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**Proceedings of the International
Association of Maritime Universities (IAMU)
Conference**



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Conference

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Preface

Dear Colleagues,

As a part of the Annual General Assembly (AGA), the International Association of Maritime Universities Conference (IAMUC) brings together academicians and researchers of each member university from all over the world to discuss recent progress and future trends in maritime education, training, research and other matters within the scope of the IAMUC. IAMUC 2019 is the 20th conference as a sequence of events that started in Istanbul in 2000, and were held more recently in Haiphong (2016), Varna (2017) and Barcelona (2018).

The theme of the AGA20 is Charting the Course for the Future of Maritime Universities: Environmental, Technological, Economical, Social, and Policy Impacts. The IAMUC program is organized within six sessions, five sessions dedicated to the main theme categories and the additional Student Session.

The Proceedings of the IAMUC Conference contains papers presented at the technical sessions of the IAMUC held in Tokyo, Japan, on 1st of November 2019. This year's IAMUC has received 140 high level abstract submissions from 29 different countries and 50 different IAMUC universities. On the basis of the following full paper submissions and the double peer-review process, 39 papers were accepted for inclusion in the Proceedings.

On behalf of the International Program Committee (IPC), I would like to thank all authors for their efforts and contributions in development of the Proceedings. Specially, I would like to thank all reviewers for their valuable time and expertise, and for their helpful assistance in improving the Proceedings of the IAMUC 2019.

Prof. Boris Svilicic
IAMUC Program Editor

Theme

**Charting the course for the future of maritime universities:
Environmental, Technological, Economical, Social, Policy impacts.**

Organization

Committees

To make the AGA 20 a success, the IAMU Secretariat, as the host, organized Executive Committee and International Programme Committee with the cooperation of IEB members and members of the working groups supervised by Academic Affairs Committees.

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Proceedings

Environmental Impact

Optimising the Energy Efficiency of Small Ferries

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Keywords: Ferries, Harbour Stay, Energy Efficiency, Practices, Training.

ABSTRACT

In order to reach the goals for CO₂ reduction and energy efficiency it is important to improve the efficiency of the maritime sector. This study explores the possibilities of improving the efficiency of the harbour stays of small ferries. Operational activities for three different ferry routes are mapped out and three important areas for improvement are identified: Time savings, Time utilisation and Leadership. The implications of these themes and their dependencies on each other are discussed. In order to improve energy efficiency, time in harbour must be minimised and the time saved used instead to increase passage time. To achieve this, a more dynamic timetable is needed. Time savings and time utilisation are closely related to leadership and how this is performed. Lastly, it is identified that education and training of personnel and leaders is important for enabling development of the three identified themes.

1. INTRODUCTION

Energy efficiency has been a major concern in the maritime industry in recent decades. This is partly due to the economic aspect, but regulations and concerns about the environment are also playing an increasingly important role. Discrepancies in international goals for CO₂ reduction and the forecast for emissions from the shipping sector underline the urgent need for solutions to reduce emissions from shipping. Several studies have been conducted on energy efficiency in ships. These studies can be divided into technical solutions and operational practices, see, for example, the study by DNV GL [1] and work of Banks [2]. The present study falls into the second category, as it focuses on operational practices in smaller ferries during harbour stays.

There are a large number of ferries worldwide. Ferries play an essential role in transporting people, cargo and vehicles across waters on fixed routes with regular schedules. The size of these vessels can range from smaller boats transporting passengers across a river to larger seagoing vessels carrying passengers, cars and trucks. Interferry [3], an organisation representing the ferry industry worldwide, estimates that the ferry industry is similar in size to the airline industry, transporting approximately 2.1 billion passengers each year, indicating a vast potential if even small improvements are implemented.

Small ferries have unique operating patterns that do not correspond to the patterns of other vessel types. They usually have short sea passages and therefore spend a relatively large proportion of their time moored in harbour. This is in contrast to other vessels such as container ships, tankers or bulk carriers, which spend most of their time at sea. If the harbour stays could be shortened for ferries this could have a significant impact on energy efficiency. The most obvious effect is that a shorter harbour stay would lead to more time for passage and manoeuvre. More time for passage allows for a decrease in speed and thus lower fuel consumption and lower emissions. A study performed by Eriksen et al. [4] shows that a significant amount of energy can be saved by prolonging the passage time of a passenger ferry by just a few minutes.

This paper explores the harbour stay with the aim of mapping factors important to reducing the energy consumption of the entire ferry operation. The harbour stay is defined as the period between the ferry touching the dockside and staying still until leaving the dockside again. The time spent in harbour and how it is spent is important. Less time used for the necessary activities during the harbour stay will result in time available for other tasks, which must be utilised to increase efficiency. If the time between arrival and departure is fixed, this available time becomes a waiting time and will be unproductive. This calls for a closer look into the harbour stay and its structure as a whole, taking into account timetables, work activities and management.

The present paper is structured as follows: in Section 2, the methods used, and the data collected and used is described. Section 3 lists the findings, which are discussed in Section 4. Finally, Section 5 presents the conclusions.

2. METHODS AND DATA

A qualitative method approach has been used to explore the factors that influence the effectiveness of the harbour stay of smaller ferries. The qualitative method is suitable for exploring this since the harbour stay is a complex operation which needs to be understood in order to determine and explain important factors and their relations.

The data used for the present study was compiled on board three ferries sailing in Danish inland waters. Data was collected through a combination of interviews and observations during field trips. The ferries operate specific routes with fixed timetables and frequent consecutive arrivals and departures. The operation characteristics, i.e. traffic volume and size of the three ferries, are large, medium and small in order to provide the broadest view possible with the limited sample size. A list of relevant data regarding the selected ferry routes is provided in Table 1.

Table 1 - Ferry route characteristics.

Operational characteristics	Timetable harbour/passage	Length overall (m)	Capacity (cars)	Max PAX Summer/winter
Large volume, main traffic lane	15 min/45 min	142	364	1140/1140
Medium volume, regional traffic lane	15 min/75 min	49.9	42	395/250

Small volume, local island traffic lane	5/0 min/30 min	35	14	98/60
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On board each of the ferries, a person involved in the unloading and loading activities was selected for interview. Three interviews were made. The respondents were all officers, and both engine and deck officers were represented. The views and opinions of other crew members, as well as other observations, were recorded in separate field notes. Written notes made during the interview by the interviewer himself and two observers documented the interviews. In all interviews, the interviewer and the observers were the same researchers. The setting: two interviews were performed on board the ferry on which the officer worked, one interview was conducted in a conference room ashore. All interviews were performed in the Danish language and all involved persons were native Danish speakers. The interviews all followed the same interview guide.

The interview guide was compiled based on the experience of the researchers who have all been professionally involved in ferry operation. A workshop was performed in which the knowledge and experience gathered was used to identify activities necessary for a generic harbour stay. The following activities were identified: mooring, unloading, loading, and let go. During some harbour stays, it is also necessary to arrange tasks such as crew change, bunkering and loading of provisions. Five topics for questions were identified:

1. Harbour stay - necessary activities and their duration;
2. Timetable;
3. Optimisation, ideas already implemented and ideas for the future;
4. Cooperation and team spirit;
5. Systematic planning.

The first topic covers which activities are done and how much time these take. The second topic clarifies to which degree the timetable corresponds with the time required for necessary activities. This is especially interesting if unproductive periods, i.e. waiting or delays, occur regularly. The third topic deals with initiatives already taken to improve energy efficiency and future ideas. The fourth topic explores how the people involved in the harbour stay cooperate and if team spirit is a factor. The fifth and final topic addresses booking and planning procedures, in particular if systematic planning is based on bookings or other information.

3. FINDINGS

The field notes were coded using inductive coding, as described by Frankfort-Nachmias et al. [5], i.e. extracting the codes from the collected data. In doing so, 33 codes were identified. Table 2 shows a list of the codes extracted from interview and field notes for all three ferry routes explored in this study. The codes were categorised and subsequently grouped into three thematic areas, namely “time savings”, “time utilisation”, and “leadership”. The first two themes, time savings and time utilisation, are similar to each other in the sense that they deal with concrete processes. The third theme “leadership” is of a different nature to the first two. Leadership acts as a catalyst for the two other. This means that leadership affects both time savings and time utilisation.

Table 2. Codes, categories and themes – findings.

Code	Category	Theme	
Load meeting	Planning	Time savings	
Booking plan available			
Sufficient personnel	Manning		
Flexible personnel			
Skilled personnel			
Teamwork			
Clear and open communication channels	Communication		
Passenger conflicts	Management of events		
Ambulance transport			
Sick passengers			
Bicycles			
Last minute passengers			
Sorting post			
Change resistance	Challenges		
Lack of knowledge of complete operation			
On-time arrival/on-time departure	Timetable paradigms	Time utilisation	
On-time arrival/flexible departure			
Flexible arrival/on-time departure			
Flexible arrival/flexible departure			
Waiting for train/bus	Infrastructure dependencies		
Need to arrive before train/bus departure			
Skip trip	Timetable flexibility		
Extra trip			
Harbour stay long enough for full load	Timetable coherency		
Harbour stay longer than full load			
Passage time long enough to catch up			
Focus on efficiency	Visible leadership		Leadership
Team spirit			
New ideas encouraged			
Facilitate communication	Structural leadership		
Facilitate change			
Knowledge sharing			
Staff meetings			

4. DISCUSSION

The aim of the present study was to explore the harbour stay with the intention of mapping factors important for reducing the energy consumption of the entire route operation. This was achieved by investigating the harbour stay in its entirety, taking into account work activities, timetables, leadership, and management. From interviews and observations on board three different vessels, 33 codes were identified and subsequently categorised and grouped into three main thematic areas, namely Time savings, Time utilisation, and Leadership. Time savings and time utilisation are inter-related. Time savings are of no consequence if time utilisation is impossible, likewise time utilisation is impossible if time is not available or no waiting time is present to be utilised. Leadership influences both time savings and time utilisation because it acts as a catalyst or a barrier for improvement in these areas.

It is worth noting that the specific codes identified are all related to operational or leadership practices and not technical limitations. This indicates that the equipment available is sufficient from the operator's perspective. It also implies that an improvement in efficiency is possible by changing the operational practices, and does not solely depend on technical solutions, as also found by Banks [2].

Developing better operational practices will largely depend on the factors represented by the codes identified. The code "Skilled personnel" covers knowledge of logistics and how well skills are employed during loading and discharging. Knowledge of logistics can be acquired through education and training. The codes in the category "Management of events" cover interaction with passengers, and how smooth operations and skilled handling of unforeseen challenges can avoid loss of time. These skills can be acquired through courses in communication, and conflict and crisis management.

An important factor is the ability of the individuals involved in the operation to understand the team tasks. This will induce back-up behaviour and flexibility. It also allows all personnel involved to prioritise the most important tasks in case of a shortage of personnel. An example of this was an observation made of the captain counting passengers coming on board, thus relieving the rating at the gangway. The rating was then free to assist the officer on deck with stowing cars during a busy period. Another example from an interview was a description of a case where no-one had been assigned to operate the suspended deck; an engineer, who was not normally a part of the loading team, stepped in and assisted. Examples such as these were coded under "Flexible personnel".

It was observed in the interviews that leadership plays an important role when trying to improve efficiency. The leader must initiate and enable the task of improving energy efficiency and continuously ensure that the focus remains on this issue. Studies show that when energy efficiency awareness is raised, this alone can lead to practices that are more effective, as found by Jensen et al [6]. Awareness is a skill that can be trained, as indicated by Rasmussen et al [7] and Jensen et al. [6], and the leaders should therefore support and arrange training. Studies show that a change in operational practices can lead to a significant increase in efficiency with little or no investment in technical equipment [2]. The findings in the present paper also show that "team spirit" is important, and that a working environment which allows for suggesting and testing alternative practices leads to better cooperation and engaged personnel. The leader is responsible for creating a work environment where ideas for improvement are welcomed. An example of this was described in one of the interviews where the leader rewarded ideas

with small tokens of appreciation and, in case ideas failed, practiced leniency so as not to discourage new ideas, which, according to the interview respondent, worked well.

Changing the timetables was mentioned in all interviews as a central piece of the puzzle. Many possibilities were discussed in all interviews, which strongly indicate the need for looking into the timetables with an open mind, and this might call for a new definition of punctuality. Johnson and Styhre [8] also suggest flexibility in arriving time as a means of allowing for longer passage time. One attempt at making the timetable flexible has already been conducted on a ferry serving two small islands. On the timetable, a harbour stay is allocated zero minutes. This is a way of allowing for a dynamic timetable since this harbour is only called on when passengers are requesting transportation. The timetable allows for either a slightly faster passage or later arrival at next the harbour to compensate for the harbour stay when needed. Another example is a route where the ferry is allowed to depart before the official departure time if no more passengers are in sight. This utilises what, under normal circumstances, would be waiting time and converts it to passage time. Changing the timetables might seem a simple solution but in practice it can be very difficult since many stakeholders are involved.

The ferry routes explored in this paper present a noticeable difference in how much optimisation of the harbour stay has already been implemented. However, during all interviews, ideas emerged that could potentially improve efficiency. This indicates that there is a potential to increase the efficiency of all three routes by changing operational practices.

The wide varieties in ferry operations makes it difficult to transfer specific findings between ferry routes. However, the three themes identified could be used as a guide to improve the efficiency of other ferry routes. The specific codes identified in this paper could serve as an example of what may be considered in order to improve efficiency. It is, however, quite clear that each individual route will need to perform its own analysis to identify specific points to improve.

5. CONCLUSION

This paper has discussed several factors important for increasing the energy efficiency of ferry routes by shortening harbour stays. Three key themes were identified: Time savings, Time utilisation, and Leadership. These themes were discussed and examples given, and it was found that many of the underlying factors can be addressed with training or courses. This is true for both leaders and directly involved personnel.

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Eco-Piloting Best Practices will Reduce Emissions of Nitrogen Oxides from Passenger Ferry Operations

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Keywords: Air pollution, MARPOL Annex VI, Ferries

ABSTRACT

Air pollution negatively impacts climate change and human health. MARPOL Annex VI regulations for the prevention of harmful emissions from ships dictate engine performance standards and fuel composition. On-land transportation in the US has a long history of regulation and has developed best practices to minimize harmful emissions. Best practices have not been developed for merchant vessels which present a missed opportunity for emission reduction, particularly for high profile inland operations such as passenger ferries. Content analysis of five eco-driving sources was conducted to identify comprehensive eco-driving best practices for adaptation to eco-piloting best practices. Quantitative analysis of engine specifications and vessel maneuvering characteristics was conducted to support the best practices and prove the emission reduction of oxides of nitrogen (NO_x). Eco-piloting best practices are a source of emission reduction that will complement existing engine and fuel requirements and allow ferries to better compete with other transportation sectors.

1. INTRODUCTION

Air pollution is an environmental health risk with an annual global financial impact of over 5.1 trillion USD, and an annual human health impact of over 3.2 million premature deaths [1]. Shipping contributes between two and six percent of global air pollution, depending on the pollutant, and the levels of pollution are disproportionately high in port cities [2; 3].

MARPOL Annex VI establishes progressive reductions on the levels of NO_x, PM, and SO_x in the exhaust gas from ocean-going ships. Vessels which operate exclusively in the inland waters of the US and transit no further than 24 miles off the coast, such as passenger ferries, are regulated under amendments to the federal Clean Air Act (CAA) [2; 3]. Engine tier standards in the CAA are similar to those in MARPOL, regulating emissions of PM and NO_x, with slight variations. For the purpose of this paper, the US CAA standards are referenced.

A complimentary strategy for NO_x emission reduction is operational modification. Speed changes are often conducted for operational goals, but Corbett, Wang, & Winebrake [4] demonstrate that speed reductions can reduce emissions from ships by 70%. The ports of Los Angeles and Long Beach reduced shipping emissions by 43-49% between 2008 and 2013 through a Voluntary Speed Reduction (VSR) program [5].

The regulatory compliance framework for on- and off-road vehicles in the US is similar to that of vessel compliance, combining engine specifications and fuel composition. After

mechanical emissions management and fuel composition standards for on- and off-road vehicles were implemented, companies turned to operational management strategies for additional emission reduction potential.

Eco-driving is an operational management modification which promotes fuel-efficient operations through reduced engine idling, light braking, coasting or using the engine to decelerate, anticipating the flow of traffic, maintaining steady speeds, using cruise control, and following the speed limit [6; 7]. Eco-driving programs achieve seven to ten percent reduction in immediate fuel consumption and between four and seven percent in the long-term [6; 8].

This study addresses the following research questions: What is a comprehensive set of eco-driving best practices? How would the eco-driving best practices be adapted for passenger ferry operations? Could NO_x emissions be reduced through the application of eco-piloting best practices? The hypothesis for this study was that passenger ferry operations can reduce NO_x emissions by adopting eco-piloting best practices.

2. METHODS

This study was conducted using a mixed methods approach with content analysis of five sources of eco-driving best practices for on- and off-road transportation. To identify a comprehensive set of eco-driving best practices, peer-reviewed articles on eco-driving programs for on- and off-road transportation sectors were reviewed. Three articles were selected based on recency and the detail of reporting the specific best practices. Multiple eco-driving training videos were reviewed, and two eco-driving training videos were selected for their recency, detail, and legitimacy. Online availability was a factor in the video selection.

The eco-driving best practices were adapted to eco-piloting best practices for passenger ferries with consideration for engine propulsion and operational demands. NO_x emitted from passenger vessels far exceeds levels emitted from on-road vehicles per passenger mile so it is a pollutant of particular concern for ships and was therefore selected for this study [9].

For the scope of this study, due to time, funding, and data availability, quantitative analysis of emission reduction from the application of the eco-driving best practices was demonstrated for only two of the five best practices. Three passenger ferries with a variety of engine type, propulsion type, in-service date, and run in the San Francisco Bay were chosen due to their high-profile activity, dependence on public funding, and engine types similar to off-road vehicles.

2.1 Quantitative Analysis of Best Practice 1: Minimize Engine Idling

The manufacturers engine specifications for each of the three ferries was analyzed to measure NO_x emission reduction from elimination of engine idling while alongside the dock. Emissions produced from operating the vessel at minimum engine speed were multiplied by the weekly and annual idling hours of each of the three ferries. Emissions produced were calculated by multiplying the power produced at minimum engine speed by the formula from the manufacturer's engine specifications for calculating NO_x emissions in grams per kilowatt-hour. Idling hours were calculated based on time alongside the dock reflected in vessel schedules [10]. It was assumed the engines would be shut down for vessel standby times which exceed 30 min.

Vessel NO_x emissions from transiting were calculated to determine the percent of emissions reduction from the application of best practices. Vessel schedules were referenced to determine transit times [10]. Transit times were separated into full ahead operations and wake restricted waters where the vessel must operate at Min AH. The main propulsion power output at FAH and Min AH were multiplied by the times spent at the respective speeds to calculate the annual kWh production. The annual kWhs for transits were then multiplied by the emissions factor for each vessel to calculate the total annual NO_x emissions in metric tons (MT). The MT were compared to the emissions reduction from the application of the best practice to calculate the percentage of NO_x emissions reduction.

2.2 Quantitative Analysis of Best Practice 4: Reduce Inefficient Revolutions per Minute (RPM) Use

Revolutions per minute (RPM) use may be inefficient during the docking operation called walking the vessel. A vessel with twin propulsion systems may operate the systems with one engine running with its propeller or jet drive in the ahead direction and the other engine with its associated propulsion package in the astern direction, and the rudder controlling lateral motion toward or away from the dock. Time spent walking the vessel on and off the dock is variable; 30 seconds for each docking/undocking was used for this study.

A quantitative analysis was conducted to evaluate the reduction of NO_x emissions from walking the vessel with minimal RPMs ahead and astern as opposed to half or full RPMs. The number of dockings were calculated from the vessel schedules [10]. Emissions produced were calculated by multiplying the power produced at the various engine speeds by the emissions factor for NO_x in grams per kilowatt-hour. The engine manufacturer, Cummins Inc., provided the emissions factor for the MV Peralta. The emissions factors for the MV Solano and MV Cetus were obtained from California EPA emissions tier level limits [11]. The percentage of NO_x emissions reduction was calculated using the same method as was used for Best Practice 1.

3. RESULTS

3.1 Eco-Driving Best Practices

After content analysis of the five sources, the following five eco-driving practices were chosen: 1. Minimize engine idling time; 2. Minimize the use of brakes; coast or use engine to slow; 3. Maintain a steady speed when possible; 4. Use the throttle conservatively; 5. Look ahead [6; 8; 12; 13; 14]. Gear selection was a heavily represented category that belongs in the eco-driving best practices but was intentionally removed from this list due to the lack of application for marine diesel engines.

3.2 Passenger Ferry Eco-Piloting Best Practices

Best Practice 1. Minimize Engine Idling: Turn off the main propulsion engine when alongside the dock, weather permitting.

Best Practice 2. Minimize the use of Astern Propulsion to Reduce Speed: Stop the propulsion when the vessel is at the stopping distance from the dock; minimize astern propulsion for slowing down.

Best Practice 3. Maintain a Steady Speed: Avoid speed changes when possible; favor early course changes for traffic maneuvers.

Best Practice 4. Reduce Inefficient RPM Use: Ensure operations such as walking the vessel on and off the dock utilize minimal RPM necessary for safe operations.

Best Practice 5. Look Ahead: Anticipate traffic, obstructions, and docking operations by practicing anticipatory piloting.

3.3 Emission Reduction from the Application of Eco-Piloting Best Practice 1

The three ferries idle alongside the dock between arrival and departure from 4.2 to 20.4 hours per week, depending on service requirements. The Peralta emits 0.7 MT per year while idling alongside the dock, the Cetus emits 0.1 MT, and the Solano 2.8 MT. Tables used have been omitted due to article length restrictions.

3.4 Emission Reduction from the Application of Eco-Piloting Best Practice 4

There is an evident correlation ($r = 1$) between RPM and NOx emission; when engine speed is reduced, NOx emissions are reduced for the three vessels. This data was used to create Table 1, which demonstrates potential emission reduction from the application of Best Practice 4 for walking the vessel for docking and undocking operations using less power.

Table 1. Summary of Emission Reduction for Eco-Piloting During Docking and Undocking as Compared to Walking Vessel Using FAH/FAS Engine Orders

HAH/HAS as Compared to FAH/FAS				
Vessel	Total Annual Power Reduction	Percentage Reduction	NOx Emissions	NOx Emissions
	kWh	%	MT	%
Peralta	71,344	46	4.4	58
Cetus	89,245	30	0.1	30
Solano	80,686	27	5.8	27

Min AH/Min AS as Compared to FAH/FAS				
	kWh	%	MT	%
Peralta	145,721	95	7.2	95
Cetus	210,527	70	0.2	70
Solano	234,780	78	17.0	78

The reduction of emissions from Table 1 are referenced in Table 2 along with the total transiting emissions of NOx.

Table 2. Annual Emissions Reduction for Eco-Piloting Best Practice 4.

Walking at HAH/HAS						
	Annual Emissions Reduction from Walking (HAH/HAS) (NOx)	Annual Restricted Wake Operating (Min AH)	Annual Transit Times	Annual Emissions from Transiting (NOx)	Annual Emissions from Transiting and Idling and Walking (NOx)	Percent Reduction Annually for Reduction of Walking (HAH/HAS)
	MT	hr	hr	MT	MT	%
Peralta	4.4	0.0	1303.6	164.3	172.7	2.6
Cetus	0.1	1261.9	2466.4	8.1	8.5	1.1
Solano	5.8	969.9	3102.5	1181.2	1205.6	0.5
Walking at Min AH/Min AS						
	Annual Emissions Reduction from Walking (Min AH/Min AS) (NOx)	Annual Restricted Wake Operating (Min AH)	Annual Transit Times	Annual Emissions from Transiting (NOx)	Annual Emissions from Transiting and Idling and Walking (NOx)	Percent Reduction Annually for Reduction of Walking (Min AH/Min AS)
	MT	hr	hr	MT	MT	%
Peralta	7.2	0.0	1303.6	164.3	172.7	4.2
Cetus	0.2	1261.9	2466.4	8.1	8.5	2.7
Solano	17.0	969.9	3102.5	1181.2	1205.6	1.4

4. DISCUSSION

The results prove that passenger ferry operations can reduce NOx emissions by adopting eco-piloting best practices. Overall operational NOx emission reduction with the application of only two of the five best practices was between 0.7 and 4.6% for each vessel.

4.1 Development of Eco-Driving Best Practices

The principles of eco-driving are similar for passenger vehicles, busses, and construction vehicles. The similarity across transportation sectors strengthens the validity of the list of eco-driving best practices that was developed for this study, particularly for a broader purpose to support the development of best practices for an alternative transportation sector.

4.2 Development of Passenger Ferry Eco-Piloting Best Practices

Three of the five practices were directly transferrable and two required significant language changes to translate to passenger ferry piloting. Brief instructions were developed to accompany each of the eco-piloting best practices to more clearly translate the practical application of eco-driving best practices. Best Practice 4. Reduce Inefficient RPM Use was the

most specific for passenger ferry operations and could have much broader application for future studies.

4.3 Application of Best Practice 1. Minimize Engine Idling.

Elimination of engine idling would reduce overall NO_x emissions by 0.2 to 0.9%. Tier II vessels achieve higher NO_x emission reduction than Tier III vessels. The application of Best Practice 1 will have the most impact if it is practiced on Tier II vessels until their retirement or until they are re-powered or modified to comply with Tier III standards.

4.4 Application of Best Practice 4. Reduce Inefficient RPM Use.

Reducing engine RPMs from FAH/FAS to HAH/HAS during walking operations reduced NO_x emissions by 30-60%. The reduction to Min AH/Min AS reduced NO_x emissions from walking operations by 70-95%. Application of Best Practice 4 showed 0.4 to 4.2% reduction in total NO_x emissions. Maintaining an efficient speed for the transit is an aspect of this best practice that was outside the scope of this study but is recommended for future research.

5. CONCLUSION

This research proves that passenger ferry operations can reduce NO_x emissions by adopting eco-piloting best practices. This paper developed five eco-piloting best practices and evaluated two of them. If the data from the application of the two best practices were extrapolated to reflect application of all five eco-piloting best practices, the overall emissions reduction of NO_x would be between 1.4 and 7.2%, which is similar to reduction figures in eco-driving studies. A recommendation for future research is to conduct a study of the application of all five eco-piloting best practices, with monitoring and operator feedback.

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Complications of robotic delineation of oil spills at sea

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ABSTRACT

Disasters at sea often run the risk of producing oil spillage. The level of spill depends on the type of vessel, the severity of damage, the weather conditions and nature of the disaster. Rapid response is crucial, yet an effective response depends on knowledge of the extent of the spill through the water column. Autonomous underwater vehicles are attractive to delineate a spill due to their capability of rapid deployment and ability to sense in three-dimensional space. This paper describes the assessment of oil sensors for their effectiveness on AUVs as rapid response instruments for delineation of an oil spillage at sea. Three sensors were tested to sense marine diesel oil in regular and breaking wave conditions. The outcomes implied that the robotic mission algorithms must account for oil in water that forms patches and clouds of droplets of various sizes and distribution at varied depths using appropriate sensors.

1. INTRODUCTION

1.1. BACKGROUND

An oil spill can have devastating consequences for the marine environment and living organisms. Humans, soil and even air qualities can be affected due to a variety of toxic chemical substances released into the environment during a spill. After being released to ocean and coastal waters, the oil continuously spreads due to the action of wind and waves [1].

The pollution risk in the Antarctic Ocean is on the increase because of the gradually growing scientific interest, tourism and both legal and illegal fishing [2]. Continuous growth of marine traffic resulted in 19 vessel accidents reported between 2001 and 2011, which have released or that had the potential to release oil near Antarctica and sub-Antarctica [3].

1.2. ISSUES OF OIL SPILL RESPONSE IN THE ANTARCTIC OCEAN

Spills in the Antarctic Ocean are infrequent; their environmental impact in such a pristine area is much more severe than in other parts of the ocean [4]. Low temperature significantly slows the biodegradation mechanism down by years when it may only take weeks or months in temperate areas [5]. Polar marine organisms consequently have longer exposure to pollutants. Once an oil spill takes place, rapid response in its early stages is crucial to restrict the spread and minimise the effect of the spill. It inevitably requires immediate ship arrangements along

with crews and survey instruments. One obvious challenge in the event of oil spills in the Antarctic Ocean, a particular focus of this paper is that the extreme remoteness and weather conditions hinder the access of professional personnel for response, ships and necessary equipment. This is even more so during winter months. Another issue is the long-term spreading of the spilled oil due to the presence of seasonal sea ice. While the closely packed floes are apt to trap the oil, reducing the spreading rate and evaporation [6], oil beneath young ice may be encapsulated by new ice within 12 – 24 hours [7]. The adhesive effect of snow and ice encapsulation may detain the oil initially yet spread it over a larger area at the onset of next warm season [8].

1.3. AUV APPLICATIONS IN OIL SPILLS

Autonomous Underwater Vehicles (AUVs) are untethered and unmanned robots that have proven to be effective and efficient in performing given tasks in dangerous, distant and dynamic ocean environments through many missions [9]. On account of a growing maximum range, increased battery life and payload sensor advancement, their application has been widely expanded [10].

The *Deepwater Horizon* offshore rig explosion in 2010 resulted in the largest oil spill incident in history. About 800 million litres of crude oil in total were spilled during the incident. The use of subsurface dispersant injection resulted in plumes of oil being trapped at around 1,000 metres depth of water, and therefore the true horizontal extent and vertical distribution of the spill could not be determined from the surface. So, AUVs were sent to the presumed water depth. The *Sentry* AUV of Woods Hole Oceanographic Institution (WHOI) equipped with a mass spectrometer was deployed to detect the underwater oil plume [11]. The *Dorado* AUV of Monterey Bay Aquarium Research Institute (MBARI) with gulper samplers returned with ten 1.8 litre oil-and-water samples and confirmed the presence of the oil plume [10].

Responding to an oil spill in polar conditions is more challenging than that in extremely deep water. There is limited bathymetry data. Many parts of both the ocean bottom and polar regions are little known or mapped. Moreover, it is very difficult to rely on guidance by human operators except when the AUV approaches the surface. When the release location of the source is unclear, an AUV must be able to adaptively track the oil down from the surface as oil does not necessarily rise vertically due to ambient currents and the nature of dispersion [12]. Therefore, a high-level of autonomy and complex behaviours by the robot are essential. The vehicle must be able to readily access the region where human and ship access is denied and prohibited. It needs to keep making decisions while conducting tasks and adaptively respond to unanticipated situations in the dynamic environment. In that sense, an AUV is the most ideal platform, provided that it has high resolution sensors that enable itself to perceive changes in its surroundings and a reliable in-situ analysis system that allows prompt reactions.

2. WAVE TANK EXPERIMENT

Fuels are complex mixtures of hydrocarbons composed of hundreds of thousands of organic and inorganic compounds [13]. They may fall into the same classes of compounds, yet have different physical properties depending on different amounts of chemical components [3]. For an AUV to correctly distinguish oil in water from other organic matter in the ocean, it is

important to use appropriate sensors that are guaranteed to detect oil compounds under the conditions similar to those in the natural environment.

2.1. WAVE TANK FACILITY AND TESTING CONDITIONS

Experiments were carried out in November 2018 in the wave tank facility operated by the Centre for Offshore Oil, Gas and Energy Research (COOGER) at the Bedford Institute of Oceanography (BIO). Marine diesel oil (MDO) was selected as the subject target oil because its properties are the most analogous to Special Antarctic Blend (SAB) diesel, one of the most commonly used fuels in the Antarctic [3]. A set of experimental varied wave conditions was triplicated (six tests in total).

The experiments were conducted in a rectangular wave tank. The dimension of the tank is 32m long, 0.6m width and 2m high with an average water level of 1.5m as shown in Figure 1. A series of manifolds equip the tank to allow a uniform current flow to pass through the tank. Both regular non-breaking and plunging breaking waves could be generated by a computer-controlled flap-type paddle located 2.8m from the fore end of the tank. The tank accommodated a total volume of 28,000 litres of filtered seawater.

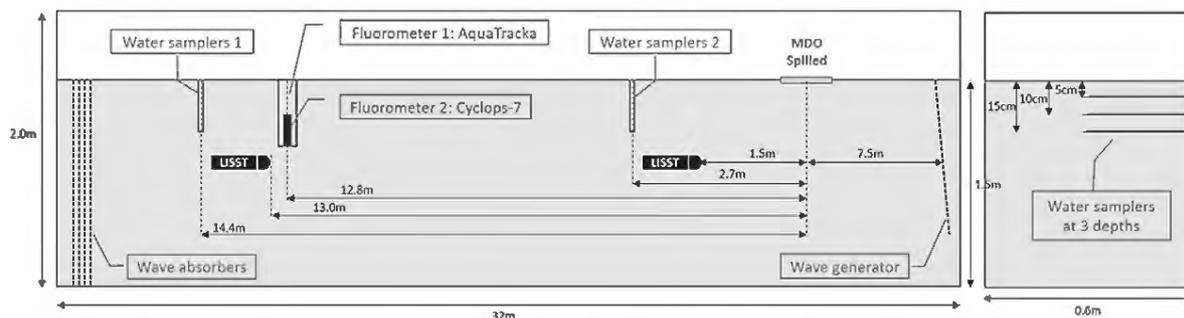


Figure 1. A schematic of the wave tank (not to scale, all values are in meters).

Inside the tank, two fluorometers, a *Cyclops-7* (Turners Design) and a *UV AquaTracka* (Chelsea) were mounted and submerged 12.8m downstream from the spilled location. Two Laser In-situ Scattering and Transmissometry (LISST) 200X particle size analysers (*Sequoia Scientific*) were installed at 1.5m and 13.0 m downstream, respectively. The frequency of both fluorometers was 10Hz. The LISST sampled every 1.5 second (0.667Hz) over a measurement range of 1.0 to 500 μm . Water samplers were installed at two locations in the tank at three depths (5cm, 10cm and 15cm).

2.2. METHODOLOGY

A fixed amount of oil (approximately 240 – 245mL) was added to the tank by pouring it into a 34cm diameter containment ring located 7.5m downstream on the surface from the wave generator. A uniform current was applied in every test at a flow rate of 230L/min, allowing the average current speed of 0.0042m/s. Having the type of waves selected, the wave generator was switched on, while the containment ring was lifted up right before the arrival of the first wave. The current and wave conditions were maintained for 60 minutes in each test. By the generated current, waves and natural wind force, the spilled oil was subjected to transport

processes (spreading and dispersion) as well as evaporation. Wave reflection was minimised by the porous screens installed at the end of the tank away from the wave maker.

Water temperature (°C) and salinity (ppt) were measured at the beginning of each test. Water samples were extracted for chemical analysis at every 5, 15, 30, 45 and 60 minutes. The tank was drained thoroughly and cleaned with absorbing pads and seawater at the completion of each test to remove oil. The specification of the test conditions is shown in Table 1.

Table 1. The wave tank experiment specification.

Testing fuel	<i>Marine Diesel Oil</i>
Testing time	60 minutes
In-situ submersible sensor	<i>Cyclops-7 (Refined), AquaTracka (Refined), LISST-200X</i>
Waves	Regular waves, Breaking waves
Current speed	0.0042m/s
Chemical analysis	Benzene, Toluene, Ethylbenzene and Xylene (BTEX) Total Petroleum Hydrocarbon (TPH) Gas Chromatography-Mass Spectrometry (GC-MS)

3. RESULTS AND DISCUSSION

3.1. SUBMERSIBLE FLUOROMETER ANALYSIS

While the *UV AquaTracka* sensed MDO in water, the measurements collected by the *Cyclops* remained at a constant level of concentration without having the high peaks sensed during all tests implying that the oil was not detected by this sensor. The following parameters must fit within the correct range to ensure successful detection of the subject oil: minimum detection limit (MDL), a maximum fluorescence wavelength and fluorescence spectral width. The peak of the spectral distribution of the marine diesel oil is at about 400nm [14], which is outside the excitation (290nm) and emission (350nm) intensity wavelength of the *Cyclops*. The MDL of the *AquaTracka* and the *Cyclops* are 0.001ppb and 400 ppb, respectively.

The test results using the *UV AquaTracka* with breaking waves and regular waves are shown in Figure 2. The peaking curves mean higher fluorescent concentration indicating the amount of oil in water that the sensor captured. Breaking waves had a significant impact on the vertical distribution of the plume. They caused the oil to break up into various sized droplets which were distributed at depth in the water column. In contrast, the spilled oil was slowly carried downstream horizontally by the regular waves, yet it stayed mostly on the surface. A dissolved fraction of the oil contributed to an increase in the average oil concentration level.

The average of the current speed in Antarctica is 5 – 10 cm/s varying from 5cm/s further offshore to 25cm/s near the coast [15]-[16]. So, the relative speed between the sensor and a plume would be faster in a real-life situation using a sensor on an AUV. Namely, there are potential risks of losing the plume when travelling at a cruising speed of 1m/s. Therefore, an AUV will need to adaptively adjust its forward speed when detecting an oil plume.

Several variations have been observed between tests with the same experimental conditions. Firstly, the extent of vertical dispersion and persistence varied amongst the three breaking wave tests. That of Set #2 was notably noisier. The background level in Set #3 was initially 33% higher than the other tests. Marginal conditions, such as the intensity and direction of wind, may have developed such variations. Since one oil spill does not involve identical environmental conditions with any other oil spill, each gets to evolve in a different way.

From visual observation, the spilled MDO formed multiple surface slicks which kept adhering and detaching from one another. This will add confusion for an AUV to determine whether it is still inside the plume or just in between patches.

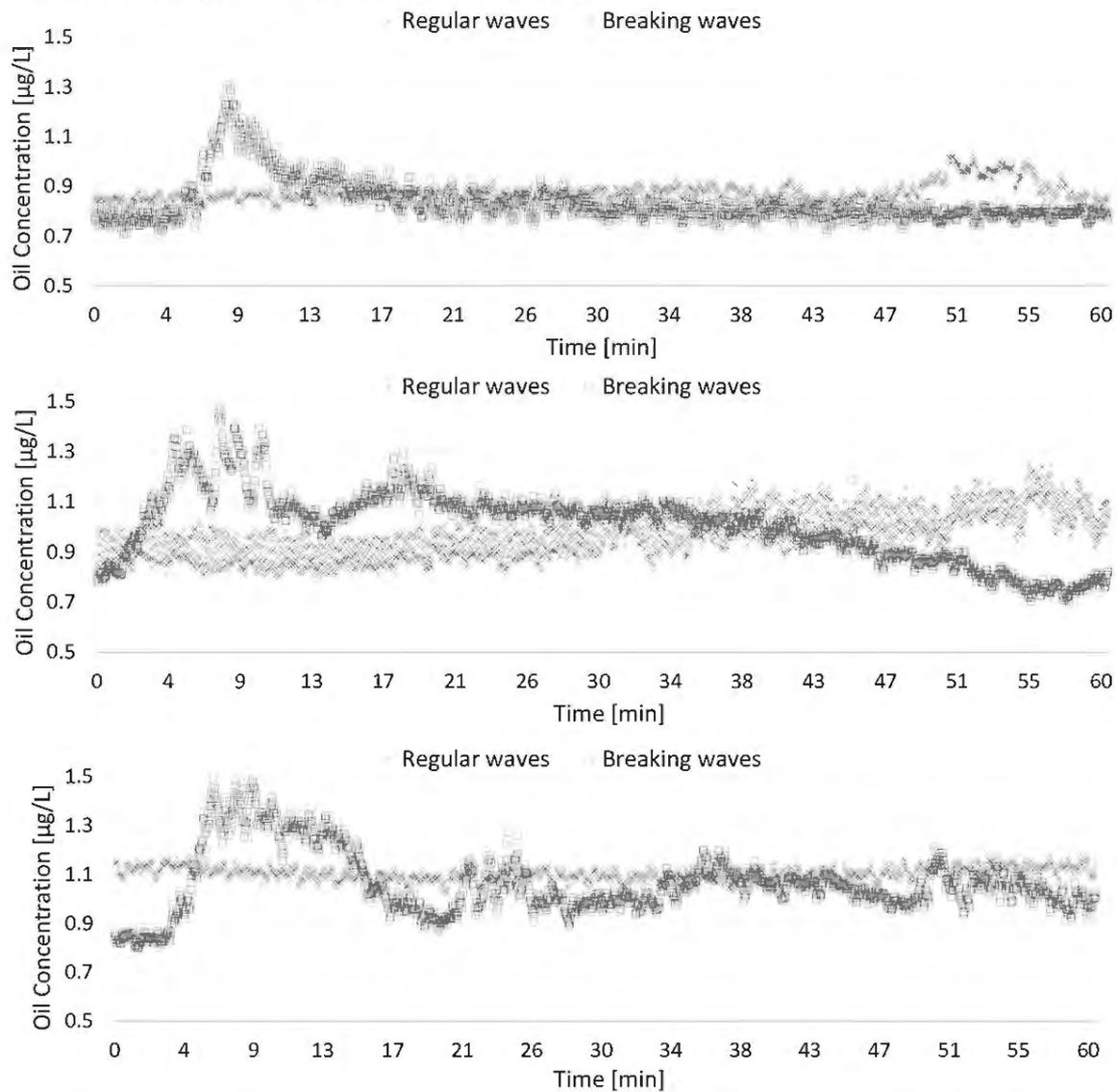


Figure 2. MDO release test sets of two wave conditions; breaking waves and regular waves.

3.2. PARTICLE SIZE ANALYSIS

Two LISST particle size analysers were deployed in the wave tank to monitor the droplet sizes of dispersed MDO during the wave tank experiments. Plots showing the distribution of droplets during breaking and regular wave experiments are shown in Figure 3. It can be seen that both wave types produced subsurface patchy plumes of dispersed oil droplets that moved down the length of the wave tank over the course of the experiment. Plume concentrations peaked 5-10 minutes post oil release, and then droplet concentrations declined, but stayed in patches over the remainder of the experiment as the water returned to pre-oil release conditions.

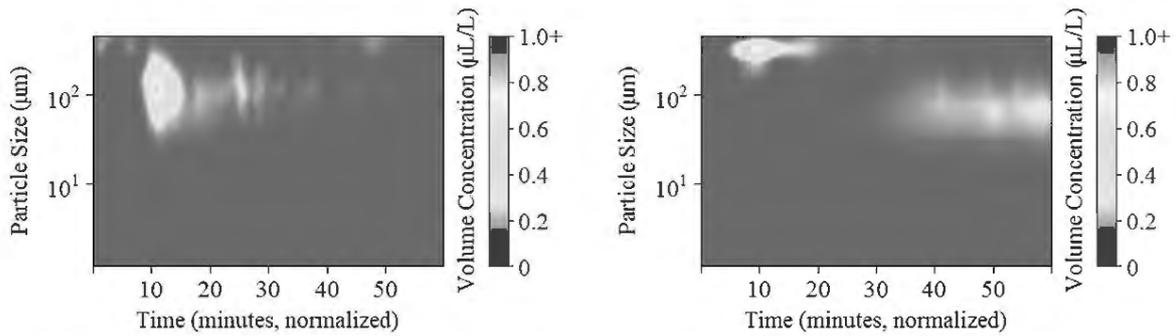


Figure 3. Contour plots showing the volume concentration of MDO droplets in the water column over time as detected by the LISST particle size analyser during breaking wave (left panel) and regular wave (right panel) experiments.

A difference in the droplet breakup was observed between the two wave energies used in the experiments. Droplet size distributions for regular and breaking wave experiments are shown in Figure 4. The higher energy breaking waves produced smaller droplets with a sauter mean diameter of 93 μm at the peak of the plume, while the lower energy regular waves had larger droplets with a sauter mean diameter of 131 μm . Droplet size has implications for the long-term fate and behaviour of MDO spilled in marine environments. Smaller droplets will remain in the water column for a longer period of time and would be more available for weathering processes and biodegradation. The greater surface area to volume ratio of the smaller droplets will also allow for more dissolution of water-soluble hydrocarbons into the water column, which would influence the response of in-situ sensors such as the fluorometers used in this study [17].

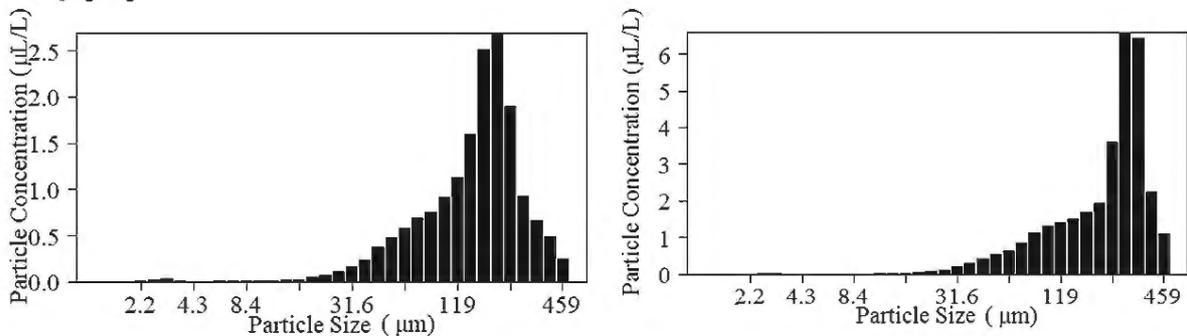


Figure 4. Oil droplet size distribution for breaking wave (*left*) and regular wave (*right*) experiments.

4. CONCLUSION

The risk of oil spills in the Antarctic remains high due to increasing volumes of marine traffic. Utilising an AUV in oil spill response is still at its early stages. Constraints in responding to such a devastating disaster in the Antarctic highlight the advantages of an AUV as an effective means to delineate a three-dimensional oil plume. The results from the fuel spill in experimental study indicated that fluorometers for the AUV must be carefully selected considering the oil type, minimum detection limit and the light intensity range. The potential for a patchy distribution of the dispersed plume also suggested that the AUV adaptive sampling algorithm must account for the discontinuous form of an oil plume.

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Impacts of Commitment and Goal Setting on Pro-Environmental Behaviors (PEBs) Toward Ocean Conservation: An Exploratory Study

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ABSTRACT

Some estimates claim that by 2050, there will be as much plastic in the ocean as fish [1]. While plastics pollution in our oceans is largely a land-sourced problem [2], public scrutiny of the shipping community persists. This study examines how seafarer pro-environmental attitudes and behaviors can be influenced. Using between-subject experimental design, current (and future) seafarers were surveyed through the IAMU members' networks. The survey measured ocean literacy [3], culture [4], and seafarer attitudes and behaviors about plastics pollution [5]. 202 complete and usable responses were received (representative of seafarers worldwide). 98 respondents participated in pre- and post-test surveys, where each respondent was randomly assigned to a control or treatment group. Descriptive statistical, mediational, and gain-score analyses were performed. As in previous shipping safety studies, analysis confirmed group- and future-oriented (and not self- or now-oriented) people are positively disposed to pro-compliance attitudes and behaviors. There was no evidence of the treatments mediating the relationship between awareness and behaviors. Analysis supported that treatments (commitment pledges [6] and goal setting) had positively influenced pro-environmental behaviors. On average, there was an 8.5% gain in attitude and a 10.4% gain in behavior. This study shows how a small, carefully planned intervention may have a desired impact on PEBs and potentially MARPOL compliance behaviors. Furthermore, this has implications on how the IMO model course on personal safety and social responsibilities [7] might be altered to shift from awareness and knowledge transfer to behavior change [8] and even introduce desirable behavioral spill-over effects [9].

1. INTRODUCTION

We rely on our high seas and oceans for food and natural resources, trade and commerce, recreation and tourism, biodiversity and clean water, as well as carbon storage and climate regulation, among many other critical life-sustaining and enriching functions. While our high seas and oceans are unusually resilient and in relatively reasonable health according to some measures [10], our high seas are also in a state of decline (e.g., [11], [12], [13]). Some of this is due to naturally occurring changes and some is due to man's behaviors. As one of our last global commons, the high seas and oceans are subject to a well-known economic effect known as the "tragedy of the commons" [14]. In such a case, shared finite resources (such as fisheries in the high seas and oceans) become depleted and diminished when rational individuals who have rights to the commons exploit the resource out of self-interest rather than to benefit the common [15]. It is particularly difficult to manage or regulate such situations. However, just as behaviors are what create a "tragedy of the commons," it is quite possible that solutions will be found by examining how to change those behaviors.

Only several decades ago, global concern for the environment varied by geography and demography – concern was higher among people in developed nations than in developing nations. More recently, at the turn of the millennium, global concern for environmental issues and support for environmental protection was at a high level uniformly across geo/demography [16]. In 2013, again based on an international survey, global concern for the environment waned to a 20-year low [17]. On the surface, you might expect environmental conservation behaviors to vary as awareness and concern increases or decreases. However, conservation behaviors did not change dramatically during fluctuations in awareness of and concern for environmental issues [18], [19]. This provides some evidence that awareness alone does not alter behavior sufficiently to affect the environmental concern. In a global survey of experts' evaluation of progress toward achieving the seventeen UN sustainable development goals, the goal for protecting our high seas and oceans ranked second from the bottom [20].

So, rather than awareness campaigns or training and educational programs, a more potentially beneficial approach to ocean conservation may be through behavior modification. While pollution of the oceans mainly occurs from land-based sources [2], [21], [22], [23]; maritime interests are always looking for ways in which to improve their records at protecting the oceans. Seafarers are required to possess personal safety and social responsibilities according to the *International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW)*, 1978 (as amended). The validated model training course on *Personal Safety and Social Responsibility* (Model Course 1.21) [7] indicates that students should demonstrate competence in "taking precautions to prevent pollution of the marine environment" through approximately three hours of instruction. Given the fact that students must develop knowledge, understanding, and proficiency in ten topics (including a brief introduction to *International Convention for the Prevention of Pollution from Ships (MARPOL)*), it is likely that this material is presented through straight lecture. As a result, it is unlikely that such training might be effective at altering compliance behaviors. As became evident from the literature, education and awareness alone are not effective in promoting behavior change [24], [25], [26].

In an effort to understand how to influence pro-environmental (or pro-compliance) behaviors more effectively than education and awareness alone, this study explores other methods to motivate altered behavior. In specific, this study looks at current and future mariners and examines how *commitment* and *goal setting* influence their attitudes about and behaviors concerning plastics pollution and *MARPOL V* compliance.

2. THEORETICAL BACKGROUND

In figure 1, the overarching framework for this study design is presented, each of the constructs are described (represented as ovals in figure 1), the measurement of those constructs are explained (represented as boxes in figure 1), and the research hypotheses are presented.

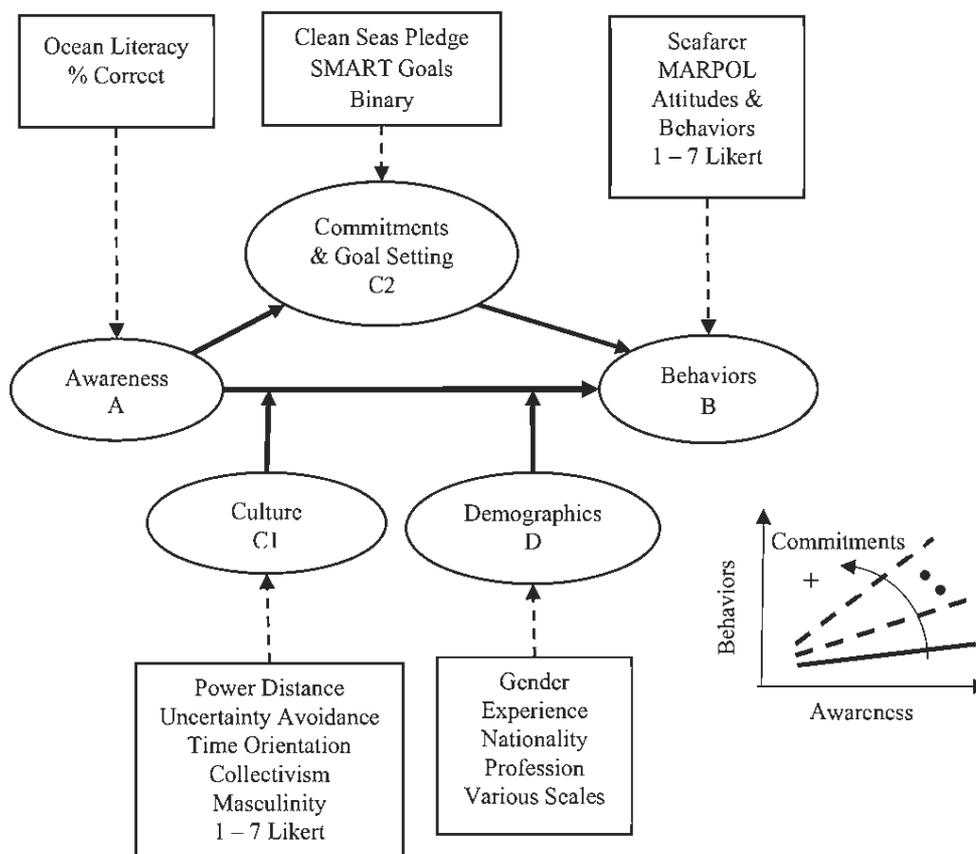


Figure 1: Research design for this study

2.1. THEORIES OF BEHAVIOR (OVERARCHING FRAMEWORK)

Ocean conservation requires behavior change [8], [27], [28], [29], [30], [31]. Many theories have explored the antecedents and influences of behavior change. For example, the seminal theory of planned behavior [32], [33], [34], which was extended by the theory of reasoned action [35], has been demonstrated through empirical evidence [36] to reasonably predict actual behavior based upon attitudes, subjective norms, perceived behavioral control, and behavioral intent. The theories of planned behavior and reasoned action are general in nature, so the theory of norm-activated theory [37] was developed to focus on a specific type of behavior – altruism

or helping behavior (of which ocean conservation may be considered [38], [39]). Even more specifically, the value-belief-norm theory [40] adapts the norm-activated theory to environmental movements and norm-activation promotes pro-environmental behaviors [41]. From that, a general model of individual (as opposed to movement) pro-environmental behavior [42] was developed. Similarly, there has been extensive study of specific variables that promote the pro-environmental behaviors [31], [43], [44]. Rather than attempting to be a comprehensive model of each of these behavioral theories and predictors of pro-environmental behaviors, this study was limited to an (over)simplified model of behavior and specific treatments which may influence pro-environmental behavior (see figure 1), as modified from [45].

2.2. OCEAN LITERACY

(AWARENESS – INDEPENDENT VARIABLE)

Ocean literacy is defined as “understanding the oceans’ influence on you – and your influence on the ocean.” [3]. Scientists and educators worked collaboratively together to develop a set of principles and a framework for fostering ocean literacy [46], [47], [48]. Studies have examined ocean literacy around the world – [49] in Ireland; [50] and [51] in the UK; [52] in Finland, Lithuania, and Sweden; [53] in Canada; and [54] in the United States. These studies demonstrated ocean literacy was an effective measurement of individual’s perception of and knowledge about (or awareness of) the ocean. In this study, we used a sample of concepts from each of the seven principles to create a short ocean literacy instrument, where each item on the instrument was a multiple-choice factual question about oceans.

2.3. SEAFARER MARPOL ATTITUDES AND BEHAVIORS

(BEHAVIOR – DEPENDENT VARIABLE)

Since this study focused on examining treatments that could affect seafarer behaviors regarding protecting the marine environment, we focused on seafarers’ attitudes and behaviors regarding MARPOL V compliance. Since this construct was not previously measured based upon available literature, an equivalent construct was selected – safety culture. Safety culture has been studied extensively in the maritime domain [55], [5], [56], [57], [58], [59], [60]. An instrument to measure seafarer MARPOL compliance attitudes and behaviors was adapted from existing safety culture scales that had been previously validated [5], [61], [62]. Thus, in this study, we used a 15-item instrument where the prompts were adapted to pollution prevention (MARPOL) compliance from safety culture (attitudes and behaviors). Each response used a five-point Likert scale of agreement/disagreement [63].

2.4. HOFSTEDE’S DIMENSIONS OF NATIONAL CULTURE

(CULTURE – MODERATOR VARIABLE)

As has been common in many maritime studies (see e.g., [64]), national culture was also included as a potential determinant of behavior. Based on the seminal studies of Hofstede [65], [66], [4], national culture consists of five dimensions, namely power distance, individualism/collectivism, uncertainty avoidance, masculinity/femininity, and long-term orientation (or Confucian dynamism). Power distance is defined as the degree to which people accept inequality in power in organizational institutions. Collectivism refers to the degree to which people are oriented towards acting as part of a group within an organization (and the opposite

is individualism where people act on their own regardless of the collective interests). Uncertainty avoidance has to do with people's tolerance for ambiguity. Masculinity refers to a preference for achievement, heroism, assertiveness, and material success (whereas femininity stands for a preference for relationships, modesty, caring for the weak groups, and quality of life). Long-term orientation is a focus on the future.

2.5. COMMITMENT AND GOAL SETTING (TREATMENTS – MEDIATOR VARIABLE)

There have been several meta-analyses about what influences pro-environmental behaviors (see e.g., [67], [68], [69]). One comprehensive meta-analysis by Osbaldiston and Schott [68] described ten basic types of treatments, which they sorted into four categories (i.e., convenience, information, monitoring, and social-psychological processes). They noted that goal setting had the second largest effect size among the studies and that when goal setting was combined with commitments, it was among the top strongest effect sizes among the studies, and considerably stronger than goal setting alone [69], [70], [71]. Additional studies examined antecedents to pro-environmental behavior in specific professional settings [71], [70]. Therefore, in concurrence with the literature, we applied a combination treatment of commitment and goal setting to a random selection of respondents to this study. The measurement of this treatment was binary for this study – either there was the presence of a commitment pledge and goals or there was not.

It would be difficult to address MARPOL compliance directly with actual seafarers due to the potential for self-preservation bias and also that future seafarers (i.e., maritime cadets and students) may not have direct experience with MARPOL compliance behaviors even if they possess MARPOL compliance attitudes. Therefore, a commitment treatment using an existing pledge about personal use of plastics was selected as being a close proxy to uncover commitments toward compliance behaviors. The UN Clean Seas Pledge [6] is a commitment treatment (or intervention) that describes seven commitment statements, which individuals, companies, governments, or non-governmental organizations can participate. As framed in this study, these are individual in nature and not specific to an organizational or maritime setting [71]. Two specific goal statements were selected for the treatment to pair with the commitment pledge. In alignment with the individual proxy nature of the UN Clean Seas Pledge, the two goal statements were derived to support the reduction of plastics.

