about ventifoils and other wind propulsion technologies that will help to fulfil the IMO target of 2050. The purpose was clearly demonstrated in this research as the authors' steps were to inform the readers and answer the research questions on ventifoils technology on cargo vessels' operation.

5.2.2. Limitations

This research gives a better understanding about ventifoils from different perspectives. Due to the pandemic and geographical situation, interviews via telecommunication applications were the most appropriate method to collect data which brought a flexibility and safety for everyone involved.

On the other hand, some of the drawbacks that appeared in the methodology section were the lack of observations on board. Since it was important for the authors to get a better understanding on how the ventifoils are working through observation and have face-to-face conversations with interviewees, it would make the research more complete.

5.2.3. Reliability and Validity

Joppe (2000) defines reliability in research as a concept where results are the same over time and can be used for further research (Golafshani, 2003). In this case, the authors of this thesis reached saturation, which means the interviewees often gave the same input about the ventifoils, on how it influences the crews' workload and the daily maintenances that the units need. Additionally, the authors performed a study which can be used in further research in the future, as wind propulsion technology is a new concept with a lot of new perspectives. One of the new perspectives, for example, could be the safety at sea after the implementation of wind propulsion systems.

On the other hand, Joppe (2000) added that validity is if the results of research are truthful (Golafshani, 2003). In the results of this research, the authors show their originality via different quotes from the interviews and from the interviewee tables added in the methodology section (see Table 1) which contain the roles and the titles of the interviewees that were involved with the ventifoils. Another element of the truthfulness of the results is the illustrations that the authors have included of the vessels that have applied ventifoils on deck.

5.2.4. Transferability

The authors investigated how wind propulsion is used to minimize emission from ships and for the shipping companies to be able to follow the IMO's target. As the suggested solution is to be applied on small and short-distance vessels, it could be a precedence for future research to examine if it is also efficient for larger ships with long distance traveling. Additionally, the results of this thesis are applicable to all ship owners that are interested in retrofitted and flatrack ventifoils.

6. Summary and conclusions

The use of ventifoil units is likely to increase efficiency and decrease fuel consumption in the shipping industry in the future, as it was proven from the MV Ankie vessel case study that by using ventifoils there is a 10% decrease of fuel consumption. As the wind propulsion technologies are one of the methods that could be used in order to fulfil the IMO's target on 50% reduction of GHG emissions from ships by 2050. Ventifoil units are one of the most promising technologies on wind-assisted approaches as it fulfils the ship owners' perspective by having a significant reduction of fuel consumptions and minimizing the environmental impact and therefore for them would fulfil the IMO target. And, for crew's perspective, by barely causing a workload increase for the crew.

Furthermore, the objectives of this thesis were to explore the impacts of ventifoil technology on cargo vessels' operations and examine the pre-requisites for crew members to work with the ventifoils. The results of the research answer the thesis' research questions.

6.1. Research questions

- *How does the use of ventifoils impact general dry cargo vessels on on-board operations?*

The ventifoils have caused some operational changes. The operational changes mostly have influenced the deck operations on the vessel, especially on cargo handling operation. Due to the installation of ventifoils, it requires a little extra time and crews' effort during the loading and unloading process to place the units in a way that it does not interfere with the cargo operation. Since both types of ventifoils are autonomous, this does not impact the operations greatly. Other on-board activities such as navigation and maintenance do not require intensive manpower.

- *What are the pre-requisites crews need to fulfil to be able to work with ventifoils?*

It is essential to provide basic knowledge of ventifoils including the working principle of ventifoils on how to work with the units safely and efficiently, to crew members. In order to achieve this, the training program is given by an expert in order to transfer the required knowledge to work with the units and to have a general idea on how the units are working. The training program will be enhanced by a clear communication between seafarers and a trainer. Moreover, an awareness and motivation of crew members are also needed in order to achieve the best performance of ventifoils. If they are not motivated to operate the system and aware of the reason why they need to operate it, they will have no reason to operate the system appropriately. It might be difficult for the ship owners and the manufacturers to achieve the goal of reducing fuel consumption and GHG emissions in that case.

6.2. Practical recommendations

There are some recommendations which enhance for the future improvements in terms of vessels' operation and the human element.

Firstly, a strong collaboration between manufacturers and ship owners should be established so that they could together make the best solution to use ventifoils which does not interfere negatively with the ship operation; meanwhile, achieve their aims to reduce fuel and energy consumption. They should work closely together to make the units suitable for the end-users (the crew). According to Kataria et al (2015), design plays an important role in efficient operation performance. And, according to Squire (2013), since manufacturers may add their distinctive features, it can be considered having standardization of equipment, which enables crews to get familiarized with the new system easily. Thus, manufacturers need to pay attention to design products in the way that it is friendly for users.

It is also important to understand what crew members have experienced with the installation of ventifoils, enabling manufacturers to improve their products. Thus, another recommendation is that crew members could contribute with their opinions to the design of the ventifoils since they are persons who work directly with the system. The communication between the end users and designers can result in a positive performance of the design (Guinan, 1986). Besides, if the shipowners and manufacturers allow crew members to participate in the design, they will feel more appreciated and valued, increasing their morale and enthusiasm with the work (Österman, et al., 2010). However, due to the nature of maritime career at sea, seafarers are usually absent from projects to develop and design maritime products (Österman, 2012). For instance, when seafarers have their time off and go ashore, it might be difficult to gather them and conduct interviews (Lurås, 2016). Therefore, there are two ways that the manufacturer and the shipowners can consider gaining access of seafarers' perspectives about the ventifoils. The first recommendation is to conduct field studies at sea which allow designers to gain better understanding and insights, resulting in improved design (Lurås & Nordby, 2015). According to the findings of Lurås S. (2016), the most beneficial way of gaining insights of the work at sea is that the designers have a direct access to users without using secondary sources to evaluate the context. In this case, the equipment provider – eConowind – has a high ability to conduct field studies since the trainer provides a training program on board and he is able to have a direct access to crew members during the time he stays on the ship. Since the clients may not want to pay for the designers to conduct field studies if they do not see the benefit of the work for design (Lurås, 2016), the trainer should take advantage of few training days on board to get a further insight of the users in order to avoid unexpected costs. Another recommendation is using online media. There are some channels such as work blogs, forums and Internet-based social networking where seafarers are able to share their works, experiences and opinions when working on board (Lurås & Mainsah, 2013). Therefore, if the shipowners and the manufacturers desire to listen to crew members' opinions about the use of ventifoils on the ship, they can create a blog or forum where all crew members in the company can have access and share their insights and opinions. Additionally, an appropriate training program should be enhanced and constructed. A possible way is the simulation methods in which crew members are able to learn the system before they go on board the ship (Harvey, et al., 2013). This way, they have time to be familiarized with the system and be aware of any situation that may occur during the voyage.

Moreover, crew members' awareness and motivation also need to be paid attention to. In order to raise seafarers' awareness regarding the use of ventifoils, the trainer could add some more slides in his presentation about the advantages of using ventifoils as well as their crucial role in not only saving fuel but also in reducing negative impact to the environment. Furthermore, in order to motivate seafarers to be more interested in the system, extrinsic motivation can be utilized. Extrinsic motivators refer to grades or monetary incentives which encourage people to accomplish a task (Birch-Jensen, 2019). Thus, ship owners can consider adding bonuses for the good work of their crew members, and it should be given to all the members on the ship that achieves the good results in order to stimulate effective teamwork. Bonuses could be a remuneration as the ship owner has a 10% fuel saving by using the ventifoils. As a result, he has a capital growth or a return on investment/profit that he/she could share with his/her employees (Mitroussi & Notteboom, 2014). Moreover, the ship owner could reward the efficiency and productivity of seafarers with the systems by giving more days off in order to keep a balance to seafarers' work life (ibid.,257).

In order to achieve the IMO's target, technology solutions are an important aspect to investigate, for example, using green technologies as a wind propulsion system to reduce GHG emissions. However, it is necessary to have more research and more attention on human element to work with wind propulsion systems because, without competent and trained crew members, the unit might not be optimized and operated safely and effectively.

6.3. Further research recommendations

Currently, the topic of this thesis is new, and it has not been investigated by many researchers. Therefore, in the future, the topic could be extended, developed, and improved.

Since this thesis focuses mostly on the operational changes on general dry cargo vessels after the implementation of ventifoils, in the future, the research could be extended to study how other types of wind propulsion such as DynaRig, kite, flettner rotors, etc., influences on different types of vessels (tanker, RoRo, etc.). This will help to bring a broader view about how wind-assisted propulsion affects on-board operation, providing more insights for ship owners and manufacturers.

The human element is also the core in this thesis. There are some suggestions on what future research might investigate to have a deeper view. For example, the topic could be the importance of crew members to be involved in the design of wind propulsion systems, or the safety at sea after the implementation of wind propulsion systems.

Potentially, the economic aspect is interesting to be examined, for example the operational cost of installing the wind propulsion or the cost of saving fuel and energy consumption due to the implementation of ventifoils, etc.

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