A detailed description of the instruments used in this study can be found in the IAMU report for the Ocean Conservation Experiment and Networks (OCEAN) project [72].

2.6. RESEARCH HYPOTHESES

The primary relationship in the model described in figure 1 is that increased awareness leads to increased ocean conservation behaviors. It was expected that a weak positive or negligible relationship between these two variables [8], [53] exists. If the latter were to be the case, then there would likely not be sufficient evidence to support the null hypothesis therefore the alternative hypothesis (i.e., that there is no relationship between awareness and behavior) should be adopted. This would be support of the concurrence in most of the theories of behavior

in that awareness (alone) does not in and of itself determine behavior. Based on this, we postulate our first hypotheses.

H1: There is a positive relationship between ocean literacy and seafarer attitudes and behaviors regarding MARPOL compliance.

Of all the dimensions of culture, long-term orientation (degree to which a culture values the future) [73] seemed to be the strongest indicator of safety attitudes and behavior – this could have potential relevance to pro-environmental behaviors. Next, again from the safety culture literature, we believe long-term orientation will have a strong positive effect. Finally, we suspect masculinity will have a negative effect on pro-environmental (compliance) attitudes and behaviors. Based upon that literature, we form our next set of hypotheses.

H2: Long-term orientation is positively related to seafarer attitudes and behaviors regarding MARPOL compliance.

H3: Collectivism is positively related to seafarer attitudes and behaviors regarding MARPOL compliance.

H4: Masculinity is negatively related to seafarer attitudes and behaviors regarding MARPOL compliance.

Finally, based upon the pro-environmental behavior literature previously described, we expect the treatments (commitment and goal setting) will mediate the relationship between awareness (as measured by ocean literacy) and seafarers' attitudes and behaviors toward MARPOL compliance.

In order to test the potential mediational relationship of the conservation treatment (or intervention), a between-subject experimental design [74], [75] was created as shown in figure 2.

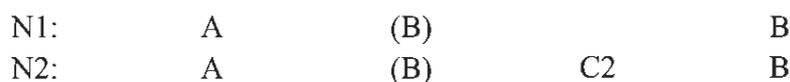


Figure 2: Sequence of surveying and treatments in experiment for control group (N1) and experimental group (N2)

In the between-subject experimental design, there are two groups (N1 and N2). These are either intact groups (e.g., from the Maritime Environmental Protection Associations) and thus non-randomly assigned or assembled groups randomly assigned (particularly where an equivalent group is needed). N1 is the control group and N2 is the treatment group (that receives treatment between the pre- and post-testing). Both groups were subjected to the same pre-testing. In this case, since we were examining awareness and behavioral action, we were interested in assessing participants *awareness* (A), or ocean literacy as measured [76], [77]. Likewise, since these groups are being drawn from a global population, we will also want to assess contextual factors [78] such as *demographics* (D) or *culture* (C1) as measured using Hofstede's cultural

dimensions [79], [80]. Treatments were *commitments* using the UN Clean Seas Pledge and *goal setting* using a pair of SMART goals – taken together as a unified treatment called *commitment* (C2). Once the treatment, noted as C2 was applied to the treatment group, then after prescribed period of time, both groups were subjected to post-testing to measure seafarer attitudes and *behaviors* (B) toward MARPOL compliance, a form of compliance behavior, which would equivalent to the pro-environmental behaviors of the literature.

Given this between-subject experimental design, we can test whether the treatment, as an independent variable, has a direct influence on behavior. The following hypotheses arise from that potential relationship:

H5: There is a positive relationship between the presence of commitment statements and seafarer attitudes and behaviors regarding MARPOL compliance.

H6: There is a positive relationship between the presence of goal setting and seafarer attitudes and behaviors regarding MARPOL compliance.

This can be determined by examining the differences between the randomly assigned control group and the randomly assigned treatment group and how they respectively perform in the pre- and post-tests without and with the treatments of commitment and goal setting. Another opportunity is to explore the potential mediator effect of the two treatment (C2) on the influence of *awareness* (A) on *behaviors* (B).

3. METHODOLOGY

Data were obtained for the study by administering a questionnaire survey to current seafarers and future seafarers from around the world. The survey was first deployed through the professional networks of the research team and then through the networks of the International Association of Maritime Universities. Of the 284 responses, 202 were usable for the pre-test survey. The International Chamber of Shipping (ICS) estimates the worldwide population of seafarers serving on internationally trading merchant ships is 1,647,500 (of which 774,000 are officers and 873,500 are ratings) [81]. Using an online sample calculator, such a sample size is sufficient to support an 85% confidence interval with a 5% margin of error. Alternatively, if a 95% confidence interval (often considered an industry standard) is desired, the sample size would be sufficient to support a 6.9% margin of error.

Due to nature of the survey design and administration, block-randomization was not possible. A time-based randomization technique was used to determine whether or not to apply the *commitment* and *goal setting* treatments. This randomization technique satisfied the two key criteria: 1. Respondents were equally likely to be assigned to either control or treatment group, and 2. Assignments were independent of other respondents (due to different start times and completion times). Of the 202 who completed the pre-test survey, 98 respondents voluntarily agree to participate in the post-test survey; 66 of which were complete and usable for this research. Of the 66 complete and usable matched pairs of pre-test and post-test surveys, 28 had the *commitment* and *goal setting* treatments applied due to random “selection” and the

remaining 38 had no treatment and were considered the control group. In psychological research, such a randomization technique is often used and will result in unequal sample sizes in different conditions, but recent texts [82] state “Unequal sample sizes are generally not a serious problem, and you should never throw away data you have already collected to achieve equal sample sizes.”

From a *demographic* perspective, the respondents overwhelmingly male (84.6%), predominantly from two nationalities (34.5% Japanese and 47.7% American), with a median seafaring experience of less than one year of experience, and predominantly from the deck side professional specialties (42.1%). This is overrepresented of women, which represent only 2% of the world’s maritime workforce according to the International Trade Workers Federation [83]. However, this gender breakdown varies by sector and is generally higher at maritime education and training institutions (when surveying mariners of the future). The two predominant nationalities are due to the fact that the researchers actively obtained survey participation at their home and neighboring institutions. Other nationalities were so low as not to be worthy of further analysis due to the small sample sizes. While the vast majority of the respondents (82.8%) had little or no experience (indicating that they were students, or future seafarers), 9.8% had two to five years of experience, 5.2% had six to ten years of experience, and the remaining 2.2% were roughly evenly split between eleven to twenty years of experience and more than twenty years of experience. Additionally, ocean literacy levels among the seafarers sampled was roughly equivalent to that of the general population as found in similar studies [53], [52], [49], [84], [85], [86].

An attempt was made to gather input from more actual seafarers, and agreements were made with shipping organizations, but the survey was not administered due to labor contractual issues.

The survey was initial pre-test survey administered between October 2018 and January 2019. The follow-up post-test survey was administered in batches four to six weeks after the pre-test survey was administered.

4. RESULTS

Table 1 presents the correlations of key variables measured in this study. Even though it would be mathematically possible to provide means, standard deviations, and ordinal ranks for the dimensions of culture (i.e., power distance, uncertainty avoidance, time orientation, collectivism, and masculinity), those statistics would be beyond the ordinal level of measurement [87]. Regardless, we are principally interested in these correlations.

Table 1: Basic regression results for seafarer *MARPOL attitudes and behaviors*

	<i>PD</i>	<i>UA</i>	<i>TO</i>	<i>C</i>	<i>M</i>	<i>MA</i>	<i>MB</i>
<i>Power Distance (PD)</i>	1.000	--	--	--	--	--	--
<i>Uncertainty Avoidance (UA)</i>	0.301**	1.000	--	--	--	--	--
<i>Time Orientation (TA)</i>	0.185**	0.547**	1.000	--	--	--	--
<i>Collectivism (C)</i>	0.249**	0.589**	0.544*	1.000	--	--	--
<i>Masculinity (M)</i>	0.011	0.125*	-0.223*	0.090**	1.000	--	--
<i>MARPOL Attitudes (MA)</i>	0.129**	0.177*	0.321*	0.297***	-0.119*	1.000	--
<i>MARPOL Behaviors (MB)</i>	0.319*	0.436**	0.555	0.573**	-0.202*	0.243**	1.000

Standard errors reported in parentheses. *, **, *** indicates significance at the 90%, 95%, and 99% respectively.

This basic regression analysis indicates there is evidence to support the hypothesis (H3) that *collectivism* is positively correlated to both *MARPOL attitudes* and *behaviors* of seafarers. This basic regression analysis also indicates evidence to support the hypothesis (H2) that *time-*

orientation is positively correlated to *MARPOL attitudes*, but not *MARPOL behaviors* of seafarers (resulting in a mixed finding). As noted in previous studies (e.g., [64]), this would tend to make intuitive sense in that individuals with collective (as opposed to individualistic) and long-term (as opposed to short-term) orientations would be more inclined to exhibit outward-oriented, future-focused pro-environmental attitudes and behaviors. Further, there is also evidence to support the hypotheses that *masculinity* is negatively correlated with seafarer *MARPOL attitudes* and *behaviors*. This also makes intuitive sense in that individuals who exhibit masculine (as opposed to feminine or nurturing) orientations (characterized by assertiveness, aggression, competition, etc.) might disrupt team dynamics and weaken pro-environmental culture, again as noted in [64], but toward safety culture.

Baron and Kenney [88] proposed a four-step approach in which several regression analyses are conducted and the significance of the coefficients is examined at each step. In this case, the following regression analyses were conducted:

1. Simple regression with *ocean literacy* predicting *MARPOL attitudes* and *behaviors*
2. Simple regression with *ocean literacy* predicting treatments (i.e., *commitments* and *goal setting*)
3. Simple regression with treatments (i.e., *commitments* and *goal setting*) predicting *MARPOL attitudes* and *behaviors*
4. Multiple regression with *ocean literacy* and treatments predicting *MARPOL attitudes* and *behaviors*

Table 2: Mediation regression results for seafarer *MARPOL attitudes* and *behaviors*

	<i>Ocean Literacy</i>	<i>MARPOL Attitudes</i>	<i>MARPOL Behaviors</i>
<i>Ocean Literacy</i>	1.000	-	-
<i>MARPOL Attitudes</i>	0.437** (0.039) R ² _{adjusted} = 0.29	1.000	-
<i>MARPOL Behaviors</i>	0.231* (0.062) R ² _{adjusted} = 0.15	0.503*** (0.037) R ² _{adjusted} = 0.45	1.000

Standard errors reported in parentheses. *, **, *** indicates significance at the 90%, 95%, and 99% respectively.

As long as there are statistically significant relationships in each of the first three steps, then step four is performed. However, in this study, as illustrated in table 2, while there was a statistically significant relationship between *ocean literacy* and *MARPOL attitudes* and *behaviors*, there were non-significant relationships in each of the second and third steps, and thus, mediation is not likely or possible, even when considering exceptions or alternative

explanations [89], [90]. Therefore, in other words, it is unlikely that the treatments are mediators to the relationship between *ocean literacy* and *MARPOL attitudes and behaviors* of seafarers. As indicated in table 2, the only significant relationship is that *ocean literacy* has weak to moderate predictive power on *MARPOL attitudes and behaviors* of seafarers.

Therefore, there is evidence to support the hypothesis (H1) that there is a positive relationship between *ocean literacy* and *MARPOL attitudes and behaviors* of seafarers. In this case, one could conclude awareness does enhance pro-environmental attitudes and behaviors. However, even though there is statistically significant positive correlations between *ocean literacy* and *MARPOL attitudes and behaviors*, this is a weak to moderate explanatory power for social sciences.

In this study, 93 respondents voluntarily participated in both the pre-test survey and the post-test survey (which occurred four to six weeks after the pre-test survey). Of those who participated, 66 provided complete and useful responses to both the pre-test survey and the follow-up post-test survey administered between four and six weeks after the initial survey. Twenty-eight “randomly selected” respondents were given the *commitment and goal setting* treatments as part of the pre-test survey and 38 of the respondents were given no treatment, the control condition. There are many ways in which to examine pre-test to post-test differences. In this study, a gain score was calculated as the difference between post-test results and pre-test results. Positive gains indicated an increase in *MARPOL attitudes and behaviors* from the pre-test to the post-test. Negative gains, or decrements, indicated a decrease in *MARPOL attitudes and behaviors* from the pre-test to the post-test.

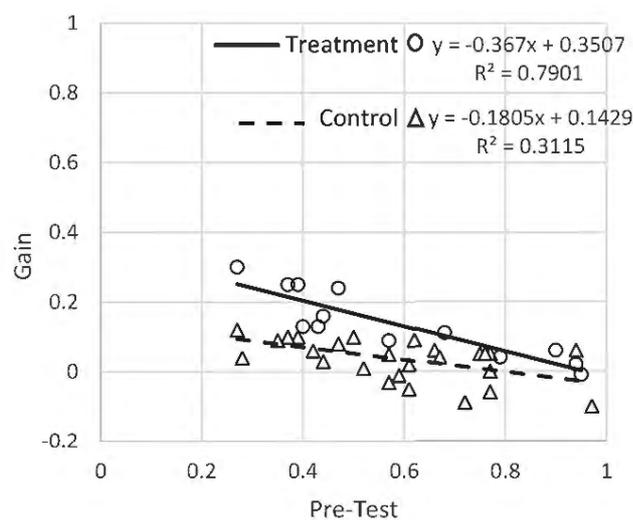


Figure 3: Comparison of (pre-test to post-test) gains in seafarers' *MARPOL attitudes* between experimental (treatment) and control groups

The survey components corresponding to seafarer *MARPOL attitudes* were aggregated into a single score and non-dimensionalized on a scale from 0 to 1 for both the pre-test and post-test results, which when subtracted to obtain the gain were also normalized on a scale of 0 to 1. In

figure 3, the pre-test scores for *MARPOL attitudes* were plotted on the x-axis and the corresponding gains (post-test minus pre-test) were plotted on the y-axis. All 38 results for the control group are represented with triangular markers and a dashed regression line. All 28 results for the treatment group are represented with circular markers and a solid regression line. The dotted line (that runs horizontally downward from 0, 1 to 1,0 with a slope of -1) represents the boundary of possible scores above which it is not possible to have a pre-test, gain combination.

Figure 3 illustrates the gains in seafarers' *MARPOL attitudes*. The mean value for gain in *MARPOL attitudes* (between pre- and post-test) for the 38 respondents in the control group is 3.8% (with a standard deviation of 6.0%). The mean value for the gain in *MARPOL attitudes* for the 28 respondents in the group who received commitment and goal setting treatments is 12.3% (with a standard deviation of 9.7%). This represents a difference of 8.5% in gain. In other words, on average, respondents subject to treatment increased their *MARPOL attitude* by almost third of an increment on the 5-point Likert scale for agreement with the *MARPOL attitude* statements.

It should also be noted that (in figure 3), in addition to this difference in slope of the regression lines between the control and treatment groups (which corresponds to the difference in gains between the two groups), almost all of the data for the treatment group dominates (or is greater than) almost all of the data for the control group. This indicates a clear and significant difference resulting from the commitment and goal setting treatments when it comes to *MARPOL attitudes* for seafarers.

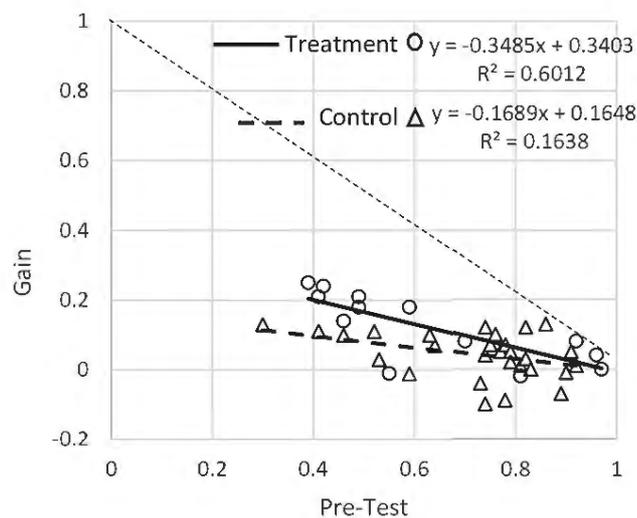


Figure 4: Comparison of (pre-test to post-test) gains in seafarers' *MARPOL attitudes* between experimental (treatment) and control groups

Figure 4 illustrates the gains in seafarers' *MARPOL behaviors*. The mean value for gain in *MARPOL behaviors* (between pre- and post-test) for the 38 respondents in the control group is 4.3% (with a standard deviation of 6.6%). The mean value for the gain in *MARPOL attitudes*

for the 28 respondents in the group who received commitment and goal setting treatments is 14.6% (with a standard deviation of 10.3%). This represents an average increase of 10.4% in gain for the treatment group as compared to the control group. In other words, on average, respondents subject to treatment increased their *MARPOL behavior* by almost half of an increment on the 5-point Likert scale for agreement with the *MARPOL behavior* statements.

However, unlike for the gain analysis regarding effects of treatments (i.e. *commitment* and *goal setting*) on *MARPOL attitudes*; in figure 4, there is considerable overlap between the data for control group and the treatment group for gains in *MARPOL behaviors* of seafarers. This tends to indicate that, while there is a significant relationship, there is less certainty (or strength) in that relationship. This is also indicated in the coefficients of determination for the regressions lines fit to control and treatment gains in both *MARPOL attitude* and *behavior* ($R^2 = 0.1638$ compared to 0.3115 and $R^2 = 0.6012$ compared to 0.7901, respectively).

5. CONCLUSION

So, in summary, as in previous maritime studies involving safety culture, the descriptive regression analysis confirmed individuals who identified as culturally group- and future-oriented (and not self- or now-oriented) are positively disposed to pro-environmental (or pro-conservation) attitudes and behaviors. There was no evidence of mediating effect from treatments on the relationship between awareness and attitudes and behavior. Finally, the gain score analysis provided support that the treatments (commitment and goal setting) had a positive influence on pro-environmental (or pro-conservation) behaviors. On average, there was an 8.5% gain in attitude and a 10.4% gain in behavior, when the treatments of commitment pledge and goal setting were applied.

It should also be noted that even though the sample size was sufficiently large enough to be representative, this study was limited by the size, diversity, and scope of the sample. Future such studies should attempt to increase the size and diversity of participation. Additionally, since the study did not observe actual behaviors (which is extremely difficult), the study was based on self-reported attitudes and behaviors and may be subject known biases. Also, future studies should be expanded to explore other treatments that promote pro-compliance behaviors in other contexts (e.g., safety, security, etc.).

Regardless, there are several potential implications of this study. First, treatments such as commitment and goal setting have a strong potential influence to positively change pro-environmental attitudes and behaviors (those by seafarers about MARPOL V and plastics pollution in this case). This has a stronger potential than education and training alone to promote the desired attitudes and behaviors. Therefore, such treatments should be adopted in conjunction with traditional maritime training and education to more effectively and completely influence seafarer behaviors. Also, there is known spillover effects in that changes of behaviors in one domain (e.g., pro-environmental behaviors) may also “spill over” into improvements in attitudes and behaviors in other domains (or enhanced pro-compliance behavior elsewhere) [9].

Additionally, it is evident that culture matters and training likely needs to be tailored to specific cultures and also to shape culture. While this study resulted in hopeful results – that pro-compliance attitudes and behaviors can be effectively *motivated*, actions taken should be tempered until such time as additional and more extensive study can be completed because this study was limited by design and sample size.

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Proceedings

Technological Impact

Quantifying Fuel Consumption & Emission in Ship Handling Simulation for Sustainable and Safe Ship Operation in Harbour Areas

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Keywords: Fast manoeuvring prediction, Voyage planning, Simulator & On-board training, Emissions & fuel reduction.

Abstract:

There is a unique approach at ISSIMS-Institute called “Rapid Advanced Prediction & Interface Technology” (RAPIT): It provides instant visualization of the ship’s track for the intended rudder, thruster or engine manoeuvres, additionally the ship can be steered by a smart interface to allow for the involvement of the professionalism of a human operator for complex manoeuvres. This technology allows for a new method of manoeuvring support which is called “Simulation-Augmented Manoeuvring Design, Monitoring & Conning” – SAMMON. A unique software system was developed together with a small company to apply this method. A novel approach is the concept for the future integration of advanced engine process models, specifically for the transient engine behaviour to predict fuel consumption and emissions during non-steady operation during ships manoeuvres. Interfaced into the SAMMON Software it will enable the user to optimize ship manoeuvring actions e.g. with respect to effective measures for safe distances, shortest time or most effective and least environmental effect.

1. INTRODUCTION – CURRENT STATE

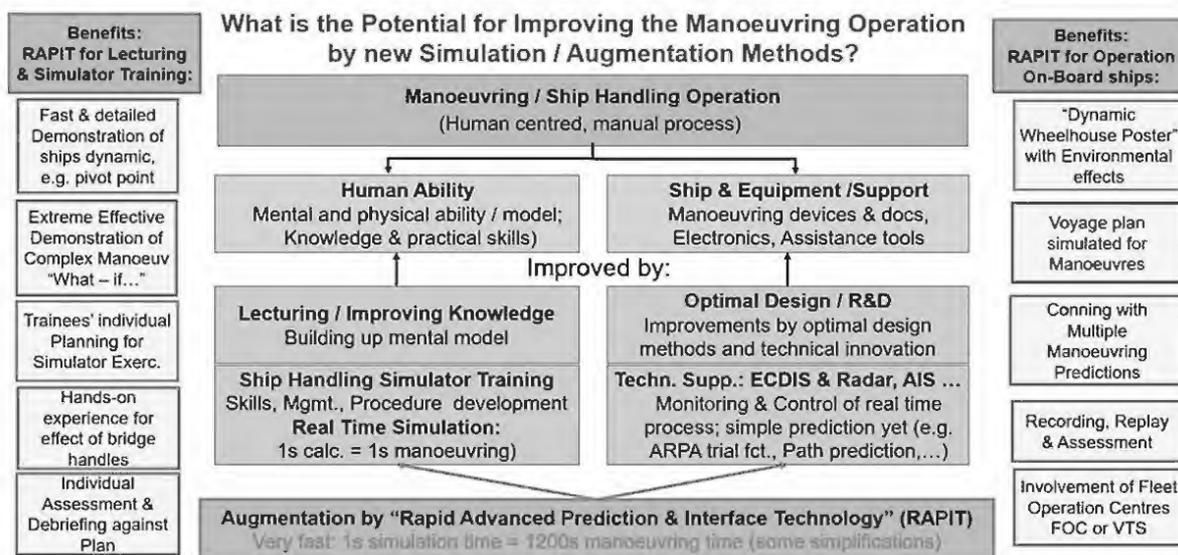
Digital models of maritime systems (nowadays also called „digital twins“) have been widely used in ship design for a long time, but now they become also important for the operation of systems, e.g. for manoeuvring ships – And not only for the well-known training in bridge simulators, but in future also for the real ship operation on-board, e.g. as assistance systems for decision support. In earlier papers we introduced specifically the use of mathematical models for Fast Time Simulation (FTS) of ships manoeuvring motion to support in planning and executing ship manoeuvres. The need of such a method, the operational concept of the innovative software and potential benefits were shown e.g. in [1] - [7] .

In contrast to conventional FTS concepts with autopilot control ([11] [12] which are already known for simple manoeuvres only, there is now a unique approach at ISSIMS which is called “Rapid Advanced Prediction & Interface Technology” (RAPIT): With this innovative simulation technology, based on complex dynamic models for ships manoeuvring motion, the ship can be steered by a smart interface to allow for the involvement of the professionalism of a human operator for complex manoeuvres.

This allows to operate the software manually by both:

- Students / young nautical officers for improving training skills and mental model of ship dynamic and
- Experts / professional ship handlers to make better use of their professional knowledge and skills and improve their performance for complex manoeuvres.

This innovative RAPIT technology allows for a new method of manoeuvring support which is called “Simulation-Augmented Manoeuvring Design, Monitoring & Conning” – SAMMON. A unique software system was developed together with a small company (ISSIMS GmbH [3]) to apply this method which consists of various modules. Fig. 1 shows the elements of manoeuvring and ship handling operation - and the potential of SAMMON: on the left side the great potential is shown for the support both for Lecturing & Simulator Training, and on the and right side the elements which could support the application on-board ships.



Key feature: Combining Fast Simulation with smart interface for professional human operation in sea chart for Simulation Augmented Manoeuvring Design, Monitoring & Conning - SAMMON –

Fig. 1 Process elements of manoeuvring operation and advantages by using Fast Time Simulation FTS in Lecturing & Simulator training as well as support on-board ships.

In Fig. 2 a list is given of the different SAMMON modules (centre) and the elements of using the tools in simulator training ashore (left) and for operation on-board ships (right). It should be highlighted that this software is unique also for training on-board supporting continuous learning. Now the modules of the system have matured and in this paper we will shortly describe some successful applications to show the benefits of the existing software but also to describe the future prospects. The main focus is on future improvements to extend the scope of application - from increasing safety and improving performance to also reduce fuel consumption and emissions during manoeuvres in future.

In Fig. 3 a sample is shown for successful application of the new software at Carnival Cruises Training Centre CSMART at Almere/NL: Two large Touch Screens are used for parallel Presentation & SAMMON application, complete manoeuvring plans can be made as concepts for full mission simulator exercises, not only by the instructor but also by the students which are using Laptops with mouse for operation of the Planning software.

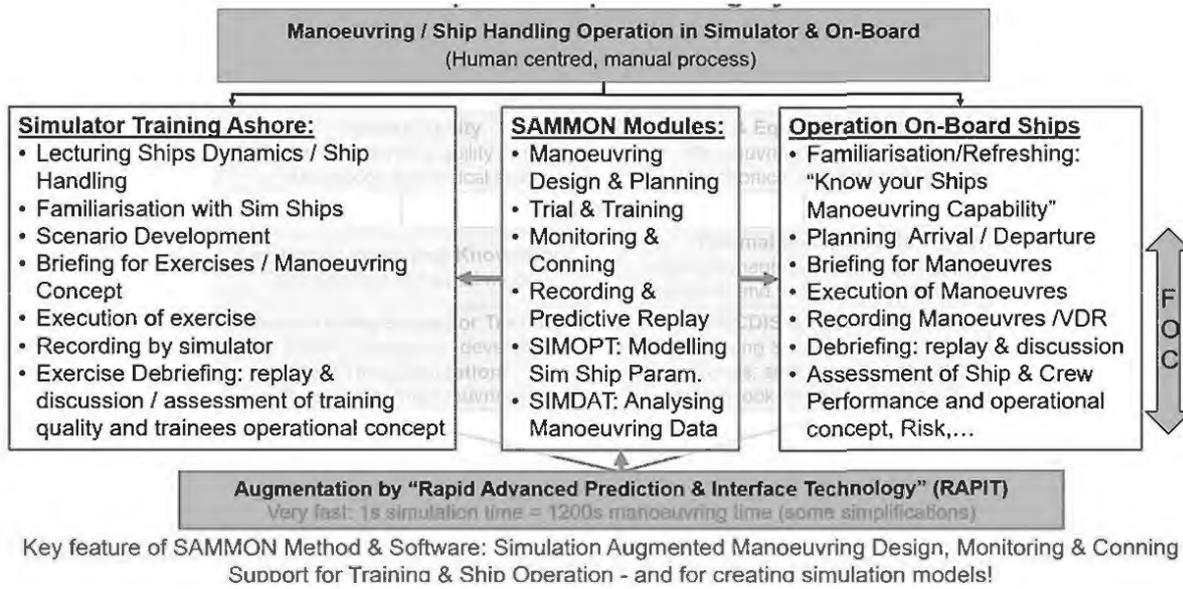


Fig. 2 Elements of Manoeuvring Training & ship operation and new SAMMON Modules/Tools to improve ship handling by innovative RAPIT



Fig. 3 Carnival Cruises Training Centre SMART: Lecturing & Training at Touch screen - “Rapid Advanced Prediction & Interface Technology” (RAPIT) is used in the SAMMON Planning for Lecturing effective turning of Cruise ships & wind impact in a Hong Kong arrival exercise

Now the new software is transforming from successful training tool to future use on-board for pre planning as new element in voyage planning for the final part for manoeuvres in ports. In Fig. 4 a sample is shown for planning a manoeuvre for a cruise vessel arrival. The ship manoeuvre is steered by the virtual handle panel on the right side, the resulting ships manoeuvring motion is immediately shown on the central ENC for up to 24 min ahead. Then the new manoeuvring point has to be chosen on that track to add the next manoeuvring segment with new control settings. The full procedure of planning takes about 10 min, this manoeuvre planning was explained in detail e.g. at INSLC 2018 [7].



Fig. 4 Manoeuvring Design & Planning Tool Demonstration: Planning of manoeuvring sequence for a cruise vessel for arrival at Ft. Lauderdale by Nautical Officer of AIDA Cruises on touch screen.

Fig. 5 is a demonstration of the Monitoring and conning tool where the FTS is used to display the result of the steering or engine control changes during the ship motion and using the bridge handles. For practical application in training and research the new FTS-features were interfaced to the new Full-Mission and Desktop ship handling simulator Systems, configured by benntec (MarineSoft) Systemtechnik GmbH, based on Rheinmetall Electronics GmbH bridge simulator software ANS 6000 [6] .



Fig. 5 Manoeuvring Monitoring & Conning Module – Demo of using bridge handles in to train “Touch and Feel” for Controls with Multiple Dynamic Prediction showing the effect of any control change immediately as future ship shape on ENC (SAMMON Demo on Bridge Simulator at benntec / Marinsoft Office at Rostock-Warnemünde Germany)

For the time being the SAMMON software is used to design manoeuvres with respect to safety (e.g. to ensure safe distances to limit lines and buoys) and feasibility of a concept (e.g. to make sure that the concept is also possible for high wind forces). In the following chapters will be shown how the software will be used to also allow for efficient manoeuvring procedures, i.e. to also compute the power consumption and analyse the use of controls. Moreover, sustainable

aspects of manoeuvring come into view: the software will be extended by modules to predict the fuel consumption and emissions will be added to the core system.

2. IDENTIFYING THE POTENTIAL FOR IMPROVEMENTS AND BENEFITS OF MANOEUVRING PERFORMANCE

2.1 Results from Test trials for Manoeuvres with SAMMON in simulators

In order to expect the possible range of consumptions different Test Trials in a Full Mission simulator had been carried out. The main task for a group of experienced nautical officers was to reach a certain destination, e.g. an anchorage, crossing a TSS and avoiding other ships at anchor. Every test candidate had to carry out different scenarios in order to eliminate bias due to the learning effect. The first attempt had to be carried out without prediction, a second one with prediction and the third one with prediction and manoeuvre planning. Every candidate had to make his own manoeuvre plan ahead, so that he can carry out his own individual concept. Fig. 6 shows a sample of the manoeuvring track generated by a candidate during the simulator trial. The blue line represents the track crossing the TSS to sail to the assigned anchorage position at the end of the track avoiding other ships at anchor.

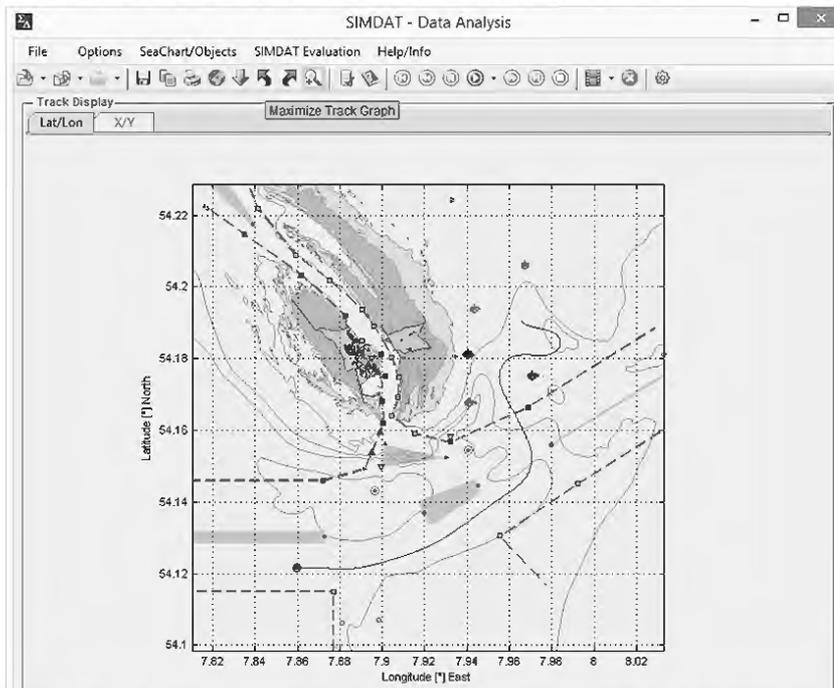


Fig. 6 Sample for manoeuvring track generated by candidate during the simulator test run

Fig. 5 shows the result of these test trials. The power consumption is dropping in average down to 80% with the sole use of prediction compared to a manoeuvres without any assistant tool. The power consumption is reduced to around 65% if the candidate has carried out its manoeuvres with pre-planning and on-line prediction. Additionally, the usage of the thruster drops around to half of the previous numbers. In Fig. 8 the average usage of rudder commands in these scenarios can be seen. The small rudder changes drop down to 60% in average.

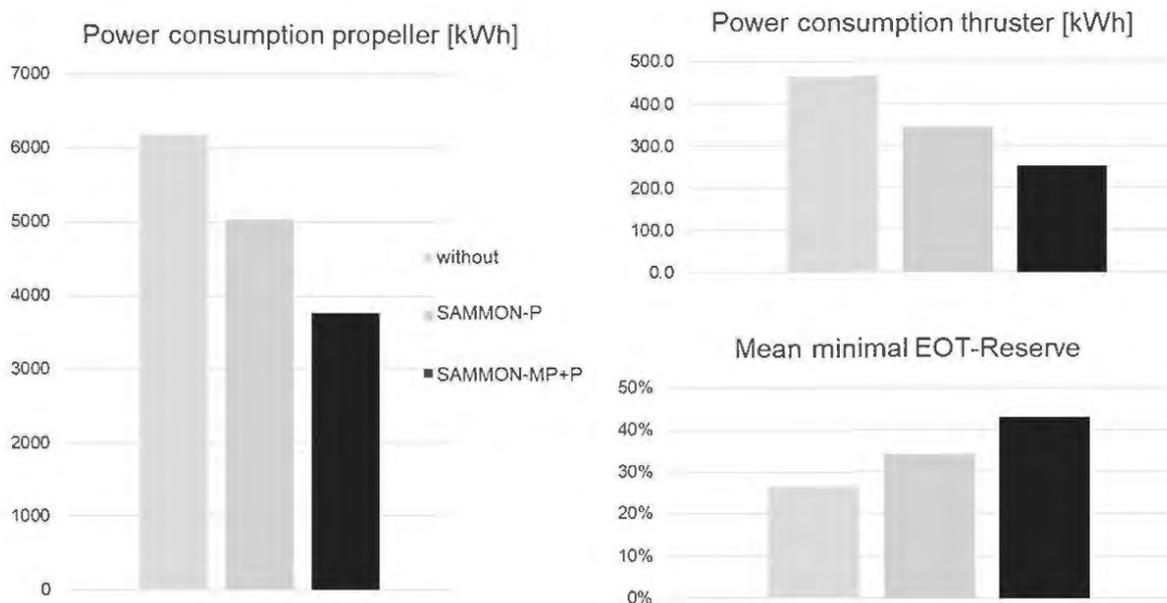


Fig. 7 SAMMON Advantage: Savings in Test runs with & without pre-planning and online-prediction

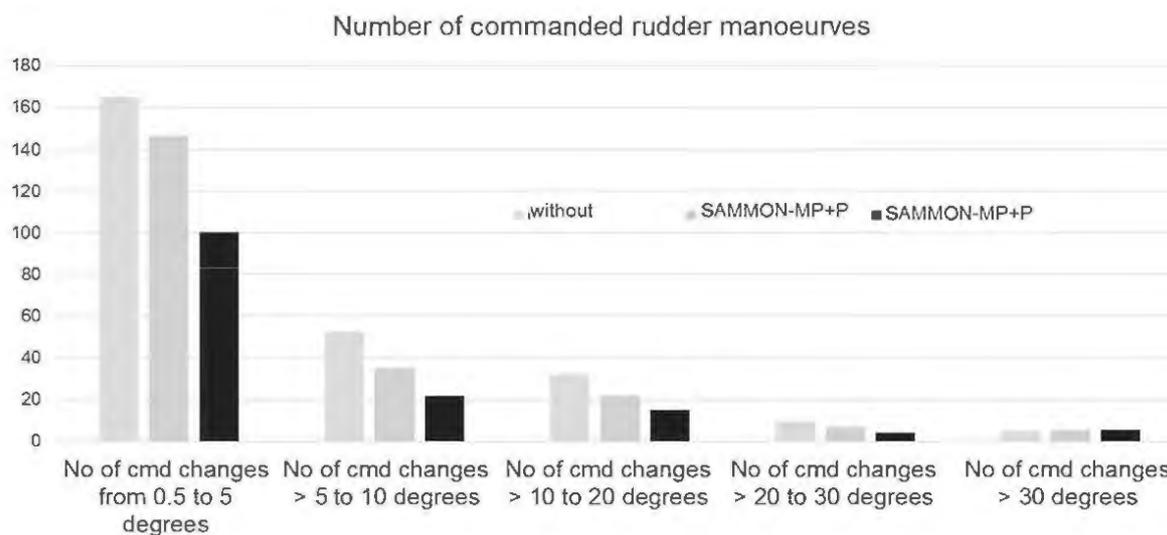


Fig. 8 SAMMON Advantage: Efficiency in Test runs with and & without pre-planning and online-prediction

For emphasizing the impact of planning and prediction in Fig. 9 the differences of rudder commands can be seen. On the left side are the rudder angles in one scenario without any prediction and assistant tools. On the right are the rudder angles displayed with planning and prediction. As a conclusion the amount and amplitude of rudder changes decrease clearly.

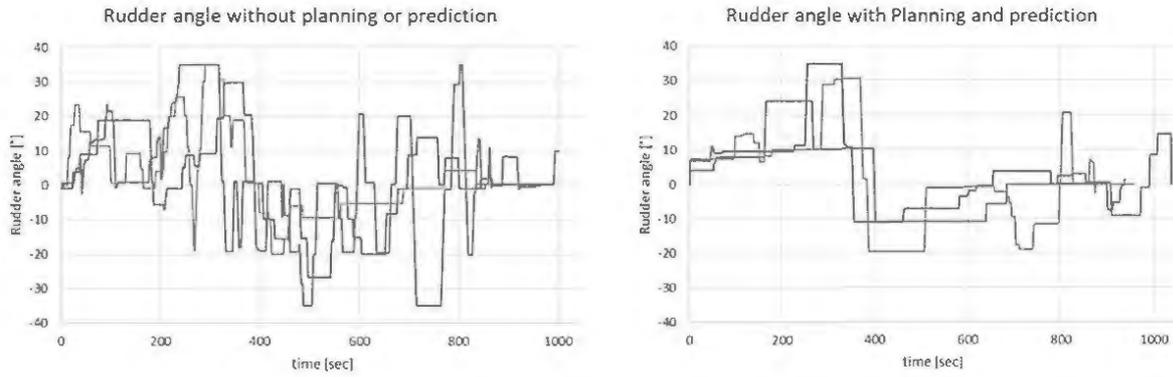


Fig. 9 Comparison of rudder angles during manoeuvring without (left) and with (right) pre-planning and online-prediction

2.2 Discussing Manoeuvres recorded for a Ro-Ro Ferry Arrival

In this chapter manoeuvres of a Ro-Ro ferry are shown which were recorded from arrival manoeuvres of the vessel at the Port of Rostock / Germany. An analysis will be made to find potentials for improvements of the manoeuvring performance. In Fig. Fig. 10 the tracks are displayed from 5 manoeuvres together with the last part of the route plan represented by the red dotted lines. It is obvious that normal route plans which are regularly only straight lines or circular segments are not suitable for the voyage planning regulation according to IMO which was already discussed and proposals were made to use the manoeuvring planning methods applying the RAPIT technology in the SAMMON planning tool to generate manoeuvring plans with Manoeuvring Points. In Fig. 11 one manoeuvre is further analysed which was the closest to the route plan. The time history of the commands to control the vessel manually and the ship responses reveals that there were many actions necessary to steer the vessel, some of them are alternating back and forth, left and right which is known to not be very efficient. As an alternative Fig. 11 b) the same manoeuvre under similar conditions was planned by means of the Planning tool – it is obvious that the controls needed not to be used so frequently and with smaller magnitudes. The responses e.g. the rate of turn is smaller and smoother. Additionally, the planned manoeuvre is about two minutes shorter than the real ship trial. The expectation is, that those manoeuvres with smaller control intensity are also smaller in fuel consumption and emissions.

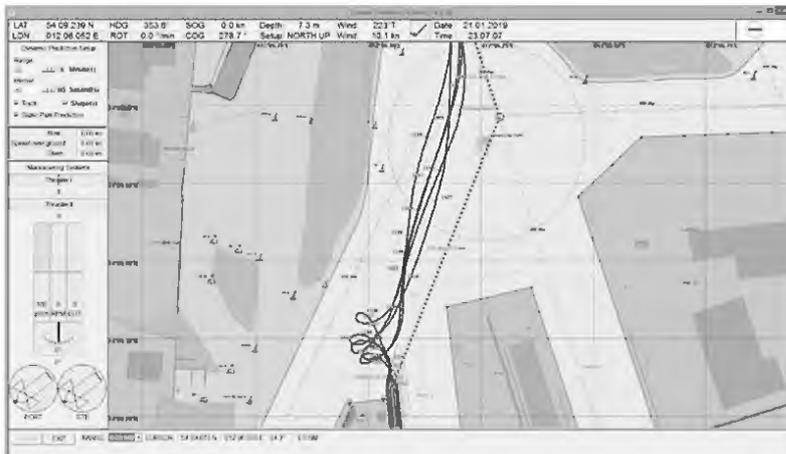


Fig. 10 Recordings of Five different manual controlled ships tracks (black) when berthing of a ferry in port of Rostock compared with the route plan (red dotted lines)

Table 1 – Comparison of power consumption during manoeuvring and berthing

Power consumption of each measurement		
Measurement	Consumption (kWh)	Percentage
0131	487.76	115%
0758	468.67	110%
1633	423.75	100%
2030	502.81	119%

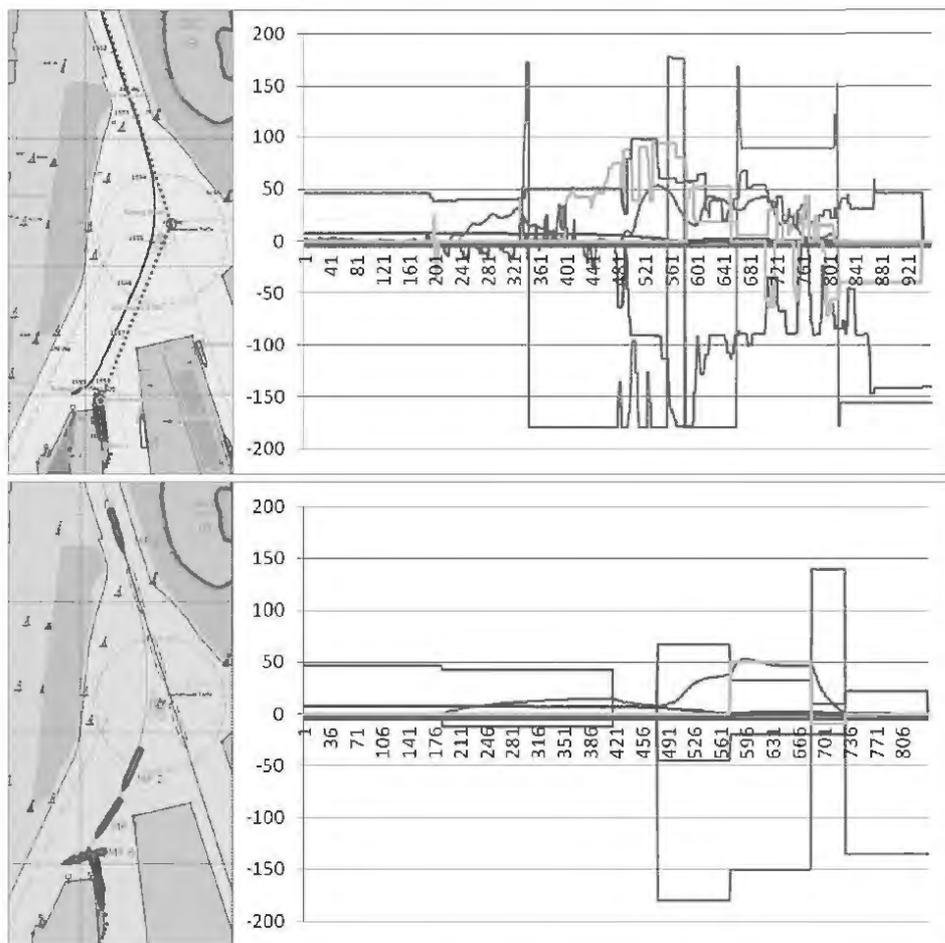


Fig. 11 Comparison of ships track (left) and time history of commands and ship responses (right) for a berthing manoeuvre of a ferry (POD power - yellow and green, POD angles - grey and blue, bow thrusters, power - salmon pink and light blue, speed over ground - dark blue, and the rate of turn - orange)

- a) recorded data from real ship manoeuvre
- b) Manoeuvring plan from SAMMON Planning tool with Manoeuvring Points to change commands at positions represented by the blue contours

To compare real ship manoeuvres it is necessary to gather data from the power output, caused by different manoeuvring approaches. Table 1 shows the differences in power consumption from the mole to the port carried out by different crew members under the same conditions i.e. low wind from the same direction, no current and no obstructive traffic. The measurements have been carried out over a time of 8 months and are leading in the way of differences in each measurement.

3. CONCEPT FOR FUTURE METHODS FOR CALCULATING FUEL CONSUMPTIONS AND EMISSION

3.1 Introduction into the Concept

In order to extend the software by modules to predict the fuel consumption and emissions the following two different approaches are followed as shown in Fig. 12. The first one as shown in chapter 3.1 is based on thermodynamic equations in order to calculate the NO_x and soot formation on a physical proven base. The second approach uses an artificial neural network (ANN) that could be trained by a variety of data bases e.g. a thermodynamic model like in chapter 3.1 or a set of measurements. Fig. 12 displays the concept of integration into the existing SAMMON model. It consists of the calculation of the existing ship's model including a simplified engine model in order to generate an engine torque for prediction. The engine model itself will be separated from an engine model and will consist of a PI-Governor for the calculation of the fuel consumption and of a detailed engine model or an ANN depending on the calculation speed, where the ANN can be trained using the data of the detailed engine model.

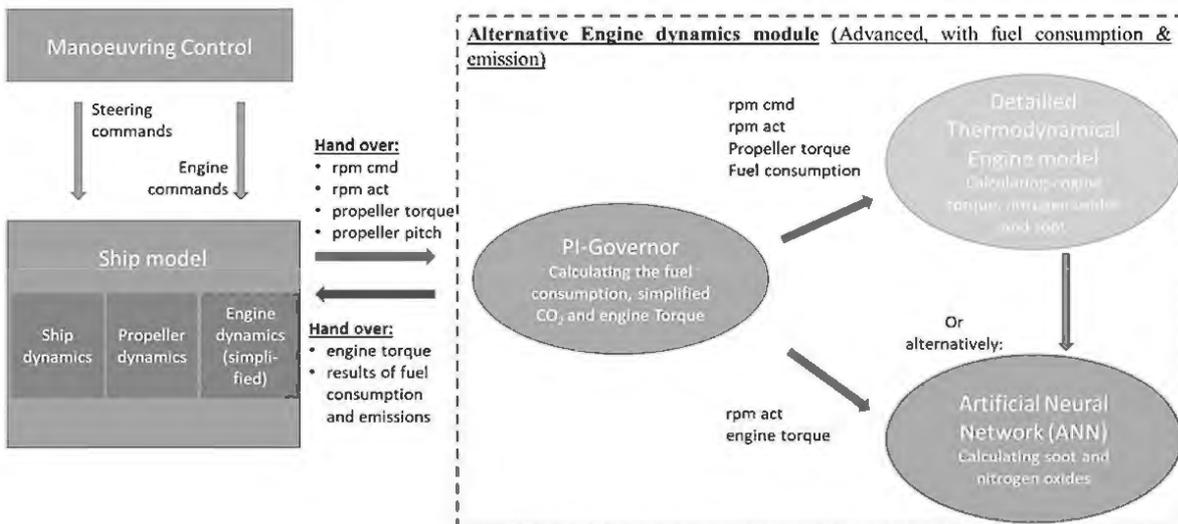


Fig. 12 Existing simulation model in the SAMMON system and intended expansion of advanced engine model

3.2 Thermodynamic simulation model for calculation of soot and Nitrogen Oxides.

The formation of soot and nitrogen oxides is strongly depending on the combustion process inside the engine. The NO_x – formation is determined mainly by the temperature inside the combustion chamber. The soot formation is additionally depending on the air to fuel ratio. The calculations of emissions are more or less an output of the fuel delivered by the governor. In order to achieve more realistic engine simulation it is necessary to model the governor and the automation system more precisely. In contrast to the existing simplified engine model (which is based on look-up table controlled processes) the signal of the Engine Order Telegraph will regulate the fuel flow to the engine and to the cylinder simulating the combustion process. The air intake into the combustion chamber is depending of the geometrical shape of the inlet valve, the opening and closing times and the charge air pressure before the combustion chamber. Also the turbocharger that is driven by exhaust gas has a substantial impact, its mass inertia is the main source for soot during manoeuvring. The main base for a calculation of the average temperature inside the cylinder is the basic energy balance (1).

$$\frac{dU}{dt} = -p \frac{dV}{dt} + \dot{Q}_B + \dot{Q}_W + \dot{H}_{BB} + \dot{H}_{in} - \dot{H}_{out} \quad (1)$$

The inner energy u in formula (2) can be ascertained by a function of temperature and air-fuel ratio λ according to [15]. The pressure volume work $p dV$ expresses the work carried out by the piston in the up and down movement during the compression or expansion phase. \dot{Q}_B is the heat released during fuel combustion. The time, duration and form of heat release can be described using approach in [16]. \dot{Q}_W is heat flow through the liner wall. The heat transfer coefficient can be calculated using the approach in [17]. \dot{H}_{in} and \dot{H}_{out} stands for the enthalpy flow through inlet and outlet valve.

$$u(T, \lambda) = 0,1445 \left[1356, + \left(489,6 + \frac{46,4}{\lambda^{0,93}} \right) * (T - T_{Bez}) 10^{-2} \right. \\ \left. + \left(7,768 + \frac{3,36}{\lambda^{0,8}} \right) (T - T_{Bez})^2 10^{-4} - \left(0,0975 + \frac{0,0485}{\lambda^{0,75}} \right) (T - T_{Bez})^3 10^{-6} \right] \quad (2)$$

With the thermodynamic average temperature it is possible to calculate the temperature of the flame front T_2 and the temperature of the unburned zone T_1 according to [18] and to estimate the formation of NO_x in (3), using the mechanism described in [19]. The Arrhenius-factor $k_{1,r}$ has the highest activation energy delivered by the temperature T_2 (detailed description can be found in [14]).

$$\frac{d[NO]}{dt} = k_{1,r}[O][N_2] + k_{2,r}[N][O_2] + k_{3,r}[N][OH] - k_{1,i}[NO][N] - k_{2,i}[NO][O] - k_{3,i}[NO][H] \quad (3)$$

Fig 13 is presenting the approach of the detailed engine model [14], that will be used to replace the simplified one in the ship's model.

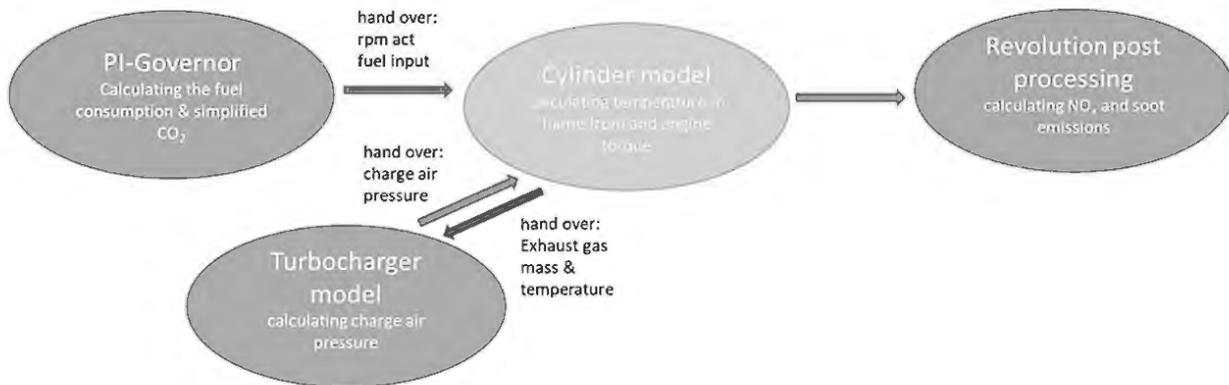


Fig. 13 Process overview of detailed engine model

3.3 Using an Artificial Neural Network (ANN) to be trained by Experiments for calculation of soot and Nitrogen Oxides

Purely data-based models do not need any information about the physical, chemical or other laws and relationships that determine the processes to be modelled. Attention is to be paid to numerous data of high quality covering as many input/output combinations as possible. Data can come from theoretical models or from test bed measurements. For the present studies the data is coming from the MAN 6L23/30 test bed engine. With respect to a restricted availability of input data from the ship model in the SAMMON software, only two input data will be

defined: The engine revolutions and the fuel consumption. For clarity, the following examples will only focus on the data-based modelling of particulate matters (PM) which consist mainly of soot. The process of soot formation is not yet fully understood and described and even less the formation of PM during transient engine operation. For this reason, it is of special interest to find a reliable data-based method to create an instrument in order to simulate the formation of PM. Furthermore, the following examples refer to the test bed engine running in generator mode. Generator mode means that the commanded engine revolutions are constant. The PI-governor is responsible to hold the revolutions as far as possible by adapting the fuel rack position.

Fig. 14 presents the particulate matters depending on the engine torque. Close to the zero-PM line, a couple of clusters can be seen. These are the measurements during stationary engine operation. The measurements used for the training and the validation of the data-based model are shown in Fig. 15. These figures make it evident, that during stationary operation in generator mode almost no soot is emitted. But as soon as increasing the engine torque the formation of PM rises to the hundredfold of the stationary values. In propeller mode, when engine torque and speed increase in parallel, the amount of emitted PM during transient operation differs even more from the values of stationary engine operation.

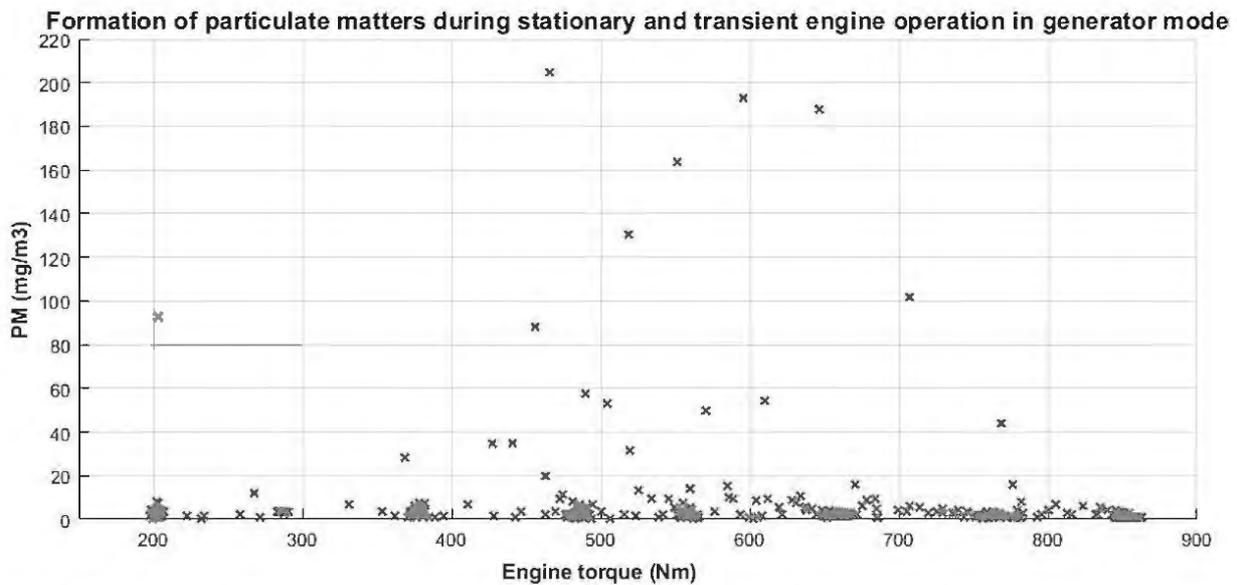


Fig. 14 PM emissions at different engine torques measured from the MAN 6L23/30 test bed engine

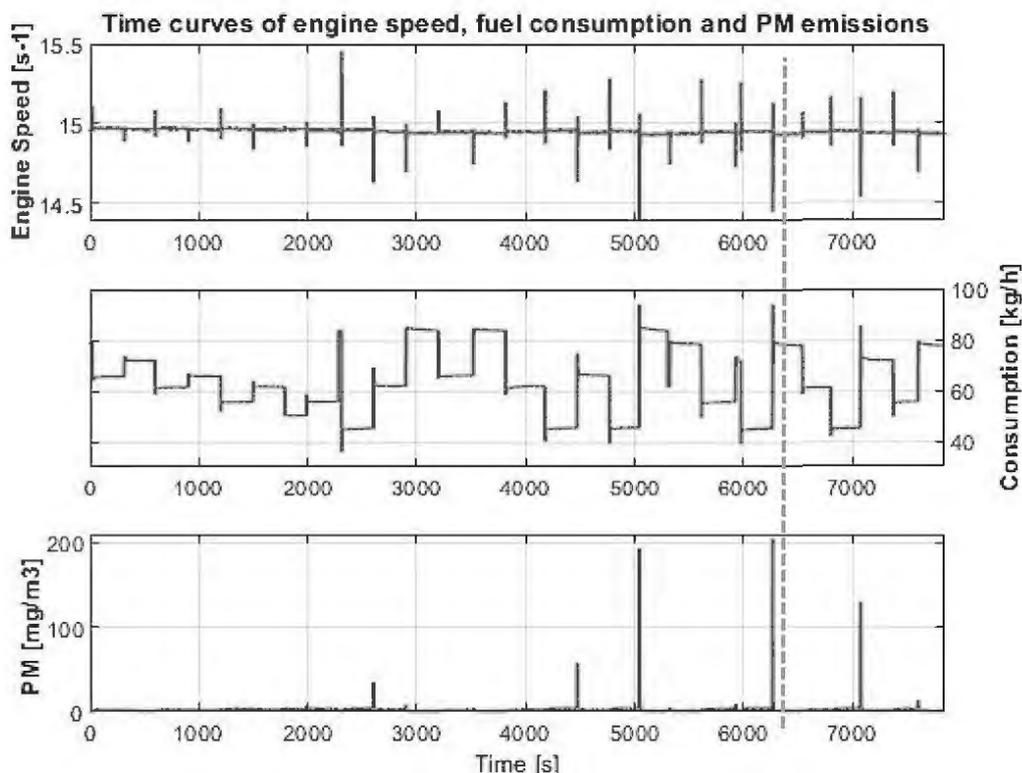


Fig. 15 Time curves of input and output data. Green dotted line shows the cut between training (75%) and validation (25%) data.

Among a big variety of data-based model architectures an Artificial Neural Network (ANN) architecture has been selected for a first attempt. Due to their flexibility regarding input dimensions and their relatively good interpolation characteristics they seemed to be adequate for the present study.

The observations presented above lead to the conclusion that PM formation during transient operation differs completely from stationary results at same load levels. Therefore, not only the inputs of the current time t_0 have to be considered in a data-based dynamic model but also their preceding values. Such a time delay neural network (TDNN), a so-called lumped dynamics recurrent network, leads to a multi-dimensional input vector exceeding the two input variables by multiples.

The Multilayer Perceptron (MLP), being a widely known ANN architecture was selected for a first approach. It consists of an input vector (u), one or more hidden layers with neuron vectors (h) and one output vector (y) as schematically shown in Fig. 16.

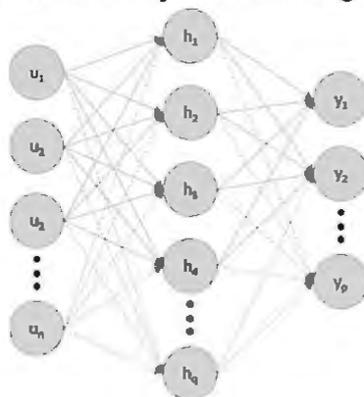


Fig. 16 MLP network architecture (inputs u , hidden neurons h , output y)

The neurons of the hidden layer are called perceptrons. All input data are multiplied by parameters (synaptical weights) in order to intensify or attenuate the input effect on the following neuron. All input signals are added up and the sum enters a nonlinear activation function that transforms the result which is then forwarded to the next layer. For the present study, a multiple-input single-output (MISO) network with one hidden layer is designed. In contrast to networks with internal dynamics the herein presented approach describes an external dynamic (lumped dynamics) network. For training purposes, the input vector contains measurement data of the input variables u and their time histories. The output value at t_0 is needed to determine the difference between the desired and the current network output. The difference is propagated back through the network in order to adapt the parameters (synapse weights). Due to the fact that the model is nonlinear in its parameters no direct optimization strategy is applicable. The Levenberg-Marquardt algorithm, a more robust extension of the Gauss-Newton algorithm, has been chosen for training with backpropagation.

First practical experiments with data from the 6L23/30 test bed engine have been performed by taking a data set of 15 load increases in generator mode (Fig. 15). 75% of the data served for training whereas 25% were retained for validation. The number of hidden neurons was set to 20 and the delay to 70 seconds, taking only one sample in ten cycles.

Fig. 17 shows the curves of the training data in green colour. The data points are almost totally covered by the blue curve displaying the simulation of the same data with the already trained network. This means that the network suits well with the dynamics of the training data except for the very high PM peaks.

For validation the last 25% of the measurement data set was taken. As already observed in the pre-validation making use of the training data (blue curve in Fig. 17) the network does not yet calculate the real height of the PM emission peaks. Zooming into the stationary simulation within Fig. 18 it can be stated that in the average the simulation suits quite well with the validation data, but there are a lot of small oscillations in the simulation.

This first attempt to simulate the dynamics of the PM emissions during transient engine operation by means of an ANN is a promising approach. Nevertheless, there is still work to be done in order to reproduce the emission peaks with more reliability and to get a smoother simulation. More training data will be provided soon, but in addition, a division of the ANN in part models as well as internal dynamics will be taken into account for further investigations.

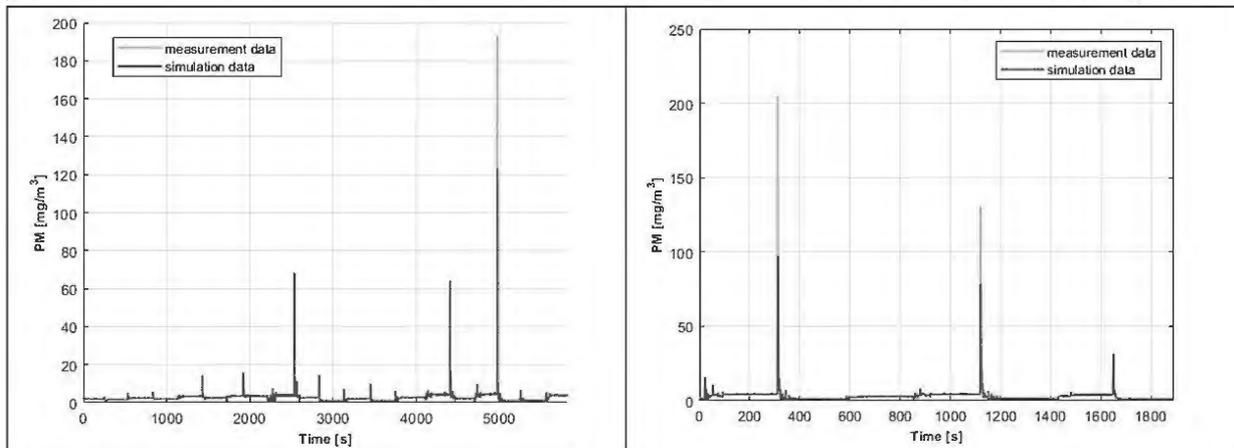


Fig. 17 Training data (green) and pre-validation by simulating with the same input data as used for training (blue).

Fig. 18 Validation of network by using the validation data set.

Recently, this trained ANN has been transferred to an interface for data exchange with the FTS ship model in order to simulate the fuel consumption and soot emissions during manoeuvres (Fig. 19). A model was generated for a fictive ship which size was adjusted to the size of the testbed engine. During the first few seconds, the ANN needs to collect data from its two inputs fuel consumption and actual propeller revolutions in order to calculate the output which is soot from the start at the green line.

Unfortunately, there is no possibility for validation, but for a qualitative verification of the method, which is working quite well. In future, measurements from a real vessel, e.g. the above mentioned Ro-Ro ferry, could be taken in order to train the ANN by data coming from a real ship.

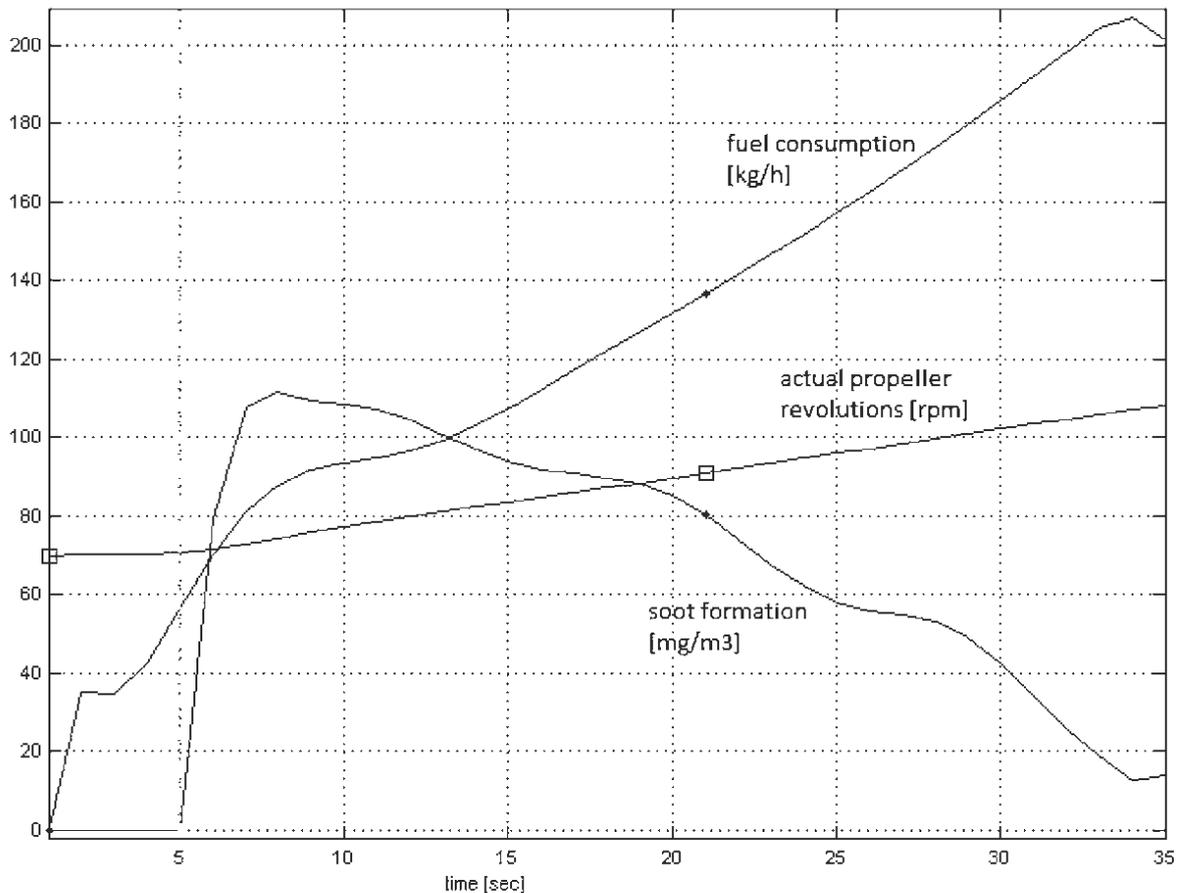


Fig. 19 Verification of network by using the trained ANN for a fictive ship model with FPP for acceleration from 20 to 90% EOT

4. CONCLUSIONS / OUTLOOK

Fast Time Manoeuvring simulation and specifically the new technology “Rapid Advanced Prediction & Interface Technology” (RAPIT) as core element of the unique SAMMON method for Simulation-Augmented Manoeuvring Design, Monitoring & Conning has proven its benefits for both lecturing and training for improving ship handling knowledge and skills. It can be used as an individual training tool but unfolds its potential interfaced to a full mission simulator which is successful implemented with the Rheinmetall Electronics ANS 6000 Ship

Handling Simulator, manufactured and distributed by MarineSoft / benntec. It increases the effectiveness of simulation training which can be seen in the fact that the success rate of the trainees is increasing: An analysis has shown that navigators are able to successfully manage demanding ship handling exercises after preparation & briefing using the SAMMON planning tool and even more to perform the manoeuvres with less power consumption.

This shows there is a high potential for optimisation to reduce manoeuvring time and power consumption due to less and better adjusted control action during the manoeuvres. A first approach was shown how to introduce modules for estimating fuel consumptions & emissions during the manoeuvring process based on thermodynamic simulation models and Artificial Neural Networks. For the time being the ANN model was trained only for a small diesel engine from our Ship Engine Lab, but in future also measurements with real ship engines will be used to achieve higher realism.

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The professional version of the SAMMON software has been further developed by the start-up company Innovative Ship Simulation and Maritime Systems GmbH (ISSIMS GmbH) [3] .

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Engine Room Simulator Training for Emergency Preparedness

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ABSTRACT

Autonomous shipping demands reliable propulsion and auxiliary machinery, zero down time, low environmental footprint and intelligent operators who can make correct decisions and take appropriate actions in a timely fashion. While the first three relate to technological advancements and appropriate operational practices, the latter depends on the knowledge, skills, competencies and attitudes of the operators. This requires adequate training to ensure that operators respond effectively in all situations. Thus, the training regimes for operators must employ suitable strategies within an appropriate context to impart the required competencies. As accident investigations indicate human errors account for more than 80% of all marine accidents and thus operators must be trained with essential competencies to deal with emergency situations arising from operation, breakdown and accidents. This paper explores the potential of full mission engine simulators to train operators to handle emergency situations in autonomous ships to reduce the risk of financial losses and effects to the environment.

AUTONOMOUS SHIPS AND THE CHALLENGES AHEAD

We live in an era of transition to autonomous shipping. The maritime world has seen a surge of stakeholders take an active interest in the development and innovation of the technology of autonomous shipping. In 2017, Rolls Royce and Svitzer successfully demonstrated the world's first remotely operated commercial vessel in Copenhagen, Denmark [1]. Continuing the trend, the most discussed autonomous ship, Yara Birkland, will be delivered in the first quarter of 2020. It will initially undertake manned sailings, gradually switching to fully autonomous mode by 2022. The 120 TEU-capacity vessel will incorporate a ballast-free design and run on battery power [2]

Like most new technological inventions, autonomous shipping will also have its fair share of teething problems, but the factors demanding automation and the advancement in technology will drive the world shipping towards more autonomous ships in the near future. Although the technology takes over the human operation in normal running of ships, the emergency situations may still warrant human intervention.

An emergency is defined as a serious, unexpected, and often dangerous situation requiring immediate action [3]. In the transition to autonomous shipping, it is important to observe how the remote operators tackle the emergencies, which may have serious legal implications for ship owners, flag states, coastal states and overarching international instruments of International Maritime Organisation (IMO) and United Nations Convention on Law of the Sea (UNCLOS). In brief - Regulation of autonomous vessels and legislation dealing with their safety, manning and operation remains a particular challenge both nationally and internationally [1]. Ultimately the success and benefits of autonomy depend not by enacting new laws, but by intelligent operators, who make the correct decisions in an emergency. There is some validity in the statement when sceptics say, still the human operator can make human errors [4, 5]. Incidentally on autonomous ships, the human who makes the error is not on-board, but in a remote operating point. The fact is that the context of the situation or the role of the person who handles it has not changed. This fact leads us to believe that the training and upskilling of the remote operator to handle emergencies is crucial for future autonomous shipping.

EMERGENCIES LEADING TO CRISES SITUATIONS

The range of emergencies that could arise in an engine room during autonomous operation can be summarized as: Operational, Break-down and Accident. The operational emergencies arise mainly due to weather conditions rendering machinery malfunctions. The break-down emergencies occur due to failure of critical equipment due to design and maintenance faults or fatigue. The accidents may cause situations from fire to flood in the engine room.

Consequences of these emergency situations will be limited to financial losses and/or environmental effects if the vessel is autonomous. As there won't be any personnel on-board it is unlikely that there will be any casualties. However, in the transition when ships are operated with a skeleton crew, in addition to above, there could be casualties as well. Preparedness is the best way to handle such emergencies. The degree of preparedness for envisaged emergencies can mitigate the consequences of an event. Software-based simulators could be used to a greater extent in improving the preparedness as modern engine room simulators come with the capability of creating a raft of emergency situations without incurring any substantial cost.

SOFTWARE BASED SIMULATION FOR EMERGENCY PREPAREDNESS

Recent developments in software-based simulators revolutionised the way operators are trained. In fact, software used in these simulators are the same used in the actual plant and thus the training has become more effective. The only difference is that in real plants the software operates with real machinery while in simulators they operate virtual machinery. Nevertheless, the virtual machinery behaves in the same way as real machinery work. This is achieved with the use of mathematical models incorporating real life parameters.

Even though the best way to acquire practical experience is to learn in a real engine room, logistic issues and safety requirements are often not in favour for on-board training and thus, engine room simulators have become a popular alternative. Apart from that, decision-making in a simulator environment opens a unique possibility to monitor the behaviour of the trainee closely and evaluate the effect of the decisions.

The opportunities to experiment on specific problems and get answers on questions such as: "what happens if?" without leading to wrecking of components and resulting in off-hire costs are unique advantage of simulators. In addition, a simulator gives an easy introduction and contextualisation to background theories through the realistic operation [6]. The most important advantage of a simulator exercise is the fact that it can be recorded and played back for those who participate in the exercise and de-briefed on the actions and responses. This debriefing is unparalleled in any other form of training where it is difficult to record each and every action of trainees during an exercise. Debriefing allows the trainers to analyse the thinking pattern and decision-making capability of trainees, so that trainees can be advised how appropriate and timely corrective action can be taken. On the other hand, debriefing allows trainees to review their actions and correct them as necessary. It provides a very effective pathway for learning through 'mistakes' they make in a situation so that they get a lifelong lesson.

EMERGENCY PREPAREDNESS

This is a general topic involving emergencies of any magnitude anywhere anytime. It may involve "man-made" emergency events or catastrophic events of the nature. Preparedness is one phase of management of the event to mitigate the consequences. The preparedness also goes further to response and recover phases. However, we limit our research into response only as it is what we need to train engineers in the transition and remote operators for autonomous ships. Emergency preparedness is not a new concept for seafarers. It has been continually practised in the past as 'the Saturday Routine' on-board ships. Safety of Life at Sea (SOLAS) regulations now demands certain familiarization and safety routines to be carried out more often as appropriate. Even in the current context, the emergency preparedness involves how to fight a fire or abandon the ship. Fighting a fire involves a 'mock fire' rather than a real one. Abandoning the ship is just symbolical. The crew takes their assigned positions and duties mechanically, knowing that it is an exercise. A seafarer gets used to this routine in no time and will not tend to treat it as a serious exercise. On the other hand, we cannot create real emergencies such as a flooding of the machinery space or a crankcase explosion on a Saturday Routine. It is not feasible to create a real emergency as that is not practicable as the cost of such will be unaffordable for any shipping company. Further, even an emergency that can be created without any cost will not be exercised by the ships' personnel for the fear of the unknown. An example is the verification of the starting of emergency generator and connecting it to emergency busbar in case of a blackout. This is a normal Saturday Routine test done as explained below:

For the testing of the automatic starting and connection to the busbar of the emergency generator, in the event of a main power failure, there are two TEST buttons in the emergency generator control panel:

TEST 1: *when pressed will start the emergency generator, but it will not connect to the emergency busbar. It ensures that the emergency generator responds to a power failure.*

TEST 2: *when pressed will start the emergency generator and connect to the emergency busbar after disconnecting the main busbar connection. It ensures that the emergency generator starts up and connect to the busbar within 45 seconds of a main power failure, which is a SOLAS requirement [7]*

This operation will not cause a “blackout” of the ship if you test it under normal circumstances. There will be a momentary power loss to emergency lighting circuits and some Navigational equipment. The only precautions that the engineers must take are:

1. running the steering gear motor that is connected to the mains power.
2. informing the bridge of temporary loss of power to some equipment and lighting.

Students inquiries revealed that only half of the engineers on-board their ships agreed to press the TEST 1 button while the ship is at sea for “testing of the emergency generator during Saturday routine exercises”. The alarming sign is that none of the engineers have agreed to press the TEST 2 button at sea, even though it is quite safe to conduct this test. This is a clear indication of the lack of confidence of engineers due to shortcomings in training. This lack of confidence leads to a chain reaction [8] of other erroneous actions when an operator is handling an emergency situation for the first time. Generally, marine engineers are reluctant to operate machinery if they haven’t operated this equipment before for the fear of the unknown.

EMERGENCY MANOEUVRING WITH RESTRICTED ELECTRICAL POWER

A very common notion among the engineers is the amount of redundancy that a ship must have in terms of the electrical power supplying generators in an emergency. SOLAS Chapter 1 Part D states that:

“Regulation 41 - Main Source of Electrical Power and Lighting Systems”

1.1 A main source of electrical power of sufficient capacity to supply all those services mentioned in regulation 40.1.1 shall be provided. This main source of electrical power shall consist of at least two generating sets.

1.2 The capacity of these generating sets shall be such that in the event of any one generating set being stopped it will still be possible to supply those services necessary to provide normal operational conditions of propulsion and safety. Minimum comfortable conditions of habitability shall also be ensured which include at least adequate services for cooking, heating, domestic refrigeration, mechanical ventilation, sanitary and fresh water. [7]

In most ships there are 3 generating sets making a 200% redundancy. Students mistakenly think that ships need at least 2 generator sets for normal operation and refuse to leave / enter a port without additional tug assistance, if a generator is out of action. In an emergency if two generators are out of action, students refuse to manoeuvre the ship with one generator. Almost all students (over 400 at AMC during the past 7 years) stated that a ship cannot be run with one generator although they are aware of the SOLAS regulation to the contrary.

Facing emergencies similar to above can be best demonstrated with a full mission simulator at zero cost. The exercise designed and developed shows how to handle a critical situation when it is required to enter a port with only one main generator working. Students learn how machinery can be prepared for this emergency by following logical steps. The strategy they employ is proved capable by effective use of all the resources available in this instant.

MODERN 3-D SIMULATORS FOR EMERGENCY PREPAREDNESS

The new safety simulators for advanced firefighting have 3-D walk-through engine rooms with X-Box control that enables trainees to explore all areas of the virtual engine room or accommodation. The simulator features visual models such as equipment for the fire teams, doors, lights, fire, smoke and people. Corridors, stairs, cabins, offices, lockers, storages, emergency exits, firefighting and lifesaving equipment are all available in the 3-D environment. Exercises can be conducted allocating various tasks to each team such as firefighting and search and rescue operations. The communication between the teams is monitored by the instructor and can be recorded and debriefed for further improvement.

Another critical emergency on board a ship can be the flooding of the machinery space. The emergency preparedness involves restricting the flooding and pumping out the water. If the flooding is due to a breach of the hull it will not be possible to restrict flooding unless it is in a watertight compartment for an autonomous ship. The modern simulators can be employed to demonstrate how a major flooding is controlled by pumping out water with main seawater pumps through bilge injection suction. The simulator clearly shows the flooding rate and the pump flow rate in addition to the 3-D view of rising / falling water level. In this exercise, students learn that pumping out of water is carried out in an un-conventional manner. However, it is very effective and most probably the only way to save the ship.

Experiencing a crankcase explosion can be the worst nightmare for a marine engineer. Monitoring the progress of a hot spot in the crankcase towards an explosion can be best demonstrated by a simulator. This could be emulated by disabling certain safety features of the simulator exercise to measure the judgment and decision-making ability of the student. Students are encouraged to use trend diagrams which play a very critical role in decision-making. The emergencies of this nature need early detection and remedial action.

THE DIGITAL TWIN AND THE EMERGENCY PREPAREDNESS

A digital twin is a virtual model of a process, product or service. This pairing of the virtual and physical worlds allows analysis of data and monitoring of systems to head off problems before they even occur, prevent downtime, develop new opportunities and even plan for the future by using simulations. Digital twins are becoming a business imperative, covering the entire lifecycle of an asset or process and forming the foundation for connected products and services. Companies that fail to respond will be left behind.” [9]. Current trend is to have digital twins for ships being built alongside the real ship. These digital twins will be the training models for remote operators of both autonomous and semi-autonomous ships of the future. The digital twin will represent the real ship in all aspects. This makes it even better for emergency preparedness as it represents both real hull and the machinery.

CONCLUSION

As the technology advances it is inevitable that the machines gradually take over the role of humans. It can be debated that the take over of controls by machines is better as machines do not make errors like humans. However, in the transition to autonomy and in certain emergencies human intervention is still required. In this context, a question arises as to the training of the human operator since the human element is gradually fading away in ships. In this context, with the prominent advantages, modern full mission simulators with walk-through functions will be the best solution for training future operators and engineers for emergency preparedness.

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Cybersecurity in the maritime industry: a literature review

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ABSTRACT

Cybersecurity has become an important issue in the maritime industry due to many reported cyberattack incidents that caused a lot of economy loss, personal or company information breach, and so on. However, there is limited research for maritime cybersecurity in the existing literature. This research aims to identify threats influencing cybersecurity in maritime operations and their control options through a state-of-the-art literature survey. A list of cyberattack incidents in various industries are presented. By restricting our attention to the maritime industry, this research identifies three maritime cyber threats, including the lack of training and experts, the use of outdated system, the risk of being hacker's target. To deal with the identified threats, a number of mitigation strategies are also proposed in this study, including developing cyber security process, providing cybersecurity training course, updating and upgrading programme regularly, and fostering cybersecurity climate.

1. Background

Around 80% of international trade is transported by sea [1]. At the same time, increased communication in international trade causes higher concerns on cyber-attacks as an emerging issue to maritime operations [2]. For example, Maersk, the largest container shipping company in the world, suffered a cyber-attack in 2017, which led to a loss of \$200-300 million [3]. The COSCO terminal in Port of Long Beach was cyberattacked in 2018 [4]. These cyber-attacks emphasize the importance of cybersecurity in the maritime industry as they caused not only economy loss, but also personal or company information breach, companies reputation harm, etc.

Cyber-attack incidents have resulted in unquantifiable losses of monetary assets, intellectual property, and customer confidence [5]. However, to the best of authors' knowledge, there is limited research for maritime cybersecurity in the existing literature. In the aspect of maritime cyber risk, it has been defined as a measure of the extent to which a technology asset is threatened by a potential circumstance or event, which may result in shipping-related operational, safety or security failures as a consequence of information or systems being corrupted, lost or compromised [6].

In order to deal with hazards in the maritime industry, risk management is fundamental to safe and secure shipping operations. Risk management has traditionally been focused on operations in the physical domain, but greater reliance on digitization, integration, automation and network-based systems has created an increasing need for cyber risk management in the maritime industry [6]. Compared to other industries such as military, financing, airlines, cybersecurity related studies in the maritime industry is sitting at the backseat (e.g. ten to twenty years behind other computer-based industries [7]). In light of the above evidence, the authors have found that the cybersecurity in the maritime industry needs to be addressed in urgency. This research thus aims to identify threats influencing cybersecurity in maritime operations and their control options through a state-of-the-art literature survey.

The rest of this paper is structured as follows. Section 2 reviews the definitions of cybersecurity and revisits cyberattack incidents in various industries. Section 3 identifies the cyber threats within the maritime industry. Section 4 proposes the potential control options. Discussion and conclusion are drawn in Section 5.

2. Literature review

2.1. The definition of cybersecurity

It has been used in a wide range of academic disciplines including computer science, engineering, political studies, psychology, security studies, management, education, and sociology [8]. Cybersecurity is commonly defined as “the protection of cyberspace as well as individuals and organizations that function within cyberspace and their assets in that space” [9]. [8] also re-defined cybersecurity as “the organization and collection of resources, processes, and structures used to protect cyberspace and cyberspace-enabled systems from occurrences that misalign de jure de facto property rights”.

2.2. Cyberattack incidents

The top 5 industries at greater risk of cyber-attack are government, financial services, manufacturing, education and law [10]. For instance, Department of Justice in the U.S was

hacked in 2016, and it took a week for the organization to recover the system [11]. Equifax, an American credit company, had suffered a cyber-attack in 2017 and caused 143 million customers' personal data were hacked, as well as 200,000 credit card numbers [12]. Marriott hotels had suffered cyberattack in 2018 and 500 million customers' personal data were hacked [13].

2.3 Maritime cyberattack incidents

Comparing to the past, more and more maritime cyberattacks are reported in this decade due to the development of ICT and largely rely on such technology in the maritime industry. Table 1 lists the reported maritime cyberattack incidents from 2001 to 2018.

Table 1 Maritime cybersecurity incidents

Year	Organization	Details
2011	IRISL	An Iranian shipping line, IRISL, were cyberattacked in 2011 and lost all data related to rates, loading, cargo number, date and place. [14]
2011-2012	Port of Antwerp	Drug traffickers hired hackers to breach IT system of Port of Antwerp. Hackers accessed secure data giving them the location and security details of containers which contained heroin and cocaine. [15]
2012	Australian Border Force	This incident allowed criminals to check whether their shipping containers were regarded as suspicious by the Customs authorities. [16]
2012-2014	Danish Maritime Authority	Danish Maritime Authority was subjected to a cyberattack from 2012 but been discovered until 2014. The attack was introduced by a PDF document infected with a virus, and the virus was propagated from the Danish Maritime Authority to other government institutions. [17]
2013	Mobile Offshore Drilling Unit	A group of hackers remotely attacked a floating oil rig off the Gulf of Mexico and gained control of its stabilization systems and programmed the platform to tilt dangerously to one side. The platform had to be shut down for 19 days. [18]
2016	Korean vessels	South Korea reported that 280 vessels suffered problems with their navigational systems. The GPS signal was jammed by hackers; consequently, some of the GPS signals died and others received false information. [19]
2017	Maersk	Maersk, the largest container shipping company in the world, was cyberattacked by a ransomware (NotPetya) in 2017, which shut downed Maersk's network system. It took almost three weeks to recover and caused a \$200-300 million financial loss. [3]
2018	COSCO terminal at Port of Long Beach	COSCO terminal at the port of Long Beach has been attacked by ransomware in July 2018 and took 5 days to recover. However, they did not suffer serious financial loss, as they took a lesson from Maersk incident in 2017 and separated their network in different servers. [20]

2018	Port of Barcelona	Hackers attacked several servers in the port's security infrastructure, without interrupting the maritime and land operations. [21]
2018	San Diego Port	The attack had not stopped vessels or boat using the port, or put members of the public in danger. The main impact would be on the issuing of park permits, public records requests and general business services. The Port said some of the disruption was because of staff shutting down computers that were in danger of being compromised as the ransomware started to spread. [22]

Based on the above cyber-attacks reports, it can be found that the number of cyber-attack incidents in the maritime industry are increasing in this decade. The impacts of maritime cyberattack include economy loss, personal or company information breach, company's reputation harm, etc. Therefore, maritime cybersecurity is becoming an important issue that needs to be emphasized more than before.

3. Threats identification to maritime cybersecurity

This section identified several threats that impact on cybersecurity in the maritime industry from the existing literature, including the lack of training and expert, the use of outdated IT system, the risk of being hackers' target, and fake website and phishing email.

3.1. Lack of training and expert for cybersecurity

Human error has been previously identified as the most significant factor that causes around 80-90% of shipping accidents directly and indirectly [23], [24]. Human can be tired to make some mistakes that cause cyberattack incidents [25]. Cyberattacks might also come from unintentional actions via individuals with little or no cybersecurity training and awareness [26]. This allows malware to deliver through individual's activities. For example, computers are infected by accidentally open unknown e-mail and access false website with virus.

3.2. Use of the outdated IT system

[27] and [28] analysed vulnerability of cybersecurity in the maritime industry and found a major problem as the over reliance on outdated technology and security practices. For instance, maritime employees still believe that firewalls and antivirus software are sufficient to deal with cyberattacks. However, hackers can attack through viruses and other assorted malware and it is difficult for traditional antivirus software to deal with such advanced cyberattacks [27]. On the other hand, as large ships are expensive and take a long time to build, many ships were built before cybersecurity as a major concern. Thus, some vessels are still operating through outdated software systems that might cause cyberattack [28].

3.3. Risk of being hackers' target

Hactivism is the most common threat for cybersecurity in the maritime industry [6]. Hactivism has two types of actions: targeted and untargeted [26], [29], [30]. Targeted attacks refer to a company or a ship's systems and data are the intended target, hackers usually use tools and techniques specifically created for a company or ship; whereas untargeted attacks are likely to use tools and techniques available on the internet, which can be used to locate,

discover and exploit widespread vulnerabilities that may also exist in a company and on-board a ship [29].

[31] suggested that cyberattack with purpose would be practiced by three categories: hacktivism or activist group, terrorist group, and criminals. For hacktivism or activist group, they are made up of ideologically motivated people, for whom the main action is an online protest aimed at accessing the system and stealing sensitive information and data for malicious purposes. For terrorism, they can use electronic and computerized media as a new modus operandi to carry out their terrorist acts against other groups, nations, and companies, gaining access and interrupting the operating system, for ideological, religious or political interests or purposes. For criminals, individuals or criminal organizations use cyber-attacks against interconnected systems and networks, with the intention to carry out criminal activities, mainly focused on fraudulent operations, extortions or theft of intellectual property. It is also recognized that these criminals, when they obtain access to the different systems, can control operating systems to facilitate the trafficking of drugs, arms and contraband money to obtain economic benefits or to sell valuable information to another.

3.4. Fake website and phishing email

Sea crew using private devices (e.g. smart phone, tablet, personnel USB device, etc.) could cause cyberattacks through accessing fake websites and phishing emails, and further installing malicious virus into vessel system [32]. Malware is one of the well-known malicious software, which assesses or damages the victim's devices without the knowledge of the victim, and spread by opening infected email attachments or access fake website with malicious malware program such as Trojan horses, worms, exploits and backdoors [33]. Cyber incident of Petya and Notpetya have spread over the world recently. The idea of ransomware attacks is, encrypting and locking the files on a computer until the ransom is paid. These attacks usually enter the system by using Trojans, which has malicious programs that run a payload that encrypts and locks the files. The basic goal of this type of attack is getting money, so hackers usually unlock the files when they receive the money [34].

4. Risk control options for cyberattacks

4.1 Develop cybersecurity process

[6] and [29] recommended the functional elements that support effective cybersecurity process: identifying, protecting, detecting, responding, and recovering. In fact, there were some changes of cybersecurity process after huge cyber incident such as Maersk in 2017. COSCO has learnt the importance of cybersecurity process, and divided data in several servers. Therefore, when they suffered the cyberattack in 2018, they cut down the connection of the infected server and operated through other non-infected servers. In addition, their quick response and notification to customer was the reason to minimize risk of cyberattack [35].

4.2. Education and training for cybersecurity

In order to deal with the threat of lack of training and expert for cybersecurity, training sea crews and staffs may be an effective method to enhance maritime cybersecurity. [28] suggested that ship crews can be educated to deal with cyberattack by protection of password and access keys. Companies need to train their staffs and sea crews how to use digital equipment in a

correct way, which can not only reduce the damage to the equipment, but also protect from cyberattacks. An event tree or standard operation process should be established to guild the staffs and sea crews to avoid or deal with cyberattacks. Companies can also follow the suggestion related to cybersecurity training from IMO STCW (International Maritime Organization Standards of Training, Certification, and Watchkeeping) code and ISM (International Safety Management) code.

4.3. Upgrade and update system

In order to deal with the threat of use of the outdated IT system, it is necessary to keep update vaccine software and using updated program to mitigate cyber risk [36]. Through the development of advanced technology, many virus and malicious program are also created simultaneously. The maritime industry need to update or even upgrade IT system for not only keep their competitiveness, but also deal with the threat from cyberattacks.

4.4 Cybersecurity climate

Cybersecurity climate is a control option for cyber threat. This concept is adapted from safety climate, which is defined as the coherent set of perceptions and expectations that employees have regarding safety in their organization [37]. Safety climate can be used to proactively assess an organization's effectiveness in identifying and remediating work-related hazards, thereby reducing or preventing work-related ill health and injury [38]. Based on the above safety climate related literature, we develop cybersecurity climate as the environment of company to enhance awareness cyber risk and to prevent for cyber accident.

To foster cybersecurity climate in a company, several activities are adopted from safety climate, such as cybersecurity attitudes of management, cybersecurity education and training program, cybersecurity regulation and the status of security personnel, etc.

5. Conclusion

It has been growing relying many electronic and automated devices in maritime industry, cybersecurity issue has been increasing in this decade. Maritime industry is nationally and globally significant; the importance will be increased. Therefore, we focused on identifying cyber threats and developing risk control option in the maritime industry. In this study, four cyber threats have been identified, including lack of training and expert, use of the outdated IT system, Hacktivism, and fake site and phishing email. Four risk control options are also proposed, including developing cybersecurity process, education and training, upgrade and update system, and change cybersecurity climate.

For the further research, a set of interview will be conducted to validate the identified threats and risk control options and explore more if they are not identified from the literature review. Based on the results of interview, another questionnaire will be sent out to collect the likelihood, consequence, and probability of failure detection of each threat. Failure Modes and Effects Analysis (FMEA) with Fuzzy Rules Bayesian Network (FRBN) and Evidential Reasoning (ER) are used to evaluate the importance of the threats in maritime cybersecurity. Risk matrix will also be conducted to present in a simple and common way of the results to the maritime industry.

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PREPARING MARITIME PROFESSIONALS FOR THEIR FUTURE ROLES IN A DIGITALIZED ERA: BRIDGING THE BLOCKCHAIN SKILLS GAP IN MARITIME EDUCATION AND TRAINING

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ABSTRACT. Blockchain technology has made headway into the global maritime industry. Touted as a disruptive technology, blockchains have the potential to drastically change business models leading to risks of job displacements given obsolete skills and talent for blockchain adoption. Our research shows that the global maritime industry is facing challenges with the leap in blockchain development and implementation, thus emphasizing the increasing need for appropriate qualification and upskilling through revamped MET regimes. Implications of digitalization on conventional MET is mostly preliminary in academic research, especially with regard to the blockchain phenomena. For this purpose, this paper aims to shed light on the implications of blockchain disruption in the maritime industry accelerating required changes in conventional MET approaches - mainly utilizing a case study methodology alongside semi-structured in-depth interviews as key elements of this exploratory qualitative research study. Our findings show the transformative potential of blockchains in the maritime landscape alongside technical barriers indicating complexities inherent with adoption. Lastly, we propose an infographic design framework to facilitate changes in MET methodologies among higher education institutions.

Keywords: Maritime Education and Training (MET), Blockchain Technology, Skills Gap, Supply Chain Management

1. INTRODUCTION

The global maritime industry is one of the key sectors of digital transformation due to advances in globalization prompting growth in containerized trade [1]. To date, maritime players have begun to realize the importance of leveraging of key emerging technologies as an urgent imperative to raise supply chain (SC)-performance to new levels in a volatile operating environment. Beyond the plethora of advanced technologies is the advent of blockchain technology that promises to transform existing legacy systems heavily rooted in traditional maritime commercial practices [2].

Nonetheless, the adoption of blockchains signifies a significant departure from traditional norms in the industry. Our research shows that the global maritime industry is already facing challenges with implementing blockchain technology – considering technical complexities posed by the technology alongside the resistance to change by organizations. This in turn necessitates the bridging of blockchain skills gap through revamped maritime education and training (MET) regimes in light of preparing maritime professionals for their future roles in a digitalized era.

Blockchain as a novel distributed ledger technology (DLT), promises transparency, immutability, and security, where transactions are validated cryptographically in a decentralized fashion (in the absence of a centralized intermediary) [3]. Amidst the blockchain hype, organizations seek to integrate such a novel platform into their businesses to streamline operational processes, ultimately causing organizations to rethink their strategies to effectively manage the adoption of this new emerging technology [4]. However, managers in the maritime landscape seem to lack knowledge about blockchains – especially with how blockchain-based applications are set to transform their industries [5]. Hence, the leap in blockchain development in the industry requires appropriate consequently compelling changes to teaching and learning curricula in conventional MET [7].

Despite the International Maritime Organization’s (IMO’s) Convention on *Standards of Training, Certification and Watchkeeping for Seafarers* (STCW) stipulating standards for training mariners, graduates seem to lack technological literacy to meet future professional standards and requirements in the maritime landscape [7]. Although block chain courses are offered in many industries however, offering this type of courses are still not compulsory under STCW and rather uncommon in the other parts of the industry.

Given the proliferation of blockchain initiatives in the marketplace, the investigation of the blockchain diffusion and its impact on existing MET methodologies is deemed timely. Changing educational paradigms in MET is therefore crucial to meet requirements for graduates in the maritime transportation and logistics (T&L) field. This inevitably challenges the status quo in terms of academic approaches to existing MET regimes. For this purpose, we have undertaken a research design that is exploratory in nature and grounded in in-depth literature review alongside a case study research methodology to facilitate better understanding of the blockchain phenomena.

2. DIGITALIZATION OF GLOBAL SUPPLY CHAIN NETWORKS: BLOCKCHAINS AND SMART CONTRACTS DEPLOYMENT

2.1.1 Introduction to Blockchain

Blockchain is a database of transactions that occurs in a “trustless” multiple stakeholder network environment, where each transaction is independently validated and digitally signed utilizing cryptographic keys to ensure secured transactions [8]. The technology is capable of recording transactions between parties in a secured and immutable manner without the reliance on any trusted intermediaries [9].



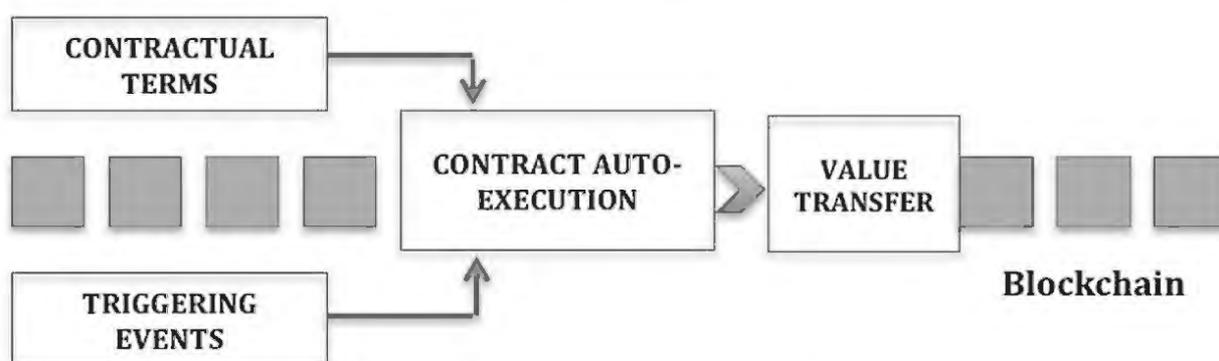
Figure 1: Blockchain Basics [10]

Descriptions of both public and private blockchains are outlined as follows [11]:

- **Private blockchains (permissioned)** - ideal for stakeholders who prefer a controlled, regulated environment, and desire high throughput.
- **Public blockchains (permission-less)** - open networks where anyone can participate. To achieve consensus is costly, and is underpinned by economic incentives (mining cryptocurrencies – i.e Bitcoin and Ethereum) are required.

2.1.2 Smart contracts

Developed by Nick Szabo in 1994, smart contracts are defined as “a computerized transaction protocol that executes the terms of a contract” to automate processes [11]. In other words, smart contracts are “self-executing” (without any human intervention) once pre-specified and pre-agreed upon conditions are fulfilled [9].



[12]

2.1.3 Navigating a paradigm shift with Blockchains

Traditional methods for handling and processing shipping documentation requirements are inefficient backed by standardized EDIFACT messages (Electronic Data Interchange) between data silos [13]. A significant breakthrough in the sector would be the digitization of paper-trail documents through blockchains to empower visibility and transparency to ocean freight. Blockchain seeks to leverage digital certification from paper-based certificate management and improve access to validated safety and seafarers’ training certifications [14]. Additionally, blockchains’ traceability features could potentially reduce fraudulent B/Ls through digitization in and trade [15].

2.1.4 Challenges facing conventional MET regimes: rising demand for Blockchain talent development

Blockchain applications and diverse use cases have led industry players to face complex and a wide-array of controversial issues. Despite IMO’s STCW being the cornerstone of MET regimes, there seems to be the lack of highly qualified seafarers in the global maritime industry, i.e. incompetent information technology (IT) skills among seafarers when dealing with the safe use of automation on board ships [16].

Moreover, only a handful of small and medium-sized companies possess little knowledge about blockchains backed by the lack of convincing use cases not clearly distinguishing the technology’s beneficial attributes over existing ICT solutions [10]. Liner

shipping players are also resistant to radical technological changes and are bewildered with the emergence of the different blockchain types in the blockchain space [17].

Notwithstanding the vast interest in academia regarding blockchains, there seems to be the lack of multifaceted insights regarding blockchain-based implications on future workforce requirements in the global maritime landscape. For this purpose, this paper aims to shed light on the implications of blockchain disruption in the global maritime industry accelerating required changes in conventional MET approaches. We further will provide recommendations to facilitate with blockchain talent development among maritime universities in line with narrowing the blockchain skills gap in MET.

To this end, we seek to address the following research questions:

- i) *What is blockchain technology's transformative potential and its limitations in the global maritime domain?*
- ii) *What are key recommendations to bridge the blockchain skills gap in MET in light of preparing maritime professionals for their future roles in a digitalized era?*

3. METHODOLOGY

The topic on blockchain technology is fairly new and complex within the scope of academic literature. In this essence, an exploratory study could facilitate with a new or vague area of investigation, thus allowing for the examination of a new emerging phenomenon to overcome difficulties facing organizations [18]. Thus, a case study was utilized as the main methodology to facilitate thorough discussion of findings alongside semi-structured in-depth qualitative interviews. A qualitative content analysis and thematic analysis approach were undertaken enabling the generation of meaning across data sets and the identification of significant themes [19].

3.2 Data collection & assessment

An empirical approach was applied by conducting semi-structured in-depth interviews (comprising both maritime and blockchain experts); wherein interview responses obtained acts as a testing factor for the chosen relevant case study. An interview guide was prepared allowing for open-ended responses and the generation of several codes concurrently. Main themes and sub-themes drawn from overall interview responses are based on proposed patterns relevant to blockchains in the maritime context. Additionally, a constructivist strategy was undertaken to ensure credibility and dependability of [20].

4. FINDINGS AND DISCUSSION

Interview responses have acknowledged the true transformative potential of public blockchains but were concerned with transparency, privacy and security features posed by the technology. Contrarily, responses were more inclined to the rolling-out of private blockchains in the maritime domain due to privacy, security and transparency (openness) concerns posed by public blockchains. These concerns indicate complexities inherent with blockchain implementation, which requires maritime players to thoroughly understand the technology's core principles and its application to use cases prior to adoption (as seen in *Figure 3* below):

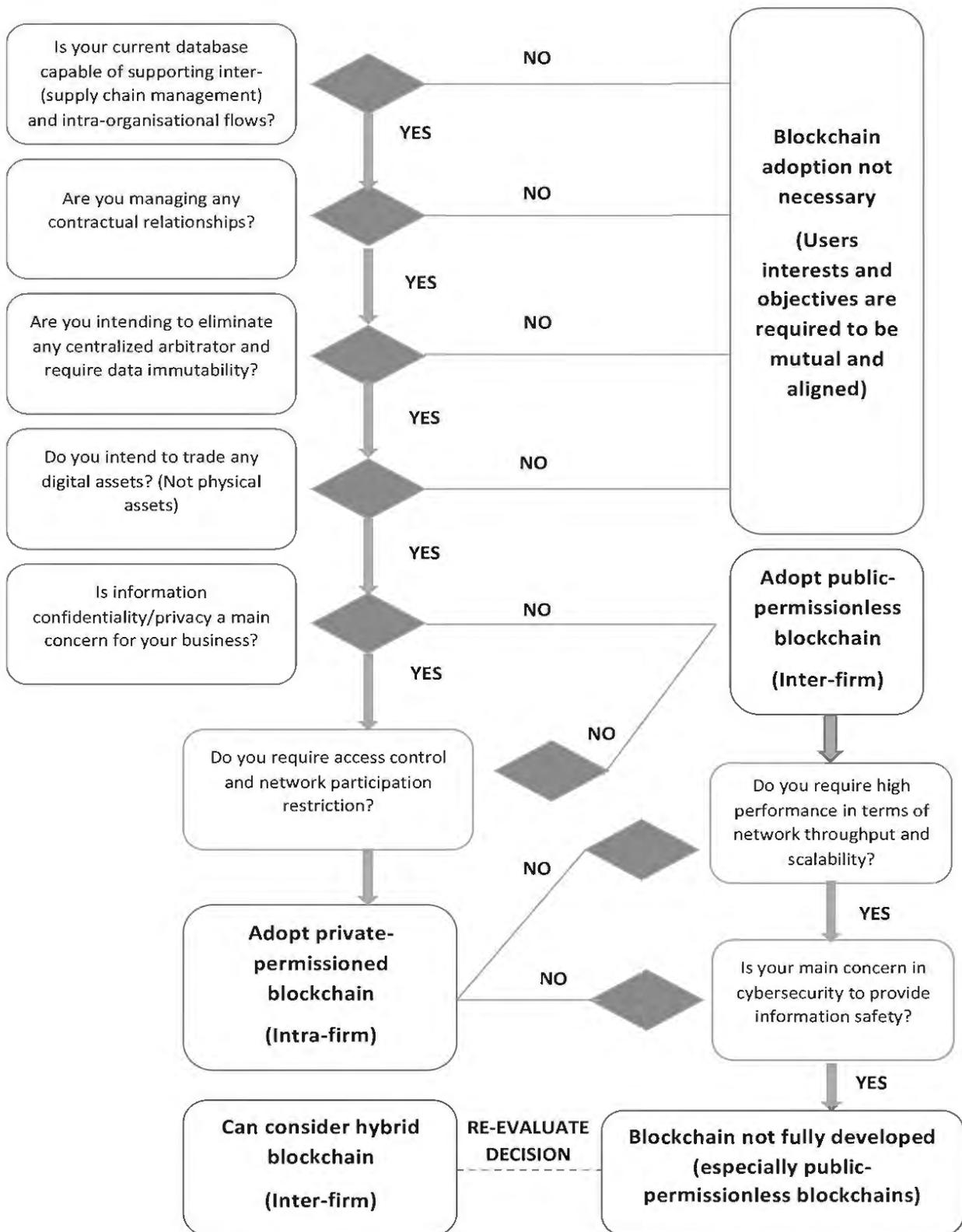


Figure 3. Decision Tree – Blockchain adoption

4.1 Digital Collaboration through Blockchains

Our data shows, to remain competitive, players have been urged to enhance integrated SC information models and the development of collaborative relationships through the deployment of blockchains to streamline operations. Further qualitative data analyses drawn have underlined equal participation by network participants in a decentralized blockchain ecosystem. Similarly, with responses from interviewees, McKinsey & Company stressed that *decentralization* is one of blockchain's unique attributes facilitating with the exchange of value and information without a trusted intermediary [21].

Data recorded on blockchains is decentralized (no longer stored centrally) and distributed across the network stored in individual nodes (computers) locally [22]. Further analysis of data responses have demonstrated that blockchains could offer equal opportunities in terms of data accessibility in real-time in a secured fashion - full control and ownership over data.

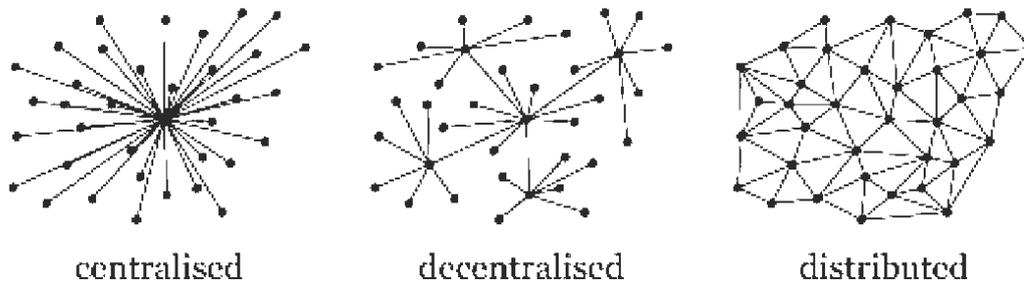


Figure 3: Decentralization and distributed networks [23]

Analyses of data have exhibited blockchain's potential of establishing new types of collaborative trusted relationships in line with enhanced integration between multiple parties along maritime SCs based on mutual trust and commitment. With blockchains, trust can be established and fostered in an entirely new manner wherein the disintermediation of trust is often embedded in settings with highly institutionalized values [24].

4.2 Blockchain Security and Privacy

The underpinnings of blockchains are based on cryptographic mechanisms through public and private keys - building the foundation for desired levels of security and trust in a network. Yet, the debate over conflicting privacy rights and security needs with blockchains continues to be distinctively evident based on the contradictory responses obtained. Such concerns include challenges with pseudonymous transactions and vulnerability to cybersecurity threats associated with blockchains.

Interviewees have unanimously agreed with the reasoning of blockchain's decentralization capable of operating with *no single point of failure* (trust distributed away from centralized authority). Hence, users are entitled to full control of trusted, immutable, and time-stamped data in chronological order rather than having data stored in centralized legacy databases with no cryptographic capabilities.

Many of our research participants have referred to blockchains as a secured technology against the backdrop of rising concerns regarding cyber security threats and

fraudulent transactions in a volatile environment. That said, being in development stages, blockchains are prone to points of vulnerability - as seen with recent malicious attacks on public-permissionless blockchains. A renowned case of blockchain hacking is Mt. Gox, where bitcoins were stolen from the exchange in February 2014 [26].

Another technical challenge facing users with public blockchains is privacy data protection and confidentiality despite the use of public-private keys to enhance security measures. Recent studies have also showed that users face risks of identity exposure through Bitcoin transactions i.e. public blockchains are not capable of securing transactional privacy and the protection of user identities [24]. Besides, confusion remains over pseudonymous transactions on Bitcoin blockchain ledgers, as most still assume that user transactions are somewhat anonymous despite identities addressed under a false name [25].

4.3 Blockchain Transparency & Openness

Interviewees have demonstrated a unified view on the growing demand for transparency integral to end-to-end integration in maritime SCs, hence favoring blockchain deployment to bring full transparency to processes along maritime SCs. Further probing of data demonstrated rising concerns regarding inadequate transparency in maritime SCs. Rising demand for transparent and trusted information across SCs acts as an impetus for blockchain adoption in the maritime domain to meet customer expectations in a rapidly changing environment.

Obtained responses demonstrated that blockchain-based solutions are ideal for the provenance of key-trade related trade documents e.g. the management of fraudulent B/Ls in international trade remains a concern given that traditional systems lack similar track-and-trace capabilities offered by blockchains [27].

Interview responses varied in terms of priority toward privacy at the expense of blockchain's transparency feature and its applicability to certain use case requirements. Academicians have also noted the intrinsic conflict between blockchain transparency and privacy – i.e. public-permissionless Bitcoin blockchain systems, where maintaining an ideal degree of anonymity could potentially deter privacy aspects [28]. Generally, interview responses indicated that both innovators and maritime experts were largely in favor of private blockchains due to less technological constraints when compared to public blockchains.

4.4 Fundamental Understanding & Technical Knowledge

Academicians have underlined the importance of having skilled and qualified professionals to accelerate blockchain development and adoption going forward [29]. Likewise, a source investigating blockchain implications in markets had also claimed that *'one of the challenges is skill set. There are not enough developers and engineers who can build what is necessary to make this transition.'*

5. CONCLUSION AND RECOMMENDATIONS

Despite the aforementioned advantages of blockchains, future maritime professionals are faced with trade-offs when implementing either private or public blockchains. Challenges with regard to the reconciliation of *transparency, privacy, and security* conceptualization

among users indicate complexities and implementation risks - in line with contradictory statements exhibited by interviewees - addressing RQ1.

5.1 Blockchain complexities and trade-offs

Given the complexities of blockchains, maritime professionals are expected to systematically re-evaluate trade-offs between the degree of transparency (openness) and privacy desired offered by blockchains, while taking into account which blockchain solution best fits their organization's scope of operations within the maritime field. Desired transparency differs on an individual preference basis, indicating that not every participant requires access to every piece of information [30].

Security and scalability limitations are also considered barriers facing public blockchain adoption. On the contrary, private blockchains are capable of offering data confidentiality the expense of transparency [30]. The case presented regarding IBM and Maersk *TradeLens* seeks to protect sensitive corporate information and consumer data through the deployment of a private blockchain enterprise solution governed by a centralized arbitrator that is ideal for B2B environments [25]. Altogether, technological constraints posed by blockchains largely demonstrates the inherent challenges faced by future maritime professionals when implementing the novel platform.

5.2 Bridging the Blockchain Skills Gap in MET

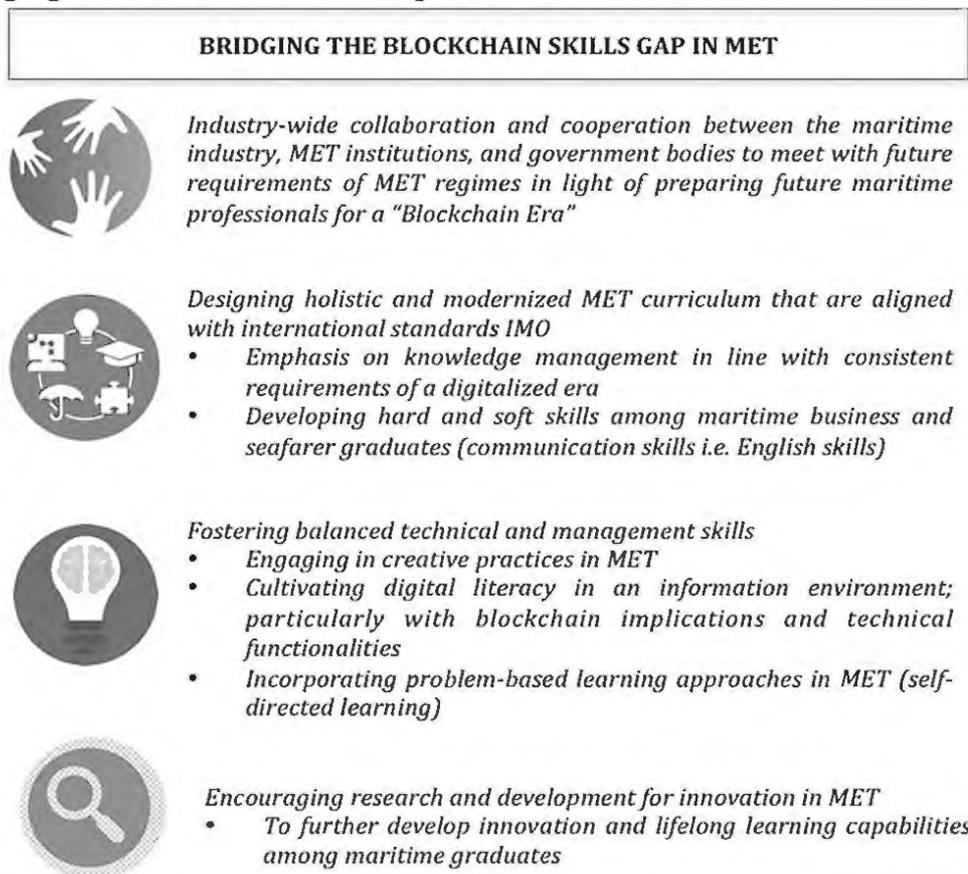


Figure 4. Bridging the blockchain skills gap in MET [31]

Essentially, education practitioners and researchers stemming from maritime communities are expected to play a major role to drive changes in conventional MET methodologies through revamped training curriculum in MET. Understanding the novel platform also demands the familiarity of an entirely new vocabulary, thus emphasizing the importance of improving English skills among future maritime professionals [32].

The magnitude of this qualitative exploratory study is limited in scope owing to time constraints, restricting the incorporation of more detailed discussion pertaining to blockchain-based smart contracts and cryptocurrencies.

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S-Mode: Challenges and Opportunities for MET

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Keywords: S-Mode, human-machine interface, standardisation, e-Navigation, safety

ABSTRACT

After more than 10 years of discussion and consultation, the guidelines for standardisation of user interface design for navigation equipment (S-Mode) were approved by the 6th Session of the Sub-Committee on Navigation, Communications and Search and Rescue (NCSR). It has been expected that the implementation of S-Mode would significantly impact maritime education and training (MET). However, the involvement of MET institutions in developing the guidelines for S-Mode has been very limited. This IAMU-funded project investigated the potential challenges faced by MET and the approaches that MET may use for preparation with the implementation of S-Mode. Nine focus group interviews were conducted in four countries. The results show that there has been a severe lack of information available for MET on S-Mode development since the beginning of the discussion over 10 years ago. A wide range of challenges have been identified and possible approaches for preparation for S-Mode implementation have been discussed.

1. INTRODUCTION

The introduction of new technologies on ships is often influenced by the drive for profit seeking through the reduction of crewmembers to reduce labour costs. The industry's continuous effort to reduce cost has led to a shift from labour to technology intensive ships. There is a lag between the introduction of new technology and the provision of training to use it, with many seafarers only receiving training 'on the job'[1]. The inability of many educational programs and training schemes to catch up with the rapidly growing complexity of shipboard technology has presented challenges for human-machine interface considerations [2]. In a questionnaire survey of 819 officers, better training of crew to use ship technology was identified as one of the most important factors for seafarers to confidently embrace new ship technologies [3].

Problems have been identified in the current maritime training system such as unsuitable education and training objectives [4], inappropriate skill assessment techniques [5], and shortage of instructors who are well-trained and up-to-date in using educational technologies [6]. The lack of standardisation in both the training processes and the real vessel technical system has also been discussed in the literature. For example, on-board training programs were identified by Chauvin, Clostermann [7] as crucial to the complex situational decision-making capacity. Sandhåland, Oltedal [8] further examined the emerged errors related to insufficient

training as demonstrated by the “incomplete mental models related to the vessel technical systems” despite the existence of the on-board training program. Schmidt [9] investigated different solutions for education and training using simulators. The importance of simulation-based and realistic training has also been stressed by Sellberg [10], Sellberg, Lindmark [11]. The advances in immersive technology and virtual reality provide more options for training programs to be more engaging where navigation operators can execute tasks through using a game controller [12].

e-Navigation was first introduced to IMO in 2006 in its 81st session of the Maritime Safety Committee to address the “*compelling need to equip shipboard users and those ashore responsible for the safety of shipping with modern, proven tools that are optimised for good decision making in order to make maritime navigation and communications more reliable and user friendly*” [13]. This initiative was developed at a time when increasing technologies, especially information and communication technologies were introduced to the shipping industry through manufacturers’ adoption of these technologies into their shipping-related products. To support the e-Navigation initiative, six priorities were identified and supported by the IMO, of which the S-Mode was to be developed to address the requirement for ‘harmonised presentation’ of maritime information under e-Navigation. Specifically, S-Mode supports two of the core objectives of e-Navigation (NAV 53/WP.8): 1) integrate and present information on board and ashore through a human-machine interface which maximises navigational safety benefits and minimises any risks of confusion or misinterpretation on the part of the user; and 2) manage the workload of users while also motivating and engaging users and supporting decision- making. Since NAV 53, there has been increasing discussions and studies around the development of S-Mode amongst the key stakeholders through their respective representative bodies.

The S-Mode concept was first proposed in 2008 [14] through a joint submission by The Nautical Institute (NI) and the International Federation of Shipmasters’ Associations (IFSMA) to raise the serious concerns about the increasing complexity and uncoordinated nature of shipboard navigational equipment. In 2016, a proposal on how best to develop guidelines for greater standardisation in the use and operation of onboard navigational equipment was discussed during 3rd Session of IMO’s sub-committee on Navigation, Communications and Search and Rescue (NCSR). The proposal was co-sponsored by the Comité International Radio-Maritime (CIRM) and the International Electrotechnical Commission (IEC), as well as the NI and IFSMA, and jointly submitted by Australia and South Korea. The 5th Session of the NCSR established a Correspondence Group on the development of the draft Guidelines on S-Mode, coordinated by Australia [15]. The draft guidelines were submitted to NCSR in 2017 [16].

S-Mode has obvious impacts on MET, although the discussions of S-Mode development in the last 10 years have occurred mainly among the representative bodies of seafarers and equipment manufacturers, for example, [17], [18], and [14], with little involvement from maritime education and training (MET). On the one hand, S-Mode may reduce training burdens and enable greater standardisation of training. There are large number of bridge equipment

manufacturers with many models making it impossible for any training institutions to develop training labs for every system. The standardisation would allow simplification of shoreside training programs. On the other hand, there is very limited information available to MET about S-Mode and how S-Mode may affect education and training, although the draft guidelines were submitted to the 5th NCSR in 2017 [16]. It is likely that additional investment is required to set up the new training program. There are also concerns that over-emphasising standard mode may result in inadequate education and training on essential knowledge and skills on which S-Mode is based. It is, therefore, critical to thoroughly exam the challenges of S-Mode implementation MET may face, and approaches MET may take to be better prepared for this significant new initiative.

2. METHODOLOGY

Since little information was available on how MET should respond to, and prepare for, S-Mode, the project employed two data collection methods, focus group interviews and a Delphi study with participants from MET institutions. This paper reports the findings from the focus group interviews. The purpose of the focus group interviews was to identify the challenges faced by MET based on S-Mode and to investigate the approaches for the implementation of S-Mode in MET settings. The outcomes of the focus group interviews were analysed using NVivo [19], a qualitative data analysis software developed by QSR International. The results of the analysis then became the input for the second phase of the project.

To reduce the logistical complexity of conducting face-to-face focus group interviews, a decision was made to leverage the locations of the three project partners, that is, to recruit participants from the project partners' institutions and other institutions that were manageable by the project team. The number of focus groups chosen from the selected countries (Australia, China, Canada and the United States) was determined by the overall number of maritime education and training institutions in the four countries. Initial contact was made to MET institutions to seek their interest in participating in the focus group interviews before invitation letters were sent to prospective participants in the selected MET institutions. Given the topics of S-Mode, it was decided that the invited participants would need adequate seafaring and maritime and training experience. This important criterion was followed when compiling the contact list for sending the invitation letter as well as when finalising the participants of the focus groups. In total, nine focus group interviews were conducted, of which five in China, one in Australia, one in Canada, and two in the United States. Group interviews, consisting of 5-7 participants, were carried out face-to-face except for the two in the United States (Table 1).

A list of nine questions was developed based on the literature review. The questions were provided to all participants prior to the commencement of each interview. Consent for recording was obtained before each interview session. Each focus group interview was coordinated by a facilitator whose main role was to facilitate the discussion in an unbiased way and to ensure participants were given equal opportunity to express their viewpoints. The sequence of the discussions on the nine questions followed more on the logic of the discussion flow rather than the actual sequence of the questions listed. This approach ensured that the

group interviews were smooth, and the discussions progressed naturally without interruption by suddenly moving one question to another.

The length of interviews ranged between 63 minutes to 116 minutes with most interviews (6 groups) being completed within 70 minutes. In total, 664 minutes of discussion were recorded. The recordings were sent to two professional transcription service providers, one for the interviews in English and the other in Chinese. The 664 minutes of recording resulted in 132,785 words in transcripts (Table 1). The Chinese version of the transcripts was translated into English before all transcripts were analysed.

Table1 Focus group interviews (participant number and length)

Group	Participants	Length (minutes)	Transcript (words)
1 (AU)	5	67	10,168
2 (CA)	5	76	12,091
3 (US1)	3	66	7,706
4 (US2)	2	68	10,897
5 (DL1)	5	63	18,440
6 (DL2)	5	116	25,517
7 (QD)	5	65	14,716
8 (SH)	6	75	17,646
9 (GZ)	5	68	15,604
Total	41	664	132,785

3. FINDINGS AND DISCUSSIONS

3.1 DEMOGRAPHIC INFORMATION AND INTERVIEW SESSIONS

The demographic profile of the participants is presented in Table 2. Two pieces of demographic information were collected. One was the seafaring experience of participants including the level of Certificate of Competency (CoC) and years of seafaring experience. The other was the teaching and training experience of the participants in years. For seafaring experience, out of the 41 participants, 37 were Master Mariners (Unlimited) representing over 90% of the participants with remaining holding other certificates of competency. The years of sea time ranged from 6 to 28 years, with a majority (56.1%) having 10-20 years of seafaring experience, over one third (34.1%) of more than 20 years and less than 10% sailing for less than 10 years. For teaching and training experience, over 63% of participants had been teaching or training for 10 to 20 years. About a fifth of the participants (8) had taught for over 20 years, and the remaining (7) had been in the maritime training and education for less than 10 years. The extensive experience of participants in both seafaring and maritime education and training

provides the confidence on the quality of the discussions in the interviews and thus the information collected from the focus group study.

Table 2 The profile of participants in the focus group interviews

	Seafaring experience No. of participants (% of total)	Teaching/training experience No. of participants (% of total)
Master Mariners	37 (90.2%)	-
Other CoCs	4 (9.8%)	-
Over 20 years	14 (34.1%)	8 (19.5%)
10-20 years	23 (56.1%)	26 (63.4%)
Less than 10 years	4 (9.8%)	7 (17.1%)

3.2 CURRENT CHALLENGES OF MET

During the focus group interviews, a large number of issues were raised and discussed. Some of these were common across all MET institutions while others were specific to individual institutions. Differences were also observed between countries. The analysis of the discussions resulted in four topics related to the current challenges of MET including: 1) organisation of training; 2) current systems used in training; 3) challenges in maritime training and education programs; and 4) challenges in operating onboard equipment.

Organisation of Training: Among the participating institutions, the levels of program offerings vary with some institutions providing bachelor's degree programs only, others offering certificates and/or diplomas (and advanced diplomas), and some offering a very wide spectrum of programs from Cert I to PhD level and everything in between. For STCW related maritime education and training programs, the governance structure may have multiple layers depending on the offerings. In addition to meeting the general regulatory requirements for higher education or vocational education and training, all STCW related programs must comply with the requirements set by the maritime safety administration or authority of the respective country. While the STCW provides the minimum requirements on education and training of seafarers, the actual administration may differ with some having little intervention in program delivery while others being more involved with. The role of the national or state maritime safety administration may significantly affect the way training is organised and delivered.

Current systems used in training: Systems used for training include simulators and real machines. For simulation systems, all participants reported that 'mainstream' brands and equipment are used. Some institutions also develop their own simulation programs or source from providers other than those 'mainstream' manufacturers. For some VET institutions, updating the main simulation program could be a significant financial burden. Consequently, the update may not be at the optimal level. Unlike simulation systems, real machines have very large numbers in varieties, brands, models with some being relatively new and others being up to 60 years old.

Challenges in maritime training and education programs: The most prominent challenge in maritime training and education on bridge equipment operation is the vast number of onboard equipment and the models that come with it. While the basic functions of the same equipment remain the same across brands and models, the way they operate may significantly differ. Given the time and resource constraints, MET institutions can only use ‘mainstream’ equipment for teaching and practical training. The associated issue with the diversity is the pressure on MET to expose students to different equipment as much as possible. However, this may bring more confusion to students. The increasing complexity of on-bridge equipment is another challenge. With the fast adoption of advanced technologies onboard ships, the demand for skills on seafarers has been increasing. This has placed significant pressure on MET. While all groups were concerned about the differences between the implemented training systems and the actual systems onboard the vessels in the real world, MET institutions can only provide training with what is available and to the extent to meet the STCW. The variety and complexity of navigation systems requires on-going training or self-learning of seafarers to be competent on what they operate. This is not always possible. The USA group revealed that there were obstacles in continuous training of their students after they have finished their training courses.

Challenges in operating onboard equipment: All groups raised the concern about the complexity and fragmented adoption of onboard systems both across different ships in general, and on the same individual ships specifically. This issue can hamper the decision-making ability of both students and seafarers alike leading to serious safety concerns. The continuous introduction of new functions into the already complicated system further amplifies its complexity. The increasing complexity requires the operators to have a thorough understanding of the equipment under operation in order not to miss any important information. Participants also expressed the concerns about possible over-reliance and emphasis on electronic equipment at the expense of experience. The reliability of electronic devices on the bridge is another concern. The reliability may be related to the performance standards of the electronic devices, which could be a problem as the speed of introducing new equipment may be faster than the updates on performance standards.

The current onboard alarm systems attracted considerable attention and discussions among all groups. The first issue is the inconsistent meanings attributed to alarms with various visual or audial signals in different volume levels, frequency, and tone. The extent of the problem may depend on the experience of the person in concern. Furthermore, the pitch, volume, and frequency of alarms can be very distracting and annoying. The reliability of the alarm system itself can be a weak point. In some cases, extreme measures may be used to ‘silence’ a faulty alarm. These actions and reactions toward alarms may pose serious safety risks. Moreover, the complexity and uncoordinated nature of alarms on bridge brings further issues. To make it even worse, manufacturers from time to time add more alarms to their equipment.

3.3 CHALLENGES OF MET FOR THE IMPLEMENTATION OF S-MODE

It was a consensus among all focus groups that information on S-Mode was scarce, be it the S-Mode itself or its development. Consequently, the discussion on this topic was very limited. Most of the comments were about the absence of information on S-Mode and how this may

affect their preparation for the implementation. Equally, it is difficult to identify the possible challenges for training on S-Mode. In addition to the concern about the lack of information on S-Mode, some groups expressed the concerns about the potential cost associated with the implementation of S-Mode and potential resistance to S-Mode. Standardisation, if not managed properly, may impede the motivation for innovation and continuous investment in research and development. Another concern is the protection of intellectual property where mandatory standardisation may deprive the intellectual properties of some products.

While there was a concern about the timeframe of S-Mode implementation which may not allow enough time for MET to prepare for appropriate resources, the other side of the concern was the inefficiency inevitably exists in the process of regulations and the time taken for enforcement. If this occurs, a new system may be very much outdated when it is put in place. The possible over-reliance, either intended or unintended, on S-Mode may cause safety concerns among MET. This could also create tension between teaching the conventional and essential principles of navigation and the simplified operation of navigational systems. While some believed that S-Mode may reduce the complexity and difficulty of training, others stated that standardisation may also bring negative impacts on MET. Over-reliance on S-mode may compromise the ability of operators in solving problems in complicated situations.

3.4 SUGGESTIONS ON THE IMPLEMENTATION OF S-MODE BY MET INSTITUTIONS

All groups suggested that the maritime education and training institutions should have been given more information about the S-Mode and its development and implementation. It is also important that educators or instructors have hands-on experience before they go and teach students. While standardisation through S-Mode may reduce the time to train people to operate onboard equipment under standard mode, specific training is still required to ensure safety. As educators and instructors, it is unclear how the training will be performed for S-Mode, through simulation or hands-on experience. It was suggested by one group that the training on S-Mode should come after students have gained enough knowledge and skills. In addition, with increasing information and communication technologies being adopted in ship design, students coming to the nautical sciences courses should have adequate knowledge on computer.

In addition to training provided by MET, the shipping companies should also take respective responsibilities to ensure that all crew are provided with necessary training especially skills related to the specific features of the ship. It is important to understand that every equipment or system has its own limitations. Underestimating or ignoring the limitations of onboard equipment may pose serious safety risks. For the MET institutions to be better prepared for S-Mode, a collaborative approach among all MET institutions was suggested.

4. CONCLUSIONS

Current challenges faced by MET are mainly related to the increasing complexity of the onboard navigational systems resulted from the continuous, yet uncoordinated innovations introduced by different equipment manufacturers. There are constraints in financial resources to keep upgrading equipment for training and time limit to exposure students to all brands and

models of onboard equipment. It is unclear among MET institutions as how S-Mode may impact the existing training scheme. However, the consensus from the focus group interviews is that information on S-Mode is scarce and that MET should be provided with more information in a timely manner. A forum accessible to all MET institutions may be beneficial for knowledge sharing on S-Mode implementation and training preparation.

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Weather Routing Software for academic purposes: A pilot study

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ABSTRACT

Academic research has focused on weather ship routing optimization through pathfinding algorithms which take into account the meteo-oceanographic forecasts (i.e. wind, waves or currents predictions). Therefore, an academic software package (named SIMROUTE) for ship routing optimization oriented to students and cadets has been developed to be used as a distance learning platform in Seafarers' Training, Certification and Watchkeeping (STCW) competences-based Maritime Education and Training (MET). The pedagogic purpose of this software package is to provide skills of ship routing optimization, to assess the impact of the meteo-oceanographic on ship navigation and to highlight the relevance of ship routing in terms of sailing time, fuel consumption and harmful emissions for the environment. This contribution summarizes the results of the pilot case identifying the strengths and weaknesses through students' questionnaire. The conclusions may help to provide distance learning in newly educated seafarers and to implement a very novel software in the framework of teaching innovation in MET institutions.

1. INTRODUCTION

Distance education is a generic term for modes of education in which the student and the teacher are separated in time and space. It includes online education (with more than 80% of online content) and blended education (with 30-79% of online content) [1]. Previous research analyses the concept of distance learning as additional modes of acquiring knowledge and skills in maritime education [2, 3, 4, 5, 6]. In this sense, new amendments of the Seafarers' Training, Certification and Watchkeeping Code (STCW) [7], as a part of mandatory training, endorsed modern methods of seafarers' education and training and mentions two options in "Guidance regarding training and assessment" (Section B-I/6): (i) in-service training and (ii) distance learning and e-learning. Then, distance learning and e-learning may be approved by the contracting parties considering the standards of training and assessment set out in section A-I/6 of the STCW Code [8]. Moreover, IMO model course 6.09 [9] specifies several remote teaching methods such as Computer-Based Teaching (CBT) and distance learning. However, neither STCW nor IMO model courses give guidelines on how CBT and distance learning can

be applied and provides a simple list of requirements for implementation. [10] shows the process of how to develop a distance education program in competence-based MET. Nowadays, some MET institutions, shipping companies, non-government organizations, classifications societies and maritime training centers have been involved in developing distance education programs in MET and providing some training courses by distance education. Following the introduction section, this paper continues with the methodology carried out to design and implement a new e-learning course identifying which STCW competences could be assessed. Afterwards, results of a pilot case study based on exercises and questionnaires in a course of the “Master Degree in Nautical Engineering and Maritime Transport” at Barcelona School of Nautical Studies (FNB-UPC, Spain) are presented and discussed. Finally, the article ends up with some conclusions drawn from the findings and observations of this research.

2. METHODS

Firstly, this contribution deals with the design of the course structure and e-learning material based on the development of a software (named SIMROUTE) which provide an optimized route in function of the ocean-meteorological conditions considering a port origin and a port destination. The SIMROUTE system is described in detail in [11, 12, 13, 14, 15] and is based in the implementation on the A* pathfinding algorithm which optimize a cost function that is the time sailed. A* algorithm solves problems by searching among all possible paths to the goal for the one that incurs the smallest cost (shortest time) and among these paths it first considers the ones that appear to lead most quickly to the goal. The algorithm also includes a formula to calculate the ship speed reduction due to waves and the final speed is computed in function of the non-wave affected speed plus a reduction of the wave parameters.

For instance, the minimum and optimized routes are presented and compared in Figure 1 for the case example of Barcelona – Taranto route under stormy conditions as a SIMROUTE output. Additional information is provided such as the maximum wave height sailed, the fuel consumption or the carbon dioxide emission. In parallel, comprehensive documentation and material is presented as a guide for teachers, instructors and cadets.

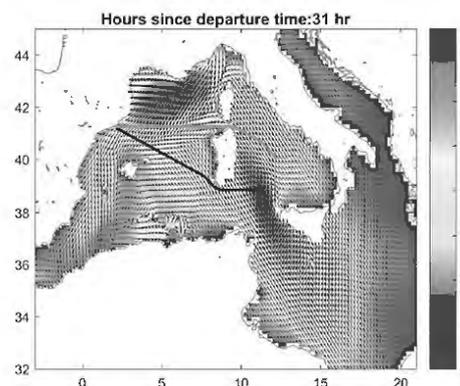


Figure 1. Minimum distance route (black line) and optimal route (magenta line) from Barcelona to Taranto on 18/12/2016. Color bar represents wave height (in meters).

Secondly, from an academic point of view, this software deals some specific topics that are part of syllabus of Maritime Education Training (MET) institutions’ programs and included in

STCW 95/2010 Code. An inventory is carried out identifying which of these topics are part of the knowledge of the STCW competences (Column 2 of part A: competences tables of STCW Code). Then, the preliminary exercises are tested “on class” as a pilot study in a course of the “Master Degree in Nautical Engineering and Maritime Transport” at Barcelona School of Nautical Studies (FNB-UPC, Spain) and also some lecturers’ feedback is obtained from Chalmers University of Technology (Sweden) as a part of the IAMU development project FY2018 entitled “Development of a weather ship routing software for academic purposes”. The pilot study is based on online exercises divided into two specific modules and all the participating students (a total of 24 students) completed individual questionnaires before (pre-testing) and after (post-testing) the exercises. The pre-testing questionnaire is based on general questions related on WSR knowledge and programming languages used before the pilot study and the post-testing questionnaire is based on the use of the SIMROUTE algorithm and the knowledge and competences acquired during the pilot study course. With the data gathered some conclusions are drawn to provide preliminary results of the pilot study identifying strengths and weaknesses.

3. COURSE STRUCTURE AND E-LEARNING MATERIAL

Course structure has been designed into two specific modules: (1) Ship Weather Routing (SWR) application module (software familiarization, forecast weather and oceanographic conditions, software feasibility) and (2) Marine Environmental (ME) module (methodology and calculation of ship emissions). The main objective of the first module (SWR module) is to get the students acquainted with the software and point out the importance and impact of meteorological-oceanographic variables in terms of sailing time comparing the minimum distance route and the optimized route. The main objective of the second module (ME module) is to get when the students acquainted with the methodology of the SIMROUTE software used for calculating emissions and assess the relevance of ship routing in terms of fuel consumption and harmful emissions for the environment. In this sense, two manuals have been developed: (i) the SIMROUTE User’s Manual explains step by step the operation of the SIMROUTE software designed for maritime route optimizations and (ii) the SIMROUTE Technical Manual, a compendium of the technical notes based on specific formulations and methods. Moreover, a set of step-by-step test cases with video-tutorials and the development of a full set of exercises for each module (with a gradual increasing difficulty) have been designed to ensure e-learning. The academic software package for ship routing optimization course, with exercises and all comprehensive documentation material has been incorporated into IAMUs e-learning platform (<http://iamu-edu.org/moodle>) for maritime instructors and cadets (see Figure 2).

SIMROUTE User's Manual

The SIMROUTE User's Manual explains step by step the operation of the SIMROUTE software designed for maritime route optimizations which carries out simulations of short and long distances. In order to run the program, there are several parameters to introduce: port of departure, port of arrival, vessel speed and the wave field for the days of the voyage to simulate.

SIMROUTE Technical Manual

The SIMROUTE Technical Manual is a compendium of the technical tools to understand how the software works.

SIMROUTE 4

Assignment 3 Software familiarization

Objectives:

Get the students acquainted with the software. Point out the importance of weather ship routing in terms of cost (time saving). This assignment is mandatory but not evaluable.

Specific objectives:

- Use the step-by-step Videotutorial 1.1
- Use the Simroute Technical Manual in order to introduce the concepts about pathfinding algorithms
- Understand the effect of waves on navigation based on the formulation included in the Simroute Technical Manual
- Make clear the procedure for executing the scripts and introducing variables correctly.
- Understand the possible errors derived of not following the right sequence

References:

- Simroute Technical Manual (Section 1, 2, 3)
- Simroute User's Manual
- Video-tutorial 1.1

Figure 2. Screenshot of the SIMROUTE course at the e-learning platform

4. STCW COMPETENCES

These academic modules meet with the requirements of the STCW 95/2010 Code and the proposed e-learning course can provide an excellent tool oriented to satisfy specific topics in all Maritime Academies and Universities related to STCW competences. Table 1 links topics dealt on SIMROUTE software with the mandatory minimum requirements for certification knowledge of STCW competences of Table A-II/1, Table A-II/, Table A-III/1, Table A-III/2 and Table A-III/6.

Table 1. Relation of deck and engine department STCW competences with the SIMROUTE modules

STCW competence (Column 1)	STCW Table	Module
1. Plan and conduct a passage and determine position	A-II/1	SWR
2. Maintain a safe navigational watch	A-II/1	SWR
3. Ensure compliance with pollution - prevention requirements	A-II/1 & A-III/1-6	ME
4. Plan a voyage and conduct navigation	A-II/2	SWR
5. Maintain safe navigation through the use of information from navigation equipment and systems to assist command decision	A-II/2	SWR
6. Manoeuvre and handle a ship in all conditions	A-II/2	SWR
7. Monitor compliance with legislative requirements	A-II/1 & A-III/1	ME
8. Monitor and Control compliance with legislative requirements to ensure safety of life at sea, security and the protection of the marine environment	A-II/2 & A-III/2	ME
9. Forecast weather and oceanographic conditions	A-II/2	SWR

We found that part of the knowledge of 9 competences out of all the ones described in the first column of STCW may be evaluated using SIMROUTE software. Most of the knowledge is

from master and deck department competences and only competences 3, 7 and 8 from Table 1 have the same knowledge for deck and engine departments.

5. PILOT CASE

The pedagogic purpose of this software package is to provide skills on marine environment, safety of navigation, ships routing, meteorology and navigation equipment, specific topics included in all syllabus of MET institutions' programs and also in STCW competences. Bearing in mind the existing study programmes at Barcelona School of Nautical Studies (FNB) of Universitat Politècnica de Catalunya (Spain) that includes the knowledge of STCW competences described in Table 1, and that the master has ultimate responsibility for the safety and security of the ship, its passengers, crew and cargo, and for the protection of the marine environment against pollution by the ship, the two academic modules have been incorporated in the Master's degree in Nautical Science and Maritime Transport Management to create new syllabus as a pilot study to assess the successfulness on real teaching course. A pre-testing of a questionnaire survey was conducted to assess the clarity of the questionnaire and the suitability to the students. Results of this pre-testing showed that 73% of 24 students had spent time onboard (as a cadet or as an officer) and many of them knew and could describe correctly what weather ship routing optimization is but only 4.5% were familiar with the programming language used in SIMROUTE software. After the e-learning course, many of the students agree that they feel comfortable using SIMROUTE software thanks to the manuals and specifically with the video-tutorials, being really helpful in order to understand step-by-step exercises and to execute the program's scripts. Moreover, Table 2 shows which STCW knowledge has been acquired by students after the pilot case course.

Table 2. STCW knowledge acquired by students after the e-learning course

STCW competence (Column 1)	Knowledge (Column 2)	Acquired
1. Plan and conduct a passage and determine position	Thorough knowledge of and ability to use nautical charts, and publications, such as sailing directions, tide tables, notice of mariners, radio nav. warnings and ship's routeing information	64%
	Meteorology	100%
	Ability to use and interpret information obtained from shipborne meteorological instruments	93%
	Knowledge of the characteristics of the various weather systems, reporting procedures and recording systems	93%
2. Maintain a safe navigational watch	The use of routeing in accordance with the General Provisions on Ships' Routeing	79%
	The use of information from navigational equipment for maintaining a safe navigational watch	79%
3. Ensure compliance with pollution - prevention requirements	Prevention of pollution of the marine Environment and anti-pollution procedures	93%
	Knowledge of the precautions to be taken to prevent pollution of the marine environment	93%
	Importance of proactive measures to protect the marine environment	100%
4. Plan a voyage and conduct	Voyage planning and navigation for all conditions by acceptable methods of plotting ocean tracks, taking into	86%

navigation	account	
5. Maintain safe navigation through the use of information from navigation equipment and systems to assist command decision making	Evaluation of navigational information derived from all sources, including radar and ARPA, in order to make and implement command decisions for collision avoidance and for directing the safe navigation of the ship	79%
	The interrelationship and optimum use of all navigational data available for conducting navigation	93%
6. Manoeuvre and handle a ship in all conditions	Management and handling of ships in heavy weather	93%
7. Monitor compliance with legislative requirements	Basic working knowledge of the relevant IMO conventions concerning safety of life at sea, security and protection of the marine environment	86%
8. Monitor and Control compliance with legislative requirements to ensure safety of life at sea, security and the protection of the marine environment	Methods and aids to prevent pollution of the marine environment by ships	86%
9. Forecast weather and oceanographic conditions	Ability to understand and interpret a synoptic chart and to forecast area weather, taking into account local weather conditions and information received by weather fax	79%

Finally, from the students' feedback obtained, following knowledge/modules could be introduced in the software in order to acquire additional STCW knowledge and improve the e-learning training: to introduce the possibility to change the vessel's speed in function of the vessel phase (sailing/approaching/maneuvering); to incorporate VHF Reports and TSS (Traffic Separation Scheme); to include new navigation areas using other meteorological authorities' information; to introduce more precise data in coastal navigation; to identify if the navigation area is an ECA or not and calculate emissions accordingly; to incorporate an advice with the best ETD (considering weather storm) and to incorporate a port location database.

6. CONCLUSION

The academic modules presented in this paper meet with the requirements of the new amendments of STCW Code using distance learning and e-learning in MET and provides schools with a modern way to assess STCW competences, the distance-learning in competence-based MET. A particular emphasis is done in terms of air emissions and safety of navigation. With the aim of charting the course for the future of maritime universities from the point of view of technological and environmental impacts, this paper provides results of the pilot study. It has been essential to identify which competences the learner will achieve, including an analysis of how many competences already gained and which still need to learn. The strengths and weaknesses have been highlighted from the post-questionnaire carried out after completing the e-learning course and also from the Chalmers Technological University feedback. On one hand, SIMROUTE have potential to be used as a learning platform for STCW learning due to: (i) the high level of comprehensiveness of contents of the course by the students and (ii) the knowledge acquired using the proposed e-learning teaching tool to assess some STCW competences. Nevertheless, the software and e-learning course still require some improvements to make easy the learning curve: (i) from a user perspective (nautical science

student or officer) it is difficult use the software platform and requires to be put in to a more user-friendly interface; (ii) using generic data for engine and hull effects gives a limitation if the software would be used in a real situation but can be accepted in an academic environment to describe the effect of weather on voyage planning for students. Therefore, further steps will be set into a more user-friendly graphical interface used in common weather routing software on the market today in order to be practically workable and to prepare the students for their coming work tasks in the best way.

Finally, distance learning is not popularized for mandatory certification of seafarers due to the lack of approved training facilities, approved examination and assessment systems and quality standards system to control the MET activities. Based on STCW Convention's Manila amendment laying the foundation for the application and development of e-learning, the software package proposed in this contribution could be implemented as a new teaching model for MET institutions and could be considered as an "approved simulator training" or "approved laboratory equipment training". In this case, only competences 1, 4, 5 and 9 may be evaluated using SIMROUTE software. Nevertheless, Marine environment protection module could be introduced to reinforce this specific knowledge improving MET practices.

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Emergent technologies and maritime transport: challenges and opportunities

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ABSTRACT

This paper provides an assessment of autonomous ships taking a contextual approach that goes beyond the traditional focus on technical feasibility. We conceptualise a model for technology adoption that relies on three contextual factors (technical feasibility, human capital and economic benefits) and the enabling environment. We discuss how these factors play a significant role in autonomous ship development, bridging technology and the future of maritime education and training (MET).

By using in-depth interviews with senior maritime stakeholders, we draw a reflection on the future of MET. We argue that technology is creating a challenging environment for institutions and universities to keep the edge on knowledge, but it equally creates the opportunity to rethink programmes and curricula for the seafarer of the future. We conclude by providing guidelines on how MET can be transformed and suggest that university-industry collaboration is key to fostering knowledge creation and transfer that fits its purpose.

1 Introduction

Over the last decades, the maritime sector has seen tremendous changes as a result of the introduction of automation and technology. More recently, the concept of autonomous shipping has raised the interest of the international shipping community leading to a scoping exercise on maritime autonomous surface ships (MASS)¹ at the International Maritime Organization (IMO). Projects such as *YARA Birkeland* in Norway, the world's first fully electric and autonomous container ship under construction, are an example of the need to start to conceptualise how seafaring may change over the next decade or two.

While very often technical feasibility is the main focus of many discussions at the moment, there are a number of other factors that need to be considered. WMU (2019) considers that six main factors that affect the deployment of autonomous ships for commercial purposes. We argue that those six factors can be reduced a simpler model, easing subsequent analysis of technology adoption. Our argument is that technical feasibility, economic benefits and human capital are the main variables determining technology adoption and that the other subset is

¹ MASS is defined as “a ship which, to a varying degree, can operate independent of human interaction.” (IMO, 2018).

embedded into the enabling environment that encompasses social acceptance, regulation and governance. And, mutually reinforcing relationship exists between the three factors and the enabling environment. For example, a positive outlook for the three factors is likely to be translated into a positive enabling environment and vice-versa.

The regulatory framework for the operation of autonomous ships is currently under discussion at national and international levels. The regulatory scoping exercise being undertaken at IMO will alone last until 2023. Drafting regulations will take much longer. According to the logic above this is a clear manifestation of the infancy of autonomous ships from a technical feasibility, human capital and economic benefits point of view. In fact, we argue that autonomous ships may not cope with the current business models, as they are thought to be too costly in multiple ways under the current paradigm where seafarers are cost effective. However, research has shown that when labour is scarce and costly, companies are compelled to introduce automation to fulfil their role (Acemoglu and Restrepo 2017). Therefore, careful attention should be taken as specific competencies required to successfully operate the ships of the future, in particular autonomous ships, is not yet available in large numbers. What competencies will be required in the years to come is still subject to debate and by consequence far away from current maritime training and education (MET) systems.

The pace of change in shipping is largely constraint by a large capital investment (Fan and Luo 2013), as shipping remains a capital intensive business. While the pace of technology change is predicted to be slower than other industries (WMU 2019), the change on MET systems is also slow and complex. Therefore, there is an absolute need for starting to rethink MET and the role of MET institution for the next decades. On 15 January 2019 during WMU/ITF report on the future of work, IMO Secretary-General, Mr Kitack Lim, has expressed the need to consider raining and standards aspects of seafarers in an increasingly automated and digital industry. The framework we develop in this article is meant to foster a university-industry dialogue that enables to best adapt MET to a fast-changing landscape.

This paper is organised as follows. In section 2, we developed a theoretical framework while applying to the autonomous ships. Section 3 describes the methodology undertaken. The findings are presented and discussed in section 4, including a reflection on seafaring as a profession in subsection 4.1. Section 5 concludes.

2 Theoretical framework

2.1 Maritime technology: autonomous ships

Ships have been supporting international trade for several centuries, with technology shocks changing shipping operations and crewing. Historical data shows that those changes do not occur overnight but take time to diffuse. For example, the change from steam to combustion engine powered ships took more than a century to surpass 50 per cent in its use and about 180 years to surpass 90 per cent (Comin and Hobijn 2010). While this example illustrates how slow technology can be, historical data also shows that the diffusion process is becoming faster. Current ships are already equipped with a large amount of technology, such as the Autopilot, the Electronic Chart Display and Information System (ECDIS), and dynamic positioning (DP) systems, and modern engine rooms can be frequently unattended. Technological innovation,

therefore, is permeating the shipping industry, including those technologies associated with the fourth industrial revolution, at a pace that is predicted to be evolutionary (WMU 2019). Almost every day, the media announces initiatives undertaken by the industry that make use of the fourth industrial revolution related technologies, such as artificial intelligence (AI), internet of things (IoT), advanced robotics or blockchain.

Recently, much attention has been devoted to the concept of autonomous shipping. Projects such as *YARA Birkeland* in Norway, the world's first fully electric and autonomous container ship under construction, have generated enough attention from the maritime community that it has led to the establishment of a Working Group on MASS at the IMO. Currently, guidelines for test trials are being drafted and a regulatory scoping exercise is being conducted. While *YARA Birkeland* might represent a mark in the history of ship operations, its design is far from fitting for current long-distance shipping business models, thus it is not generating much traction among shipowners.

Automation in ships has been around for several decades. In 1964, IMO's (Inter-Governmental Maritime Consultative Organization, IMCO, at the time) VIII Maritime Safety Committee (MSC) under Agenda item 11, the Secretariat has provided several definitions related to automation in ships. This document provides definitions for fully-automated systems, partly-automated systems and remote-control systems for technical systems on-board ships. For example, remote control refers to monitoring and controlling machinery from the navigating bridge. It is clear that the scope of automation in 1964 was very different from the rationale behind the establishment of the MASS Working Group in 2018. Modern ships are becoming digitalised and connected with many automated technical systems, and monitored and optimised by onshore control centres or fleet operations centres which keep the human element in the loop to varying degrees. It is currently highly uncertain how much and to what extent the shipping industry will adopt further automation and autonomy at large. A guiding scale delivered by IMO MSC 100/WP.8 (IMO, 2018) provides a guide to the degrees of autonomy currently being considered at IMO, which we summarise in Table 1. The table shows that under the scoping exercise currently being undertaken at the IMO, Conventions are to be assessed not only for the fully autonomous ship, but also for several partially automated and autonomous ships. Although the aim of the MASS Working Group is mainly to perform a regulatory scoping exercise (RSE), by establishing a scale and definitions for the MASS, the group has contributed to increasing the clarity that is often missing in debates on MASS related subjects (Kitada et al. 2019).

Table 1: IMO MASS degrees of autonomy

Degree of autonomy	Remote control	Seafarers on board	Description
ONE	NO	YES	Ship with automated processes and decision support: Seafarers are on board to operate and control shipboard systems and functions. Some operations may be automated and at times be unsupervised but with seafarers on board ready to take control.
TWO	YES	YES	Remotely controlled ship with seafarers on board: The ship is controlled and operated from another location. Seafarers are available on board to take control and to operate the shipboard systems and functions.
THREE	YES	NO	Remotely controlled ship without seafarers on board: The ship is controlled and operated from another location. There are no seafarers on board.
FOUR	-	NO	Fully autonomous ship: The operating system of the ship is able to make decisions and determine actions by itself.

Notes: Adapted from MSC 100/WP.8, IMO (2018).

For the reasons above mentioned, it is factual that autonomous ships and shipping are an important topic for the maritime community. Despite that, it is very blurry how autonomous shipping will develop. At the current stage, different stakeholders have different views, much influenced by the context in which they belong, a key factor that has often been disregarded by some. We claim precisely that autonomous commercial shipping is mainly a function of an array of contextual factors that need to be in line in order for the technology to be deployed. The underlying hypothesis is that for technology to become widely used, this set of contextual factors needs to be met first, and without the correct alignment of these factors technology will not take over and, therefore, never arrive at a mature state (Gort and Klepper 1982; Ayres 1994).

2.2 A contextual model approach for technology

The literature on the determinants of technology and innovation is vast. Most authors focus on firm-level factors or macroeconomic factors. These studies mainly focus on different industries or the whole economy and are therefore unable to capture the idiosyncrasies from the transport industry, in particular maritime. To fill this gap, we propose a model that takes into account several contextual factors. Our model builds on the model of WMU (2019), which posits six factors that determine the adoption of technology. The contextual model we propose in this paper is based on the same factors but endogenizes parts of it, thus making it more applicable for identifying future opportunities and challenges within the system. The contextual model asserts that technology adoption is determined by three main macro-level pillars. The first is technical feasibility; the invention needs to exist prior to its commercialisation. While its commercialisation is of key importance for its success, the technological invention itself shall

not be discouraged, as it is an important piece for its successful commercialisation (Nerkar and Shane 2007). That technological invention results from a highly uncertain process of combination, recombination and integration of individual technologies (Fleming 2001). For example, at the moment, the technologies associated with autonomous ships are not on a readiness level that permits autonomous shipping in commercial operations, especially for deep-sea-going voyages.

The second relates to human capital. Human capital goes beyond the formal knowledge and skills but also encompasses accumulated experiences (Becker 1962) and is of strategic importance for organisations (Wright et al. 2014). Prior research has shown that complementarities between physical capital and human capital are of great importance as they are tightly linked, for example, to industry performance and productivity (Acemoglu and Autor 2011; Fonseca et al. 2018). Naturally, the human capital dimension is closely associated with the labour market and, therefore, subject to the factors affecting it. A close analysis at those is out of the scope of this article.

The third pillar relates to the economic benefits associated with technology. Recent research has shown that wages and investments in automation of tasks depend on the relative prices of capital and wages (Acemoglu and Restrepo 2018), thus making shipowners sensitive to labour costs and capital rents when maximizing their profits and investing in new technology. Currently, the strategies undertaken by most firms in the shipping industry fall under cost advantages rather than differentiation strategies. For autonomous ships to thrive, it is predicted that higher capital cost needs to be compensated by lower operational expenses, either from a fleet or from a supply chain perspective. At this point in time, it is very uncertain whether that is attainable. Some authors have already produced hypothetical cost analyses for autonomous ships (e.g., Kretschmann et al. 2017); however, those remain highly speculative and subject to a high level of uncertainty.

The original model also considers regulation and governance, and social acceptance as key determinants of technology adoption. Conversely, we argue that those factors are underlying factors rather than determinants. The rationale behind this is that the three key factors considered (technical feasibility, economic benefits, human capital) directly influence technology but the underlying factors, that is, regulation, governance and social acceptance, indirectly influence technology through the key factors. The underlying factors are the enabling environment for the three key factors. This logic is illustrated in Figure 1.

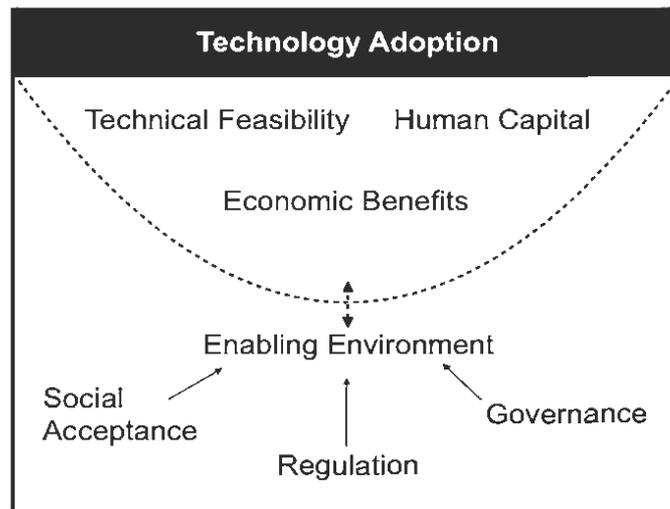


Figure 1: Technology adoption model

3 Methodology

The contextual model of technology adoption described above sets the foundations for our analysis of the current status of technology in maritime transport. We centre our analysis on ships with a varying degree of autonomy. Currently, the information sources for feeding the model are limited. Because of the tacit nature of innovation, much of the information is not codified in the literature but rather scattered in press releases and individual experts' knowledge. Therefore, for our analysis, we rely on in-depth semi-structured interviews with maritime professionals triangulated with a review of press releases and, when available, academic literature. The individual in-depth interviews took place during 2018 and the first half of 2019. While following the guide, the interviewers gave space for the interviewees to express their views in an almost open format. The number of interviewees is 25 senior professionals and stakeholder groups include shipowners, technical developers and experts, seafarers, regulators and classification societies, some from top management of international companies.

All interviews were conducted under strict confidentiality rules and anonymised prior to the analysis. Most stakeholders interviewed are in Europe, the region that has been the most publicly active on autonomous ships, from a technological point of view. The context of the interviews was recorded, or detailed notes were taken, depending on the preference of interlocutors. The qualitative data (transcripts or text-notes) were codified according to the model's variables for analysis. Thus, the findings and reflections of this paper are result of the analysis of the coded interviews triangulated with a review of press releases, academic literature and authors expert knowledge. The framework developed provides the lens through which the analysis was conducted.

4 Findings

4.1 Autonomous ships: technology adoption assessment

The assessment of technology adoption (see Table 2 for the summary), starts with the technology on the market. At the current moment, the adoption of autonomous ships is very limited. The data shows that most projects are in their infancy with limited practical use. The shipowners and operators consulted report limited interest in autonomous shipping but a large interest in making ships smarter, and thus increasing their sophistication not only onboard but

also onshore (e.g., by creating fleet control centres). These views are supported by most stakeholders consulted, especially when it comes to seagoing vessels. Autonomous shipping as a concept is currently only relevant for short-distance shipping and coastal trade. Therefore, the overall trend is to focus on already available and upcoming technologies that digitalise and network fleet operations rather than focus on autonomy. An interesting metric that can be used for assessing the diffusion of innovation is the number of producers (Gort and Klepper 1982). Currently, only a few firms are promoting autonomous ships, notably Kongsberg, Rolls-Royce (now part of Kongsberg) and Wärtsilä. This relatively small number of firms is a sign of the infancy of autonomous shipping. However, when it comes to smart shipping, the number of competitors supplying the various related innovations is much larger. The assessment of the status of smart shipping is out of the scope of this paper, yet it is an interesting avenue to be investigated.

Table 2: Technology adoption assessment: autonomous ships

Variable	Trends
Technology adoption	The technology is at its infancy, limited to specific contexts and geographical regions. The lack of firms pursuing autonomous ships' technology is a sign that the innovation is at its first phase.
Enabling environment	Legal and regulatory discussions are at a very early stage. Also, research has been founded by industry and governments to explore and develop autonomous ships but still that it is not enough to come up with a concrete picture about the design of the ships of the future.
Technical feasibility	Partial automation of several systems has been made successful over the last few years. Autonomous ships related R&D projects have been developed but Yara Birkeland is the one that stands out due to its commercial nature. It is thought that several gateway technologies already exist but the integration of all of those in a safe way is still a technical challenge.
Economic benefits	The cost of autonomous ships remains highly uncertain, averting the interest of shipowners in investing in it. It is predicted that autonomous ships will not fit the current business models followed by shipowners and operators, where cost advantages are the underlying strategy followed.
Human capital	Current seafarers are lacking in digital and other skills that are thought to be complementary and fundamental to autonomous ships' operations. Reassessing human capital, general and specific, and changing MET programmes is needed as technology adoption increases.

From a technical point of view, advances have been made toward ship autonomy. Notably, *Yara Birkeland* is taking the lead, not only regarding autonomous navigation but also on automated cargo handling. It is expected that similar projects will emerge in a few years as new projects are being funded. However, concerns regarding safety have been put forward by several stakeholders. These concerns are shared with similar applications in other industries

such as autonomous cars, in particular in regard to artificial intelligence-based systems. Most of these systems rely on algorithms that are highly non-transparent, acting as black box models (Samek et al. 2017). These systems can be highly biased, relying on correlations rather than causal links, depending on their training data. It is often impossible to interpret the models which create the question of compliance with regulations and general principles. Currently, research is trying to address this issue by developing strategies for auditing the algorithmic decision-making process behind AI. Advanced techniques are able to do this without violating the secrecy of the algorithmic decision-making processes (Lepri et al. 2018).

The current business model used by firms operating ships is based on economies of scale. As a result, over the last 20 years, the average container ship has grown significantly, by about 153% from 1996 to 2017, to take advantage of a lower average cost due to increased scale (Lian et al. 2019). Some authors have suggested that autonomous ships might not be more costly than conventional ships (e.g., Kretschmann et al. 2017). However, the stakeholders consulted were not optimistic about the introductory cost as more redundancy is required. Adding to that, the research and development (R&D) costs need to be amortised along with the cost of the infrastructure required. It is clear that at the current moment autonomous shipping does not fit the business models for sea-going voyages, a premise that is not foreseeable to change soon. Conversely, it is clear that newbuilds are being equipped with more and more technology that makes the socio-technical system much more sophisticated, digitalised and partially autonomous.

The last component under analysis is the human capital, a key component of a socio-technical system such as a ship. The standardisation of seafarers through IMO's International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) 1978, as amended, contributes to a harmonisation of maritime education and training (MET). However, this approach is often criticised by some of the consulted stakeholders as contributing to an education based on minimum standards that has led to a decline in seafarer human capital. Seafarers are currently signalled in the market as having similar qualifications that are often not corresponding to the factual seafaring capabilities, a problem observed in many other labour markets as described by Spence (1973), and which led to Spence winning a Nobel prize. While better signalling might help the employers to hire the right seafarers for the job, this does not solve the root cause of the problem. Most interlocutors that were consulted refer back to proper MET as a tool for solving the problem and providing seafarers with the actual competencies required by shipping companies of today and the future. For most shipowners and operators that were consulted, there is a lack of general and specific human capital, which creates a problem for the industry as a whole, including seafarers. As advanced technology becomes pervasive in ships, this lack of human capital is manifested even more than in the past.

Besides the technical development of ships towards automation, a lot of discussions have been started related to autonomous vessels. Numerous research projects are being undertaken in different parts of the world exploring and testing various technical aspects of unmanned and autonomous ships, in close collaboration with the maritime industry and research institutions. One example is the Maritime Unmanned Navigation through Intelligence in Networks project (MUNIN), which was completed in 2015 by a cluster of European maritime stakeholders,

aimed mainly to explore the technical, economic, and legal aspects of unmanned ships. Another example is the Advanced Autonomous Waterborne Applications project (AAWA), which has been supported by the Finish Government and led by Academia and industry and completed in 2018. It aims to produce the specification and preliminary designs for the next generation of advanced ship solutions. Remote-controlled and Autonomous Vessels for European and National waters (RAVEN) is a further innovative research project that aims to explore ways to convert an existing ship into an autonomous ship and explores the technical feasibility of its function as well as the infrastructure needed to be operational. Adding to that is the well-known project called Revolt and the Yara Birkeland cited above. DNV GL supported by Transnova, Norway, launched in August 2014 an innovative ship concept for an unmanned, zero-emission, shortsea vessel called the Revolt. This concept was the basis of the conceptualisation of the Yara Birkeland vessel which is expected to begin operations as a fully autonomous ship in the upcoming months.

The international maritime community has also been investing in some research projects related to regulation and policy. Lloyds Register, for example, released in February 2017 a code called “LR Code for Unmanned Marine Systems (UMS)” providing a goal-based framework to ensure the safety and operational requirements for UMS based on a set of performance standards developed to support design innovation. The Maritime Autonomous Systems Working Group (MASRWG) based in the United Kingdom prepared a voluntary Code of Practice in November 2017 for MASS. This code provides necessary practical guidance for the design, construction, and safe operation of autonomous and semi-autonomous vessels under 24m. The ideas in this Code are aligned with another research programme called the Safety and Regulation for European Unmanned Maritime Systems group (SARUMS) part of the European Defence Agency’s UMS (Unmanned Maritime Systems), which has sorted out best practices for unmanned ships including operations, design and regulations. The SARUMS group has members from Belgium, Finland, France, Germany, Netherlands, Italy and Sweden.

In this regard, nine maritime nations (UK, Denmark, Estonia, Finland, Japan, Netherland, Norway, South Korea and the United States) took the initiative in delivering a proposal to the IMO’s Maritime Safety Committee for a “regulatory scoping exercise” to determine the extent to which the existing corpus of IMO regulations are suitable for the introduction of unmanned ships. The proposal paper, submitted to the Maritime Safety Committee session 98 (MSC 98/20/2), was submitted in February 2017 and proposes that the MSC identify IMO regulations which: (a) preclude unmanned operations; (b) have no application to unmanned operations; and (c) do not preclude unmanned operations but may need to be amended in order to ensure that the construction and operation of marine autonomous systems are carried out safely, securely and in an environmentally safe manner.

At its 99th session, MSC at IMO endorsed the preliminary definition of MASS as a ship which, in different levels can operate without human interaction. The framework of the regulatory scoping exercise was approved as a work in progress and concluded the four levels of autonomy that were designated previously in this paper. Further, in its recently concluded 101st MSC session at the IMO, the MSC approved the framework and encouraged countries to participate

further in the regulatory scoping exercise (RSE). The Committee also completed and updated the list of statutory IMO instruments provided to address regulatory gaps related to autonomous ships. Moreover, the MASS has developed trial guidelines that aim to be a single document for the use of industry, administrations and relevant stakeholders. It is worth highlighting that discussions about autonomous ships, either among industry or various other stakeholders, are still at an early stage. The development of these discussions depends mainly on social and political acceptance.

4.2 Future of seafaring: a reflection

As mentioned previously, the maritime industry technological transformation in the future has the potential to change the way ships operate. The adoption of innovations in shipping is progressively becoming a reality and is already transforming seafaring as a profession. Some simulations show that the introduction of highly automated ships (IMO MASS autonomy level 2 and above) can lead to a decline in crewing that manifests in reduced global demand for seafarers by about 22% (WMU 2019). However, the same simulations also show that overall demand for seafarers is unlikely to shrink due to a continuing increase in global trade. By 2040, the global demand for seafarers is projected to almost double, despite having some highly automated ships sailing alongside. The ships of 2040 are expected to be more technological, some autonomous, and thus requiring seafarers and onshore operators with different skills, knowledge and expertise than today.

The results of simulations are subject to a high level of uncertainty, which also manifests in uncertainty regarding the extent to which the jobs of seafarers will be affected by technology, especially when most of the seafarers come from developing countries (UNCTAD 2019). Important questions are raised by the maritime community, specifically about how the role of the human element onboard may be affected by technological change. Discussions about the impact of new technologies on seafarers differ between those who take a more cautious approach and are reluctant about the adoption of new technologies on ships and those who are more optimistic about its use and wish to foster and promote it. These views depend on local contexts and economic self-interest. For some, embracing technological change means redefining the professional profile of “*the seafarer*,” and seeing it from a completely different perspective by conceptualising the seafarer not only in the classical sense but also as a professional able to perform non-seafaring tasks that emerge due to increased technology use (e.g., working as onshore fleet operations control officers). This view takes the seafarer away from their traditional role towards high-level problem solving and mastering of unusually complex situations, which might create fears among several stakeholders working in the field.

In January 2019, at the launch of the WMU/ITF report: Transport 2040: Automation, Technology and Employment – the Future of Work, the IMO Secretary-General, Mr Kitack Lim, pointed out the need to consider seafarer training and standards aspects as the shipping sector increases levels of automation and digitalisation. The IMO Secretary-General set out subjects that stakeholders at the maritime community have to focus on: “*How will the seafarer of the future manage the challenges related to an increasing level of technology and automation in maritime transport? How will the new technologies impact on the nature of jobs*

in the industry? What standards will seafarers be required to meet with respect to education, training and certification to qualify them for the jobs of the future?'. The importance of the future of seafaring is clear.

In this sense, it is essential to understand which qualifications and skills will be needed in the future. The future of seafarers is promising in the predictions of some (HSBA 2018; WMU 2019), but maritime education and training needs a profound change to adapt to this future. So far, limited literature exists that can provide guidance on shaping MET of the future. The maritime community, including the companies developing and potentially using advanced technologies, have just recently started to brainstorm on the training, skills and motivation for *“the seafarer of the future”*.

One of the hardest aspects of professional development of seafarers for the future is to build it on the foundation of the past, but with a vision of what is ahead. A seafarer might need to know the traditional maritime knowledge such as celestial skills, ability to read paper charts, parallel rules, and dividers, while recognizing the clouds, waves, and weather. Traditional maritime knowledge needs to be enhanced with extra knowledge and competencies that enable seafarers to constantly adapt to new and emerging technology. For example, in March 2018, a merchant vessel suddenly and inexplicably lost all connection to GPS on board. The master and officers set out their situation by applying traditional maritime knowledge, common sense and seamanship (S&P Global Platts 2019).

A framework to accomplish this vision can be found in the model of technology adoption described, which can inform the technology-induced gap that needs to be addressed by MET. Furthermore, as frequently referred to by the interlocutors that we consulted, a close consultation between MET institutions and universities, and the rest of the maritime community is needed for building the MET of the future. This logic is illustrated in Figure 2 which bridges the contextual model above explained with future of MET, which we term MET 4.0 in resemblance of the industry 4.0 or fourth industrial revolution.

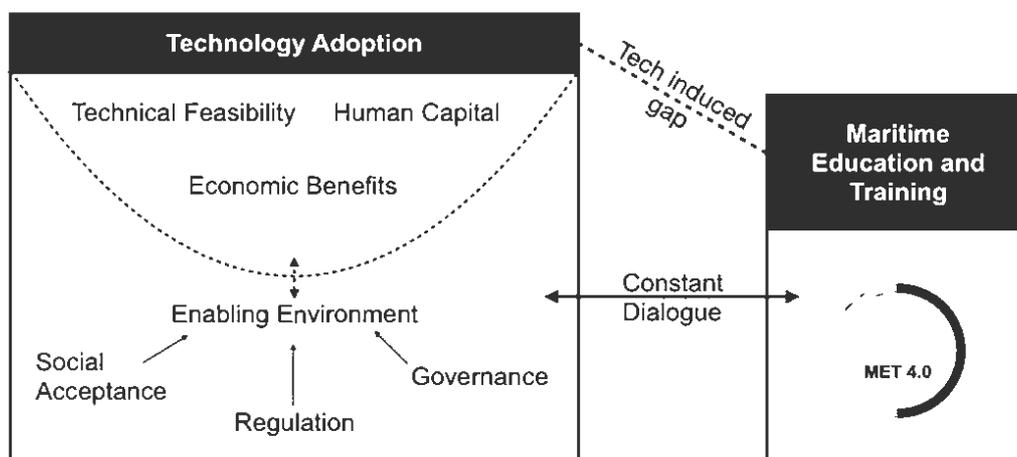


Figure 2: Technology adoption and MET 4.0 - a framework

The future MET or MET 4.0 will not just have elements of classical maritime competencies

but also capacitate seafarers to adapt to the fast-changing landscape, while equipping them with competencies that can be used for onshore jobs and even in other industries. According to our interlocutors, some MET institutions are already taking the first steps toward combined MET programmes that provide seafarers with research-based education that combines digital skills (e.g., computer programming), and elements from other specialisations such as engineering, shipping management and logistics. Cross-fertilisation between disciplines capacitates MET students with the tools for tackling problems in a fast-changing landscape as well as providing students with the foundations to successfully benefit from life-long learning.

Universities-industry (U-I) collaboration is also fundamental for translating the needs of the industry into MET programmes. Such collaboration has existed for a long time but not without barriers (Bruneel et al. 2010). However, as technology changes rapidly the pressure on both, industry and universities, builds up and the need for increased collaboration becomes more evident. The pressure for universities to incorporate new knowledge leads to a large burden in establishing solid collaboration that permits universities to remain on the edge of knowledge (Hagen 2002). While research provides some guidance on how to strengthen U-I collaboration (e.g., Ankrah and AL-Tabbaa 2015), the interlocutors that were consulted are still reporting a lack of alignment between MET and the real needs of increasingly complex and digital business.

As technology in the maritime field is advancing, the training methods are slowly starting to change. However, the question remains: *what will be the subjects to be learned in the future and how is this learning going to be delivered?* The answer seems to be the same as to the question: *what will machines and computers be unable to do onboard ships and onshore?* As highlighted in the framework of Figure 2 a gap assessment that is forward-looking is key to ensuring MET is constantly updated to address this. Current intelligent machines have limited capacity to handle all situations, as some may require a complex combination of intuitive reaction, creativity, decision making, social intelligence and complex discernment and manoeuvring that are not reflected in the training data. As written by McKinsey&Company (2017): “Yet machines cannot do everything. To be as productive as it could be, this new automation age will also require a range of human skills in the workplace, from technological expertise to essential social and emotional capabilities.”

With the rapid introduction of technology, seafarers, as many other transport workers are in need of MET that is able to provide them with the tools to master the changing nature of work. These tools come from establishing a close I-U link, and taking onboard classical maritime subjects, complemented with courses in other disciplines as described above. They can provide the foundations that enable the seafarer of the future to be adaptable to a fast-changing working environment. Naturally, this encompasses research-based education on science, technology, engineering, math (STEM) subjects, as well as an emphasis on soft skills. This holistic approach can provide seafarers with the absorptive capacity to benefit from continuous learning, a work value and mindset that both seafarers and stakeholders involved in the maritime sector should always keep in mind.

5 Conclusions

Current maritime rules require ships to be manned. While increasing automation raises questions about the role of the human element in the whole process. Most signals make us believe that the human element will not be taken out of the loop over the next decades. However, the social-technical environment seafarers will operate in the future will change. Therefore, adapting MET to the future is key so that the industry remains at least as efficient and safe as today. Many questions are rising regarding the exact competencies required in the future. To answer these questions, we propose a framework that takes into account not only technology adoption but also the link with its drivers.

Our framework suggest that MET of the future is the result of a continuous scanning for the gaps introduced by technology and that attention is given to the underlying factors of technology: technical aspects, human capital aspects and economic benefit aspects, as well as the enabling environment. By closely monitoring these key factors and developing an efficient and effective interface between MET institutions and universities and the industry, so that future programmes for seafarers encompass, not only classical maritime competences but also enables the maritime professionals to work even in other sectors. A holistic approach is only viable through collaboration and consultation within the maritime community.

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Cyber Security Testing of Shipboard Chart Radar

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ABSTRACT

Shipboard navigation systems have been intensively developed for the last two decades, resulting in complex and computer based technology systems. The chart-radar is an onboard navigation system that integrates electronic navigational charts with the full radar functionality, thus allowing improved efficiency and safer navigation. In this work, we present cyber security testing of a chart-radar system implemented on an SOLAS ship sailing on international route. The cyber security testing method aligns with the upcoming maritime standard IEC 63154. The testing was performed using a widely deployed solution for application vulnerability detection. Solving solutions for the identified vulnerabilities are studied.

1. INTRODUCTION

Shipboard navigation systems have been intensively developed for the last two decades by means of digitalization, network integration and software development, which resulted in complex and computer based technology systems. Therefore, safeguarding shipping from cyber threats is gaining increasing relevance in the development of shipboard navigation systems [1-6]. Recently, the International Maritime Organization (IMO) issued the Guidelines on maritime cyber risk management, which offers general recommendations for shipping protection from cyber vulnerabilities and threats. [7]. IMO has also placed to incorporate cyber risk assessment in the implementation of the International Safety Management Code on vessels by start of the year 2021 [8]. In addition, International Electrotechnical Commission (IEC) is preparing a new maritime standard IEC 63154 “Maritime navigation and radiocommunication equipment and systems - Cybersecurity - General requirements, methods of testing and required test results”, which should be published in April 2021 [9].

The radar equipment is considered as a critical navigation system for safe navigation and collision avoidance. With additional integration of electronic navigational charts (ENC) with the full radar functionality (the chart-radar system), the improved efficiency and safety at sea is provided. The chart-radar is, however, essentially a software application running on a standard computer with installed a general operating system. While IMO regulations

standardize radar operational software performance [10], the supporting hardware and software is arranged by ship-owners and implemented by radar equipment manufacturers.

Recently, we presented a cyber risk assessment of a ship based on computational cyber security testing method for identification of cyber threats [1]. In this work, we have tested cyber security of a chart-radar implemented on a SOLAS certified ship sailing on an international route (Figure 1). The chart-radar (which is IMO compliant) was tested by performing vulnerability scanning using a widely deployed solution for application vulnerability detection. The identified cyber vulnerabilities together with possible solutions are studied.



Figure 1. The vessel on-board which cyber security testing was conducted.

2. CHART-RADAR

The tested chart-radar is of Wärtsilä SAM Electronics manufacture, model NACOS RADARPILOT Platinum. The chart-radar is IMO compliant and the radar software meets IMO performance standards. The type approval dates from the year 2017 and chart-radar was installed on the ship in the year 2018. The chart-radar technical specification is given in Table 1.

Table 1. The chart-radar specification.

INS	Manufacturer	Wärtsilä SAM Electronics GmbH
	Model	NACOS RADARPILOT Platinum 2017
	Software version	2.1.02.10
	IMO compliant	Yes
Charts	IHO ENC	IHO S-57 (Edition 3.1.1)
	IHO RNC	IHO S-61 (Edition 1.0)
	IHO Chart Content	IHO S-52 (Edition 6.1.1)
	IHO Data Protection	IHO S-63 (Edition 1.2.0)
Interfaces	Serial NMEA	IEC61162-1
	Serial high speed	IEC61162-2
	Network	Ethernet (LAN)
	Chart Update	USB
	Remote maintenance	Possible

The chart-radar is installed in the stand-alone configuration, with no Internet connection established. Data from radar, GPS, AIS, gyrocompass, log and NAVTEX are

gathered directly via serial interfaces, while the Electronic Navigational Charts (ENC) are updated with an USB memory stick provided by the manufacturer.

3. CYBER SECURITY TESTING

The cyber security testing was performed using a widely deployed solution for application vulnerability detection, Nessus Professional [11]. The vulnerability scanning provides automatic detection of all cyber vulnerabilities that are known not only to software manufactures, but as well to potential attacks [12]. The testing was conducted by directly internetworking a laptop with Nessus Professional scanner to the chart-radar. The testing setup is shown on Figure 2.



Figure 2. Cyber security testing of the chart-radar.

The testing was performed without administrative privileges, while the chart-radar software was running under administrative privileges. Even the testing is a passive process, during the scan the ship was docked in a port.

4. RESULTS DISCUSSION

Summary of the results obtained with the test is shown on Figure 3. In total, 14 risky vulnerabilities were detected. According to the severity level, 2, 1, 9 and 2 were assigned with critical, high, medium and low level respectively.



Figure 3. The test summary report.

List of detected vulnerabilities is given in Table 2. The critical severity vulnerabilities detected (Table 2, vulnerabilities 1 and 2) are related to weaknesses of services running on

the chart-radar underlying operating system, Microsoft Windows 7 Professional Service Pack 1. For the maritime community, Server Message Block (SMB) service vulnerability (Table 2, vulnerability 1) is particularly important because of the NotPetya ransom-ware attack on Maersk container shipping company, in which the NotPetya malicious software was worldwide spreading using the detected vulnerability [13]. In addition to system patching and anti-malware software usage, the preventive solution recommended by the manufacturer (Microsoft) is to disable or block SMB v1 [14].

Table 2. The chart-radar cyber vulnerabilities detected.

Name	Description	Severity
1 SMB v1 service	Chart-radar is affected by remote code execution vulnerabilities exist in the Server Message Block (SMB) service version 1.	Critical
2 Secure Channel	Chart-radar is affected by a remote code execution vulnerability due to improper processing of packets by Secure Channel security package.	Critical
3 RDP service	An arbitrary remote code vulnerability exists in the implementation of the Remote Desktop Protocol (RDP) on the chart-radar.	High
4 SAM and LSAD protocols	Chart-radar is affected by an elevation of privilege vulnerability in Security Account Manager (SAM) and Local Security Authority (Domain Policy) (LSAD) protocols.	High
5 Terminal Service	Remote Desktop Protocol Server (Terminal Service) running on the radar is vulnerable to a man-in-the-middle attack.	Medium
6 Terminal Service	Terminal Services service running on the radar doesn't use Network Level Authentication only.	Medium
7 Terminal Service	Terminal Services service running on the radar is not configured to use strong cryptography.	Medium
8 SMB signing	Signing is not required on the chart-radar through Server Message Block (SMB) service.	Medium
10 SSL certificate	Secure Shell Layer (SSL) certificate of the chart-radar cannot be trusted.	Medium
11 SSL certificate	An Secure Shell Layer (SSL) certificate in the certificate chain has been signed using a weak hash algorithm.	Medium
12 SSL certificate	Chart-radar supports the use of medium strength Secure Shell Layer (SSL) ciphers.	Medium
13 SSL certificate	Secure Shell Layer (SSL) certificate chain for the chart-radar ends in an unrecognized self-signed certificate.	Medium
14 SSL certificate	Secure Shell Layer (SSL) certificate of the chart-radar supports the use of RC4 in one or more cipher suites.	Low

The high severity vulnerabilities detected (Table 2, vulnerabilities 3 and 4) are related to weaknesses of active services on the chart-radar, allowing for possible unauthorized remote code execution and unauthorized access gaining. The recommended solution is installation of security patches released by the underlying operating system provider. The detected medium and low severity vulnerabilities (Table 2, vulnerabilities 5 - 14) are related to the active services' weaknesses that allow for establishment of unauthorized access or cause a denial of service condition of the char-radar. Possible solutions include installation of the provider's security patches and adequate reconfiguration of the underlying operating

system. Implementation of all of the solutions could impact the chart-radar functionality, and therefore is to be conducted only by the chart-radar manufacturer. While the solutions provide protection from known vulnerabilities, protection from newly discovered vulnerabilities would be to disable unnecessary services offered by general operating systems. As it is shown with the cyber security test conducted, source of the detected vulnerabilities (Table 3) is in active services of the chart-radar underlying operating system, which are actually not required for the expected chart-radar functionality.

5. CONCLUSIONS

Cyber security testing of a shipboard chart-radar is presented. The testing method is based on cyber vulnerability detection using a widely deployed solution for application vulnerability detection. The results have shown that cyber vulnerabilities are in active services of the chart-radar underlying operating system, which are all unnecessary for the expected chart-radar functionality. The cyber security testing and obtained results contribute to the knowledge on maritime cyber security and highlights importance for development of the upcoming maritime cyber security standard IEC 63154.

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Training Model Based on The Anchoring Training

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ABSTRACT

This paper examines the effect of anchoring training given to trainees on the training ship at Tokyo University of Marine Science and Technology in 2017 and 2018. Two teachers, who were experienced as captains, evaluated the anchoring training using an evaluation rubric. High effectiveness evaluations were given to the skills associated with heaving up the anchor and the anchoring procedures; however, low effectiveness evaluations were given to situation-based skills associated with the give-way or stand-on ship handling and route voyage. For more effective overall anchoring training, a training model that combines ‘group work’, ‘actual ship training’ and ‘debriefing’ is proposed.

1. INTRODUCTION

Maritime knowledge and skills are achieved through both classroom education and actual shipboard training. The maritime classroom training generally involves lectures, exercise assignments and experiments, and the shipboard training involves active learning with authentic equipment. Compared with classroom training, it has been found that the practical shipboard training is more effective. However, simply practicing course content is not sufficient as students also need to be able to perform taught tasks and master active thinking, problem-solving and decision-making. Kashima et al. (2001) found that anchoring training on a training ship has a significant effect on the acquisition of ship handling skills [1], and Kunieda et al. (2018) found that that anchoring training could develop active thinking and problem-solving skills [2]. In this paper, the on-board anchoring training effect was examined, the results from which were used to inform the development of an effective training model.

2. ANCHORING TRAINING

Anchoring training, which is performed by student teams without instructor assistance, is a suitable exercise to improve ship handling skills through various manoeuvres. At first, the students heave up the anchor and sail on a planned route. Then, after passing planned waypoints, the students anchor at the planned anchorage. Anchoring training is generally performed in four-person teams, each of which has defined roles such as captain (Role of Captain-ROC),

first officer (Role of 1st Officer-RO1O), third officer (Role of 3rd Officer-RO3O) and quartermaster (Role of Quartermaster-ROQ); the training flow is as follows:

- (1) The ROC takes the lead and develops a navigation plan for the anchoring. This type of active student planning of ship handling is designed to develop leadership skills for the ROC and to create opportunities for peer learning. The ROC explains the navigation plan to his or her teammates and instructors, who then give them advice and feedback to correct the plan. After correcting the navigation plan, the ROC provides a briefing to the team members and instructors, who then check their notes and roles.
- (2) The ROC positions the leaving anchorage station and before heaving the anchor chains, directs the RO3O to prepare the main engine and then directs the heaving up of the anchor.
- (3) When the anchor is aweigh, the ROC sets off on a predetermined course using the main engine and rudder.
- (4) The ROC corrects the course appropriately to ensure that the planned route can be navigated. The ship then passes two scheduled waypoints and navigates a predetermined route.
- (5) The ROC slows the main engine, adjusts the course and stops the ship by applying the main engine to the sternway to ensure it is anchored correctly at the planned anchorage.
- (6) The ROC lets the anchor go at the planned anchorage, lets out the cables to a predetermined length, stops the main engine and finally dismisses the anchoring station.
- (7) Shortly after the end of training, the students complete a self-evaluation based on an evaluation rubric.
- (8) The anchoring training is then discussed within each group. Each team member presents their ship handling notes and the other students listen and engage in active thinking. The positive aspects and points for training performance improvements are then discussed within each team, after which it is presented to all teams, and the instructors give comments based on the evaluation rubric.

3. RESULTS OF ANCHORING TRAINING

In May and June, 2017 and 2018, anchoring training was conducted with third-year students from the undergraduate maritime systems engineering course at the Faculty of Marine Technology, Tokyo University of Marine Science and Technology and was evaluated using an evaluation rubric by two instructors experienced in captaining large training ships. The nine evaluation items were as follows: (1) Procedure for heaving up the anchor; (2) Lookout; (3) Course setting; (4) Give-way or stand-on ship handling; (5) Position fixing and anchoring position; (6) Anchoring procedures; (7) Gradual speed decrease; (8) Bridge Resource Management (BRM)/Bridge Team Management (BTM) and (9) Overall training. Course syllabus of all nine items (Extract) is shown in Table 1. The items were evaluated with a four-level indicator. The average marks given by the instructors for each evaluation item in 2017 and 2018 are shown in Fig. 1.

Table 1. Course syllabus of all nine items (Extract)

No.	Evaluation items	Performance goal	Evaluation criteria
1	Procedure for heaving up the anchor	The trainee can lift an anchor appropriately and can make it a predetermined speed.	1) An understanding and execution of the procedure which heaves up an anchor. 2) An understanding and execution of the procedure which raises the ship's speed.
2	Lookout	The trainee can do the lookout for a safe navigation.	1) The ability to discover a target at an early stage. 2) The ability to watch a target carefully continuously.
3	Course setting	The trainee can do a setup of the suitable course according to a situation.	1) Ability which can perform a proper course setup in raising the ship's speed. 2) Ability which can perform a proper course setup in consideration of the influence of external force, etc.
4	Give-way or stand-on ship handling	The trainee can do suitable ship handling for avoiding a collision according to law and a situation.	1) Ability which can do suitable Ship handling in accordance with the law 2) Capability which can do suitable Ship handling according to the situation at that time.
5	Position fixing and anchoring position	The trainee can do the grasp a ship's position in suitable time and high accuracy.	1) The ability to grasp the ship's position appropriately. 2) The ability to anchor in the planned anchorage.
6	Anchoring procedures	The trainee can do anchoring in a suitable procedure.	1) An understanding and execution of the procedure which anchor. 2) An understanding and execution of a relation of ship's speed and the anchoring procedure
7	Gradual speed decrease	The trainee can reduce speed appropriately.	1) Gradual decrease of the ship's speed in accordance with a standard. 2) Gradual decrease of the ship's speed according to the situation at that time.
8	Bridge Resource Management (BRM)/Bridge Team Management (BTM)	The trainee can utilize resources appropriately and can attain performance high as a bridge team.	1) Ability for using the resource in Navigational bridge. 2) Ability to tell team members the Ship handling intention
9	Overall training	The trainee can perform suitable Ship handling through the whole training.	1) Ability which can perform Ship handling with calm mind. 2) The whole impression.

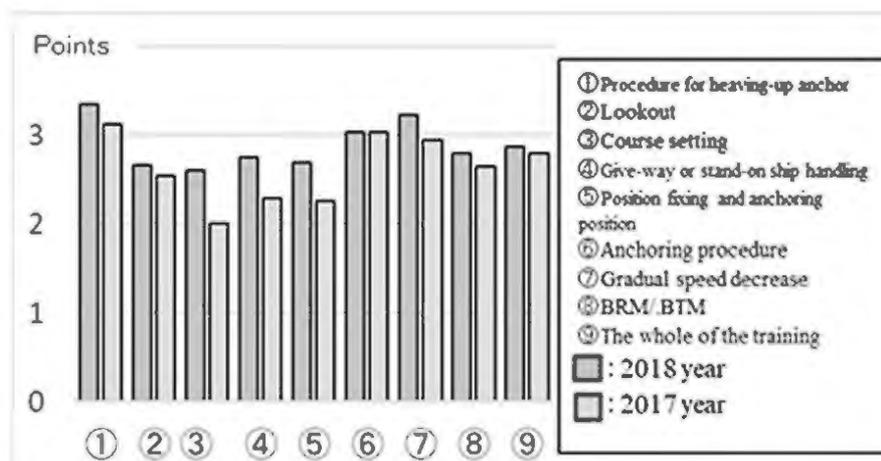


Fig.1 Instructors' average mark for each evaluation item

The average mark for all items was 2.62 in 2017 and 2.88 in 2018. Evaluation items (1), (6) and (7) had generally high scores, while items (2), (3), (4) and (5) had generally lower scores, which appeared to indicate that the items that required memorized procedures gained significantly higher scores than the items that required the students to make decisions based on the situation at hand, such as give-way ship handling and route navigation. At the same time, about (3), (4) and (5), it turns out simultaneously that the difference in 2017 and 2016 is large. This will be considered because in 2017, the experiment using various cards which are effective for navigating on the route and for determination of ship's position was conducted [3]. However, we think that the further investigation and examination will be required from now on.

The instructor evaluation scores in 2018 for high- and low-scoring trainees are shown in Fig. 2. The high-scoring trainees had slightly lower scores for evaluation items (2), (3) and (5), and the low-scoring trainees had low scores even for evaluation items (6) and (7) for which the other students had comparatively higher scores. Because there were many overlapping tasks when approaching the final anchoring, it was surmised that the low-scoring trainees were unable to calmly approach overall ship handling.

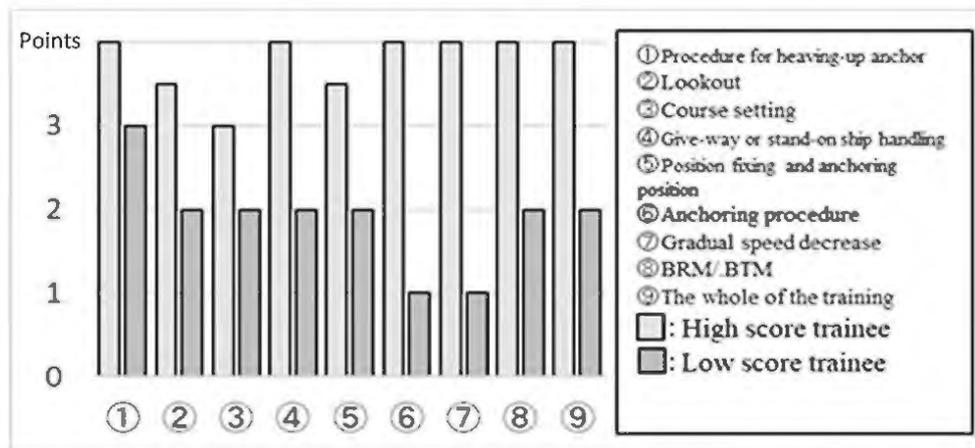


Fig.2 Instructors' average mark in each evaluation items of a high score trainee and a low score trainee.

The planned anchoring position and the anchoring position achieved by each trainee in 2018 are shown in Fig. 3, and the relation between the evaluation score and the distance of the actual anchoring position to the planned anchoring position is shown in Fig. 4. Fig. 3 indicates that the high-scoring trainees were able to anchor the ship close to the planned anchoring position, but the low-scoring trainees anchored much further away from the planned anchor position. The dotted line in Fig. 4 is an approximation straight line, and the correlation coefficient of -0.28 indicated that there was a weak negative correlation. While the high-scoring trainees mostly anchored close to the planned anchoring position, some anchored a fair distance from the planned anchoring position. While this is a key skill in this training, achieving the anchoring skill of exact positioning is only one of the nine evaluation items.

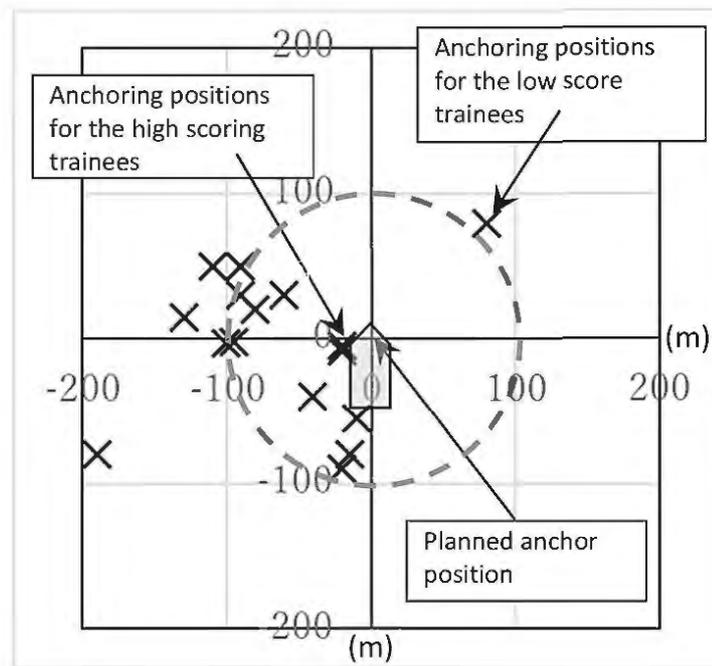


Fig.3 Relation between the planned anchoring position and the trainee anchoring positions

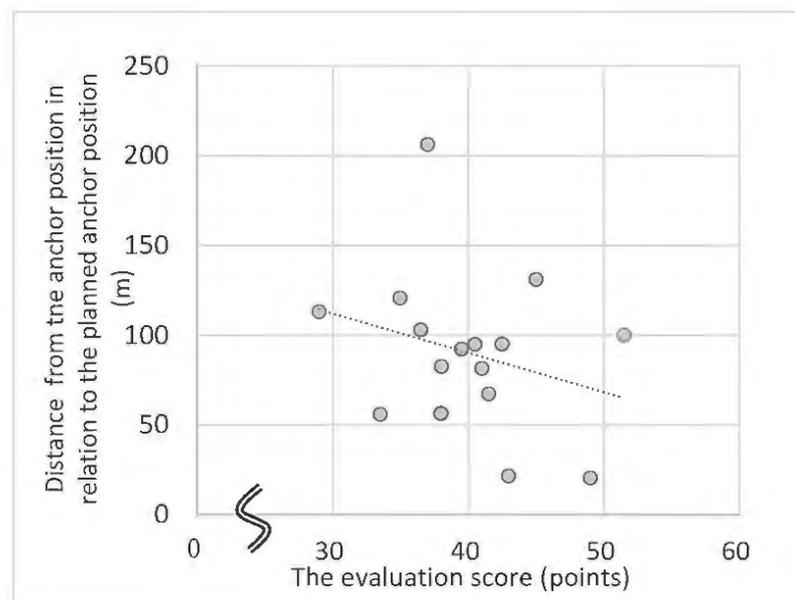


Fig.4 Relation between the evaluation score and the distance of the anchoring position from the planned anchoring position

To determine and classify the factors for each score, the training effect comments from the high-scoring trainees, the bridge teams and the instructors were examined, from which the following observations were made.

- (1) For ship handling planning, understanding was improved through group dialogues and peer learning, which improved the overall team performances.
- (2) Role plays and simulations for skills acquisition could be considered to understand and explore various assumptions before actual shipboard practice.
- (3) The presentation of the ship handling plan was effective in reinforcing the knowledge and skills.
- (4) Telling team members about the ship handling intentions was vital for information sharing, clearing up any misapprehensions and preparing for possible emergencies.
- (5) Discussing the effective points of training and the areas that needed improvement enhanced the trainees' knowledge and skills.
- (6) The debriefing presentation reinforced trainee knowledge and developed thinking and assessment skills.

4. EXAMINATION OF A TRAINING MODEL

The anchoring training evaluation results and instructor and trainee comments and observations were used to propose a more effective GTGP training model shown in Fig. 5. About group work, the effect is proved also in other fields [4][5][6]. We think that the training model which combines group work before and after actual ship training is very effective. Moreover, we think that the training effect goes up when students make a presentation as reflection. Moreover, we think that the training effect goes up when students make presentation as reflection as Uno et al. show [7].

In ship handling planning, an understanding of the procedure and the checking of notes can be performed through dialogue, discussion and peer learning through group work.

Prior to the ship handling exercise, planning sessions could be held to ensure trainees fully understand the procedures through dialogue, discussion, role plays, simulations, group peer learning and authentic briefing practice, with the emphasis being on group/team work learning (G).

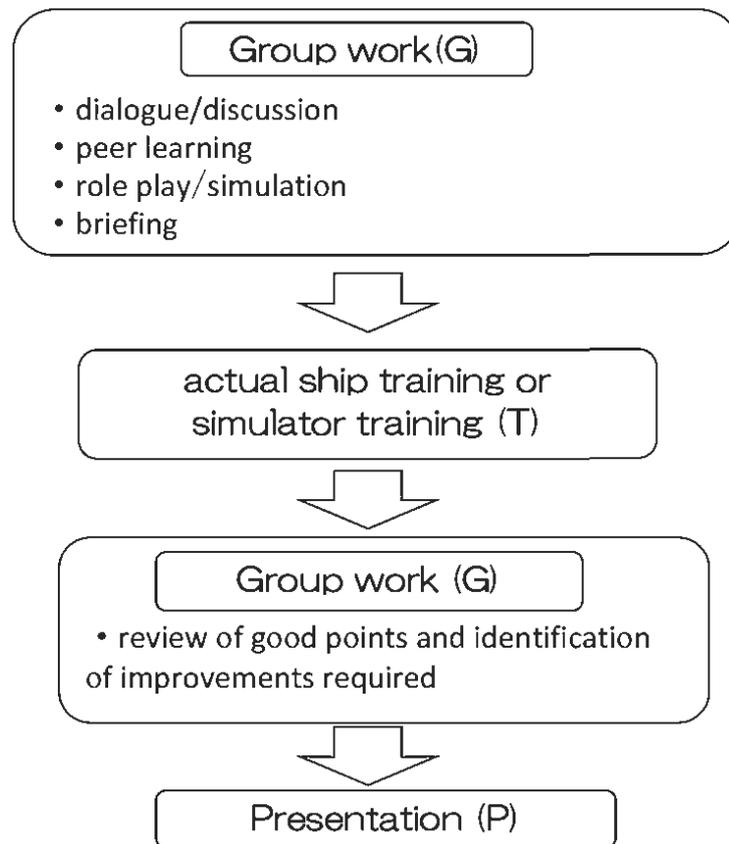


Fig. 5 Effective training model for anchoring training

Next, during actual ship training, the trainees practice memorized procedures and demonstrate their ship handling skills based on the given situation using the knowledge and technologies discussed in the first session. It is proposed that actual training at sea on an actual ship is the most effective (T) as trainees must apply the learned ship handling knowledge to an actual team situation.

After the ship training, each group then identifies the good points from the training exercise and identifies those areas in which improvements are required, all of which requires the trainees to reflect on both their individual and team knowledge and skills, which raises awareness and stimulates decision thinking (G).

Finally, based on the group discussions, each group/team assesses their own performances, presents these findings to the other groups and come to understand the results from the other groups, thereby further deepening both individual and team understanding, all of which improves trainee knowledge and skills (P).

Although this training model is specifically based on anchoring training and considered it, it could easily be used for other types of practical maritime-based training, such as lifeboat lowering, on-board work procedures, emergency procedures and accident investigations among several other areas. The key aspect of this type of peer learning or jigsaw method is that the trainees have the opportunity to reflect on their experiences and to learn from the experiences of others. This training model involves the trainees in reviewing their training and understanding their role in the groups/team and, therefore, expands their critical thinking and decision skills, both of which are vital for effective on- and off-board maritime operations.

5. CONCLUSION

The paper examined anchoring training evaluations from training conducted at the Faculty of Marine Technology, Tokyo University of Marine Science and Technology in 2017 and 2018. Nine specific procedures were evaluated by experienced instructors from which it was found that procedures (1) Procedure for heaving up anchor, (6) anchoring procedure and (7), all of which were memorized procedures, had generally high evaluation scores, but procedures (2) Lookout, (3) Course setting, (4) Give-way or stand-on ship handling and (5) Position fixing and anchoring, all of which required on-board decision-making based on the situation, had much lower evaluation scores.

As the high-scoring trainees demonstrated that it was possible to correctly perform the ship handling procedures, to better assist the trainees in thinking for themselves, they need to be better prepared to respond to unknown situations. From the results of the anchor training effect evaluations, a revised training model was proposed that had four main stages:

- group work that includes peer learning, discussion, dialogues, role plays and simulations;
- actual ship training to improve problem identification, problem-solving and decision-making capabilities;
- group reflection on the training and the identification of the strong and weak aspects;
- presentations and overall class discussions on the results.

The aim of each of the identified training stages is to develop trainee abilities to think for themselves and respond confidently in all situations. We would like to apply the built training model to various training, and would like to verify the training effect from now on.

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POLICY RECOMMENDATIONS FOR AUTONOMOUS UNDERWATER VEHICLE OPERATIONS THROUGH HYBRID FUZZY SYSTEM DYNAMICS RISK ANALYSIS (*FuSDRA*)

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Keywords: Risk Analysis, System Dynamics, Fuzzy Logic, Autonomous Technology, Policy Setting

ABSTRACT

The advancement of science and technology has resulted in an emerging trend in the use of autonomous equipment in many maritime universities. One such example is the use of autonomous underwater vehicles (AUV) for marine research. However, a key challenge lies in preventing loss of the AUV during deployment. To better control this risk of loss, a new form of hybrid fuzzy system dynamics risk analysis (FuSDRA) is proposed. The three-step framework was demonstrated by a case study, analysing how reducing government support and increasing technological obsolescence can impact the long-term risk of AUV loss. Both results showed increase in risk of loss after 7 years into the AUV program and a synergistic combined effect when compared to a base scenario. A suite of risk control policy recommendations was proposed based on these results. Lastly, broader applications of the framework to other autonomous equipment is proposed.

1. INTRODUCTION

The advancement of science and technology has resulted in an emerging trend in the use of autonomous equipment for research purposes in many maritime universities. With advantages such as the ability to reach inaccessible locations, reduce personnel dependence and improve safety, it comes as no surprise that a diverse range of research activities is now performed autonomously without human interference. One such example is the Autonomous Underwater Vehicle (AUV).

Autonomous Underwater Vehicles (AUVs) are self-powered robotic devices that operate underwater. Apart from the ability to operate autonomously, their versatility with customizable payloads allow AUVs to perform a wide range of research tasks⁽¹⁾. However, the risk of losing a research AUV during deployment is ever present. Here, the term 'risk of loss' refers to the likelihood that during a mission, an AUV vehicle will be rendered unusable for future missions. Not without precedent, two examples of loss are the Tadpole, an AUV operated by the Institute

of Antarctic and Southern Ocean Studies, Australia, ⁽²⁾ and Autosub 2, an AUV developed and owned by the National Oceanography Centre, UK ⁽³⁾. Like most autonomous equipment, the loss of an AUV can be financially costly due to higher resulting insurance premium, result in delay of research projects, damage reputation, loss of valuable research data and there is a possibility of contaminating the environment.

To reduce the risk of loss, a robust risk analysis approach is required to facilitate the formulation of effective risk control policies. Although different risk analysis approaches have been proposed in the literature ⁽⁴⁾⁽⁵⁾⁽⁶⁾⁽⁷⁾ there are still shortfalls to be addressed. First, these approaches tend to adopt a chain-of-event perspective, which views the loss of an AUV as the final unintended outcome. Such view promote a reductionist mentality, which often displaces more complex, and potentially fruitful accounts of multiple and interacting contributions. Second, these approaches mainly depended on the elicitation of expert’s opinions for subjective probability quantification. However, experts may face difficulties to provide precise numerical figures due to the vagueness and ambiguity nature of risk ⁽⁸⁾.

To address these shortfalls, a hybrid fuzzy system dynamics risk analysis (FuSDRA) approach is proposed; one which accounts for both the dynamic complexity of the system, as well as uncertainties about the interrelationships between risk variables. Despite being applied for the analysis of other problems ⁽⁹⁾⁽¹⁰⁾, the use of fuzzy system dynamics remain rather uncommon. To our best knowledge, it has never been used for analyzing the operational risk of autonomous equipment.

2. METHODOLOGY

The FuSDRA approach follows a three step iterative framework comprising of the identification of risk variables, modelling and evaluation (Fig.1).

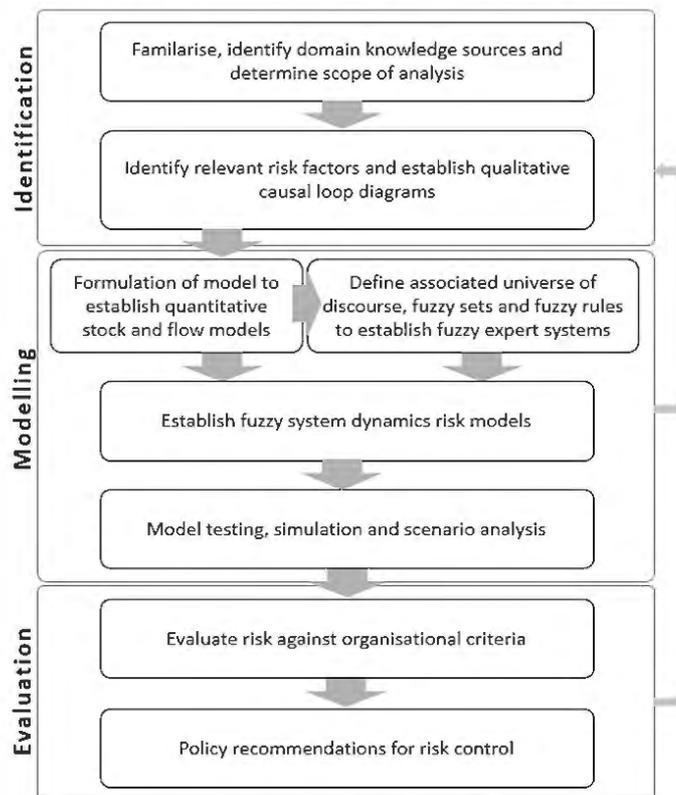


Fig 1: An overview of the FuSDRA framework

In the identification step, the first task is to gain familiarity with the AUV program and identify domain knowledge sources, which very often comes from domain experts ⁽¹¹⁾. Tapping into these sources, the next task involves the identification of risk variables which may influence the long-term risk of AUV loss as well as the causal relationships between these risk variables. In the next modeling step, system dynamics stock and flow models ⁽¹²⁾ are constructed through parameters' estimation, formulation of causal relationships and establishing initial conditions. For causal relationships which are uncertain, a fuzzy expert system ⁽¹³⁾ is applied next. This involves determining the universe of discourse, fuzzy sets, membership functions and constructing fuzzy rules. The fuzzy expert systems are subsequently incorporated back into the stock and flow models to form the hybrid fuzzy system dynamics risk models. The models are tested and calibrated before simulation and scenario analysis.

In the final step of risk evaluation, insights are attained through simulation and scenario analysis, with the aim of identifying leverage points and leading indicators. Based on these insights, risk control policies can be derived and recommended to decision makers for implementation. To ensure effectiveness of the recommended policies, regular review of the risk models is necessary.

3. CASE STUDY

To demonstrate practicality of the FuSDRA framework, it was applied on an actual AUV named *nupiri muka*. Funded by the Australian government and managed by the University of Tasmania (UTAS), the AUV program aims to conduct research in the Antarctic and contribute to the research capabilities in Tasmania. With the AUV being relatively new, there are very limited historical data for probabilistic risk analysis. Therefore, the FuSDRA approach was applied to better understand the long-term risk of AUV loss.

In the identification step, two pressing issues were identified by the primary AUV operating team as having a long-term influence on the risk of AUV loss. First, a gradual reduction in government support to the AUV program. Apart from directly influencing the risk of AUV loss through budgetary pressure, several domain experts also expressed concerns on how such reduction can affect the continued renewal of employment contracts. Second, the availability of alternatives to AUVs for research data collection. Technological evolution can render existing AUV technologies less practical and competitive either against newer AUVs or other means of data collection. With more options available, scientists and other users will naturally choose the most effective and cost-efficient means of data collection, rendering the *nupiri muka* AUV obsolete. Risk variables with their causal relationships associated with the two issues were identified and presented as a causal loop diagram in Fig 2. Construction of the FuSDRA model was carried out next to quantify the risk of loss, with a simplified version shown in Fig 3.

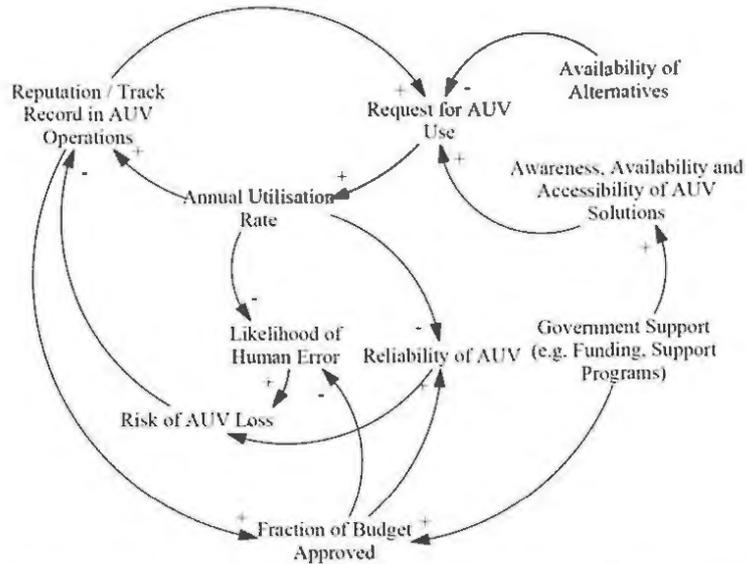


Fig 2: Causal loop diagram showing feedback loops and causal relationships between the identified risk variables.

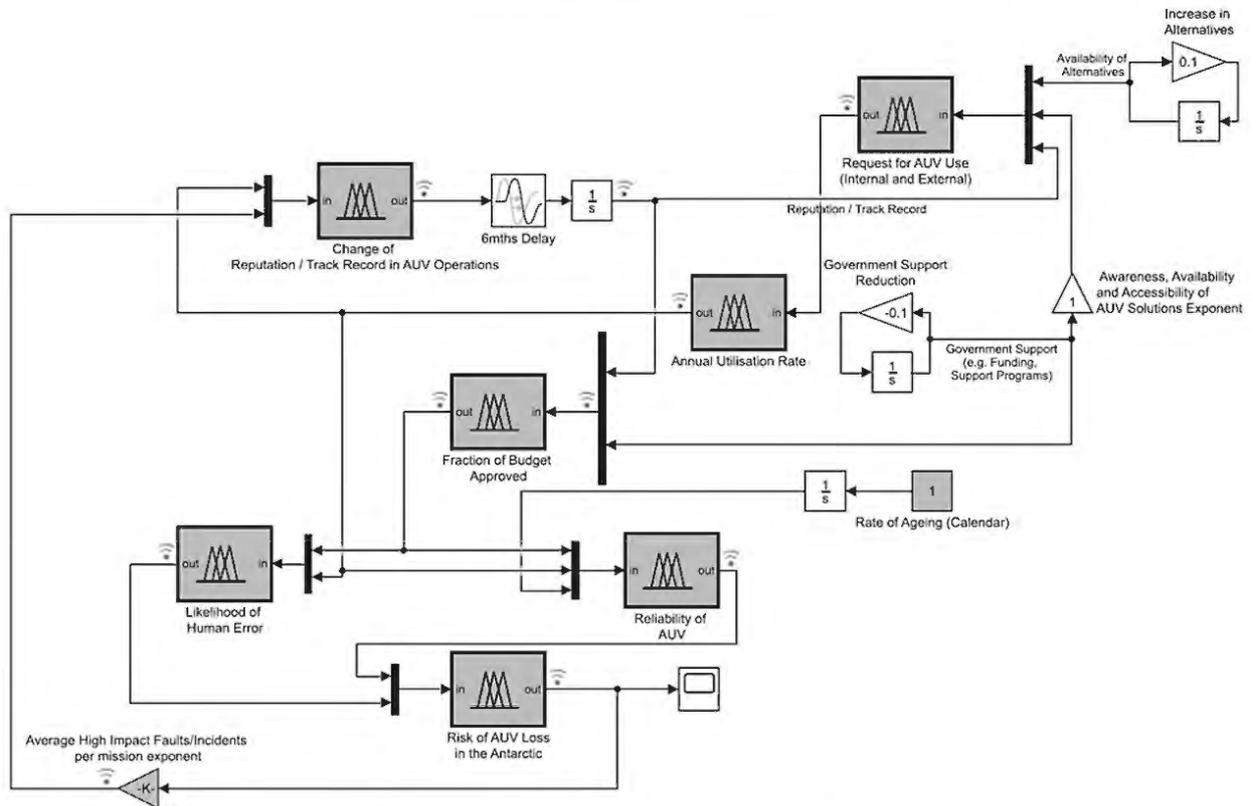


Fig 3: The resultant FuSDRA Model.

After testing and calibration, the base scenario was simulated based on a set of assumptions on parameters, causal relationships and initial conditions. Three different scenarios were then simulated next and compared to the base scenario to analyse the impact on risk of AUV loss. First, a gradual reduction of government support at a rate of 10% annually was simulated. Second, the effect of increasing alternatives to the *nupiri muka* AUV, at a rate of 10% annually was simulated. Last, the combined impact of gradual reduction in government support (rate of 10% annually) and an increasing number of alternatives (rate of 10% annually) was simulated.

The risk of loss, as presented in Fig 4, is dimensionless and intended to measure probability of occurrence between year 0 and year 10 of the AUV program.

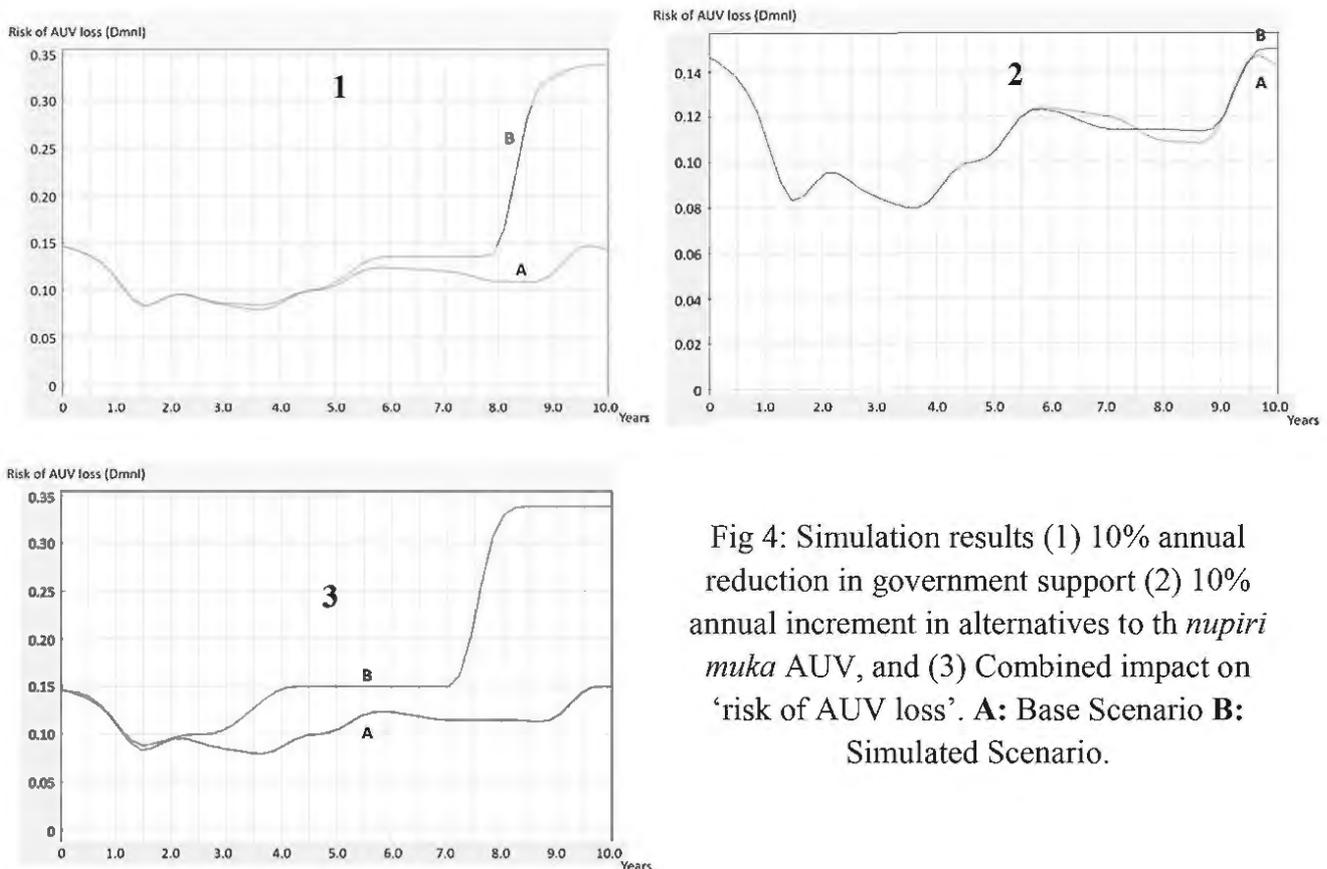


Fig 4: Simulation results (1) 10% annual reduction in government support (2) 10% annual increment in alternatives to the *nupiri muka* AUV, and (3) Combined impact on 'risk of AUV loss'. A: Base Scenario B: Simulated Scenario.

In the first scenario, a difference in risk of loss emerges from the third year of the AUV program when compared to the base scenario. This is due to a latency period represented by delays in the system. The risk of loss is also observed to increase sharply in the last 2 years of the simulation. This jump in risk can be attributed to the reduction of budget below a threshold level, where experienced personnel may leave the team and critical AUV components fall into disrepair. For the second scenario, the difference to risk of loss is only apparent in the last year of the AUV program, with the reason being twofold. First, the *nupiri muka* adopts newest AUV technologies and is considered state-of-the-art, manufactured by one of the leading company. Second, the use of AUV for Antarctic marine science research is a relatively new development with many potentials and advantages over existing means of data collection. Therefore, the obsolescence rate for the *nupiri muka* AUV is currently deemed to be very low, having an impact on the risk of loss only in the late stages of the AUV program. In the third scenario, the combination of reducing government support and increasing alternatives showed a synergistic effect on the risk of AUV loss, resulting in a greater increase in the risk of loss than the sum of their individual effects. Although the complex calculations and extensive fuzzy rules makes it challenging to pinpoint the reason behind this synergistic effect, the significant increase in risk clearly requires attention for tightened controls.

In the final risk evaluation step, policies are recommended based on the simulation results to dampen the effect of reducing government support and increasing obsolescence. As the gradual

reduction in government support has a substantial effect on the risk of loss later in the program, the recommended measures should be implemented as early as possible. These include: (1) Having a robust system for monitoring budgets and forecast future additional funding requirements. (2) Actively seek diversity in funding base, such as commercial contracts and establish strong stakeholder relationships. (3) Establish a robust finance strategy, with regular review, which is aligned to the strategic plan, and. (4) Implement a process for reviewing and updating strategic or operational plans in response to changes in government support.

Recommended measures to better manage the risk of obsolescence in the later stages of the AUV program includes: (1) Ensuring a comprehensive repair and preventive maintenance program is in place. (2) Implementing a process for regular review of published literature and other information sources to spot emerging trends in both AUV technologies and alternatives to the AUV (3) Developing a strong partnership with the AUV manufacturer. The company should be well-aware of any impending obsolescence and have a migration or upgrade strategy. (4) Establishing a robust and clear long-range plan for the AUV program. This plan should assign a return of investment, state cost avoidance strategies, process optimization and best practices. In addition, the plan should position the AUV program as a multipurpose research program going beyond the AUV itself, such as battery capabilities or adaptive controls. This should lead to a strong underwater robotics research program at the University of Tasmania, exploring next generation alternatives to AUVs. Another Explorer AUV operated by Memorial University of Newfoundland, Canada is an example of an AUV program with robust and clear long-range plan.

4. CONCLUSION

The risk of losing autonomous equipment during deployment is a dynamic and complex problem. Data may not always be available, and the vagueness and ambiguous nature of risk makes the analysis of risk challenging. This paper presents a three-step hybrid FuSDRA framework to facilitate risk control policy recommendations.

The FuSDRA framework was applied in a case study to analyse two issues: a reduction in government support to the AUV program and increasing availability of alternatives to AUVs for research data collection. Both results showed increase in risk of loss in the later stages of the AUV program and a synergistic combined effect. A suite of risk control policy recommendations was proposed based on these results. These include implementing a system for budget monitoring and forecast, seek funding diversity, establish a finance strategy, prepare for changes, having a repair and preventive maintenance program, establish strong partnership and having a long-range plan for the AUV program.

Due to the generic nature of the approach, the FuSDRA framework can also be applied to other types of autonomous equipment. For example, in the field of autonomous cars, unmanned aerial vehicles and unmanned surface vessels. Therefore, the FuSDRA approach provides both contribution to knowledge, as well as a pragmatic tool for maritime universities for better analysis of risk.

5. ACKNOWLEDGEMENT

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Using a web-based simulation software in education

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Keywords: Simulator, manoeuvring, teaching

ABSTRACT

Manoeuvring ships in confined waters is a complex issue and requires extensive education, training and practical experience. Using Seaman Online™, the instructor builds and publishes specific exercises which the students can access by logging in to their account from any computer connected to the internet at any time. After having completed an exercise, students can replay the simulation on an evaluation page where all important manoeuvring data are presented in a graphical and numerical format. There are several areas in ship handling where Seaman Online™ may not only support the student in their training and understanding of the complexity of ship behaviour in various manoeuvring conditions but also their analytical skills. These areas may be categorized into applied hydrodynamics, ship handling using tugs and repetitive training in berthing/un-berthing manoeuvres. On a general level, Seaman Online™ was perceived by the students as a useful complement to the desktop and bridge simulators.

1. INTRODUCTION

Manoeuvring ships in confined waters and ports is a complex issue and requires extensive education, training and practical experience. As no maritime academy will conceivably be able to provide a student with enough practical experience (which in addition may be ship specific), the challenge for the educator lies in how to convey valuable and essential understanding and skills in ship handling with limited resources such as simulation exercises.

The requirements on the competency for Masters and Chief Mates on ships of 500 Gross Tonnage or more to manoeuvre and handle a ship in all conditions are specified in STCW Table A-II/2 [1]. Many of these requirements are covered during the third year of the Master Mariner education at Chalmers University of Technology in the course “Ship handling and navigation in confined waters” which primarily focuses on the following topics:

- Applied hydrodynamics (IMO manoeuvre tests, shallow water effects, interaction, etc.).
- Manoeuvring characteristics of different ships including the controllable, semi-controllable and uncontrollable forces involved in ship handling.
- Planning, executing and monitoring passages in confined waters such as archipelagos (blind pilotage techniques on radar, controlled turns, etc.)
- Manoeuvring large ships with and without the use of tugs.

The teaching methods consist of lectures, exercises in the bridge simulator and some limited practical manoeuvring training on a small ship. To further support the student's learning, Chalmers and SSPA have developed a web-based simulator, Seaman Online™. This web application builds on SSPA's simulation software Seaman™ and uses high-quality mathematical models originating from SSPA's comprehensive data bank from model tests conducted during the last 60 years.

1.1. SEAMAN ONLINE™

Seaman Online™ is the most recent extension of SSPA's existing core simulation software with an interface influenced by the work done in the European Commission project CyClaDes [www.cyclades-project.eu] and by further user feedback during other full-mission simulation projects [2].

Seaman Online™ consists of being able to run simulations using SSPA's well-known and high quality ship and tug models in a 2D birds-eye visualization of the Electronic Navigational Chart (ENC) combined with a conning display and an evaluation page of the simulation results, including quantitative feedback to users about their manoeuvring exercise performance and ship dynamics forces and effects. Using Seaman Online™, the instructor builds and publishes specific exercises which the students can access by logging in to their account from any computer connected to the internet at any time. No software needs to be downloaded as Seaman Online™ runs directly on a web page.

After having completed an exercise, students can replay the simulation on an evaluation page where all important manoeuvring data such as forces, moments, rudder angles, etc. from the run are presented in a graphical and numerical format facilitating the analysis of the run (see figure 1 and 2). By saving and flagging a completed exercise by the student, the instructor gains access to the evaluation page of the run to assess the performance.

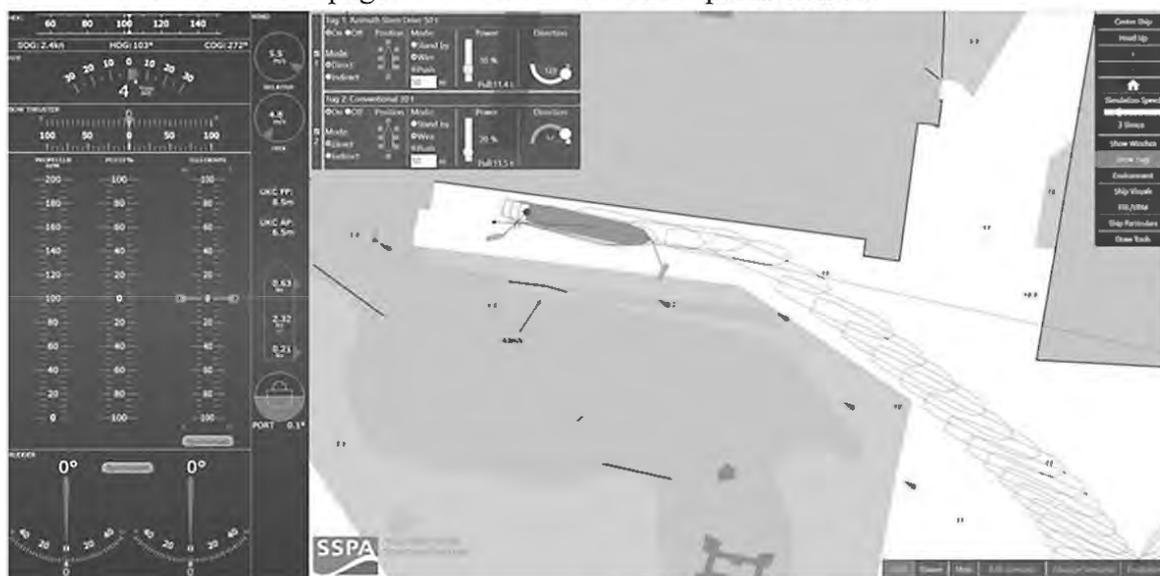


Figure 1. Running a berthing exercise with tugs in Seaman Online™.

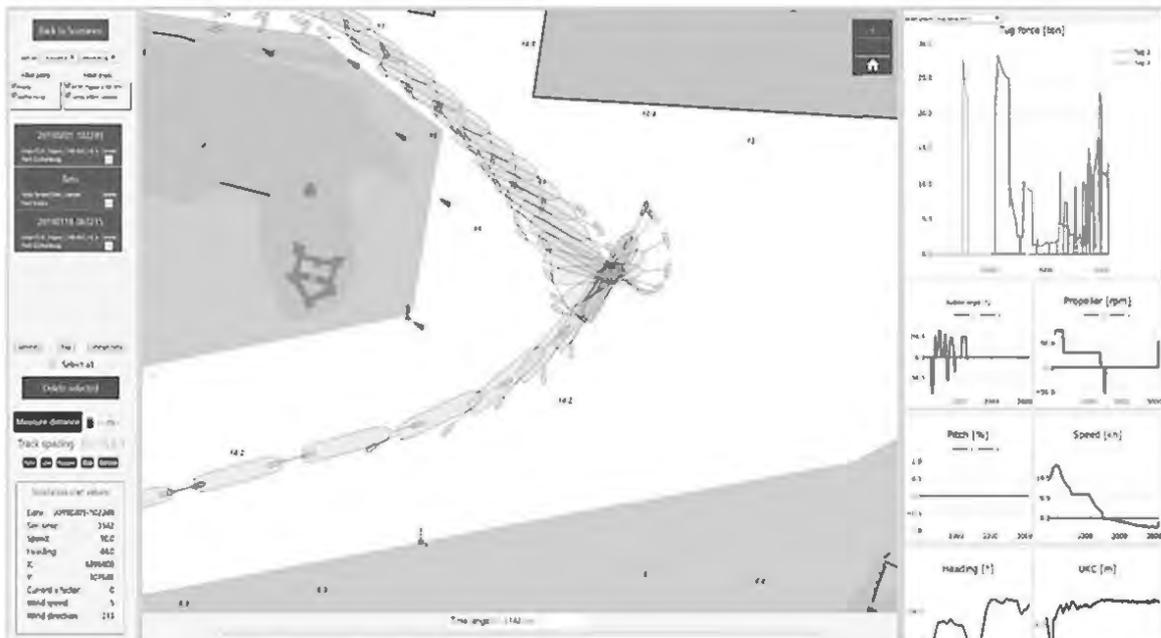


Figure 2. Evaluation page of a simulator run.

1.2. USING APPROPRIATE SIMULATION TECHNOLOGY TO FACILITATE LEARNING AND UNDERSTANDING

In the course “Ship handling and navigation in confined waters”, simulators ranging from relatively simple desktop stations to bridge simulators are used extensively to mainly train blind pilotage radar techniques in confined waters, anchoring and berthing manoeuvres with relatively large ship models (i.e. a Panamax tanker and a PCTC).

The main purpose and goals for these simulation exercises is to bridge the gap between theory and practice and as an effective aid for training and competency assessment of future ship masters and deck officers. All exercises are run in confined waters (chart areas Sydney and Gothenburg) with bridge teams consisting of a navigator and co-navigator. The students are observed and assessed by the instructor(s) during all exercises focusing on the objectives and goals as stated in the exercise instructions. If it is found that the student is not showing enough proficiency, a re-run of the exercise is arranged. For such kind of exercises, a bridge simulator is highly suitable as it not only enables the use and training concerning all relevant and necessary navigation and communication equipment but also as it provides enough space to accommodate a bridge team. However, training using bridge simulators is relatively expensive and requires a lot of resources.

In contrast, certain aspects of ship handling may not need the infrastructure and resources of a bridge simulator and may be better trained, visualized and analysed by preferably using other simulation tools especially if the goal of the exercise is not only to provide training and skills but also to encourage the students to critically examine and understand the behaviour of ships in certain manoeuvring situations. As an additional benefit, students are given the possibility to practice and learn at any time and in any place they wish at a comparatively low cost.

2. SUITABLE EXERCISES FOR SEAMAN ONLINE™

There are several areas in ship handling where Seaman Online™ may not only support the student in their training and understanding of the complexity of ship behaviour in various

manoeuvring conditions but also their analytical skills. These areas may be categorized into:

- applied hydrodynamics,
- ship handling using tugs and
- repetitive training in berthing/un-berthing manoeuvres.

2.1. APPLIED HYDRODYNAMICS

Applied hydrodynamics in ship handling is understood as the effect of various hydrodynamic forces due to e.g. hull form, under-keel clearance (UKC), interaction with banks and other ships. Although some of these hydrodynamic effects may be shown and experienced using a bridge simulator, the student will have a “bridge perspective” and in the case of interaction with e.g. bank or other ships conceivably only try to counteract the forces without having the possibility to study and analyse the exact nature of the forces. Other effects such as the influence of the UKC on the drift angle of a ship or the influence of the hull form on the turning properties are even less suitable to be run in a bridge simulator as they are basically only visible when running a log file after the completed simulation run.

Seaman Online™ not only uses high-quality mathematical ship models but also provides the user with an evaluation page where significant data from a simulation run is presented in both graphical and numerical form forming the basis for an analysis. Parameters such as water depth, ship model, distance to the bank or other ship, etc. are easily changed giving the possibility to really study and analyse the behaviour of a ship in various conditions. Example of a simulation of bank effects and its evaluation page are shown in Figure 3 and 4.

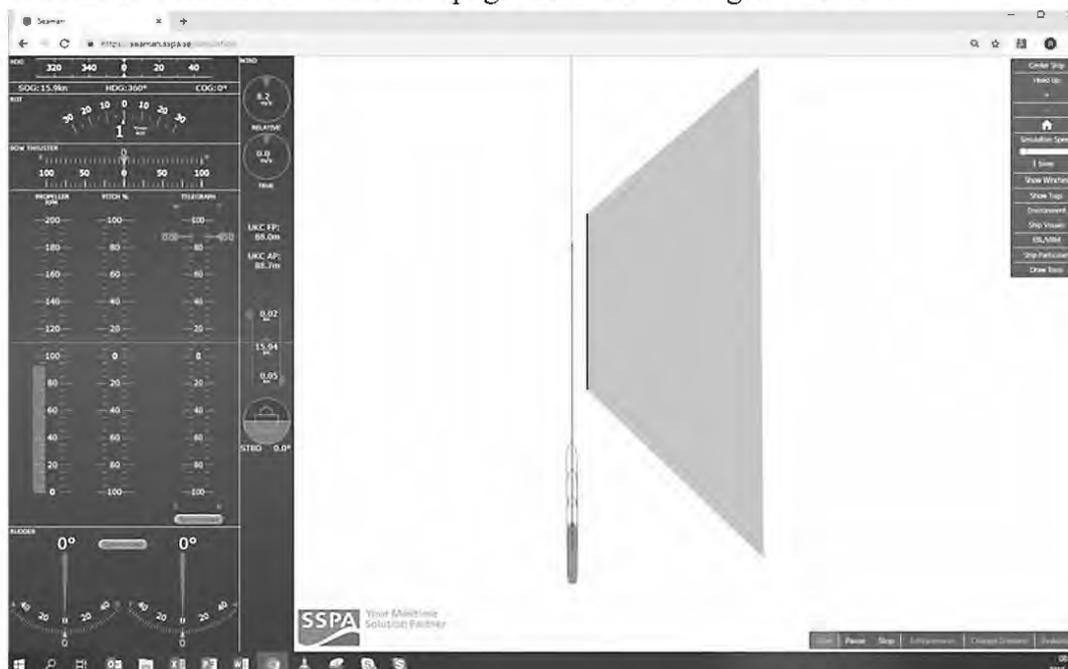


Figure 3. Running an exercise simulating bank effects

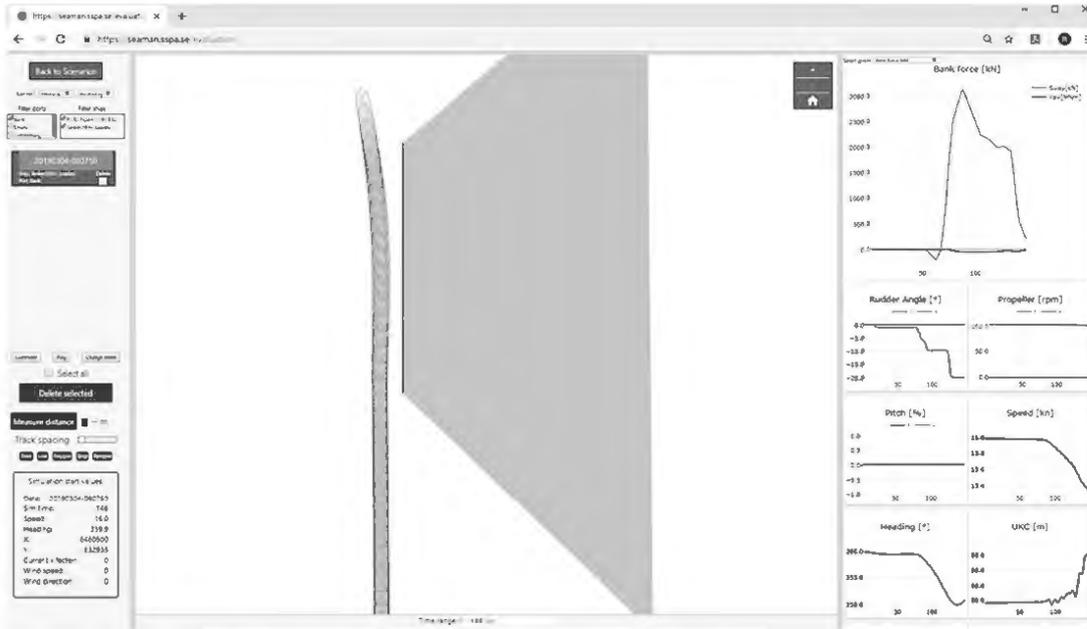


Figure 4. Evaluation page on bank effects

2.2. USING TUGS

Combined with lectures on handling ships with tugs, Seaman Online™ provides an ideal platform for students to execute and analyse manoeuvres with tug assistance to obtain a far clearer idea on how such manoeuvres may be performed. Usually bridge simulators are seldom used for students to practice with tugs and in case an exercise involves tugs, these may be run only by the instructor as a target.

Different tug types are available in Seaman Online™ and depending on their properties may be used in both direct and indirect mode as depicted in Figure 5. The user is both manoeuvring the ship and the tug(s) and thereby gaining an overall perspective on the complexity of handling ships with tugs. As with all simulations run in Seaman Online™, the evaluation page after a completed exercise provides the student with data to examine and analyse the manoeuvre (see figure 6).

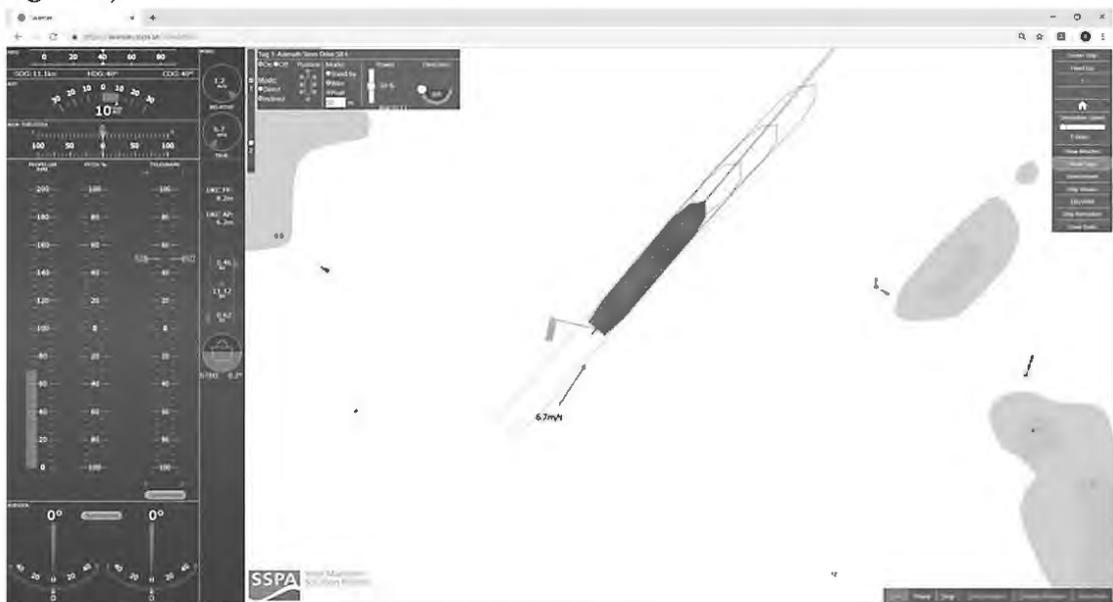


Figure 5. Simulation with a tug in indirect mode

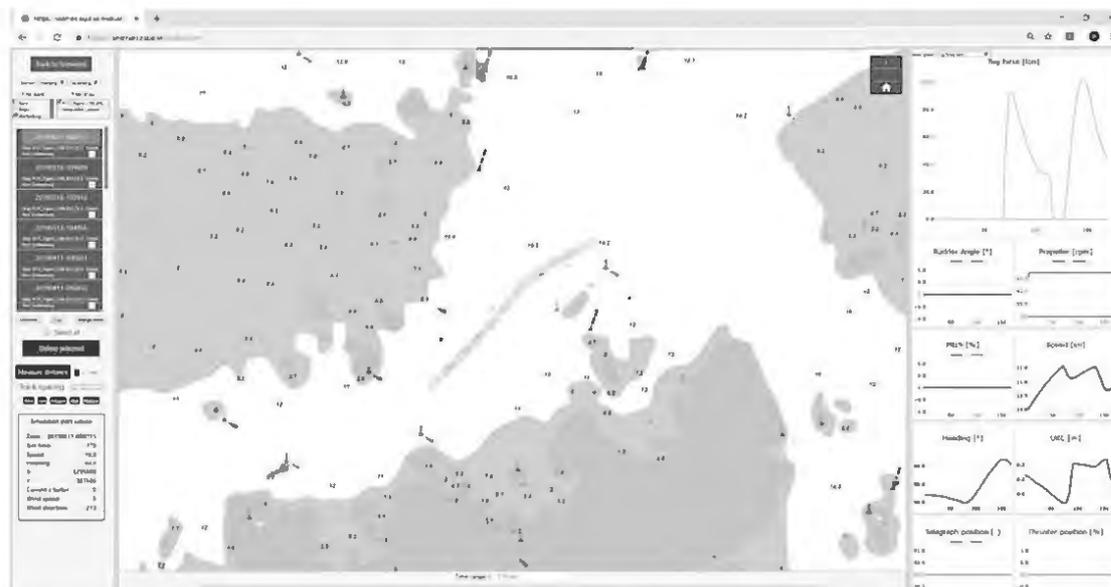


Figure 6. Evaluation page of a simulation with a tug

2.3. REPETITIVE TRAINING IN BERTHING/UN-BERTHING MANOEUVRES

To become proficient in handling ships requires both theoretical knowledge and years of practice and no simulation is likely to replace reality as the technical and environmental challenges, the real risks involved, and possible commercial pressures cannot be simulated. Nevertheless, simulators have matured into a valuable asset in education, training and studies by providing realistic real time rendering of an almost real environment. However, the degree of fidelity does not necessarily determine the success of the learning outcomes and may on the contrary add unnecessary complexity and distraction [2]. Complex simulation techniques have been found to be less suitable in basic skill training, and different types of simulation technologies can be used as a complement to each other to increase fidelity [3]. Or to phrase it differently, different levels of simulation throughout different points of the curriculum are normally required for training [4].

Seaman Online™ will not provide an environment as realistic as in a bridge simulator except the behaviour of the ship model itself. However, the simulation tool provides the user with the possibility to practice “bulk” training of manoeuvres such as berthing and un-berthing with and without tug assistance (see Figure 1 and 2), testing limits (e.g. wind limits) and experiment with alternative berthing plans. Being web-based, Seaman Online™ significantly increases the availability of a ship manoeuvring training tool and may be one step in a progressive continuous learning program in which the student first studies the theory and then progresses with applying the theory and practices the manoeuvre(s) in Seaman Online™ followed using the bridge simulator and eventually gaining real life experience.

3. INSTRUCTOR’S ROLE IN USING SEAMAN ONLINE™

Seaman Online™ was made available to Master Mariner students enrolled in the course “Ship handling and navigation in confined waters” as an additional resource. Four different exercise assignments (pertaining to applied hydrodynamics and manoeuvring with and without tugs) were set up by the instructor to be executed and analysed by the students. Instructions, purpose

and goals for each exercise were documented and published on the course web-page. Through saving and flagging a completed exercise by the student, the instructor gained access to the evaluation page of the run to assess the performance. Additionally, the students were to send in a written report by e-mail reflecting their analysis of the performed manoeuvre(s) as per instructions.

In contrast to instructor led exercises using the bridge simulator, the user of Seaman Online™ is very much on his own when doing the exercises and may not get any immediate feedback or help. The objective of a simulation may seem obvious to an instructor but possibly not fully understood by the students and thereby influencing their perception, experience and learning [2]. Clear task description and instructions are essential and may even be combined with a short briefing during an ordinary lecture. Depending on the exercise, particularly the instructions concerning the analysis task need to be very specific even to the point that students are to compare and explain numerical values at specified events in their analysis.

Debriefings to gauge and ensure that students do not learn something incorrectly are an essential part in any simulator-based training [5]. When executing simulations outside of an instructor's supervision, this process differs from the usual class room debriefings and feedback may be given by e-mail instead. Having access to the evaluation page combined with a written report/analysis allows the instructor to assess the performance of the students individually and any mislearning or incorrect analysis may be easily captured. However, it is of utmost importance that the assessor takes this task seriously and is prepared to be engaged in potentially lengthy e-mail conversations with the students.

From the instructor's perspective letting students execute exercises outside of their supervision may also raise concerns related to the possible "video game effect" i.e. that students regard the web-based simulations as purely a game without any correlation to reality and thereby may neither appreciate nor fulfil the learning objectives of the exercises. To a certain extent these concerns are justified and there are likely to always be some students which consider all simulation exercises as games. However, on the other hand one of the advantages of using Seaman Online™ in e.g. berthing manoeuvres is that the students are encouraged to test and experiment with different approaches and will eventually be able to not only appreciate the complexities in ship handling but also gain confidence in being able to safely manoeuvre the ship alongside without any instructor interfering. It is believed that although there is the risk of some students considering the web-based simulations as purely a video game, the majority of students actually take the exercises very seriously and the benefit of Seaman Online™ outweighs the concerns of the "video game effect".

4. FEEDBACK FROM USERS

The unpublished paper "Testing Proof of Concept of a Web-Based Ship Manoeuvring Training Tool in the Classroom" by Costa et al. [2] describes the first-time implementation of Seaman Online™ in the context of a Master Mariner university programme and the students' perception on its usability and usefulness. On a general level, Seaman Online™ was perceived as a useful complement to the desktop and bridge simulators and appreciated as an opportunity to test, on a personal computer, manoeuvres and situations normally not tested in the desktop or bridge simulators or onboard ships [2].

5. CONCLUSIONS

There are several areas in ship handling where Seaman Online™ may not only support the student in their training and understanding of the complexity of ship behaviour in various manoeuvring conditions but also their analytical skills. Being web-based, Seaman Online™ significantly increases the availability of a ship manoeuvring training tool and may be one step in a progressive continuous learning program. Clear task description and instructions are essential and depending on the exercise, particularly the instructions concerning the analysis task need to be very specific. Having access to the evaluation page combined with a written report/analysis allows the instructor to assess the performance of the students individually and any mislearning or incorrect analysis may be easily captured. However, it is of utmost importance that the assessor takes this task seriously and is prepared to be engaged in potentially lengthy e-mail conversations with the students.

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A Study on Work Load Evaluation Method and Quantitative Evaluation Method for Engine-room Resource Management training

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ABSTRACT

This study aims to propose work load evaluation method and quantitative evaluation method of trainee's non-technical skill regarding ERM training. The necessity of work load evaluation during simulator training exercise is considered to evaluate trainee's performance. The effect of the trainee's work load during training exercise is evaluated by objective evaluation using VACP (Visual, Auditory, Cognitive, Psychomotor) method and heart rate data comparing subjective evaluation NASA-TLX (Task Load Index). We studied the difference of trainee's work load and biological reaction during training exercise. VACP work load scale is modified for ERM training exercise. For quantitative evaluation, we used IMO model course 2.07 2017 Edition evaluation form: behavior markers for non-technical skills. Evaluation criteria is based on sample evaluation form and evaluation markers are modified. This paper report the result of both evaluation method from recorded video and audio data of ERM training evaluation experiment.

1. Introduction

In 2010 Manila amendments of Standard of Training Certification and Watch-Keeping (STCW) convention, the requirement concerning Engine-room Resource Management (ERM) have been introduced into mandatory requirement for engineer and full implementation is required on 1st January 2017. Amended requirement increased needs of simulator training to evaluate engineer's non-technical skills. To carry out ERM training and evaluate non-technical skills, IMO Model course 2.07 Engine-Room Simulator 2017 Edition program was introduced to provide guidance with a view to supporting training providers.

Even though model course program is designed to provide flexibility so as to allow training providers to adjust the course program to the needs of trainees. Evaluation forms are also suggested to develop by instructor in accordance with simulator facilities and functions.

According to these background, maritime education institute and universities are developing suitable ERM training program and effective evaluation method of the training exercise [1] [2]. This study aims to propose work load evaluation method and quantitative evaluation method of trainee's non-technical skill regarding ERM training. Evaluation of trainee's work load during ERM training is to understand validity of developed ERM training program and to know whether the training is effective or not when work load of trainee is too high or too low.

Also the necessity of work load evaluation during simulator training exercise is considered to

evaluate trainee's performance. Relation of workload and task performance is considered in several industry such as aviation industry and automotive industry [3].

The effect of the trainee's work load during training exercise is evaluated by objective evaluation using VACP (Visual, Auditory, Cognitive, Psychomotor) method [4] and heart rate data comparing subjective evaluation NASA-TLX (Task Load Index) [5]. We studied the difference of trainee's work load and biological reaction during evaluation experiment. For quantitative evaluation, we used IMO model course 2.07 2017 Edition evaluation form. Evaluation criteria is based on sample evaluation form and evaluation markers are modified.

2. Methodology

Work load evaluations are categories to subjective and objective evaluation. Subjective evaluation is carried out by collecting trainee's opinion using questionnaire. Subjective evaluation may pointed out that personal sense and feelings are influence to the result of questionnaire and certain results may not be reproduced. To avoid this concern, using rating scale such as NASA-TLX are developed. NASA-TLX is developed by human performance group at NASA and widely used for subjective work load evaluation.

Objective work load evaluation research is carried out by using biological data such as heart rate data to measure navigator's work load [6]. Using heart rate data for objective evaluation was effective in finding the difference of the work load. However, heart rate data may affected by physical activity and there is a concern in work load evaluation using only the heart rate data. Therefore, work load evaluation is performed by the proposed objective evaluation VACP (Visual, Auditory, Cognitive, Psychomotor) method. As a reference of the validity of the work load estimation, we also compared the workload estimation with the subjective evaluation NASA-TLX. Detail of VACP method is explained in the following.

2.1 Work load evaluation VACP method

The basic idea VACP method is to divide trainee's information processing resource into four different channels: Visual, Auditory, Cognitive, Psychomotor (VACP) and express the amount of resource consumed as a scale. The total VACP scale is calculated as quantified work load by summing up each consumed scale.

The VACP method originates from the study of workload components in the operation of light weight helicopter [4]. They recognized four workload components and evaluation criteria description and scale are defined. There are research adopting VACP method to evaluate work load in different industry such as Anesthesiology field [7].

Developed VACP scale for ERM training is shown in Table 1. The standards of each scale and description is based on original research and action code is modified according to the characteristics of engine room operation and ERM training. In this research, work load of trainees are evaluated using this VACP scale from recorded video and audio data of ERM training evaluation experiment.

In order to quantify the work load of the trainee's tasks, the content of the tasks to be quantified by comparing with the description of the VACP scale to determine the amount of consumed resources. For example, when the subject verbal confirmed orders from C/E by transceiver, the auditory weight is A3. VACP scale should include a P1 since the trainee have to use on hand to hold the transceiver. Furthermore, notice that A4 is defined as the Auditory

Interpretation of high attentional auditory signal, such as alarm signals, which happens in blackout situation. Each scale is summed up in task execution timing. In this research, VACP scale were summed each for a four-second timing.

Main tasks occurred in evaluation experience and VACP scale of each task is shown in Table.2.

In addition to these main tasks, other people's conversations that can be heard indirectly is added as Auditory Disturbance AI to the work load quantify. PI was added as a psychomotor scale when push alarm stop button or pointing out of confirmation and so on.

Table I VACP Scale

VISUAL		
Scale.	Description	Action Code
V1	Visual Detection	Gaze<=2s
V2	Visual Discrimination	Gaze >2s, Static
V3	Visual Trucking	Gaze >2s, Dynamic, Monitor + Gauge
V4	Visual Read, Searching,	Dynamic, Visually high attentive. Find out target
AUDITORY		
Scale	Description	Action Code
A1	Auditory Detection	Digital Signal, Sound.
A2	Auditory Verification	Auditory Feedback. Answer back
A3	Auditory Decoding	Speech, Semantic Content, Order, Report
A4	Auditory Interpretation	Sound patterns, Alarm sound
A1	Auditory Disturbance	Non-directive
COGNITIVE		
Scale	Description	Action Code
C1	Automatic, Alternative Selection	e.g. Open valve as ordered, Answer back
C2	Sign/Signal Recognition	e.g. Alarm occur, Alarm information
C3	Evaluation/Judgement (Single Aspect)	e.g. Situation evaluation, Condition Judgement
C4	Evaluation/Judgement(Several aspect)	e.g. Alarm situation evaluation,
PSYCHOMOTOR		
Scale	Description	Action Code
P1	Discrete Actuation	e.g. Push Button, Talk, , monitoring, Point out
P2	Continuous Adjusting	e.g. Telegraph operation
P3	Symbolic Production	e.g. Writing, typing
P4	Convergent Multiple Operations	e.g. Walk, Check condition

Table 2 Main tasks VACP scale

Task Name	Visual	Auditory	Cognitive	Psychomotor
① Alarm Occur	2	4	4	0
② Order	0	3	0	2
③ Answer Back	0	2	2	0
④ D/G Auto Start	3	0	2	4
⑤ M/E Reset	3	1	3	2
⑥ Restart Boiler	3	0	3	1
⑦ Pump Auto Start	3	0	3	4
⑧ Steering Auto Start	3	0	3	4
⑨ E/R Round check	3	0	4	4
⑩ M/E Restart	3	1	3	2

2.2 Quantitative evaluation method for Non-technical skill

In IMO model course 2.07 2017 Edition sample evaluation form: Behavior markers for non-technical skills consist four non-technical skill evaluation criteria which are shown in Table.2. Evaluation markers in sample form was described by four scale score A,B,C,D. In this report, evaluation criteria is followed this sample evaluation form and evaluation markers were modified to 90-0% and original four scale score was calculated by weight criteria after completed evaluation by A,B,C,D. Weight criteria is defined by score 4 to 1 meaning that the performance is Very good, good, fair and poor. Two type of evaluation markers were conduct to propose reliable and valid quantitative evaluation method for non-technical skill.

An evaluator team, consisted 14 evaluator who have different onboard experience, gave a two type of evaluation marker to evaluate based on their personal judgement.

Table 3 Evaluation criteria

Evaluation criteria
1. Understanding of roles and responsibilities in operating plant machinery as a part of an engineering watch
2. Instruction, report, answerback and other communication patterns
3. Leadership and assertiveness
4. Situational awareness and notification of any doubt

3. Evaluation experiment

3.1 Experiment device

The experiment was conducted using Marine Engine Plant Simulator (MEPS), installed at Kobe University Maritime Science Graduate School. MEPS shown in Figure 1 consist of control room system, Engine room system and instructor system. Two fixed point cameras for video recording are provided on the control room and engine room side. Recorded evaluation

experiment data is shown in Figure 2. A microphone at control room is used to record audio data. Heart rate data was collected using a wristband type optical heart rate meter (Polar A 360). This optical heart rate meter calculates heart rate by beat per minutes in every time step and this calculated heart rate is expressed as heart rate (bpm) in this report.



Figure 1 MEPS (a) outline of MEPS; (b) Engine room; (c) control console.



Figure 2 Recorded evaluation experiment data

3.2 Experiment contents

The evaluation experiment scenario is modified and proposed for MEPS environment, based on IMO Model Course 2.07 sample exercise ERM training blackout roll play.

The applicability of the proposed method for evaluating work load and non-technical skill quantitative evaluation regarding ERM training was demonstrated by proposed evaluation experiment. Four students (participant 1 to 4) who have onboard experience took the roles of engineer under the blackout scenario. Scenario was carried out twice with different role for each participant.

A scenario starts with occurrence of a blackout (power loss) due to an emergency stop of Turbo Generator and Main Engine emergency stop due to L.O. Low press. Then Diesel and emergency generator start automatically, power supply and recovery work at engine room will be carried out. After Confirmation of each machinery, restart operation of Maine Engine will be the end of scenario. Communication between control room and the engine room are carried out by transceiver during the experiment.

4. Result of Evaluation experiment

4.1 Result of Work load evaluation

Result of four participant work load evaluation are shown in Table 4.

By comparing the role of each participant into C/E, 1/E and 2/E, 3/E, the work load of control room side and engine room side are verified. Figure 3 to 10 shows result of VACP SUM and heart rate (HR) of each participants. Circled number describe main tasks shown in Table 2.

Result of VACP evaluation method indicates quantified work load of control room task are higher than engine room task. This result can be considered that control room role had higher consumption of each VACP resource by reacting for alarm occurrence and order for recovery tasks. Engine room tasks had higher psychomotor resource consumed by check condition and operating valves but other auditory and cognitive resource consumption were smaller compare to control room. Heart rate data of all participant are higher in the control room task than

engine room task. Also Subjective evaluation by NASA-TLX also resulted control room task required higher work load to all participant. The correlation between the heart rate data and the VACP evaluation quantified work load resulted positive correlation with a correlation coefficient of 0.4 or more for participant1,3 and 4 in the control room side results, and for participant 2 resulted weak positive correlation of 0.21.

These results may consider that higher work load of control room task explained higher performance were required to these task responses.

Proposed and developed VACP scale for ERM training provides a useful way to evaluate trainee’s work load objectively from recorded video and audio data of evaluation experiment.

Table 4 Comparison of NASA-TLX, HR Average, VACP SUM and HR-VACP Correlation

Participant	Role	Task Location: Control Room				Role	Task Location: Engine Room			
		NASA-TLX	HR Average(bpm) - HR Rest(bpm)	VACP SUM	HR-VACP Correlation		NASA-TLX	HR Average(bpm) - HR Rest(bpm)	VACP SUM	HR-VACP Correlation
1	C/E	14.87	11.29	549	0.41	2/E	13.20	6.03	476	0.23
3	C/E	16.20	13.37	531	0.42	2/E	9.80	6.44	469	0.08
2	1/E	7.33	11.64	429	0.21	3/E	5.47	6.11	388	0.01
4	1/E	14.60	15.17	420	0.42	3/E	11.13	6.32	386	0.47

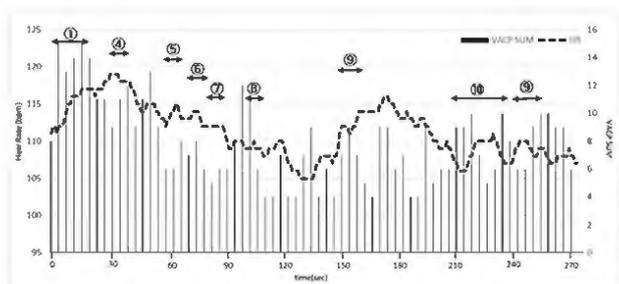


Figure 3 VACP SUM and HR of Participant1:C/E (1st Scenario)

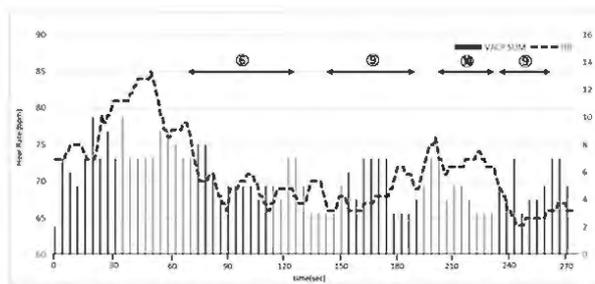


Figure 6 VACP SUM and HR of Participant4:3/E (1st Scenario)

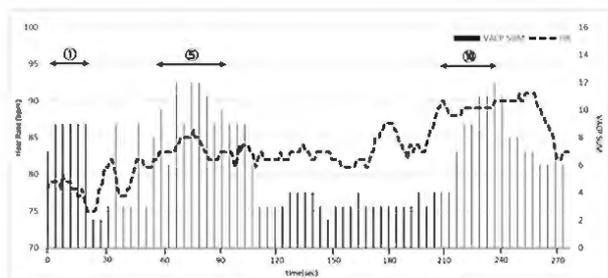


Figure 4 VACP SUM and HR of Participant2:1/E (1st Scenario)

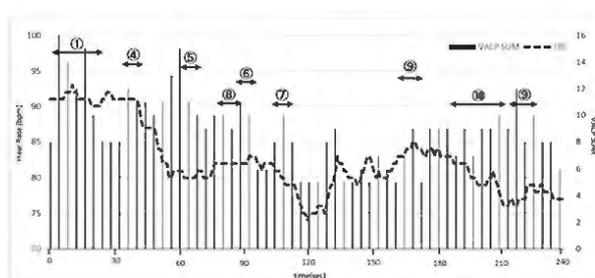


Figure 7 VACP SUM and HR of Participant3:C/E(2nd Scenario)

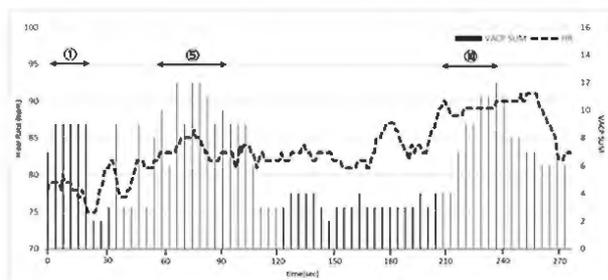


Figure 5 VACP SUM and HR of Participant3:2/E (1st Scenario)

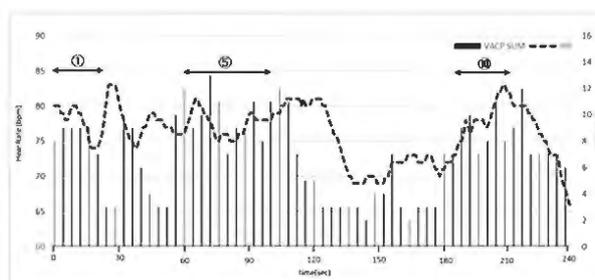


Figure 8 VACP SUM and HR of Participant4:1/E(2nd Scenario)

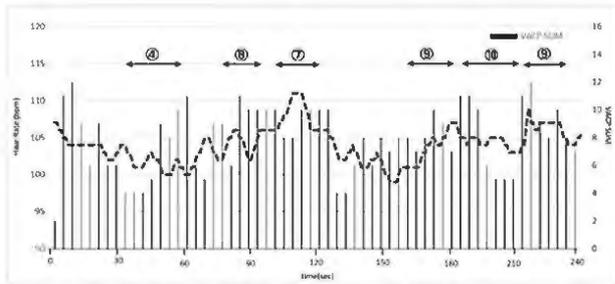


Figure 9 VACP SUM and HR of Participant 1:2/E (2nd Scenario)

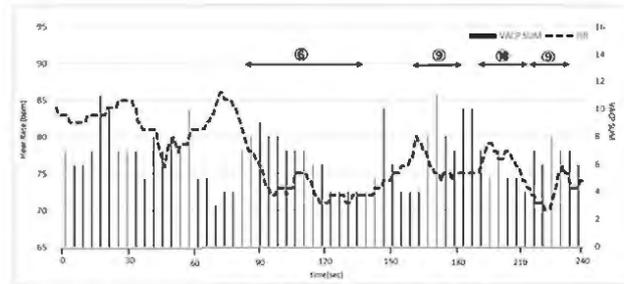


Figure 10 VACP SUM and HR of Participant 2:3/E (2nd Scenario)

4.2 Result of Quantitative evaluation for Non-technical skill

Quantitative evaluation of non-technical skill was carried out by evaluator team and result of averaged evaluation marker score is shown in Table 5. Also Fig 11 shows each participants average score of control room side and engine room side are verified

From result of participant 1, role difference can be described that control room side task had higher non-technical markers specially by comparing evaluation criteria 3, 2/E task was lower score compare to C/E in both four-scale score and percentage score. Similar result can be seen for participant 3 who took the same role of 2/E and C/E. Difference between 2/E and C/E can be described by qualitative evaluation.

In other hand, Participant 2 and 4 who took a role of 1/E and 3/E had different tendency of result. Participant 4 resulted evaluation markers scored for 1/E engine room task was slightly higher compare to 3/E engine room task, but participant 2 shows 3/E evaluation markers was higher than 1/E in all evaluation criteria. Result of this quantitative evaluation shows C/E and 2/E had more clear difference of non-technical skills compare to the role of 1/E and 3/E. Propose quantitative evaluation clarified the difference of evaluation markers score for each participant role and each evaluation criteria.

Table 5 Average of evaluation marker score

Participant	Evaluation criteria	C/E		2/E	
		ABCD	%	ABCD	%
1	1	88.39	85.00	83.57	80.71
	2	88.39	85.00	85.18	85.00
	3	88.39	84.29	75.54	81.43
	4	80.36	80.71	80.36	80.00
Participant	Evaluation criteria	1/E		3/E	
		ABCD	%	ABCD	%
2	1	69.11	72.14	81.96	75.71
	2	77.14	73.57	81.96	80.00
	3	64.29	62.86	67.50	73.57
	4	67.50	70.71	73.93	76.43
Participant	Evaluation criteria	2/E		C/E	
		ABCD	%	ABCD	%
3	1	73.93	70.00	73.93	72.86
	2	70.71	74.29	80.36	80.71
	3	65.89	65.71	80.36	77.14
	4	67.50	67.86	72.32	75.00

Participant	Evaluation criteria	3/E		1/E	
		ABCD	%	ABCD	%
4	1	69.11	66.43	70.71	70.00
	2	70.71	71.43	75.54	77.14
	3	62.68	61.43	67.50	67.86
	4	61.07	63.57	69.11	72.14

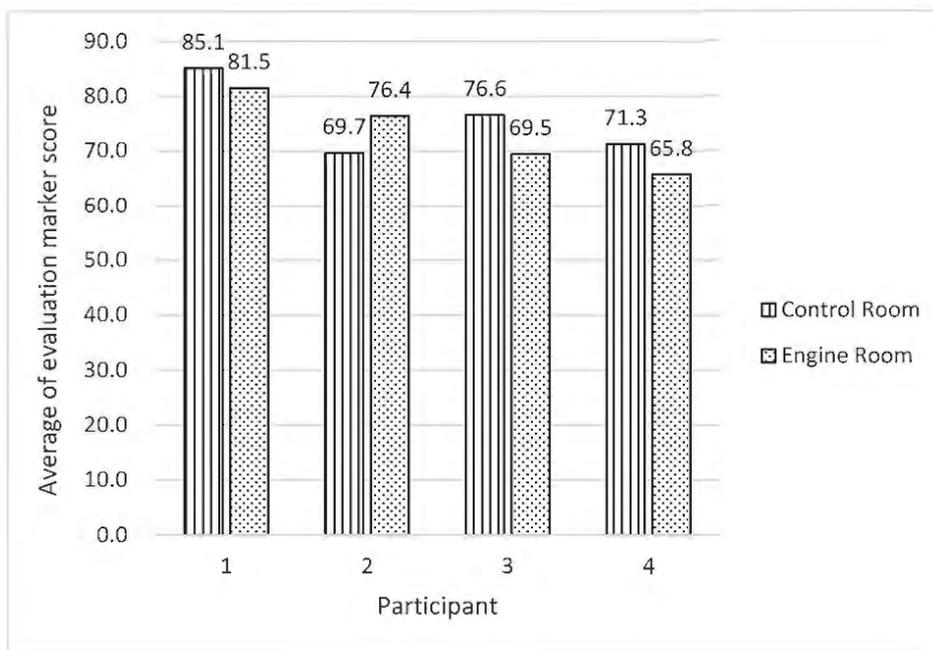


Figure 11 Average of evaluation marker score

4.3 Overall Result

Each result of work load evaluation and quantitative evaluation of non-technical skill are explained and discussed. From result of work load evaluation, control room task showed higher work load compare to engine room task for all participants. When difference of work load was occurred by task response as work performance, result of quantitative evaluation of non-technical skill may explain more precise for each participant role.

For participant 1 and 3 who took role on C/E and 2/E had clear difference of performance required and as mentioned in result of quantitative evaluation, evaluation criteria 3 had biggest difference for both participants.

For participant 2 and 4 who took role on 1/E and 3/E work performance also resulted control room task performance are higher compare to engine room task. But result of quantitative evaluation for non-technical skill for participant 2 indicated higher evaluation criteria score on 3/E role. When we compare result of evaluation criteria 3 score difference for C/E, 2/E and 1/E, 3/E, result of 1/E, 3/E score difference was lower score. Also result of work load VACP SUM indicate 1/E, 3/E difference were lower compare to C/E, 2/E.

5. Conclusion

This study focused on work load evaluation method and quantitative evaluation method of

trainee's non-technical skill regarding ERM training. The proposed method of workload evaluation provides a useful way to measure trainee's work load objectively and required performance difference of control room task and engine room task regarding to ERM training was expressed. Result of correlation between the heart rate data and the VACP evaluation quantified work load pointed out higher accuracy of work load evaluation in control room task. In other hand, Engine room task resulted variation for each participants regarding evaluation timing of VACP and evaluation scale. Evaluation scale consider possible extension to develop scale action code for each control room and engine room task. Also further verification for evaluation timing should be considered. In this study, Work load of each participants are evaluated by comparing subjective NASA-TLX and objective VACP scale and heart late. In the further studies additional objective assessment such as EEG measurement would be considered to interpreting the cognitive resource of the participants.

Quantitative evaluation method is also indicated each trainee's non-technical skill during ERM training. Evaluation markers proposed in this method was applied to compare evaluation criteria qualitatively and difference in each role and each criteria were discussed.

Proposed evaluation experiment scenario was developed with assuming that control room tasks require higher non-technical skill compared to engine room task.

Difference of C/E role and 2/E role resulted that proposed evaluation scenario and quantitative evaluation method can demonstrate role behavior of ERM training without personal bias. Result of 1/E and 3/E role was discussed from both performance and non-technical skill point of view. Both result may consider that role difference effecting performance and non-technical skill evaluation between 1/E and 3/E was not as clear as C/E and 2/E in this ERM training evaluation experiment. Difference in both results considered possible extension of proposed evaluation experiment ERM training scenario. Also further studies to the proposed method would be to consider evaluation criteria.

Main idea of the proposed method is to evaluate work load objectively and also evaluate non-technical skill qualitatively to discuss the performance of trainee and conduct sufficient ERM training. Both evaluation method and developed evaluation experiment scenario described certain effective result for evaluating ERM training by objective and quantitative point of view.

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VR Training Videos: Using Immersive Technologies to support Experiential Learning Methods in Maritime Education

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Keywords: virtual reality; 360-degree videos; experiential learning; immersive technologies

ABSTRACT

The use of David Kolb's experiential learning theory which involves the process of gaining an experience and then reflecting upon that experience in order to formulate ideas is interwoven throughout maritime training schemes worldwide. Unfortunately, experiential learning can be difficult to implement due to cost and resource issues.

With the recent advancements in immersive technologies, new opportunities to engage students in the experiential learning process are becoming available. The combination of instructional 360-degree videos and virtual reality, or VR Training Videos, creates a highly immersive experience which can be created at a significantly lower cost when compared to simulators or real-world platforms.

This paper will discuss the pedagogy and research-based foundation behind a proposed course design using these VR Training Videos as a part of an experiential learning process. It will also discuss the steps which SUNY Maritime College has undergone to implement this technology and course design into the classroom along with some of the initial findings of this project.

1. INTRODUCTION AND THEORY

Historically, the education of mariners was based heavily upon slowly gaining experience and learning by watching another individual or by taking part in shipboard operations. Although regulations have evolved over time and Maritime Education and Training Centers and Universities (MET's) have begun to educate mariners in a more classroom like setting, the overall training scheme for mariners continues to be heavily reliant upon gaining experience as an integral part of the learning process. As experience is seen as a critical aspect of maritime education, one of the most commonly utilized learning pedagogies is the experiential learning process. David Kolb defined the experiential learning theory as being a process in which the learner progresses through the four stages of experience, reflection, abstract conceptualization, and application. Although it generally starts with experience and flows through the following stages, the learner can jump into any part of the stage so long as all four stages have been achieved [1]. An example of this process occurring in maritime education is the common use of simulation and real-world platforms throughout the curriculum of many MET's. As pointed out by Kazuo Yoshii et al. (2017), the effectiveness of learning with multiple experiences which occur throughout the learning process is much more effective than a single experience as a part of the learning process. Due to this, California Maritime Academy and other MET's follow a curriculum structure which alternates between experiences gained throughout their curriculum [2]. Today, the experience portion is provided to the mariner primarily through the use of real-world platforms (in the form of both commercial vessels and training vessels) as well as through utilizing simulators. Both platforms provide their own advantages and disadvantages. Real-world platforms have the advantage of genuine

experience which does not lack degradation due to unrealistic situations or representations. However, they also have increased risks due to real-world consequences and safety factors and are extremely expensive to operate. Simulators are wonderful at replicating specific tasks which can be repeated as many times as needed. Unfortunately, simulators are also relatively expensive and often require an instructor to operate the system, limiting the availability of the platform to the students. As the number of regulations continue to increase and the standards for mariner education continues to evolve, MET's are continually looking for new ways to create and share these essential experiences with their students which are effective and efficient.

One technology that MET's are exploring as a new platform for experiential learning is Virtual Reality (VR). Although VR is not necessarily a new technology, recent advancements have made it an accessible platform which has the potential to create and share experiences in revolutionary ways. There are many areas throughout literature where MET's are beginning to use VR for education. One example is the U.S. Navy's use of Mixed Reality (Augmented Reality combined with Virtual Reality) for medical training and ship familiarization training [3]. Another example is that of the VR mobile lifeboat simulator which was recently launched by the Norwegian company ASK Safety [4]. Additionally, MET's are exploring the use of VR Training Videos which are 360-degree videos which are displayed on VR headsets. This combination allows for a fully immersive experience which allows for a high level of immersion while combining the benefits of video-based instruction. There have been several studies such as the one conducted by G. Meadow et al. (2017) from Solent University, which have identified the beneficial nature and instructional quality of VR Training Videos but also identified a great need to identify the proper methodology to effectively implement these VR Training Videos into a curriculum [5]. At SUNY Maritime College, we propose that one way to effectively implement VR Training Videos into a curriculum is to utilize them as an introductory platform for the experiential learning process. The VR Training Video would create the first experience within the experiential learning cycle, leading to reflection and abstract conceptualization which would be conducted through standard classroom lecture and quizzes/tests, leading into application which would be completed in a simulated or real-world environment. This would begin the experiential learning cycle earlier, better preparing the student for their interaction in the simulated or real-world environment.

2.0 IMPLEMENTATION AND RESEARCH

The use of VR Training Videos as an experiential platform alongside standard classroom lecture first began to be implemented and studied at SUNY Maritime College in the Summer of 2018, progressing through three distinct phases, and ended in Summer of 2019. Phase I consisted of a pilot study which was conducted to explore the general design of the VR Training Videos and the User Experience associated with them. It also allowed for the testing of the intended research design for the following phases. After reviewing the findings from Phase I, a new VR Training Video was developed for a lesson within the established curriculum. The researcher then requested that instructors use the materials alongside their normal instruction in the Bridge Resource Management Course (Phase II) and during the Summer Sea Term Course (Phase III). The lesson materials and lesson design was intended to follow an experiential model which involved creating an experience using the VR Training Videos, engaging in reflection and formulating abstract conceptualization through the use of lecture/discussion and quizzes/tests, and then applying this knowledge and creating a new experience through the use of simulation or real-world application.

2.1 Methodology

The research design which was intended for all three phases was that of a Mixed-Method, which combined the quantitative evaluation through the comparison of student achievement on tests and

student responses to a survey along with an explanatory research design which used student responses to open ended response questions on a survey and instructor observations.

2.2 Subjects

The subjects were students who attended SUNY Maritime College and were currently within a Maritime Transportation Degree program ranging from their first year of study to their final year of study. The student body at SUNY Maritime in a Marine Transportation Degree includes individuals who are 19-25 years old, predominantly male (88%), and predominantly Caucasian (76%). These students were contacted to volunteer for the study as they should be familiar with the terms but are still progressing through the levels of instruction within the program.

2.3 Implications of Research on Subjects

The risk to the students involved with the study was very low. The only potential risk was due to the risk of VR sickness. Filming techniques were used to minimize motion and increase a sense of stability within the VR Training Videos to reduce this risk. The students were also notified of this risk and were instructed to immediately remove the VR headset if they began to feel any indications of motion sickness. None of the students mentioned feeling a sensation of motion sickness throughout this study. An IRB for Phase I and a second IRB for Phase II and Phase III was submitted for and accepted through the SUNY Empire State review board. All research was conducted in line with the ethical procedures outlined in both IRBs.

2.4 PHASE I: Pilot Study

Phase I was the pilot stage and was intended to obtain information to help guide the full study (Phase II and Phase III) which would be conducted the following academic year. A full discussion on both the procedure and the results of Phase I are covered in depth in the Final Project Thesis paper which was submitted by Tamera Gilmartin in August of 2018 to SUNY Empire State College and can be referenced on the cadet360.org website [6]. This is a short overview of the study so that it can be compared to the following phases.

First, the lesson design was developed and the materials to support the lesson were created including lecture notes, a quiz, and the VR Training Video. The VR Training Video was created using 360-degree cameras which were placed in several locations on a vessel which conducted the operation of having a small vessel coming alongside. This recorded film was then edited using a video editing program which had 360-degree video editing capabilities. These videos were then uploaded into the VR headsets. The participants were broken up into two groups; one group received lecture first and then watched the VR Training Videos while the other group watched the VR Training Videos first and then received the lecture. After completing the lesson, the students were asked to take a short quiz covering the material and were asked to fill out a short survey.

The quantitative results from the tests indicated that although instruction in general made a major impact on student achievement of learning outcomes, that a combination of lecture and VR Training Videos was best. Qualitative results from the observations collected from student interaction and student comments also indicated that the use of VR Training Videos should be done first and then be followed by a discussion. Both quantitative and qualitative results related to the user experience indicated that the overall user experience for the VR Training Video was high, but that some improvements upon the camera location and presentation of information on the screen could be improved through slight refinements. Issues such as camera angle being crooked or unfamiliarity with the platform were indicated as being significant distractors which took away from the experience but did not impact the overall enthusiasm or satisfaction with the use of VR Training Videos as a learning platform.

2.5 PHASE II: Bridge Resource Management

Phase II was intended to be the first stage of full implementation of integrating VR Training Videos into a structured lesson using the proposed experiential learning format which involves creating the first experience (VR Training Video), conducting reflection and formulating abstract concepts (lecture/discussion), and then applying the concept through the creation of a new experience (Simulator) and was conducted in the Bridge Resource Management (BRM) course which is at the end of the student's curriculum and uses simulation heavily as an experiential learning platform. The original research design was intended to follow the same format as Phase I, using a Mixed-Method approach with quizzes, surveys, and observations. Due to issues related to constraints of the BRM course, the quizzes were not implemented during this phase and there was no opportunity to alternate the placement of the VR Training Videos in relation to the lecture.

First, the materials were created by using a 360-degree camera to record the evolution of anchoring the vessel onboard the school's training vessel, which was then edited using a video editing program, and was finally uploaded to the VR Headsets for use. This was done utilizing the information gained on proper angles and camera placement from Phase I. Lesson materials including lecture notes and quizzes were also created. The instructors who taught the intended BRM course were contacted and the process of the how the study would be conducted was agreed upon. However, throughout the course, the instructors found it difficult to add the VR Training Video evolution into the classroom portion due to course requirements and time constraints. This caused the VR Training Videos to be offered as a voluntary evolution outside of designated class time. The students all received a lecture on the operation of anchoring in class first, watched the VR Training Videos outside of class, and then participated in the simulation exercise as a part of the original course. Although the simulation exercise was designed to be an anchoring exercise, many of the students did not have the opportunity to demonstrate an impact on their ability to anchor due to delays in the BRM simulation due to vessel traffic. This prevented any analysis on the observations of any impact the VR Training Videos had on the application of a subject.

2.6 PHASE III: Summer Sea Term

Following Phase II, the Anchoring VR Training Video was used again during the Summer Sea Term course. The Summer Sea Term course is an essential part of the Maritime Transportation curriculum at SUNY Maritime College, where the students gain their sea time requirements and learn through real-world application onboard the training vessel through standing bridge watches, conducting deck maintenance, and taking lecture-based classes. The researcher asked one of the instructors who was teaching the Ship Operation lecture portion of the Summer Sea Term course, to go over anchoring with the students using the VR Training Videos and then allow the students to watch the anchoring operation be conducted on the vessel first-hand. The Ship Operation lecture portion is taken by students who have completed their first year of instruction and are still at the beginning of their curriculum. This was intended to fully engage the experiential processes by creating the first experience (VR Training Video), conduct reflection and formulate abstract concepts (lecture/discussion), and then apply the concept by creating a new experience (watching/participating in the real-world evolution). The original research design was intended to follow the same format as Phase I, using a Mixed-Method approach with quizzes, surveys, and observations. Due to issues related to constraints of the Ship Operations portion of the Summer Sea Term course, the quizzes were not implemented during this phase and there was no opportunity to alternate the placement of the VR Training Videos in relation to the lecture.

The videos had already been created for Phase II, so Phase III began by implementing the VR Training Videos directly into the course. The instructor was provided with some quick instruction on how to operate the headsets and was then asked to use them in class, instruct the students, allow the students to watch the real-world anchoring operation on the training vessel, and then collect the surveys

at the end. As this was conducted the same way for all the groups of students within the Ship Operations lecture portion, preventing the opportunity for a control, a comparison between tests was not completed.

3.0 Phase II and III: Qualitative Results

Although there were many barriers to conducting Phase II of this study within the intended course, significant findings and indications were identified throughout the study. One of the most significant findings was that the use of VR Training Videos within a structured lesson must be a conscious decision on the part of the instructor conducting the class. Courses which already have a high number of learning objectives and may also have a difficult time integrating VR Training Videos into established lesson plans. Providing this material as an outside of class resource however, such as through the internet, may allow the students the opportunity to use these materials while not impacting the established structure of the course. An interesting observation was that although it is often commented that VR can be an isolating experience, the students were talking to each other throughout the experience, asking questions and making comments about the VR Training Videos. Additionally, it was observed that students who participated in the original filming of the videos commented on how it was strange to watch themselves and that they were able to see and understand more of what was happening when watching the VR Training Video when compared to participating in the original event. Finally, most of the participants during Phase II stated that the VR Training Video would have been better placed earlier in the curriculum as it would have been good as an introduction. When the video was used earlier in the curriculum as a part of Phase III, the students indicated that it seemed to be placed in the correct location for the curriculum and their current knowledge level.

The results from Phase III of the study indicated a high level of enthusiasm towards the use of VR Training Videos as a learning platform. The comments in the surveys indicated that the narration provided in the video, along with the text-based prompts and labels were very helpful as they guided the students towards the important learning material. Overall, the user experience levels were high, however the issue of the sound being too low was also consistently indicated. This lesson took place in a classroom aboard the training vessel which had very loud air blowers for ventilation. This made it difficult to hear the narration. The instructor moved the class into the library where the ventilation noise was much lower, fixing the issues with sound. Finally, it was noted in both Phase II and Phase III that the participants were very enthusiastic about the VR Training Videos and the potential they had as a teaching platform, often suggesting other lessons where they would be beneficial such as cargo operations or docking operations.

4.0 PHASE II AND PHASE III: Quantitative Responses

As issues arose during both Phase II and Phase III for properly implementing a comparison on the impact VR Training Videos made upon performance on a quiz/test, the quantitative results for these two phases came from the survey responses. Although Phase II was conducted with students towards the end of their studies and Phase III was towards the beginning of their studies, the responses between

both groups were very similar and carried similar percentages so the results below are combined from Phase II and Phase III.

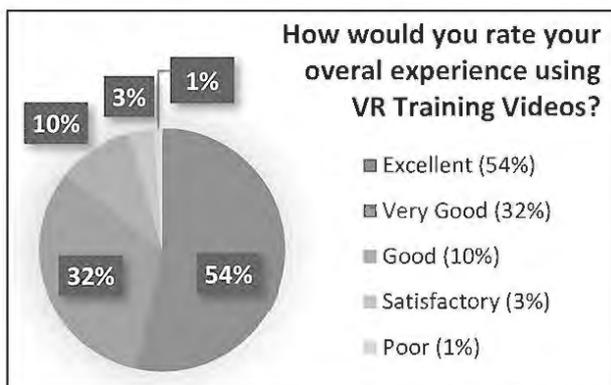


Figure 1. Overall Experience of VR Training Videos. n = 90

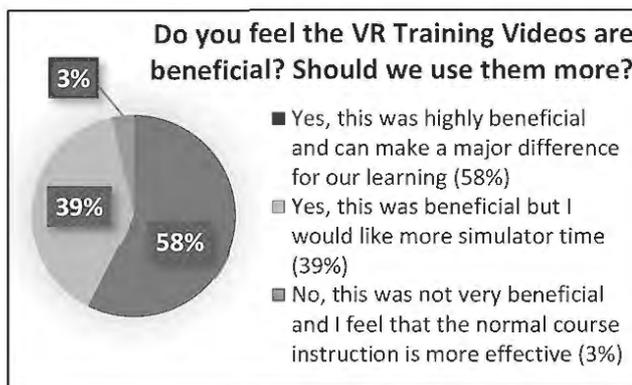


Figure 2. Student perception on how beneficial the VR Training Videos were for education. n = 90

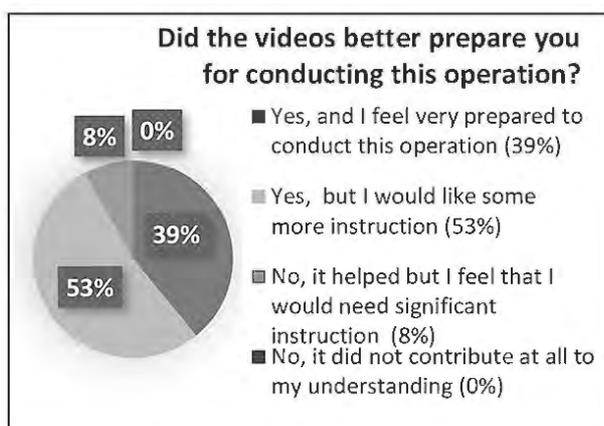


Figure 3. Effectiveness of VR Training Videos at preparing students for participation in shipboard operations. n = 90

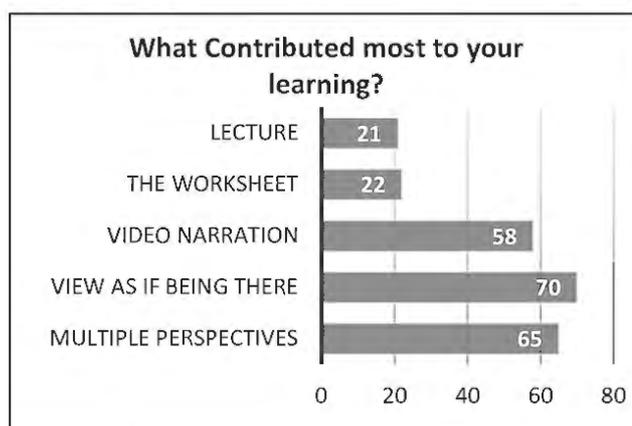


Figure 4. VR Training Video contribution to student learning. n = 90 (multiple responses allowed)

The responses concerning the overall experience of using the VR Training Videos along with the perceived benefit of the videos indicated a high level of enthusiasm and perceived benefit from the students. Although there were a small number of responses which indicated a satisfactory or poor experience, there was an overwhelming majority of responses for excellent or very good indicating that overall, the students were very pleased with the experience (see Figure 1). There was also an overwhelming majority which responded that the VR Training Video was beneficial, but some also noted that more time practicing with the simulator would be beneficial. Very few indicated that normal course instruction was more effective than the VR Training Videos (see Figure 2). As for the question on how prepared the students felt, almost all responded that the VR Training Videos had contributed to their learning with a majority indicating that more instruction would be beneficial (see Figure 3). The responses to the question asking what contributed the most to the student's learning, items related to the design of the VR Training Videos received the majority of the responses. These included that the videos were the immersive nature of the first person view, being able to view the event from multiple perspectives, and/or the narration of the video (see Figure 4).

5.0 CONCLUSIONS AND FUTURE RESEARCH

The purpose of this project was to implement and test the use of VR Training Videos as an experiential learning platform. The proposed methodology of implementing the VR Training Videos within an experiential learning framework was to first have the students interact with the VR Training Videos to gain an experience, then conduct reflection and formulate abstract conceptualization through the use of lecture and quizzes/tests, and then apply the knowledge through the use of simulated or real-

world scenarios. Both Phase II and Phase III did not follow the exact flow which was intended, but rather did lecture first, followed by VR Training Videos, more discussion, and then application. However, the students did progress through all the stages. As Kolb also states in his experiential learning theory, it is possible to jump anywhere in the process but it is critical to allow all of the stages to occur for deeper learning [3]. It was difficult to force a strict format following this methodology for VR Training Videos into a class which had already been designed. However, when the experience aspect through the use of VR Training Videos was allowed to fall naturally where it fit the best in the individual class, such as an outside assignment or within a flexible classroom setting, it could be very effective. The students also indicated that although they felt the VR Training Videos were very effective as a learning platform, the lecture/discussion portion was also important and had contributed to their learning as well. The students also placed a very high emphasis on the need to continue with further experiences such as in the simulator or in the real-world, allowing for true application of what they had learned. It was also noted that VR Training Videos were more effective at an introductory level, essentially creating the first step in the experiential learning process by allowing the student to observe the evolution safely, focusing on the lower knowledge levels such as learning the nomenclature and processes through the guided narration and text provided in the VR Training Videos, before moving into higher levels of knowledge and application.

Although the placement of the VR Training Videos within the experiential learning cycle did not seem to impact their overall effectiveness so long as all stages were addressed, more research into the use of VR Training Videos as an experiential learning platform should be conducted to establish if there truly is an impact or if there is a preferable method as was indicated in the pilot study. The comments by the students who had been present for the filming of the video on how they saw things differently when watching the event through the VR Training Video also presents interesting opportunities for research. As the students commented that they were able to see things from different perspectives and noticed things they did not during the filming of the video, VR Training Videos might present a good opportunity as a debrief tool as well, making it a potential tool for the reflection and abstract conceptualization portion of the experiential learning process, following an activity which occurred in the real-world or in the simulator. This and other new or unique uses for VR Training Videos should be explored further as VR Training Videos have the potential to create revolutionary teaching methods which were unavailable in the past.

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Joint Production of Web-learning Material by IAMU Member Universities

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ABSTRACT

Joint production of web-learning material on maritime cyber security management was carried out by three IAMU member universities: Gdynia Maritime University (GMU), Satakunta University of Applied Sciences (SAMK) and Svendborg International Maritime Academy (SIMAC) as part of the IAMU research project CYMET. The IAMU e-learning platform and Moodle open source code software was used in producing and publishing the training material.

There is unexploited potential in producing training material in collaboration between MET institutions. The convention on Standards of Training, Certification and Watchkeeping (STCW) forms a natural basis for this collaboration.

Even though combining material from different sources into a high-quality training material can be challenging, the international community of MET institutions could benefit from the exchange of special expertise. It is proposed that the quality of education and training of seafarers globally could be enhanced by increasing collaboration between IAMU member universities in joint production of web-learning material.

1. INTRODUCTION

In all areas of higher education, the use of the internet and web-based learning have gained much attention, for several reasons. Firstly, the internet is a source of useful material for educational purposes. Secondly, affordable and versatile software tools are available for development and running web-based courses. Thirdly, conducting lectures online for a larger number of students is cost-effective. Fourthly, web-based courses can be followed online by students anywhere in the world.

The convention on Standards of Training, Certification and Watchkeeping (STCW) by IMO [1] forms a useful basis for collaboration between maritime education providers. Since STCW forms the minimum standard for training of seafarers, the essential contents of training material should be similar all over the world. Naturally, this does not fully apply due to linguistic and cultural differences, variation in the educational system between countries and different pedagogical methods applied. However, there may be unexploited potential in producing training material in collaboration between MET institutions.

The objective of the CYMET project, initiated by the International Association of Maritime Universities (IAMU) is to increase the knowledge and awareness of cyber safety issues within the seafaring industry and to enhance proper consideration of these issues in education and research activities of the IAMU member universities. One of the concrete outcomes of the CYMET project is a package of web-learning material, developed by the partners SAMK, GMU and SIMAC and made available for all IAMU member universities.

Even though it is challenging to compose a uniform and unified set of high-quality training material from texts and presentations produced by teachers from different universities, this kind of collaboration can be very beneficial and rewarding. The Basic Agreement of IAMU states: *The members shall cooperate with each other in a range of scientific and academic studies, developments, and practical applications associated with Maritime Education and Training and endeavour to achieve measurable and worthwhile outcomes for Maritime Education and Training through IAMU activities* [2]. Thus, active promotion of the collaboration between the member universities in joint production of web-learning material should be considered in IAMU to enhance the quality of education and training of seafarers globally.

2. SOME PEDAGOGICAL ASPECTS

The world-wide-web became popular in the early 1990's. The potential of the internet in higher education was immediately discovered by education professionals. Exploiting of the new possibilities started in different variations of e-learning and web-based learning.

One can't say that the results of web-based training are worse or better than the results of traditional face-to-face classroom training. There are more factors affecting the learning process than just the applied technology. Figure 1 shows that even though we can place the technology to the center of the educating process, pedagogy, implementation and even institution play an important role in this process.

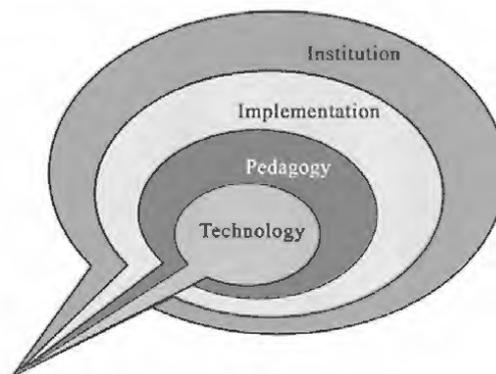


Figure 1 The four components of flexible learning in higher education [3]

Learning is a complicated process affected by a large amount of factors, such as the motivation of the student - and the teacher- , experience and the learning style of the student, learning environment, readiness to utilize the technology, language skills, timing, structure of the material, visual outlook of the training material, stress, fears, other emotional factors and so on. Efficient web-based -training, especially when it is based on self-education, is based on different pedagogy than traditional face-to-face classroom lecturing. Web based learning

methodology, practices and pedagogical principles have been a subject to discussion and active research for decades, see [4], [5], [6] and [7]. Although deeper analysis of these matters is beyond the scope of this report, there are some aspects worth mentioning, which should be considered in development of web-based and self-learning courses:

- In the beginning of the course, wake up the motivation to learn and the curiosity of the student towards the subject in concern. This can be done for instance by presenting a video of an eye-opening case from real life. Wondering is a key to learning.
- The self-learning course should be organized so, that the student can study it in smaller pieces. The material should be divided into lessons or chapters. It should be organized in a logical order guiding the student to build his/her knowledge effectively.
- Each lesson or chapter of the self-learning course should end with control questions or exercises which provide the student with feedback about his/her progress.
- The typical amount of student's working hours should be in balance with the amount of credit points earned from passing the course.
- The English language of the material should not be too difficult to understand. It must be kept in mind that the students of the self-learning course come from different parts of the world and that many of them do not speak English as their native language. All difficult terms and phrases should be explained for instance by using pop-up type help texts.
- A good web-learning course is exciting. If there are enough resources available, the attractiveness and effectiveness of the self-learning course can be enhanced by using simulations and challenging interactive functions, like in video games, into it.

The internet offers an enormous number of ready-made videos, lectures, presentations, articles, photos, graphics etc. that could be useful for the self-learning course. However, the teacher must keep in mind that the international and national copyright laws shall not be violated.

3. SELECTION OF THE WEB-LEARNING PLATFORM

Before the web-learning material could be developed and made available to IAMU member universities, the software tool for producing, sharing and using the material in teaching had to be selected. The platform to be chosen should meet at least the following criteria:

- the material should be available to IAMU member universities
- the platform should be commonly used
- it should be easy to use and simple to maintain
- it should contain key functions and features of an advanced web-learning platform

An important aspect is also the price of using the platform. If possible, it should not be too expensive, preferably free.

There are number of web-learning platforms, services and systems available on the market. Based on a preliminary study about the supply the project group decided to have a closer look at two alternatives: **Moodle** and **Itslearning**.

Moodle has been a very popular web-learning environment worldwide among institutions of higher education. Moodle is a free open source code software system, originally developed

by Martin Dougiamas. The first version was released in 2002. The Moodle Project is led and coordinated nowadays by an Australian company Moodle HQ and it is financially supported by a network of Moodle Partner service companies worldwide. Moodle has at the moment (May 2019) over 160 million users in 227 countries [8]. Moodle is widely used also by the member universities of IAMU.

IAMU has established an e-learning portal on its web pages. It is based on Moodle. The member university wishing to use a course available at the IAMU e-learning portal, needs to download and install the course to its own server. This is because IAMU does not have the possibility to take care of thousands of student enrollments from maritime universities or the necessary resources for online maintenance required to provide the users with a proper and reliable service. This kind of service does not belong to the core activities of IAMU.

As an alternative to Moodle, the cloud based learning platform *Itslearning* was studied by the CYMET project group. Itslearning is a commercial service, maintained and distributed by the company Itslearning AS, Norway [10]. Itslearning was developed in Bergen, Norway, in 1999 and it is said to have over four million active users worldwide [11].

Itslearning is a comprehensive learning management system offering tools for curriculum management, objective-based course plans and assessments in one online location. The platform gives easy-to-use tools for creating online courses, for collaboration and sharing materials, and it automates routine tasks within the education processes of the institution.

From IAMU's point of view, there would be some advantages of using a cloud based system like Itslearning:

- the courses are available worldwide without the need to download and install material to the university's own IT system
- enrollment of students from different universities is managed by the system
- development and maintenance of the course material in collaboration of several teachers is easy

On the other hand, since the service is not free, the costs of using Itslearning may reduce the willingness of using the service. However, pricing today (May 2019) is rather moderate and it is based on the number of students. Moreover, it includes full maintenance of the system, which reduces indirect costs on the IT management side.

After studying the two alternatives, Moodle at the IAMU e-learning platform was chosen by the project group for producing and publishing the web-learning material. The main reasons to this selection were:

- Moodle is more widely used, and it is already familiar to the member universities of IAMU and it is free
- the e-learning portal on the web site of IAMU is based on Moodle

Although Moodle has some weaknesses compared to Itslearning regarding the management of student enrollments and the need to download and install the course material to the IT system of each university, it clearly fulfills the requirements for a functioning web-learning platform.

It would be a strategic decision by IAMU to establish or buy a cloud based service for development and maintenance of jointly developed e-learning courses instead of the present IAMU e-learning platform.

4. JOINT PRODUCTION OF THE TRAINING MATERIAL

A web-based training package on cyber security issues for maritime professionals was created jointly by the partners of the CYMET project. The material consists of texts, images and links to relevant material in the Internet. Personal exercises were included to provide the students with feedback of the progress of their learning. It was agreed by the producers of the material that each member will produce the material for one whole chapter and then the chapters are put together to form the whole course. In other words, there was no group work was done during the production. However, the producers had the possibility to study and comment the others' texts.

This may not be the optimal way of working together from the point of uniformity of the result. But due to limited resources of CYMET project this was the only practical way to get the work done. It would be better in the future to have a named editor, or a group of editors, having the responsibility of checking the material and editing it into a standardized format. Also updating the course material in the future must be planned. The editor could assure the correctness of the contents, the correctness of the English language and the uniformity of applied expressions and terminology.

Another important area of consideration is copyright regulation. There might be differences in Copyright rules and practices from country to country. The material must be produced in such a way that it will not violate any international copyright legislation.

The Maritime Cyber Security learning package was developed by the members of CYMET project for 100% self-education and it was organized into seven consecutive lessons: 1) Introduction, 2) Understanding cyber threats, 3) Awareness across the organization, 4) Elements of cyber security management, 5) Good practices, 6) Rules, standards and guidelines and 7) Examples from the real life.

The material consists of plain text with links to videos and articles in the internet and multiple choice questions in the end of each lesson to give the student some feedback about learning of the contents of the lesson. No new animations or videos were developed within this project. The training material contains also additional special chapters on Network integrity, GPS jamming & spoofing and Safe information exchange, which were not included into the basic course. They can be used in the advanced courses mentioned above.

The web-learning course was pilot tested by students of the participating universities in Finland, Denmark and Poland. The Students were asked to study the Moodle course and after completing the course to express their opinion about the course by answering ten open questions.

The response indicated that the course was found useful, interesting and suitable for self-learning. Some of the students felt that the topics were somewhat too general, i.e. they would prefer more examples from the shipping industry and about ship equipment, even though the real life examples of cyber-attacks were taken from the shipping world. Some of the students had difficulties in understanding the English language, which is quite understandable, since none of the students were native English speakers.

Another important source of feedback would be teachers of IAMU member universities. However, collecting of this feedback was not included in the CYMET project.

5. CONCLUSIONS

Maritime universities and other MET institutions around the world have shared needs to develop courses on seafaring and marine technology. However, teachers do not often use texts, PowerPoint presentations, exams etc. made by someone else. They prefer to use their own material. Lecturing is a very personal matter. It can be compared to coaching or performing arts. An experienced lecturer may not want to follow the logic of another lecturer's presentation, because he/she may prefer another approach to the subject in concern or he/she wants to put emphasis and priority on matters differently than the colleague who made the presentation. The reason for omitting the ready-made material could also be the English language.

Despite of these challenges, there is room for joint development of training material on selected topics. Management of maritime cyber security is one of those topics. Maritime cyber security is a highly critical area for the shipping industry and there is an acute need for training of seafarers to be aware of and to cope with cyber threats.

One conclusion of the the CYMET project by IAMU is that jointly developed web-learning material should be as easy to use as possible. A good solution from the teacher's point of view would be to have it available through a cloud service. However, it does not fall in the area of core activities of IAMU to maintain such services. The solution could be to outsource the cloud service for IAMU web-learning courses. In that case all IAMU member universities would have to become customers of this service provider.

Another solution would be to use IAMU web pages as a storage of material that could be downloaded and installed to the member university's own computer network. This approach was selected in CYMET-project. The web-learning course was pilot-tested at GMU, SIMAC and SAMK. The feedback from students was positive. However, maintenance of the developed course must be arranged in the future in some way or other. The contents of the web-learning course on maritime cyber security needs to be updated on a regular basis.

It is obvious that the international maritime education community could benefit from collaboration in the area of training material development. IAMU could promote the quality of MET globally by utilizing the expertise within its member universities in the form of collaboration in production of high-quality web-based training material.

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A Cluster-Based Approach to Maritime Data Analysis: The Case of SAT-AIS Data Analysis

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ABSTRACT

The paper deals with a problem of determining packages in SAT-AIS dataset and dealing with a AIS packet collision problem. Transponders from different terrestrial AIS service areas, being in the satellite, are not synchronized between themselves or with the satellite. The AIS satellite receiver records signals transmitted by ships located in different areas, although in the satellite field-of-view. Lack of synchronization causes packet collisions and results in difficulties in identifying packages received by a satellite. In the paper a clustering procedure, i.e. machine learning technique, is proposed for packages recovering. Aim of the carried out computational experiment was to answer the question whether clustering can be helpful in a recovery of data when they are lost as is the case with a SAT-AIS system. The obtained results are interesting and gave a possibility to formulate future direction research.

1. INTRODUCTION

Modern and intelligent vessels, including autonomous ships, can contain thousands of different sensors. These sensors can generate huge data every day, so consequently, thousands of data can be collected. Use of these data requires looking for and implementing new technologies and techniques, including new approaches to data processing. Data analysis is opening up to new opportunity to create values from data. Data analysis is the process of discovery and drawing conclusions from information - from technical point of view, from data collected in different repositories. Data analysis supplies different tools for data processing, among them based on machine learning algorithms, and becomes increasingly important also for ship control. This importance should be merged with different critical decisions and ship's automation. Data analysis is also becoming crucial for shipping, where greater volumes of data are today more natural than ever before. In this case, data analysis is needed to improve performance of monitoring and optimization of operations, condition of monitoring the maintenance of equipment and assets, as well as safety improvements. DNV underlines that data analysis will not only be beneficial in the current environment, but will prepare the organization for the future. So, it is the reason why data analysis is pointed as a one of six key technologies that will transform the marine and shipping operations [2]. In [2] there are also pointed out four primary technology enablers for the collection and use of data analysis tools in shipping, i.e.:

- availability of affordable, reliable and accurate sensors for data collection,

- high data transfer speeds between ship and shore,
- continuously increasing computational power and development of IT platform solutions,
- development of analytical methods and algorithms for creating value from collected data.

An example where machine learning tools can be successfully implemented is the AIS data analysis. The Automatic Identification System (AIS) is an automatic tracking system based on transponders located on ships and used by vessel traffic services (VTS) (see, for example [4]). Based on AIS statistics and vessel data, machine learning tools can relatively accurately predict future vessel movements, several port steps ahead [2], [8]. Due to increasing ship traffic in ports, the maritime traffic safety needs more attention, and analysis of data collected from AIS can help to control and prediction of ship behaviors. Based on deep and wide analysis of data from the AIS system, a big set of different parameters and factors can be monitored [3]. Combining different data, which are available in a public domain, like for example vessel position and speed derived from AIS data, as well as weather data and others different reports for own or market needs can be created for optimization of different operations or for managing of vessels and transportation operations.

Analysis of AIS data can bring new outputs and provide concrete safety threshold for components under scrutiny [2]. AIS data are also the object of different analysis concerning behaviors of vessels which are or can be carried-out with respect to the vessels security or to monitoring and predicting of future behaviors of vessels on open sea or restricted waters. Examples of such analysis can also concern detection of anomalies in behavior of vessels, unreasonable approaching of ships, illegal activities, pollution of the environment, detection and warning against danger of collision or other dangerous situations. Vessel behaviors' analysis are now important from global scale point of view. The rationale for such analyzes are maritime terrorism and growing number of acts of piracy [6].

Thinking about increasing the effectiveness and effective of different processes, from monitoring of the environment pollution to illegal activities and behaviors of the vessels, it is reasonable to collect and analyze of AIS data from a global perspective. It is a reason of introducing of the satellite Automatic Identification System [5]. *“Space-based AIS (SAT-AIS) will make it possible to track seafaring vessels beyond coastal areas that are equipped with AIS tracking devices. SAT-AIS is a promising solution to overcome terrestrial coverage limitations with the potential to provide AIS service for any given area on Earth”* [9].

However, from a technology point of view, the SAT-AIS is more complex. Data collected by the satellite component of SAT-AIS are incomplete and contain noise. So, it is difficult to determine the AIS data packages in their basis. It means, that numerous incomplete packages result in decreasing volume of useful data. It also means, that the satellite transponder can't provide in a regular way full and complete data on vessel traffic to the ground component. Thus, numerous incomplete packages result in decreasing volume of useful data and result, that the accuracy of ongoing different analysis business can be poor or incomplete.

Machine learning tools can be very helpful in data processing for the needs of different systems, including marine systems, in case when the data is incomplete. In this paper the clustering-based approach, i.e. unsupervised machine learning, for analyzing of AIS data and for determining packages are considered. In general, aim of the research was to answer the

question, whether clustering algorithms can be helpful in a recovery of data when they are lost as is the case with the SAT-AIS system.

2. PROBLEM FORMULATION

2.1. SAT-AIS FOR MARINE TRAFFIC MONITORING

Based on the International Maritime Organization regulations, ships of 300 tons or more in international voyages, cargo ships of 500 tons or more in local waters and all passenger ships, irrespective of size, are required to be equipped with Automatic Identification System (AIS). In result, the Automatic Identification System (AIS) has been introduced in late 90s., and according to the IMO regulations, it has been prepared for identifying ships and support the navigation procedures. Since then, AIS is one of the basic tools for maritime traffic monitoring. AIS is also included in Aids-To-Navigation and Search and Rescue transponders.

AIS as a radio-based communication system was originally developed to prevent collisions of large vessels. It transmits the course and speed as well as identification and position information to other vessels and shore stations. While AIS has been deployed for global operations, it has a major limitation. The limitation follows from the Earth's curvature which limits its horizontal range to about 74 km from shore. This means that AIS traffic information is available only around coastal zones or on a ship-to-ship basis. Thus, AIS has been classified as a system for exchange of information at a local scale [9].

SAT-AIS has been introduced as a system for exchange of information at a global scale. The ship's identity is recorded and decoded by satellite then sent to ground stations for further processing and distribution [10]. Such system is promoted, among others by European Space Agency (ESA) [9].

2.2. SAT-AIS PACKETS COLLISION

SAT-AIS has been introduced based on generic assumptions of AIS, especially considering transmission of packages directly from mobile components (located onboard of vessels) to the receivers. Consequently, it generates a number of problems for a satellite system (component of the satellite-based AIS), which is between the mobile components and the receivers and which aim is to detect signals from vessels and then retransmit them to the receivers in a global scale.

Main problem for a satellite system is AIS packet collisions. Collisions are observed onboard of a satellite. The AIS receiver, installed onboard of a satellite records signals transmitted by ships located in different areas, but being in the satellite field-of-view (FOV) - for example, Fig. 1 shows terrestrial AIS service areas. Transponders from different terrestrial AIS service areas, being in the satellite FOV, are not synchronized between themselves or with the satellite [10].

In other words, signals transmitted by ships from different areas but within the same FOV and within the same time slot result in the collision of AIS messages. The signals transmitted within each slot are received by the satellite with different amplitudes, time delays, and different Doppler frequency shifts due to the spatial separation of the ships [11]. It results in an interference of different signals in time and difficulties with decoding the packets, so, it is difficult to establish current information concerning the ships. It means that the AIS receiver

would not have a problem with receiving packets from only one area, for example from N_0 (see fig. 1), or if the transponders from different terrestrial AIS service areas were synchronized.

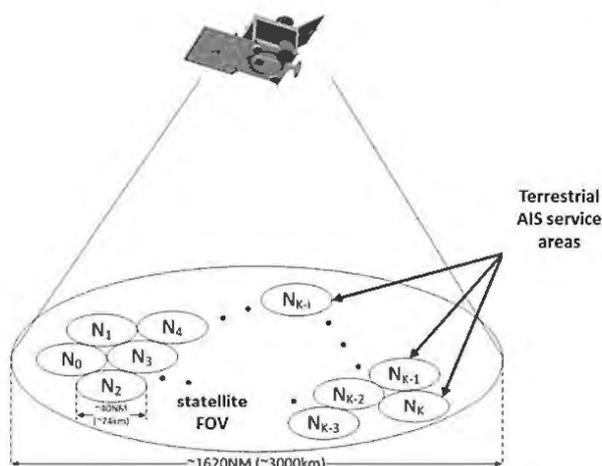


Fig. 1. AIS service areas in the satellite field-of-view [11]

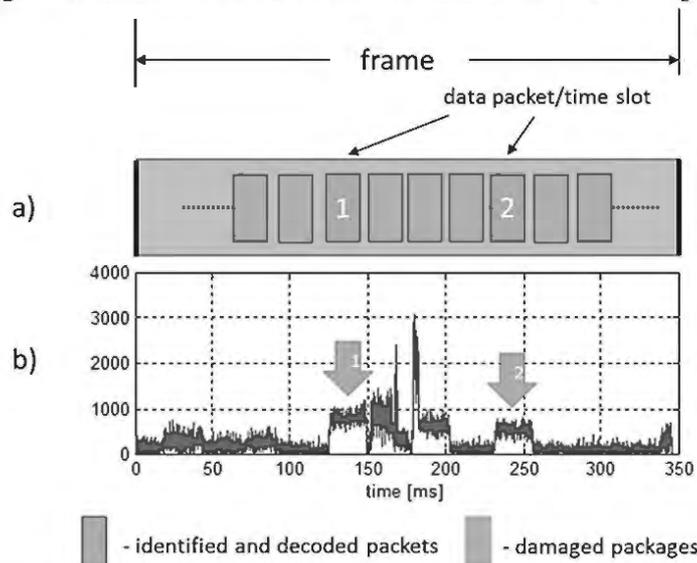


Fig. 2. A time frame presenting of location of received AIS packages - data packages (a) and a fragment of the AIS signal received by the satellite (see in [10]) (b).

Fig. 2 shows an example of data received by a satellite and data packages decoded from these data. On the picture we can observe that only two packages have been correctly identified. The rest of packages have not been decoded. We can only assume where in the frame there should be time slots.

As per statistical observations, the probability of receiving more than three ship correct packages in each frame at the satellite is quite low (see [11]). Thus, it is a reason for looking for solutions for eliminating of AIS packet collisions. The existing research directions concentrate on packet recovery by analyzing of received and sampled AIS signal. Among different approaches and methods we can find decollision methods of the packages by recognition of shape of the received sequence, decoding methods using the Viterbi algorithm, methods for progressive, reverse or hybrid estimation of signal samples or blind source separation algorithms (see, for example, [11], [12], [13] and [14]).

In this paper a clustering approach has been proposed for packages recovering. The approach is discussed in the next section.

3. A CLUSTER-BASED APPROACH TO SAT-AIS DATA ANALYSIS

3.1. UNSUPERVISED LEARNING FOR DATA ANALYSIS

The key objective of machine learning is to design algorithms that are able to improve performance at some task through experience. Learning from examples is the most important paradigm of machine learning. Learning from examples is an example of so-called supervised learning, where the data used in learning process has previously known labels. In other words, our data has some target variables with specific values that is used in the process of producing knowledge model, which next can be implemented for support in different decision aided making process. In such case we consider models and algorithms for solving classification problems, as well as regression problems or time series prediction problems.

However, in case of most problems in real-world, data do not come with predefined labels. In such case the aim of learning process is to develop machine learning models that can classify correctly this data, by finding by themselves some commonality in the features, that will be used to predict the classes on new data [14]. Such approach belongs to so-called unsupervised learning paradigm.

Unsupervised learning can be applied to: segmentation of datasets by some shared attributes, detection of anomalies that do not fit to any group or aggregate variables with similar attributes, thus to simplify datasets [14]. An example of unsupervised learning is clustering. The main aim of clustering is to find different groups within the elements in the data. It means that clustering algorithms find the structure in the data so that elements of the same cluster (or group) are more similar to each other than to those from different clusters. In this case, the strength of machine learning model results from the fact that it is able to infer that there are two different classes without knowing anything else from the data. The unsupervised learning algorithms have a wide range of applications and are useful to solve real-world problems such as anomaly detection, recommending systems, documents grouping, etc. Among the most known clustering algorithms there are: k-means, hierarchical clustering and Density Based Scan Clustering (DBSCAN).

Hierarchical clustering is one of alternative approaches for clustering. The main idea of hierarchical clustering bases on preparing dendrograms which are visualizations of a binary hierarchical clustering. An agglomerative method for preparing of dendrogram starts with each sample being a different cluster, and then in following iterations merge these that are closer to each other until there is only one cluster. However, different criteria of defining closeness can be applied (single linkage, complete linkage, average linkage, ward's linkage-method, etc.), as well as different clustering distance measures (Euclidean, Manhattan, etc.). The obtained dendrograms provide information on relationships within data. Using hierarchical clustering we do not need to initially specify the number of clusters, but they can be found after the analysis on the dendrogram.

3.2. UNSUPERVISED LEARNING FOR RECOVERING PACKAGES IN SAT-AIS

The main goal of the paper is to propose a procedure which may be utilized on board a satellite for identification and decoding of AIS messages and especially for recovering the damaged packages.

The pseudo-code explaining how the damaged packages can be recovered is shown as Algorithm 1. The proposed algorithm bases on a hierarchical clustering of packages, which at

the beginning of analysis are identified in data stream received by a satellite. Assuming that within data stream there can be correct packages, after clustering analysis the induced clusters are compared with the correct packages. Based on identified similarities between the correct packages and the obtained clusters, we can start to predict of damaged parts of packages.

Algorithm 1 Recovering the damaged packages in SAT-AIS data stream

Input: Z_t – set of received data in time t

Output: P_t – set of packages identified and decoded in time t

Begin

$P_t := \emptyset$ - set of identified packages

$P'_t := \emptyset$ - set of damaged packages

Run a decoding procedure of the dataset Z_t and identify time frame Z_{t1}, \dots, Z_{tK} , where K is a number of time frame

For $i:=1$ to K do

 Identify in Z_{ti} correct P^{ij} and damaged P'^{ij} packages, where j is a number of identify package in frame i

$P_t = P_t \cup P^{ij}$

$P'_t = P'_t \cup P'^{ij}$

End For

Run the clustering procedure on data from $P_t \cup P'_t$, where G is a set of obtained group of packages

Evaluate of the similarity between packages in G and correct identified packages in P_t and update P_t

Return P_t

End

4. COMPUTATIONAL EXPERIMENT

The proposed approach has been validated experimentally. The main research question was whether the clustering can be helpful in a recovery of data when they are lost as is the case with the SAT-AIS system.

Datasets used in the reported experiment have been obtained from AIS receiver and include data from the Gulf of Gdansk. The data has been recorded in 35 minute time period and include 1077 different packages, which identify 36 vessels. Then only part of the packages describing each of the 36 ships have been preserved in the original. The remaining packages were damaged. Errors were introduced based on the mechanism of random disturbance of the package structure. It means, that dataset in the experiment consisted of original and damaged messages (packages). Finally, three sets of data were used, consisting of 500, 600 and 700 numbers of damaged packages, respectively. Aim of the experiment was to assess the possibility of identifying packets in group of damaged packages.

The clustering procedure within Algorithm 1 has been implemented basing on a hierarchical approach and using the Ward's method. Table 1 includes results obtained for the proposed approach. Fig. 3 shows an example of dendrogram obtained for considered problem.

Table 1. Results obtained for the proposed approach

Number of damaged packages	The percentage of correctly identified packages	The number of correctly identified packages
500	73%	365
600	57%	342
700	55%	385

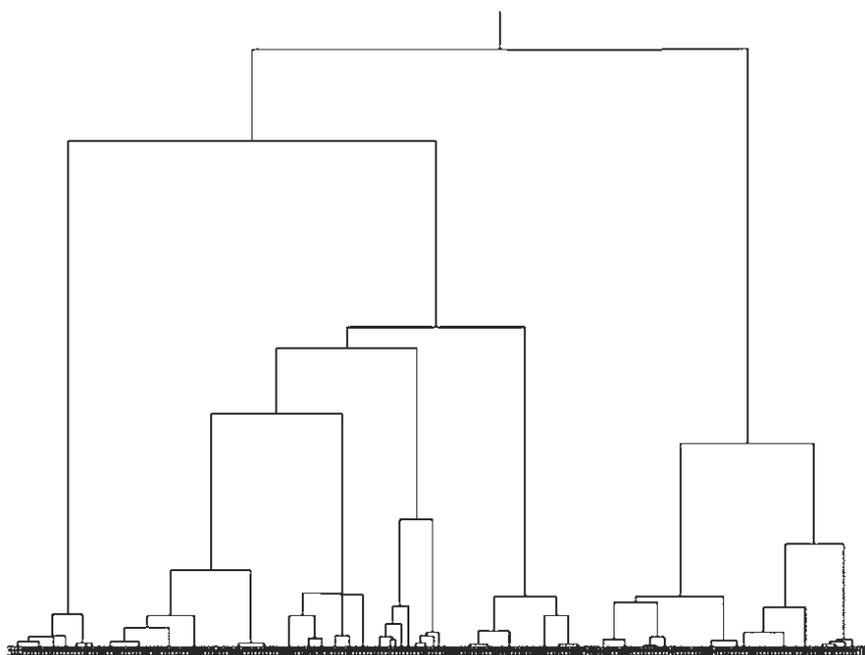


Fig. 3. Dendrogram obtained for considered problem

Based on the results, it can be observed that clustering approach can help to identify packets in the group of damaged packages. Of course we observe that the number of identified packages depend on the number of damaged packages in data. In our experiment, when the number of damaged packages was smaller, the number of identified packages has been bigger.

5. CONCLUSIONS

The paper presents experiments' results where the clustering approach has been used for recovering of damaged packages from data series received by a satellite. Although, the discussed experiment has been carried out basing on artificial data, we can conclude that the proposed approach can be considered as a promising tool for package recovering from data stream onboard of a satellite of SAT-AIS system. Of course, the paper shows initial results, but future research can result in fruitful and valuable conclusions.

Future research will focus on studying the influence of different criteria of defining closeness between packages, as well as different clustering distance measures, on performance and quality of the proposed approach.

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Proceedings

Economical Impact

A Combined Qualitative Ship Valuation Estimation Model

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Keywords: Ship Valuation, Future Estimation, Maritime Management, International Management.

ABSTRACT

The determination of the direction in which supply-demand balance will occur due to instability in periods of economic crisis, and the volatility of the market, necessitate the use of combined mathematical methods. Brokers experience difficulty in determining a ship's real value because of the lack of instant and unbiased data that can be accessed at anytime and anyplace in the world. Mostly, brokers use a marketing approach to determine a ship's value. However, a marketing approach does not give an accurate solution under all conditions. Ships, especially those ranging in age from 6-25, that is, more than five years old, need to be evaluated with a combined method which differs from marketing approaches. There is no systematic and standard mechanism to determine a ship's value worldwide. The aim of this study is to develop a reliable ship valuation mechanism using the "*Combined Qualitative Ship Valuation Estimation Model*" to validate the ship's actual price. Within this model, the ship's value can be calculated more accurately. This model will be useful in determining the adjusted ship value and to provide decision-making support for willing buyers and willing sellers.

1. INTRODUCTION

To date, many academic studies have been written about the subject of value. However, only a few of them are about the "Ship's Value". The main reason for this deficit in academic studies is that the estimation of a ship's future value is very difficult to ascertain and complex methods are needed to determine the value accurately. Brokers experience difficulty in determining a ship's real value because of the lack of instant and unbiased data that can be accessed at any time or anywhere in the world. Mostly, brokers use a marketing approach to determine a ship's value. However, a marketing approach does not give an accurate solution under all conditions. Ships, especially those ranging in age from 6-25 that is, more than five years old, need to be evaluated with a combined method which differs from marketing approaches.[1] Generally, willing buyers and willing sellers have no need for systematic rules to determine ship valuation, but ship valuation depending on systematic rules is vitally important for Sales and Purchase Brokers in terms of Long-Term Asset Values (LTAV). Reduced income (freight) cash flows covering the following 10 to 15 years, with accounts projections, are made by them.[2] However, it is very hard to estimate net asset values precisely. As a sample, in accordance with US bankruptcy codes, US courts do not accept Debtor's analysis. Even if both experts have used the same methodology (comparable company analysis; comparable transaction analysis; and discounted cash flow analysis), seller's experts and buyer's experts determine different values.[3] In this study, a ship's valuation mechanism, namely the "*Combined Qualitative Ship Valuation Estimation*

Model- CQSVEM” has been formed. Within this model, the ship’s value can be calculated more accurately.

2. GENERAL EVALUATION OF PREVIOUS SHIP VALUATION METHODS

Within the scope of the study, certain limitations related to valuation have been applied because of the very different types of ships in the shipping trade. Because of the major and minor commodities of world production cover more than 30% of the world trade, dry bulk carriers have been selected for this study [4]. In order to improve “CQSVEM”, previous valuation methods were scrutinized. The differences and deficiencies of these valuation methods have been interpreted. In order to develop a new hybrid method to eliminate the gaps in the valuation methods, a field study was conducted to collect the appropriate data. These data were collected by reviewing official web sites such as Clarkson Research, Lloyd's List, Baltic Exchange, Shanghai Shipping Exchange, Hellenic Shipping News, etc. Data included the year of construction, sales year, tonnage, and sale price of the ships, the shipyard where it was built, and to which ship-owner company it was sold. In the related literature, it is understood that the most important factors that determine a ship's price are ship type, age, tonnage, and specific features according to the findings obtained from previous studies. The time element is also a very important factor for ships' valuation. Whether the estimates are to be made instantaneously, short term, medium term or over the long term, changes the methods to be applied. There are three different approaches in the literature to predicting the future. These are a market report, a forecasting model and a scenario analysis [5]. Regression models confirm these coefficients for almost every period. In addition, whether the effect of each unit increases these variables and whether there is a correlation or not between these variables on the ship's price were also predicted. Major determinants of newbuilding prices are determined as shipbuilding cost, shipyard capacity, vessel order book, freight rates, and secondhand prices by distinguished authors.

3. A PROPOSAL: THE CQSVEM MODEL

The main objective of this new improved model is to determine the variations between nominal and real sale prices. The price margin will be determined according to the anomalies of prices. Thus, the adjusted price will be calculated for investment or disinvestment decisions. The concept of the improved model is shown in Figure-1.

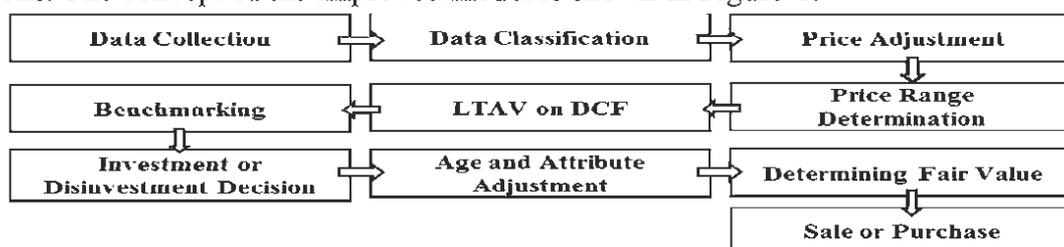


Figure-1 Combined Qualitative Ship Valuation Estimation Model

In this study, clusters are not classified by the category of bulk carriers. Initial calculations based on raw data show that 0-5-year-old bulk carriers reflect market values, but 6-20-year-old second-hand carriers are not in harmony with predicted sale values and the purchase market. 1446 dry bulk carriers’ data were collected for this study. The process of determining optimum ship prices has been divided into three main methods. Firstly, ships of different ages, but similar tonnage have been classified within approximately 10.000 dwt range. The second group consists of vessels of different tonnage but the same age and same year of sale. Thirdly,

selected vessels in harmony with each other in terms of tonnage and age were classified together. The third option is more favorable for meaningful multi-regression analysis. As described in Figure-1, at the first stage, the age of the dry bulk carriers was calculated by the difference between the sale or purchase year and the construction year. In the second stage, price anomalies were detected by applying Regression Analysis. In the third stage, before making LTAV on DCF Analysis, the optimum adjusted value should be determined.

4. APPLYING THE MODEL

Within a case study to apply this model, the dry bulk carrier M/V True Frontier was selected to determine the optimum price. Firstly, the current value (market value) was calculated. Secondly, the market value was compared with reasonable value.

Table-1 The Sample of Market Valuation for a Dry Bulk Carrier.

Ship Name	DWT	Built	Sold	Age	Price (\$M)
Pacific Capella	180.346	2012	2017	5	27,00
Pacific Canopus	180.330	2012	2017	5	25,00
Shin-Zui	180.201	2007	2017	10	15,00
N Fos	179.294	2010	2017	7	21,80
IVS Cabernet	177.173	2007	2017	10	20,50
Portage	176.391	2002	2017	15	9,00
Teh May	175.085	2004	2017	13	10,00
Bulk Prosperity	172.964	2001	2017	16	8,00
Blue Island	152.398	2000	2017	17	7,50
True Frontier	179.294	2010	2017	7	?
Mean Price:					\$15,98M

Source: Data compiled from Clarkson Research by authors [6]

In order to calculate the reasonable value, regression analysis would be a satisfactory method on which to make any investment or disinvestment decision. Sister ship transactions were collated in Table-1.

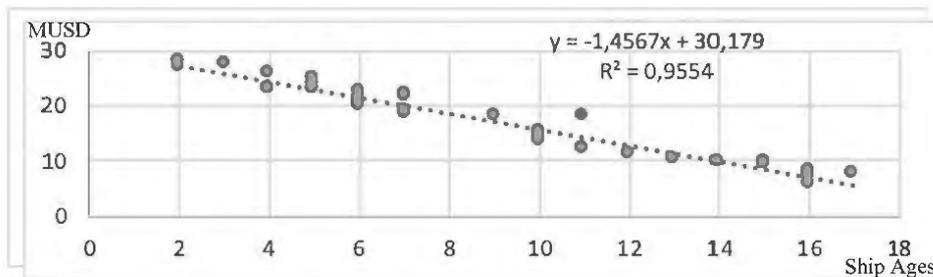


Figure-2 Regression analysis of Capesizes [7]

According to the results of regression analysis in Figure-2, it can be said that it is reasonable to sell M/V True Frontier for 21.4 million dollars. But she was actually sold for \$ 30 mil. by Global Maritime Investment to Clients of H-Line Shipping. When it is considered that the mean price in Table-4 is between \$15,98 mil. and \$16,086 mil. in 2017, it is understood that overpricing occurred under free market conditions.

Table-2 Multi-regression analysis of Capesizes' Summary Output

<i>Regression Statistics</i>					
Multiple R	0,978099929				
R Square	0,956679471				
Adjusted R Square	0,954272775				
Standard Error	1,423660835				
Observations	39				
<i>ANOVA</i>					
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	2	1611,344065	805,6720323	397,5073953	2,88727E-25
Residual	36	72,9651662	2,026810172		
Total	38	1684,309231			
	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>
Intercept	42,30933179	11,96918065	3,534856147	0,001142048	18,03470832
X Variable 1	-6,5796E-05	6,48719E-05	-1,014244685	0,317234489	-0,000197362
X Variable 2	-1,509944363	0,073665618	-20,49727416	1,93803E-21	-1,65934516

To determine the attractive price of "M/V True Frontier" shown in Table-3, the LTAV on DCF will be calculated, and then LTAV on DCF for M/V True Frontier in Table-4 will be compared with a predicted value that is calculated by multi-regression analysis. After comparing this with the actual market price and LTAV, the decision-making process has been applied (as seen in the criteria in Table-5).

Table-3 Calculation of LTAV on DCF for M/V True Frontier

Year (Y)	Age (A)	ABD (%95)	OD	DGCR (%2 IR)	1_CRAAD (%30)	2_CRAAD (%15)	1_DNCR %6.5	2_DNCR %6.5	1_ANCR	2_ANCR	AOE	SV	1_FCF	2_FCF	WACC %	PVF	1_PV \$	2_PV \$
2017	7	326	343	18500	18500	18500	17298	17298	6031000	6031000	2184200		3846800	3846800	73,00	0,93	3585089	3585089
2018	8	340	358	22000	22000	22000	20570	20570	7480000	7480000	2249726		5230274	5230274	73,00	0,87	4542814	4542814
2019	9	340	358	16000	16000	16000	14960	14960	5440000	5440000	2318066		3121934	3121934	73,00	0,81	2527112	2527112
2020	10	340	358	17500	17500	17500	16363	16363	5950000	5950000	2386406		3563594	3563594	73,00	0,75	2688372	2688372
2021	11	340	358	16500	16500	16500	15428	15428	5610000	5610000	2454746		3155254	3155254	73,00	0,70	2218379	2218379
2022	12	326	343	16830	16830	16830	15736	15736	5486580	5486580	2523086		2963494	2963494	73,00	0,66	1941805	1941805
2023	13	340	358	17167	17167	17167	16051	16051	5836644	5836644	2588612		3248032	3248032	73,00	0,61	1983455	1983455
2024	14	340	358	17510	17510	17510	16372	16372	5953377	5953377	2656952		3296425	3296425	73,00	0,57	1876054	1876054
2025	15	326	343	17860	17860	17860	16699	16699	5822403	5822403	2725292		3097111	3097111	73,00	0,53	1642704	1642704
2026	16	340	358	18217	18217	18217	17033	17033	6193893	6193893	2790818		3403075	3403075	73,00	0,49	1682187	1682187
2027	17	340	358	18582	18582	18582	17374	17374	6317771	6317771	2859158		3458613	3458613	73,00	0,46	1593327	1593327
2028	18	326	343	18953	18953	18953	17721	17721	6178780	6178780	2927498		3251282	3251282	73,00	0,43	1395912	1395912
2029	19	340	358	19332	19332	19332	18076	18076	6573009	6573009	2993024		3579985	3579985	73,00	0,40	1432468	1432468
2030	20	340	358	19719	13007	15794	12162	14768	4422440	5370105	3061364		1361076	2308741	73,00	0,37	507559	860953
2031	21	326	343	20113	13267	16110	12405	15063	4325146	5251963	3129704		1195442	2122259	73,00	0,35	415463	737569
2032	22	340	358	20516	13533	16433	12653	15364	4601106	5587058	3195230		1405876	2391828	73,00	0,32	455357	774701
2033	23	340	358	20926	13803	16761	12906	15672	4693129	5698799	3263570		1429559	2435229	73,00	0,30	431526	735097
2034	24	340	358	21345	14079	17096	13164	15985	4786991	5812775	3331910		1455081	2480865	73,00	0,28	409348	697924
2035	25	340	358	21771	14361	17438	13428	16305	4882731	5929030	3400250	8165855	9648336	10694635	73,00	0,26	2529634	2803956
																Mean Price	33858564	35719878

LTAV: Long Term Asset Value, **Y:** Year, **SA:** Ship Age, **OD:** Operation Days, **AD:** Age Discount, **DGCR:** Daily Gross Charter Rate, **ABD:** Actual Booked Days **AD:** Age Discount, **CRAAD:** Charter Rate After Age Discount, **F&C:** Fees and Commissions, **DNCR:** Daily Net Charter Revenue, **ANCR:** Annual Net Charter Revenue, **AOE:** Annual Operating Expenses, **SV:** Scrap Value, **FCF:** Free Cash Flow, **WACC:** Weighted Average Cost of Capital (Discount Rate), **PVF:** Present Value Factor, **PV:** Present Value. LTAV on DCF Formula as follows.

$$LTAV \text{ on DCF} = \sum_{t=1}^T \left(\frac{(C_t - B_t)}{(1+i)^{t-p}} + \frac{RV_T}{(1+i)^{T-p}} \right) \quad [8]$$

C_t = Charter Income, C_{1-} Current Net-TC Rate in running year, C_{2-r} Average Net-TC Rate of the past 8-10 years, B_t Average OPEX of the last 8-10 years, i = Discount Rate, t = period, t_1 : current year, t_2-r : period end, T = Remaining period until Age 20/25, RV_T = Residual Value, p = time after construction.

Table-4 Fair Value of M/V True Frontier

Process	Method	Value (\$M)
STEP-1	Marketing Value (Mean Price)	15,98
STEP-2	Marketing Value (Adjusted Mean Price)	16,086
STEP-3	Marketing Value (Predicted Price)	21,40
STEP-4	LTAV on DCF (Reduction Rate 15%)	34,04
STEP-5	LTAV on DCF (Reduction Rate 30%)	35,90
STEP-6	Age Adjustment	30,92
STEP-7	Attribute Adjustment	29,90
STEP-8	Regression Analysis (Age Adjustment include 2014-2017 Sales)	19,98
STEP-9	Regression Analysis (Age Adjustment include 2017 Sales only)	28,45
STEP-10	Multi-regression Analysis (Age and Attribute Adjustment include 2014-2017 Sales)	23,26
STEP-11	Multi-regression Analysis (Age and Attribute Adjustment include 2017 Sales only)	24,83
Fair Value		25,52

Source: Described by the authors

In line with the case study, the following values listed in Table-4 were calculated within each step and the optimum price (fair value) determined by "CQSVEM" as \$25.52M.

Table-5 Decision Making Process for Investment or Disinvestment

Actual Market Price	Vessel Owner	Potential buyer
> LTAV	Sell	Don't buy
< LTAV	Don't Sell	Buy

In the LTAV calculations, it is assumed that operating days are 358 (maximum number of available running days-charter days in a typical year), and operating days in years with drydocking 343 (maximum number of available running days in years with dry docking-class renewal). Gross Charter Rate per day for Current Year and next four-year estimations were obtained from "Baltic Capesize Indexes" and "Advanced Shipping and Trading S.A. Weekly Reports". In addition, "Actual Booked Days" were assumed to be 326 days, which is 95% of total available running days. Daily Gross Charter Rates (Current Charter Rates) are realized as \$18.500 for 2017, \$22.000 for 2018 and, \$16.000 for 2019 [9]. The following two years' estimations are \$17.500 for 2020 and \$16.500 for 2021 [10]. Other estimations of Daily Gross Charter Rates from 2021 to 2035 are consecutively calculated by the following year's daily charter rates at 2.0% interest. However, the percentage of reduction rate in the daily gross charter rate for ships with age more than 20 years was assumed to be 30% for sample-1 and 15% for sample-2 because the percentage of reduction rates can change the estimated ship prices. Ship prices can change by approximately \$ 1-2 M when reduction rates between 15% and 30% are added into the calculations. After these operations "Daily Net Charter Revenues" with 6.5% (ship management fee and freight commissions as a percent of gross daily charter rate) were calculated. The next operation is to calculate Annual Operating Expenses. According to Baltic Exchange data, the daily operating expense for Capesizes was \$6,700 in August of 2017 [11]. Annual Operating Expenses up to the year 2035 are consecutively calculated by the next year's daily operating expenses at 3.0% interest. M/V True Frontier's lightweight tonnage is approximately 21,990 ltd. Scrap prices per long ton change worldwide. These prices can be reduced depending on transportation needs. Scrap prices are \$295 (Turkey), \$260 (China), \$380 (Pakistan), \$385 (Bangladesh), and \$375

(India) [12]. The scrap value of True Frontier is calculated as \$8,165,855 for 2035 and the scrap value is discounted. Free Cash Flows from 2017 to 2035 are calculated considering Annual Net Charter Revenue, Annual Operating Expenses, and Scrap Value. FCFs provide data to calculate the present value of True Frontier. To calculate the LTAV on DCF, the Weighted Average Cost of Capital (WACC) and Present Value Factor should be determined. In this study, it is assumed that the risk-free rate is 2.2%, equity beta is 1.2 and MRP is 4.1. These data are obtained from US Treasury bond yields at 10-years for r_f in Drobetz's study for β_E [8] and in Dimson's study for Market Risk Premium [13]. Hence, the cost of equity r_E was calculated as 7.4%. The debt risk (r_D) is composed of the swap rate and credit spread. The US 10 Year Treasury Rate is 2.27% [14]. It is assumed that credit spreads are 1.5-5.0% [15], and M/V True Frontier's financed debt is 70% [16] [17], therefore r_D is calculated as 3.57%. In light of these data, the Weighted Average Cost of Capital (WACC) was calculated as 7.3%. Present Value Factors (PVFs) were used to determine the Present Value (PV) of the ship by considering Free Cash Flows (FCF). LTAV on DCF is compared with the actual market price to then decide on investment or disinvestment. However, nobody is sure whether this value is a normal or excessive price at which to purchase or sell the ship. For that reason, the actual market price should be adjusted and then compared with the LTAV on DCF. As a result of the case study, LTAV of M/V Frontier was calculated as \$34-35 M. Hence, the predicted value of the ship is \$21,4 M. When compared with each other, the investment or disinvestment decision should be taken as follows:

\$21,4 M < \$34-35 M → “Do Not Sell” for Vessel Owner, “Buy” for Willing Purchaser
According to Andreas Mietzner's study “Developing a Dynamic Vessel Valuation Method Based on Real Market Transactions”, age and attribute adjustments are necessary to reduce the anomalies of sale and purchase prices [18].

5. CONCLUSION

In this study, the "CQSVEM" model has been proposed. The model is composed of eleven operational steps as summarized in Table-4. The case study shows that both marketing value and the LTAV on DCF approaches alone do not reliably assess ship value. These approaches can be used as complementary data in decision-making processes. According to Clarkson Research Data, M/V True Frontier was purchased in 2/2017 under the name “M/V N Fos” at \$21,80M. However, M/V True Frontier was sold in 8/2017 at \$30M. At first glance, it can be explained that M/V True Frontier's last transaction (\$30M) was within Step-6 (\$30,92M) and Step-7 (\$29.90M), but a very important question is "For which party was this sale price advantageous?" It is very obvious that \$30M is moderate for the seller whereas \$21,80M is acceptable for the purchaser. Regression analysis is important to determine a reference point. This reference point will provide the buyer or seller with a reliable guide to which price ranges are reasonable for purchase or sale. CQSVEM will be helpful in determining the upper limit for the buyer and the lower limit for the seller. Hence, the calculated optimal price point (\$25,52M) will provide a significant input for brokers and other third parties' decision-making procedures.

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Determination of Dry Port Location within the Hinterland of Kocaeli Ports by Applying AHP

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Keywords: Dry port, Maritime Management, Transportation Strategy, Analytic Hierarchy Process, Container Terminal.

ABSTRACT

It is considered that a dry port connected with Kocaeli container terminals would enable quicker and effective transportation through both production and consumption centers within the hinterland of Kocaeli ports. An "Analytic Hierarchy Process (AHP)" have been conducted to determine the most appropriate location for these terminals. The possible locations have been determined related to some certain qualities in coordination with two different public institutions. The criteria that would affect the selection of dry port location were determined by taking the expert opinions from the relevant sectors. These criteria were graded by a survey method which includes the opinions of 85 experts from 11 sectors. The "Convenience for transportation within the hinterland" among these criteria, has been determined as the highest priority criterion. Kosekoy location, at a distance of 20-50 km from Kocaeli ports, has been determined as the most suitable dry port location by applying AHP.

1. INTRODUCTION

The increase of containerized traffic has led to the development of dry ports within the hinterlands of seaports all over the world [1]. Determining the most appropriate location for a dry port is a delicate process that requires careful consideration of many criteria [2]. A dry port must have a large enough land area and connection to a high capacity transportation network that will easily connect it to the ports, to the production centers and to the consumption centers. Especially the railway connection is preferable due to enabling mass transportation [3]. The size of a dry port may differ related to the needs, but the current examples in the world indicate that ideal dry port should have a uniform land area with more than 10 hectares, at a location available to expand for future needs.

Possible locations in East Marmara Region were designated in a working group meeting at "East Marmara Development Agency". Thereafter the feasibility of rail connection to these locations was discussed in another working group meeting held at First Regional Directorate of "Turkish Republic State Railways (TCDD)". At the end of the studies, five locations (see Figure-1) were determined as candidates (decision points) for dry port location.

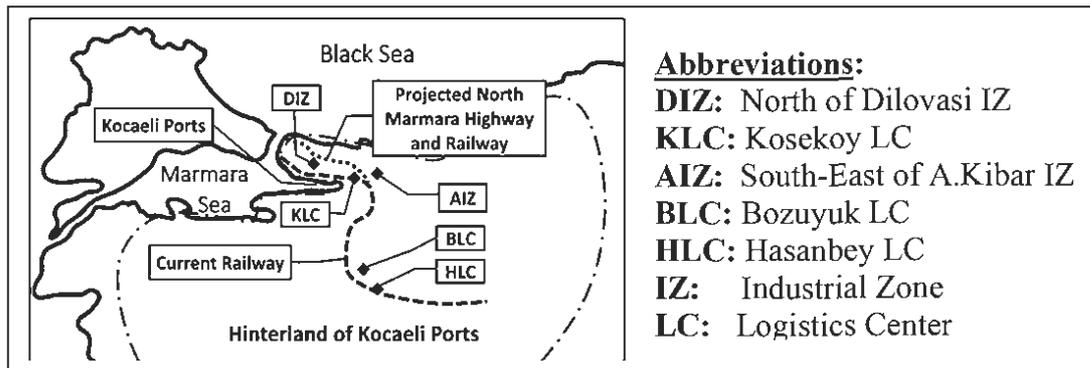


Figure-1: Hinterland of Kocaeli ports and the alternative locations for a dry port (Described by the Authors).

A simple AHP model has been developed to determine the most appropriate location among these five candidates. AHP is a methodology for relative measurement [4] through pairwise comparisons [5]. It is a mathematical tool to select the best from a number of alternatives evaluated regarding to a number of criteria [6]. Since its appearance in 1980 AHP has been used all over the world [7] widely in decision-making processes, including transportation and determination of location [8]. As an example, Ka [9] applied AHP method to find the best location among seven sites, using the criteria of transportation, economic and trade levels, infrastructure, environment and cost.

2. DETERMINING THE CRITERIA OF AHP AND GRADING THEM

After reviewing the literature and taking the opinions of the experts, it was decided that seven criteria would be taken as a basis in the AHP study. The criteria were graded by a survey method which includes the opinions of 85 experts from 11 sectors (see Table-1).

Table-1: Sectors of the Participators and Total Number of Participators (Described by the Authors).

Nu.	Related Intuitions/Sectors of the Participators	Nu. of Participators	Percentage (%)
1	Researcher/Scholar	15	17,65
2	Port	14	16,47
3	Transportation	25	29,41
4	Logistics Center/Logistics Facility	3	3,53
5	Railway Infrastructure/Rail Freight	8	9,41
6	Municipality	2	2,35
7	Industry	3	3,53
8	Investment Specialist/Investment Planning	3	3,53
9	Ministry of Environment and Urbanization	2	2,35
10	Ministry of Transport and Infrastructure	7	8,24
11	Ministry of Customs and Trade	3	3,53
Total		85	100

The result of the survey demonstrates that the weights of the criteria are conspicuously very approximate values to each other. However, the "Convenience for transportation within the hinterland" has been designated as the highest priority criterion among the seven criteria. The

weights of the criteria, which are effective in determining the most appropriate location at a later stage of the AHP, are exhibited in Table-2.

Table-2: Result of the survey for grading the criteria related to their priority (Described by the Authors).

Nu.	Abbr.	Criteria	Rating %
1	TRA	Convenience for <u>transportation</u> within the hinterland	16,62
2	POR	Proximity to the <u>port</u>	14,81
3	IND	Proximity to the <u>industry</u>	14,49
4	COS	<u>Cost</u> of investment	14,07
5	CEN	<u>Centrality</u> in the transport network	13,95
6	ENV	<u>Environmental</u> effect on urban areas	13,90
7	EST	Process of <u>establishing</u> a dry port	12,16

3. SURVEYING THE DECISION POINTS RELATED TO THE CRITERIA

Among the candidate locations, DIZ is an empty state land area very close to the projected North Marmara Highway and Railway; AIZ is also an empty but private land area, very close to both current and projected highways and railways. Other three candidates are projects of TCDD to serve as logistics centers. KLC and HLC are in service with limited capabilities, KLC waits for a modernization plan on expanded area, and BLC is still on construction.

From the point of railway transportation: KLC and HLC are located on the main railway line, whereas BLC is planned to connect to the main railway. On the other side, DIZ and AIZ do not have any connection to the main railway but the projected North Marmara railway line will pass close to these locations. The new railway line is planned to be connected to the current railway at a point around KLC. As for the point of highway transportation, KLC, AIZ, and BLC are more advantageous than other candidates since they provide very easy access to highways. HLC requires 10 km road way within the city to reach the highways. DIZ is predicted to have easy access to the new highway in the future.

From the point of proximity to Kocaeli ports (five container terminals): DIZ is the closest one with distances 16 through 43 km, followed by KLC with 17 through 48 km, AIZ at 22 through 56 km, BLC at 188 through 221 km and HLC at 233 through 266 km. Although DIZ is the closest candidate, due to the geographical constraints, rail transportation to the ports is not an economic way. In order to transfer the goods by train from DIZ, it will require to alter the route to the opposite direction at the intersection point of the two railways (see Figure-1).

There are 327 Organized Industrial Zones (OIZs) totally in Turkey [10]. A total of 121 OIZs, equivalent to 37% of Turkey's total, are located within the hinterland of Kocaeli ports. From the point of proximity to industry, ranking the candidates with the number of OIZs that are located as closest to these candidates is as follows: (1) BLC (42 OIZs; 35%), (2) KLC and AIZ together (40 OIZs; 33%), (3) HLC (31 OIZs; 25%), and (4) DIZ (8 OIZs; 7%).

All alternatives have different conditions and different capabilities as of the moment. Necessary investment stages and expense items can be sorted as (1) Cost for land acquisition, (2) Cost for the construction of infrastructure facilities, (3) Cost for procurement of operating equipment, and (4) Cost for connection of the transport system.

If either DIZ or AIZ is selected, the dry port will be built from the ground up, all cost items will be required. In terms of land acquisition, AIZ will be more costly since it is a privately

owned land. On the other side, DIZ will cost more in terms of the transport system's connection since there is no road or railway passing over there yet. KLC and HLC mainly require investment for operating equipment, but BLC requires additional investments for infrastructure and for junctions to main railways and to the OIZs at the proximity.

For an assessment in terms of centrality position, it is necessary to determine the hinterland of the Kocaeli ports. The cities and the candidate dry port locations together within the hinterland constitute the transportation network as seen in Figure-2.

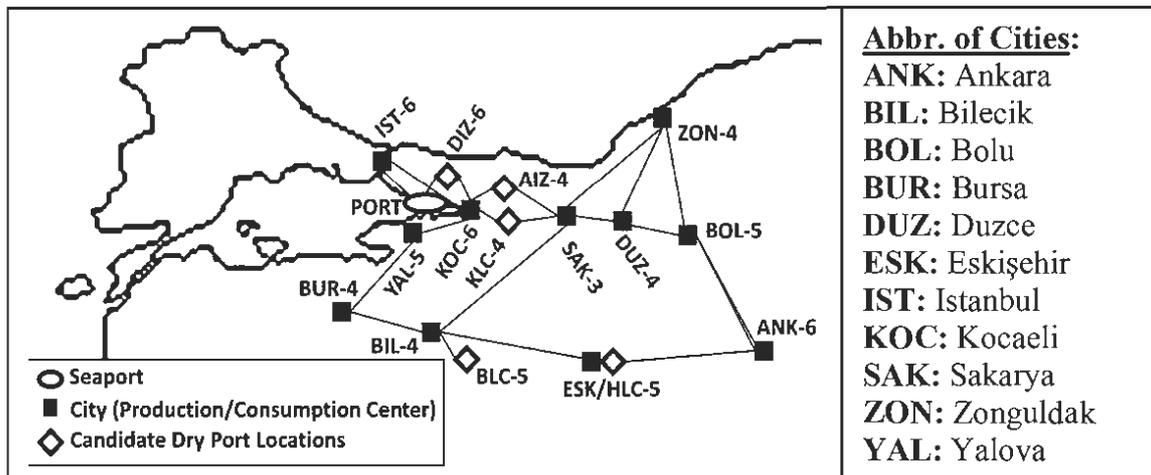


Figure-2: Nodes with Konig numbers within the core hinterland of Kocaeli ports (Described by the Authors).

It is assumed that origins and destinations in a network are vertices while the road and rail linking them are edges. The Konig numbers in Figure-2 represent the total number of edges which must be traveled along in order to reach each of the vertices from the most distant location [11]. KLC and AIZ, getting the lowest Konig number within this network, are regarded as the best sites for constructing a dry port, from the viewpoint of centrality.

From the point of environmental effect, a dry port is expected to lessen the negative effects (harmful gas emission, health problems, noise, traffic congestion, etc.) caused by road transportation in the port city and also in the vicinity. All candidates are expected to support the environmental purposes at a high level but for DIZ and BLC at the highest level since having a very limited residential area around them.

From the point of the process of establishing dry port, it will take a long time to establish a dry port on the locations of DIZ and AIZ. DIZ, of which the altitudes vary from 280 to 350 meters, would have even a longer process due to the additional efforts to flatten the land. The process of BLC would also be longer than KLC and HLC due to the continuing constructions.

4. APPLYING AHP

The objective of the AHP model in this paper is "Determination of the most appropriate dry port location within the hinterland of Kocaeli ports". The structure of the decision hierarchy is seen in Figure-3 (explanation of the abbreviations are as in Figure-1 and Table-2).

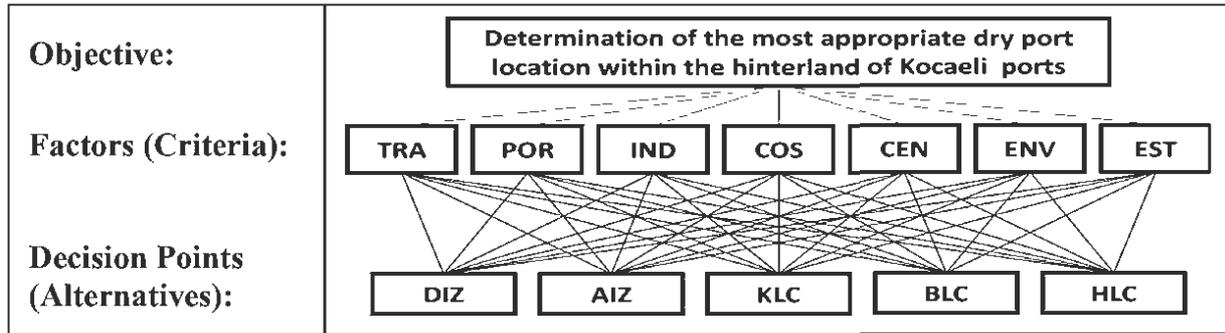


Figure-3: The structure of the decision hierarchy (Described by the Authors).

The pairwise comparison matrices are constituted for each factor (criterion) to compare the alternatives mutually. The scales of relative importance and definitions are seen in Table-3.

Table-3: Scales of relative importance to be used in the pairwise comparison (Source: [5]).

Scale	Definition of Scale	Scale	Definition of Scale
1	Equal importance	6	Strong plus importance over another
2	Weak/slight importance over another	7	Very strong importance over another
3	Moderate importance over another	8	Very strong to extreme importance over another
4	Moderate plus imp. over another		
5	Strong/essential imp. over another	9	Extreme importance over another

Pairwise comparison matrices for each criterion (CRT.) are seen in Table-4.

Table-4: Pairwise comparison matrices (Described by the Authors).

CRT.	Pairwise Comparison Matrices (Pn)						Explanation about the comparison
TRA	P1	DIZ	AIZ	KLC	BLC	HLC	Very strong importance of KLC over HLC; strong importance of KLC over DIZ and BLC; moderate importance of KLC over AIZ; strong importance of AIZ over HLC; moderate importance of AIZ over DIZ and BLC; moderate importance of DIZ and BLC over HLC.
	DIZ	1	1/3	1/5	1	3	
	AIZ	3	1	1/3	3	5	
	KLC	5	3	1	5	7	
	BLC	1	1/3	1/5	1	3	
	HLC	1/3	1/5	1/7	1/3	1	
POR	P2	DIZ	AIZ	KLC	BLC	HLC	Very strong importance of DIZ, AIZ, and KLC over HLC; strong importance of DIZ, AIZ, and KLC over BLC; moderate importance of BLC over HLC.
	DIZ	1	1	1	5	7	
	AIZ	1	1	1	5	7	
	KLC	1	1	1	5	7	
	BLC	1/5	1/5	1/5	1	3	
	HLC	1/7	1/7	1/7	1/3	1	
IND	P3	DIZ	AIZ	KLC	BLC	HLC	Very strong importance of BLC over DIZ; strong importance of BLC over HLC; strong importance of AIZ and KLC over DIZ; moderate importance of BLC over AIZ and KLC; moderate importance of AIZ and KLC over HLC.
	DIZ	1	1/5	1/5	1/7	1/3	
	AIZ	5	1	1	1/3	3	
	KLC	5	1	1	1/3	3	
	BLC	7	3	3	1	5	
	HLC	3	1/3	1/3	1/5	1	
COS	P4	DIZ	AIZ	KLC	BLC	HLC	Extreme importance of KLC over DIZ and AIZ; strong to very strong importance of HLC over DIZ and AIZ; strong importance of KLC over BLC; moderate to strong importance of BLC over DIZ and AIZ; moderate importance of KLC over HLC; equal to moderate importance of HLC over BLC.
	DIZ	1	1	1/9	1/4	1/6	
	AIZ	1	1	1/9	1/4	1/6	
	KLC	9	9	1	5	3	
	BLC	4	4	1/5	1	1/2	
	HLC	6	6	1/3	2	1	
CEN	P5	DIZ	AIZ	KLC	BLC	HLC	Strong importance of AIZ and KLC over DIZ; Moderate importance of AIZ and KLC over BLC and HLC; Moderate importance of BLC and HLC over DIZ.
	DIZ	1	1/5	1/5	1/3	1/3	
	AIZ	5	1	1	3	3	
	KLC	5	1	1	3	3	
	BLC	3	1/3	1/3	1	1	
	HLC	3	1/3	1/3	1	1	
ENV	P6	DIZ	AIZ	KLC	BLC	HLC	Strong importance of DIZ and BLC over AIZ and KLC; moderate importance of DIZ and BLC over HLC; moderate importance of HLC over AIZ and KLC.
	DIZ	1	5	5	1	3	
	AIZ	1/5	1	1	1/5	1/3	
	KLC	1/5	1	1	1/5	1/3	
	BLC	1	5	5	1	3	
	HLC	1/3	3	3	1/3	1	
EST	P7	DIZ	AIZ	KLC	BLC	HLC	Extreme imp. of KLC over DIZ; extreme to very strong imp. of KLC over AIZ; strong to very strong imp. of HLC over DIZ; strong imp. of KLC over BLC, and HLC over AIZ; moderate to strong imp. of BLC over DIZ; moderate imp. of KLC over HLC, and BLC over AIZ; equal to moderate imp. of KLC over HLC.
	DIZ	1	1/2	1/9	1/4	1/6	
	AIZ	2	1	1/8	1/3	1/5	
	KLC	9	8	1	5	3	
	BLC	4	3	1/5	1	1/2	
	HLC	6	5	1/3	2	1	

In the following step, the sum of each column of each P matrix is calculated. Each matrix element is divided by this column sum. This operation is performed for each column. The resulting matrix is the normalized matrix (N). The average of the row elements of matrix N is calculated. These averages form the final vector (F) indicating the weights of the decision points (alternatives). The weights of the decision points are combined to create the decision matrix (D) by using the F vectors. The weights of the criteria, which were obtained through the

survey (see Table-2), constitute vector (W). The resultant matrix (R) is obtained by multiplying matrix "D" with vector "W" as seen in Table-5.

Table-5: Obtaining the resultant matrix (Described by the Authors).

Matrix D (Decision Matrix)	Alt.	F1	F2	F3	F4	F5	F6	F7	
	DIZ	0,1053	0,2967	0,0436	0,0445	0,0557	0,3579	0,0400	
	AIZ	0,2454	0,2967	0,2017	0,0445	0,3424	0,0646	0,0597	
	KLC	0,4971	0,2967	0,2017	0,5271	0,3424	0,0646	0,5261	
	BLC	0,1053	0,0721	0,4641	0,1432	0,1298	0,3579	0,1371	
	HLC	0,0469	0,0377	0,0888	0,2407	0,1298	0,1549	0,2371	
X (Multiply)									
Vector W (Weight of the criteria)		w1	w2	w3	w4	w5	w6	w7	
		0,1662	0,1481	0,1449	0,1407	0,1395	0,1390	0,1216	
= (Equal to)									
Matrix R (Resultant weights of the decision points)	Alt.	r1	r2	r3	r4	r5	r6	r7	Sum
	DIZ	0,0175	0,0439	0,0063	0,0063	0,0078	0,0498	0,0049	0,1364
	AIZ	0,0408	0,0439	0,0292	0,0063	0,0478	0,0090	0,0073	0,1842
	KLC	0,0826	0,0439	0,0292	0,0742	0,0478	0,0090	0,0640	0,3507
	BLC	0,0175	0,0107	0,0673	0,0201	0,0181	0,0498	0,0167	0,2001
	HLC	0,0078	0,0056	0,0129	0,0339	0,0181	0,0215	0,0288	0,1286
	Sum	0,1662	0,1481	0,1449	0,1407	0,1395	0,1390	0,1216	1,0000

The values in the column "Sum" gives the resultant weights of the alternative dry port locations. The KLC with the highest rate (35,07%) is seen as the best alternative dry port location, followed by BLC with a rate of 20,01%. The consistency ratios for each comparison matrices were calculated less than 0.1 implying that comparisons were reasonably consistent. The results of the AHP solution and sensitivity analysis are seen on Table-6. Case-1 indicates the original weights of the criteria and the original results of solution. In Case-2, the rate of "ENV" criterion, and in Case-3 the rate of "IND" criterion are increased individually, and in Case-4, the rates of both "IND" and "ENV" criteria are increased together, and all other criteria are decreased at an equal rate in cases 2 through 4. The sensitivity analysis exhibits that minimum 30% change in only one criterion and a total of 25,5% change in two criteria would require to change the selected alternative (BLC would take over the first rank from KLC). Actually, such high changes in the weight of the criteria appear to be quite far from the actual situation.

Table-6: The results of the AHP solution and sensitivity analyses (Described by the Authors).

Cases	Weights of the Criteria in %							Ratings of the Decision Points in %				
	TRA	POR	IND	COS	CEN	ENV	EST	KLC	BLC	AIZ	DIZ	HLC
Case-1	16,62	14,81	14,49	14,07	13,95	13,90	12,16	35,07	20,01	18,42	13,64	12,86
Case-2	11,52	9,81	9,49	9,07	8,95	44,00	7,16	25,01	25,52	14,39	21,48	13,61
Case-3	11,32	9,51	46,29	8,77	8,65	8,60	6,86	29,54	29,76	19,25	10,26	11,19
Case-4	11,50	9,69	27,00	8,95	8,83	27,00	7,03	27,22	27,50	16,73	16,10	12,45

5. CONCLUSION

Considering that a dry port would support the container terminals in Kocaeli Gulf, a total of five locations were identified as the candidates of a dry port in the hinterland of Kocaeli ports.

These candidates have been assessed in relation with seven criteria to determine the best site by applying an AHP model. Determining the criteria of the model is an important stage which guides the whole process until the end. So, it is advisable to determine the factors (criteria) by gathering the opinions of the experts from relevant sectors. Weighting the factors is also a critical step, which might affect the result. Instead of one's opinion, it would lead to more factual results, getting the opinions of a large experts group to prioritize the factors.

In this study, the pairwise comparisons have been made according to the assessment of the authors themselves. But the critical point is that those assessments depend on the detailed research about the candidate locations in relation to the criteria of the AHP. At the end of this AHP, the KLC has markedly placed the top rank. KLC has got the top weights related to five criteria, whereas BLC has got that of two criteria. The sensitivity analysis, a step within the AHP, has shown that any of these two criteria should have an extremely high increase to be able to affect the result. The decision will be made based on the results and sensitivity analysis of this AHP. Sensitivity analysis is considered as a useful and important mechanism in supporting the decision-maker in order to show to which extent a change in the weight of a criterion can affect the result. This study has exhibited that AHP is a clear methodology, an effective and reliable decision making tool, applicable for any kind of problem requiring a decision. It is believed that AHP will be used in various fields for decision-making issues. And, it is assessed that the criteria of the method applied in this study can be taken as a sample for studies with similar purposes in different regions of the world.

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Information Flows in the Global Shipping Industry: A Cointegration Approach

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Abstract: In this study we examine how global maritime stock prices impact the stock prices of large transportation companies in the U.S. and other large markets. Maritime stocks are chosen because they are central in global trade and may be good indicator of future global stock market and economic trends. Maritime companies are often owned by families or governments, and are traded in stock markets with lower standards of accountability. We use cointegration and vector error-correction analysis to analyze the short-term and long-term relationship among our chosen stocks. We find evidence of a gradual diffusion of information from maritime stock prices to large U.S.-based transportation companies.

1. INTRODUCTION

Few industries are more central to international trade than the maritime sector, with 80% of world trade by volume and 70% by value being carried by ships. The maritime industry is also unique in that in spite of its large size, leadership in this sector often comes from smaller countries such as Greece, Singapore, Norway, and South Korea with shipping the U.S. and U.K. playing a surprisingly modest role. In addition, ownership of even the largest companies tends to be concentrated in the hands of a single family. But in spite of the central importance of the maritime industry and its unique global ownership structure, very little research has been done on maritime stocks.

Giannakopoulou, et al. (2016) point out that in spite of the large size of the maritime sector, family ownership is common in many countries that have large shipping industries. For example, Denmark's AP Moller-Maersk in spite of being the world's largest shipping company has over 50% of its voting shares controlled by a holding company owned solely by the founding family. The Mediterranean Shipping Company and CMA CGM Group are the second and third largest shipping companies in the world respectively, but both are majority owned and operated by the founding families. None of the top twenty shipping companies are traded on U.S. stock exchanges, perhaps because foreign stock exchanges can be more conducive to family controlled companies.

Even those shipping companies listed on American stock exchanges are often controlled by the founding family. Syriopoulos and Tsatsaronis (2011) find that Greek shipping firms listed in U.S. stock markets follow a model of corporate governance similar to maritime companies listed on non-U.S. stock exchanges. 80% of these Greek shipping firms were found to have a CEO from the founding family, and on average the board of directors controlled 28% of the shares.

The fact that many of the leading maritime shipping companies are family-owned and headquartered in dispersed countries has several implications for how their stock prices may behave. First of all, family-ownership and control may lead to information being closely held and not widely released to the public. This may slow information available to stock traders and slow information flows. Secondly, the maritime shipping companies compete for the same customers around the world in a global market so their fates are tightly intertwined. However, their shares are traded on different exchanges around the world (many of which don't have higher standards for transparency) so stock price adjustments may be slow.

In this study, we will be looking at the long-term relationship between global shipping company stock prices and the stock prices of some large truck and rail transport companies. We expect maritime stock prices to reflect information relevant for other transportation companies involved in the same supply chain. But due to corporate governance and transparency issues in the maritime industry, we expect that stock price adjustments in other portions of the transportation sector may be slow. We will use unit root and cointegration to test for short-term and long-term relationships between maritime, trucking, and rail stocks.

2. LITERATURE REVIEW

Prior research on maritime shipping stocks has been limited, and has focused on general risk and return attributes of shipping stocks. Merikas, et al. (2009) and Merikas et al. (2010) look at shipping stock IPOs and find evidence of significant opening day underpricing and longer-term underperformance. Kavussanos, et al. (2003) and Drobetz, et al. (2010) find that shipping stocks are overall low risk with low betas. Drobetz, et al. (2010) finds that shipping sector betas are driven heavily by industry-specific factors such as freight rate volatility and financing risk. Evidence of the unique nature of shipping stocks was found by Greck, et al. (2009) who found that adding shipping stocks has diversification benefits and can lead a higher Sharpe ratio.

Interest in the maritime industry's impact on the stock market has focused heavily on the Baltic Dry Index (BDI), which is a measure of freight rates in the global dry bulk shipping sector. Erdogan, et al. (2013) find bidirectional causality between the BDI and the Dow Jones Industrial Average. Bakshi (2011) find that the BDI not only predicts global stock prices but also commodity prices and economic activity. They find informational spillovers to be time-varying and dependent on market conditions. Alizadeh and Muradoglu (2014) find that the BDI can be used to predict U.S. stock prices, which they attribute to gradual information diffusion. Other evidence of gradual diffusion comes from Xiao (2012) who finds that the BDI has a fast impact on Chinese shipping stocks but a slower impact on port and shipbuilding stocks.

Just as the BDI can be a vital indicator of the global economy or global stock markets, it may be the case that maritime stocks transmit vital information useful for stock market investors around the world. Just as Alizadeh and Muradoglu (2014) and Xiao (2012) find a gradual diffusion of information from the BDI, other studies have demonstrated the gradual diffusion of information from stock market returns. Rapach, et al.(2013) find evidence of gradual information diffusion by demonstrating that U.S. stock market returns can predict future returns in other stock markets around the world. They attribute their result in part to the possibility of stock market traders focusing on the U.S. exchanges before giving attention to other global markets. Similarly, Lin (2015) finds that stock returns in many Asian markets can be predicted by Singapore stock market returns.

While it is logical that maritime stock prices information of importance to global stock markets, this information may diffuse quite slowly. Chan and Hameed (2006) argue that family ownership or poor corporate governance may also slow down information flows from stocks. Lagoarde-Segot and Lucey (2008) find that poor corporate governance is associated with market inefficiency in emerging markets, which should also lead to slower information flows. Thus we should expect lagged rather than current period maritime stock prices to exert their influence on other stock prices around the world.

3. DATA

Monthly stock price data was collected on the ten largest publicly traded marine transportation companies in the world based on the twenty-foot equivalent unit (TEU) capacity of their fleet. All but two of these companies are from Asia, with AP Moeller-Maersk headquartered in Denmark and Hapag-Lloyd headquartered in Germany. None are listed on U.S. stock exchanges. Data was collected up to January, 2018 with no company going back further than 20 years

To test the information flows from these maritime companies, collected monthly stock price data from the largest publicly traded trucking and rail companies. These include Union Pacific (UNP), which is a U.S. based rail company and JB Hunt (JBHT), which is based on the U.S. While many of the other large rail and trucking companies are privately held, we also found data on the second largest rail and trucking companies. We collected data on Canadian National Railway (CNI) and DSV A/S (DSV), the latter of which is largest Danish trucking and logistics company. Finally, we include monthly data on the BDI.

Table 1: Companies or Indices Used in This Study

Company or Index	Country	Sector	Abbreviation
A.P. Moller–Maersk Group	Denmark	Maritime Freight	MAERSK
Evergreen Marine Corporation	Taiwan	Maritime Freight	EVERGREEN
Hapag-Lloyd AG	Germany	Maritime Freight	HLAG
Mitsui O.S.K. Lines	Japan	Maritime Freight	MITSUI
Nippon Yusen Kabushiki Kaisha	Japan	Maritime Freight	NYKA
Yang Ming Marine Transport Corporation	Taiwan	Maritime Freight	YANGMING
China Ocean Shipping Company	China	Maritime Freight	COSCO
Wan Hai Lines Ltd.	Taiwan	Maritime Freight	WANHAI
Hyundai Merchant Marine	South Korea	Maritime Freight	HYUNDAI
Kawasaki Kisen Kaisha, Ltd.	Japan	Maritime Freight	K-LINE
Union Pacific Railroad	U.S.	Rail Freight	UNP
Canadian National Railway	Canada	Rail Freight	CNI
J.B. Hunt Transport Services, Inc	U.S.	Trucking	JBHT
DSV A/S	Denmark	Trucking	DSV
Baltic Dry Index	U.K.	Freight Rate Index	BDI

4. METHODOLOGY

As a first step in our analysis of the long-term and short-term relationships between our chosen stocks, we check for stationarity in all of our series. The test we use is the Phillips and Perron (1988) test. This is a widely used test for stationarity and it controls for serial correlation through non-parametric methods. To test for cointegration, we use the Johansen (1995) test. This test is widely used, including in related studies to this one such as Ergodan, et al. (2013), Alizadeh, A. H., & Nomikos, N. K. (2007) Jamaani, F., & Roca, E. (2015). and Bildirici, et al. (2015)

We chose to include a linear trend in the cointegrating equation (levels) since all of the rail and trucking stocks in our sample had a clear upward linear trend and most of the maritime stocks had a linear trend as well. The general form of the vector error correction model in this case is (Harris,1995;StataCorp,2017):

$$\Delta Y_t = \alpha(\beta Y_t + \mu + \rho t) + \sum_{i=1}^{p-1} \Gamma_i \Delta Y_{t-1} + \gamma + \tau t + \epsilon_t$$

The key parameters in this case are α , which denotes the error-correction process as to how each of the stocks adjusts back to the long-term equilibrium. Γ refers to the short-term reactions of each stock price to changes in the other stock prices. We will use these parameters to assess the long-term and short-term inter-relationships between maritime stocks, trucking stocks, rail stocks, and the BDI. Lag lengths are chosen through the Schwartz-Bayesian Information Criteria (SBIC).

Our cointegration equations will be carried out as follows. For each maritime stock, we will examine its cointegrating relationship with UNP, JBHT, and BDI. Including UNP and JBHT in the equations will allow us to test information flow from the maritime sector (all traded on exchanges outside the U.S.) to two large non-maritime transportation stocks traded on U.S. exchanges. Since UNP and BDI are the U.S.-based companies, we will run a second set of cointegration tests with each maritime stock and CNI, DSV, and BDI. Since CNI and DSV and not U.S.-based firm, this will serve as a robustness test.

5. RESULTS

Results from the Phillips-Perron unit root test can be shown in Table 2 below. For all stock prices levels (in logs) the test statistic is not significant at the 5% level. Hence we cannot reject the null hypothesis of a unit root and non-stationarity. However, for first-differences the null hypothesis of a unit root was rejected at the 1% level in every case. Thus we can conclude that all of our series are integrated of order 1 and we can proceed to our cointegration tests.

Table 2: Unit Root Tests

Variables	Levels	First-Differences
MAERSK	-2.18	-14.438**
EVERGREEN	-2.731	-16.721**
HLAG	-0.642	-4.844**
MITSUI	-1.922	-13.468**
NYKA	-2.203	-8.524**
YANGMING	-1.722	-13.595**
COSCO	-2.201	-11.948**
WANHAI	-2.233	-16.75**
HYUNDAI	-0.186	-15.323**
K-LINE	-1.669	-13.199**
DSV	-2.787	-33.343**
CNI	-0.842	-16.192**
UNP	0.222	-17.337**
JBHT	0.086	-14.986**
BDI	-2.501	-12.517**

*Significant at the 5% level, ** Significant at the 1% level

Table 3 presents the cointegration results for each maritime stock when tested for cointegrating relationships with UNP, JBHT, and BDI. In all ten cases, the Johansen results for each maritime stock revealed the presence of one cointegrating vector. However, in the case of Yang Ming there was no significant coefficient for the error correction term for any of the four series. The only significant coefficient was positive, which indicates a lack of a conversion to the long-term equilibrium and in fact implies a divergence away from. So the result for YANGMING is disregarded.

The main pattern shown in Table 3 is that for most case UNP is the stock that responds to diverges from the long-term equilibrium and thus it is the variable that lags rather than leads in the long-term in most of these cases. In only three cases (EVERGREEN, NYKA, HYUNDAI) does the maritime stock move in response to divergence from the long-term equilibrium. In three cases JBHT has the significant error-correction term. Overall, this is evidence that information is flowing gradually to the large American rail and trucking companies.

Table 3: Cointegration Results with Maritime Stocks, UNP, JBHT, and BDI

Maritime Stock	Cointegrating Vectors	Negative and Significant Error-Correction Terms
MAERSK	1	UNP*, JBHT**
EVERGREEN	1	EVERGREEN**
HLAG	1	UNP**
MITSUI	1	UNP**, JBHT
NYKA	1	NYKA**, UNP**
YANGMING	1	None
COSCO	1	UNP**
WANHAI	1	UNP*
HYUNDAI	1	HYUNDAI*
K-LINE	1	UNP*, JBHT*

**Significant at the 1% level, Significant at the 5% level

Table 4 presents a comparison between the stocks that react to changes in the long-term equilibrium and the short-term lead-lag relationships found for the maritime stocks. This was done by looking at the significance of the coefficients on one-month lags for each of the four series. While quite a few significant relationships were found between non-maritime stocks, Table 4 only reports the lead/lag relationships that involve maritime stocks. Overall we find evidence of bi-directionality, but a trend for maritime stocks leading with five such relationships found as opposed to three relationships with maritime stocks lagging. Interestingly enough, BDI does not lead any maritime stock which is surprising considering that the BDI is a direct measurement of sea freight costs. Perhaps since BDI is a real-time measure of freight rates rather than a stock its information is included in maritime stocks quickly so a lagged relationship is not found.

Table 4: Long-Term Short-Term Result Comparison (UNP, JBHT, and BDI regressions)

Maritime Stock	Long-Term Lag Stocks	Maritime Short-Term Lead-Lag Relationships
MAERSK	UNP*, JBHT**	UNP leads Maersk*
EVERGREEN	EVERGREEN**	EVERGREEN leads JBHT**, JBHT leads EVERGREEN
HLAG	UNP**	None
MITSUI	UNP**, JBHT	MITSUI leads UNP**, MITSUI leads JBHT**
NYKA	NYKA**, UNP**	JBHT leads NYKA*
COSCO	UNP**	COSCO leads UNP**, COSCO leads BDI*
WANHAI	UNP*	None
HYUNDAI	HYUNDAI*	None
K-LINE	UNP*, JBHT*	None

**Significant at the 1% level, Significant at the 5% level

Table 5 presents the results of the Johansen tests when CNI and DSV are substituted for UNP and JBHT. Overall the cointegration results are not as strong with CNI and DSV. For two of the cases no cointegrating vector was found. In another two cases, no negative and significant error-correction term was found indicating no convergence to equilibrium. In the remaining five cases, maritime stocks were found to have a significant convergence to the long-term equilibrium with a significant impact of the error-correction term. In four of these cases, DSV was also found to have a negative and significant coefficient for the error-correction term. In all four of these cases the maritime companies are Asian, and four of them are Taiwanese. It may be the case that diffusion of information between a European company like DSV and companies in smaller Asian countries like Taiwan and South Korea is slower than information flows between DSV and European stocks such as MAERSK and HLAG.

Table 5: Cointegration Results with Maritime Stocks, CNI, DSV, and BDI

Maritime Stock	Cointegrating Vectors	Negative and Significant Error-Correction Terms
MAERSKA	1	None
EVERGREEN	1	EVERGREEN**, DSV**
HLAG	1	HLAG**
MITSUI	1	None
NYKA	0	N/A
YANGMING	1	YANGMING**, DSV**
COSCO	0	N/A
WANHAI	1	WANHAI**, DSV**
HYUNDAI	1	HYUNDAI**, DSV**
K-LINE	1	None

**Significant at the 1% level, Significant at the 5% level

Table 6 presents the comparison between long-term and short-term lead lag relationship. While several lead-lag relationships were found between non-maritime stocks, only two were found with maritime stocks. In both cases, DSV leads the maritime stocks. Again, BDI is not found to have any lead relationship with the maritime stocks which again suggests that information from the BDI is quickly factored into pricing of maritime stocks.

Table 6: Long-Term Short-Term Result Comparison (CNI, JBHT, and BDI regressions)

Maritime Stock	Long-Term Lag Stocks	Maritime Short-Term Lead-Lag Relationships
EVERGREEN	EVERGREEN**, DSV**	DSV leads EVERGREEN**
HLAG	HLAG**	None
YANGMING	YANGMING**, DSV**	None
WANHAI	WANHAI**, DSV**	DSV leads WANHAI*
HYUNDAI	HYUNDAI**, DSV**	None

**Significant at the 1% level, Significant at the 5% level

6. CONCLUSION

In this paper we find relatively strong evidence of slow but significant information flows from non-U.S. maritime stocks to large U.S. stocks like UNP and JBHT. This is shown both by long-term cointegrating relationships and short-term first-difference results. Just as Rapach, et al.(2013) found evidence of gradual diffusion of information from U.S. to other stock markets in the world, we find evidence of gradual diffusion of information from maritime companies to large U.S.-traded companies. This result is different than those by Rapach, et al. (2013) and Lin (2015) in that they find evidence of gradual information flow from more developed markets to smaller or lesser developed markets. This study on the other hand examines information flows from smaller and lesser developed stock markets to larger and better developed markets. While this study has examined individual stocks rather than market indices, the stocks we have chosen represent the largest players in the global freight transportation industry.

It is also noteworthy that gradual information diffusion is not nearly as present when examining the impact on two non-U.S. stocks. It may be that information flow are much quicker between transportation stocks for companies located outside the U.S. The main exception we find is for DS) and five maritime stocks from small Asian countries. This suggests information may be slow between geographically distant or linguistically different stocks. Two of these stocks (HYUNDAI and EVERGREEN) have heavy family ownership which might also lead to slow information diffusion.

Our results are also somewhat contradictory of prior studies on BDI and stock markets. Unlike Erdogan, et al. (2013) and Bakshi (2011), we don't find evidence that the BDI leads stock prices including maritime stock prices. More specifically, this also contradicts Xiao (2012) who finds that the BDI leads maritime and other transportation-related stocks. While Alizadeh and

Muradoglu (2014) suggest that information from the BDI is diffused gradually, it may also be the case that its information is diffused quickly. Since it is an objectively calculated freight rate, information from it should be easy to process. Also, freight rates are already a part of transportation company operations and profits so BDI information may already be factored into maritime stock prices.

An implication of this study is that maritime stock prices may be a useful predictor of stock prices around the world and global trade trends, similar to how the BDI has been used. The maritime stocks used in this study account for a large portion of world trade, but are generally from lesser developed stock markets and often have less than transparent corporate governance. This factors may slow the important information from these stocks.

A limitation of this study is that many of the world's largest freight transportation companies are privately held. This excludes important information on how valuation of the global shipping sector impacts other markets. We also only used the largest companies in this study. It may be the case that smaller maritime stocks have even slower diffusion of information. In addition to examining smaller stocks, another area for future research is to examine indices of different transportation sectors and perhaps sub-indices of transportation stocks within single countries.

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Toward Sustainable National Shipping: A Comparative Analysis

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ABSTRACT

This study aims to analyse the relationship between national shipping and various factors and its relevance to the blue economy. The analysis using data of 84 countries has found the strong effect of shipping building, international trade and registration on the size of national fleets. In addition, all else being the same, top oil exporting countries and open registry countries have stronger fleet than the other countries. While tourism and fisheries are known to be important contributors to the blue economy, they do not have a significant effect on national shipping. This could be due to the fact that relationships between these sectors have yet been significant. The comparison of sustainable (weighted) ranking and weighted rankings show very significant differences between these. The former is more in favour of countries with a significant maritime industry.

1. BACKGROUND

Traditionally, it has been widely perceived that national shipping was important to economic development because 90% of international trade is carried by ships. While the dependence of international trade on the maritime industry remains, the role of national shipping has shifted for at least four main reasons. First, the shipping is highly international, and the freight market is competitive. This suggests that shippers can access competitive freight rates without relying on their national fleet. Second, bilateral and multilateral trade agreements restrict the government from export protectionism and subsidy. Third, the past two decades have seen a trend in the formation of multinational companies as a result of globalisation, foreign investment and outsourcing. Fourth, the trend in globalisation has also seen the rapid development of the private sector in many export-led, transitional economies, which used to be dominated by state-owned companies.

Yet, new factors have emerged influencing the role of national shipping. Climate change impacts and natural disasters have caused concerns about governments' capability to respond to maritime emergency and the capacity of the national fleet to facilitate the emergency process e.g. evacuation, aids. The development of the blue economy relies more on the

relationship between and within the maritime and marine sectors. This includes, for example, the development of coastal and cruise shipping, shipping policy and shipbuilding, and maritime infrastructure (Smith-Godfrey, 2016), that are better encompassed in a national shipping agenda. National shipping remains important to maritime nations due to its role in maritime, coastal trade, shipbuilding, ports, offshore and fisheries.

Despite of much research on national shipping, there is limited research on national shipping especially from the perspective of the broader maritime sector and blue economy, which is well regarded as one that comprises of “economic and trade activities, and emerges from a need to integrate conservation and sustainability in the management of the maritime domain. It can also be extended to include the marine ecology or environment” (Smith-Godfrey, 2016). In (Spalding, 2016), the term ‘ocean economy’ was used instead to refer to an economy highly similar to blue economy. Moreover, a traditional and new ocean economy concepts are defined; with a traditional ocean economy including the offshore oil and gas, recreation and commercial fishing, aquaculture, shipping, coastal tourism, and telecommunication sectors; a new ocean economy adds renewable energy, seabed mining, ocean restoration and blue biotechnology, blue carbon, blue technology, and other related sectors such as nutrition, nutraceuticals, cosmetics and the innovative marine molecules sector.

To, and Lee (2018) studied the growth of the Chinese maritime economy using the logit model and found that its growth has been dominated by the contribution of the transport industry. Salvador, Simões, and Soares (2016) studied the Portuguese maritime economy using the input-output analysis and Delphi research methods. Their study focused cross and intra maritime sectoral relationships. It has been found that the three sectors shipping, ports, and recreational boating and marinas, are the main contributors to the maritime economy.

Fernández-Macho et al. (2015) conducted a socio-economic assessment of the Spanish maritime cluster’s contribution to the maritime economy. The study proposed a four-digit classification system for economic accounting of maritime activities, which are divided into four groups for ‘fully maritime activities’, ‘mainly maritime activities’, ‘Strong partially maritime activities’, and ‘Weak partially maritime activities’ respectively. The goal of the maritime cluster is “to strengthen integration between maritime activities, from capture fisheries and aquaculture, to boat and shipbuilding and repair, maritime transport, recreational boating, marine renewable energy systems, ports and port services, among others.”.

The focus of this study is to analyse the relationship between national shipping and various factors and its relevance to the blue economy. The analysis is an extension of the studies by Nguyen (2011) and Nguyen, and Bandara (2015) on national shipping competitiveness. For completeness, the study covers two measures of national shipping, namely the own fleet and the beneficial fleet. The latter is defined as the fleet owned and operated by companies located in the country (UNCTAD, 2014). The data set used by the study covers the effect of various factors such as international trade, shipbuilding, shipping history, policy, registration, access to ocean, oil exports, financial system, and the technology development of 84 maritime countries.

The rest of the paper is organised as follows. Section 2 explains the analytical method and data set. Section 3 presents the analysis results. Section 4 discusses the results and

implications for the blue economy. Section 5 summarise the study and discusses the limitations and implications for future research.

2. METHODOLOGY

This study seeks to analyse the development of national shipping using econometric methods presented in Nguyen (2011), and Nguyen, and Bandara (2015). The analysis essentially shows statistical relationship between national fleet as the dependent variable, and a number of influential factors such as international trade, shipbuilding, shipping history, policy etc. as the independent variables. In particular Nguyen (2011) proposed the following equations to explain the effect of various factors the national fleet and the beneficial fleet:

$$\begin{aligned} \text{NATFLEET}_i = & \beta_0 + \beta_{01} \text{DUMOX} + \beta_{02} \text{DUMTOPOX} + \beta_{03} \text{DUMTOPOI} \\ & + \beta_{04} \text{DUMREG} + \beta_1 \text{FINDEV}_i + \beta_2 \text{BUILDING}_i + \beta_3 \text{HISTORY}_i \\ & + \beta_4 \text{TRADE}_i + \beta_5 \text{OX}_i + \beta_6 \text{COAST}_i + \beta_7 \text{POLICY}_i + \beta_8 \text{REG}_i \\ & + \beta_9 \text{GDPCAP}_i + u_{1i}. \end{aligned} \quad (1)$$

$$\begin{aligned} \text{BENLEET}_i = & \gamma_0 + \gamma_{01} \text{DUMOX} + \gamma_{02} \text{DUMTOPOX} + \gamma_{03} \text{DUMTOPOI} \\ & + \gamma_{04} \text{DUMREG} + \gamma_1 \text{FINDEV}_i + \gamma_2 \text{BUILDING}_i + \gamma_3 \text{HISTORY}_i \\ & + \gamma_4 \text{TRADE}_i + \gamma_5 \text{OX}_i + \gamma_6 \text{COAST}_i + \gamma_7 \text{POLICY}_i + \gamma_8 \text{REG}_i \\ & + \gamma_9 \text{GDPCAP}_i + u_{2i}. \end{aligned} \quad (2)$$

In (1) and (2), the dependent variables NATFLEET and BENFLEET are the deadweight tonnage (all in natural log) of the national fleet and the beneficial fleet as defined by UNCTAD (2014). u_1 and u_2 are the error terms assumed to be a normal variable that is identically and independently distributed, $i.i.N(0, \sigma)$. The subscript i refers to the country under study. The above equation allows for the effect of the following factors on the national fleet:

- DUMOX is the dummy variable representing the effect of oil exports (Spalding, 2016).
- DUMTOPOX is a dummy variable for top ten oil exporting countries.
- DUMREG is the dummy variable to capture the effect of open registration countries.
- FINDEV is the development level of the financial system.
- BUILDING is the output of the shipbuilding sector.
- HISTORY is the shipping history (Nguyen, 2011, Harlaftis, & Kostelenos, 2012).
- TRADE is international trade that represents the country's demand for shipping.
- OX refers to the effect of oil exports on national fleet.
- COAST is the coastline length that represents the country's access to the ocean.
- POLICY refers to the number of national maritime regulations adopted by the country.
- REG refers to the registered tonnage.
- GDPCAP refers to per-capita income representing the overall development level.
- β s and γ are coefficients to be estimated.

Nguyen's (2011) proposed Shipping Competitiveness Index (SCI) rankings are calculated as:

$$SCI_i = \text{rank}(\sum \hat{\beta}_j X_{ij}), \quad (3)$$

where $\hat{\beta}_j$ s are obtained from the estimation of equation (1). Note that this calculation method cannot be used to estimate national shipping competitiveness ranking when there are multiple indicators of national shipping, i.e. national fleet and beneficial fleet; $\hat{\beta}_j$ s only explain the effect of various factors on the national fleet NATFLEET but not the beneficial fleet BENFLEET. Therefore Nguyen, and Bandara (2015) proposed the ‘combined rankings’:

$$SCI_i = rank \left(\sum \hat{\beta}_j X_{ij} + \sum \hat{\gamma}_j X_{ij} \right), \quad (4)$$

where $\hat{\beta}_j$ and $\hat{\gamma}_j$ are the estimates of the coefficients from equations (1) and (2) above. While the above calculation considers both the national fleet and beneficial fleets, it requires separate analysis of equations (1) and (2). Therefore they also proposed the ‘weight rankings’ that are calculated as:

$$SCI_i = rank \sum \hat{\theta}_j X_j, \quad (5)$$

where the coefficients $\hat{\theta}$ are the estimates of θ (s) from the following equation:

$$\begin{aligned} NATFLEET = & \alpha BENLEET_i + \theta_0 + \theta_{01} DUMOX + \theta_{02} DUMTOPOX + \theta_{03} DUMTOPOI \\ & + \theta_{04} DUMREG + \theta_{01} FINDEV_i + \theta_2 BUILDING_i + \theta_3 HISTORY_i + \theta_4 TRADE_i \\ & + \theta_5 OX_i + \theta_6 COAST_i + \theta_7 POLICY_i + \theta_8 REG_i + \theta_9 GDPCAP_i + \theta_{10} TOUR_i \\ & + \theta_{11} FISH_i + u_{6i}. \end{aligned} \quad (6)$$

This study uses weighted rankings due to their advantage over combined rankings. The main difference between this study and the previous studies on national shipping by Nguyen (2011), and Nguyen, and Bandara (2015) is the addition of TOUR and FISH as the two new, additional variables that were not included in previous studies. The aim of this extension is to explore the potential relationship between the blue economy on national shipping. Because fisheries and tourism, especially cruise shipping, are one of the key contributors to the blue economy, they are expected to have potential effect on sustainable development of national shipping within the blue economy framework. Note that although ocean renewable energy is predicted to be one of the main sources of future energy and blue economy, this sector is in an early stage of development with very limited data availability. As such it will not be included in the analysis. The data set covers 84 maritime nations. Variable description and data sources are detailed in Table 1. Except the TOUR and FISH variables, all other variables have the same definitions as explained in Nguyen, and Bandara (2015). Note in order to compare the results, this study uses most recent data for the new variables and data for the remaining variables are similar to those in Nguyen, and Bandara (2015).

Table 1: Variable names and data sources

Variable	Description	Data source
NATFLEET	National fleet's tonnage	Lloyd's Register Fairplay (2013a)
BENFLEET	Beneficial fleet's tonnage	UNCTAD (2014)
FINDEV	Financial system development level	World Bank (2014)
BUILDING	Shipbuilding capacity	Lloyd's Register Fairplay (2013b)
HISTORY	Shipping history	UNCTAD (1977)
OX	Oil exports	EIA (2014)
TRADE	External trade	World Trade Organisation (2013)
COAST	Coastline length	Pruett, and Cimino (2000)
POLICY	Shipping policy	IMO (2014)
REG	Registered fleet's tonnage	Lloyd's Register Fairplay (2013a)
GDPCAP	Technological advancement	IMF (2014)
TOUR	Output of the tourism sector	UNWTO (2015)
FISH	Output of the fisheries and aquaculture sectors	FAO (2017)

3. ANALYSIS RESULTS

Tables 2 provide descriptive statistics and the correlation matrix for all variables with 84 observations. All variables have exhibited relatively small variations. FINDEV has the largest coefficient of variation of 1.47 followed by OX with the coefficient of variation of 1.39. It is interesting to note TRADE has the lowest coefficient of variation followed by POLICY with the coefficient of variation of 0.11 and GDPCAP with the coefficient of 0.17.

Table 2: Descriptive statistics of the variables

	N	Minimum	Maximum	Mean	Standard Deviation	Coefficient of Variation
NATFLEET	84	6.91	19.2	14.11	2.63	0.186393
BENFLEET	84	2.01	12.46	7.64	2.44	0.319372
FINDEV	84	0	134.02	20.98	30.91	1.473308
BUILDING	84	0	18.02	9.33	6.66	0.713826
HISTORY	84	5.96	18	13.31	2.59	0.194591
TRADE	84	20.87	28.92	25.37	1.78	0.070162
OX	84	0	12.74	3.50	4.85	1.385714
COASTLINE	84	3.28	12.49	8.31	1.75	0.21059
POLICY	84	2.2	3.99	3.42	0.38	0.111111
REG	84	6.91	19.58	13.60	2.78	0.204412
GDPCAP	84	0	11.52	9.16	1.62	0.176856
TOUR	84	9.012	18.252	15.324	1.66	0.11
FISH	84	6.987	18.197	12.342	2.38	0.19

Table 3 presents the variables' correlation matrix. The correlation between BENFLEET and NATFLEET of 0.87 indicates their strong relationship. TOUR has positive correlation with all variables except GDPCAP and FISH. There is also strong correlation between many of the

explanatory variables suggesting analysis of their subsets is useful to gain more comprehensive understanding of their relationships.

Table 3: Correlation matrix

	BENFLEET	NATFLIT	BUILDING	REG	POLICY	COAST	GDPCAP	TRADE	HISTORY	OX	FINDEV	TOUR	FISH
BENFLEET	1.000	0.874	0.971	0.972	0.771	0.747	0.047	0.545	0.362	0.409	0.795	0.729	-0.235
NATFLIT	0.874	1.000	0.857	0.848	0.662	0.878	-0.292	0.413	0.432	0.336	0.690	0.716	-0.220
BUILDING	0.971	0.857	1.000	0.958	0.753	0.722	0.049	0.544	0.379	0.396	0.792	0.724	-0.110
REG	0.972	0.848	0.958	1.000	0.736	0.707	0.043	0.540	0.352	0.397	0.793	0.714	-0.219
POLICY	0.771	0.662	0.753	0.736	1.000	0.672	0.092	0.495	0.326	0.325	0.596	0.621	-0.161
COAST	0.747	0.878	0.722	0.707	0.672	1.000	-0.352	0.426	0.309	0.361	0.554	0.630	-0.192
GDPCAP	0.047	-0.292	0.049	0.043	0.092	-0.352	1.000	0.041	-0.056	0.075	-0.020	-0.167	-0.011
TRADE	0.545	0.413	0.544	0.540	0.495	0.426	0.041	1.000	0.130	0.440	0.483	0.626	-0.059
HISTORY	0.362	0.432	0.379	0.352	0.326	0.309	-0.056	0.130	1.000	0.178	0.425	0.437	-0.078
OX	0.409	0.336	0.396	0.397	0.325	0.361	0.075	0.440	0.178	1.000	0.415	0.393	-0.083
FINDEV	0.795	0.690	0.792	0.793	0.596	0.554	-0.020	0.483	0.425	0.415	1.000	0.691	-0.158
TOUR	0.729	0.716	0.724	0.714	0.621	0.630	-0.167	0.626	0.437	0.393	0.691	1.000	-0.098
FISH	-0.235	-0.220	-0.110	-0.219	-0.161	-0.192	-0.011	-0.059	-0.078	-0.083	-0.158	-0.098	1.000

Given that the study uses cross sectional data that are prone to heteroskedasticity, Breusch-Pagan (BP) test was conducted. The P-value of the test is 0.00003935 indicating the existence of heteroskedasticity. Thus, regression analysis using the heteroskedasticity consistent variance covariance matrix is applied. Table 4 shows the results of the regression analysis. Adjusted R-squared is 0.8444 indicating the strong fit. The key factors explaining the size of national fleets are the shipping building, international trade, registered tonnage. In addition, all else being the same, top oil exporting countries and open registry countries have stronger fleet than the other countries.

Table 4: Regression Results for the National Fleet

Variable	Coefficient	St error	t statistic	P-value	Sign level
Constant	-1.866096	2.503865	-0.745	0.45867	
DUMOX	-2.075187	1.163638	-1.783	0.07899	*
DUMTOPOX	0.541434	0.303089	1.786	0.07849	*
DUMTOPOI	0.187199	0.300902	0.622	0.53594	
DUMREG	-4.44906	2.566194	-1.734	0.0875	*
FINDEV	-0.00182	0.003398	-0.536	0.59384	
BUILDING	0.128066	0.038284	3.345	0.00134	***
HISTORY	-0.013581	0.070796	-0.192	0.84844	
TRADE	0.27632	0.145162	1.904	0.0612	*
OX	0.15785	0.108775	1.451	0.15133	
COAST	-0.01831	0.094568	-0.194	0.84705	
POLICY	0.564323	0.340735	1.656	0.10229	
REG	0.451021	0.086597	5.208	0.00000	***
GDPCAP	0.012779	0.11521	0.111	0.912	
TOUR	0.016782	0.081366	0.206	0.83721	
FISH	0.003817	0.069354	0.055	0.95627	

Table 5 reports the sustainability weighted rankings ('Sustainability ranking') based on the regression equation (6) incorporated with the two new variables TOUR and FISH. Weighted rankings from Nguyen, and Bandara (2015) are also presented for comparison purposes. The differences between the two rankings are north worthy. For example, Greece ranks the top in terms of sustainability, but 27 in weight rankings (without considering blue/maritime economy factors). Malta stays at the bottom in terms of sustainable shipping, yet its weighted ranking was 3, etc. Overall, the large differences in the two ranking suggest that the competitiveness rankings of national shipping could vary substantially depending on the calculation method and even variables used.

Table 5: Sustainability Rankings and Weighted Rankings of National Shipping Competitiveness

Country Code	Country Name	Sustainability ranking	Weighted ranking	Country Code	Country Name	Sustainability ranking	Weighted ranking
50	Greece	1	27	11	Bangladesh	43	60
68	Japan	2	8	134	Thailand	44	26
24	China	3	5	75	Latvia	45	58
145	United States	4	4	106	Portugal	46	43
109	Russian Federation	5	22	99	Pakistan	47	70
48	Germany	6	6	2	Algeria	48	46
61	India	7	17	107	Qatar	49	59
97	Norway	8	24	3	Angola	50	49
63	Iran, Islamic Rep. of	9	14	5	Argentina	51	42
73	Korea, Republic of	10	15	40	Estonia	52	56
66	Italy	11	35	108	Romania	53	40
132	Taipei, Chinese	12	16	37	Ecuador	54	64
144	United Kingdom	13	11	124	South Africa	55	55
33	Denmark	14	31	8	Azerbaijan	56	74
21	Canada	15	28	103	Peru	57	61
44	France	16	19	89	Morocco	58	62
62	Indonesia	17	34	79	Lithuania	59	51
114	Saudi Arabia	18	25	91	Myanmar	60	67
139	Turkey	19	23	138	Tunisia	61	57
82	Malaysia	20	20	76	Lebanon	62	76
16	Brazil	21	21	126	Sri Lanka	63	63
143	United Arab Emirates	22	18	25	Colombia	64	37
125	Spain	23	29	60	Iceland	65	81
129	Sweden	24	36	101	Papua New Guinea	66	71
119	Singapore	25	9	94	New Zealand	67	53
87	Mexico	26	30	117	Seychelles	68	83
148	Viet Nam	27	39	1	Albania	69	79
23	Chile	28	47	70	Kazakhstan	70	66
96	Nigeria	29	38	10	Bahrain	71	65
131	Syrian Arab Republic	30	69	146	Uruguay	72	78
30	Croatia	31	54	69	Jordan	73	75
93	Netherlands	32	33	32	Cyprus	74	7
104	Philippines	33	2	71	Kenya	75	77
74	Kuwait	34	12	55	Guyana	76	82
38	Egypt	35	50	140	Turkmenistan	77	72
13	Belgium	36	13	127	Sudan	78	73
43	Finland	37	45	39	Eritrea	79	84
105	Poland	38	32	9	Bahamas	80	10
142	Ukraine	39	41	100	Panama	81	1
18	Bulgaria	40	48	81	Madagascar	82	68
98	Oman	41	52	137	Trinidad and Tobago	83	80
6	Australia	42	44	84	Malta	84	3

4. CONCLUSION

This paper presents a comparative analysis of national shipping and the effect of various factors on the national fleet, including international trade, ship building, registration, policy, history, oil exports, coastline length, tourism, fisheries and the overall development level. The study results indicate that the strong effect of the shipping building, international trade, registered tonnage. In addition, all else being the same, top oil exporting countries and open registry countries have stronger fleet than the other countries. While tourism and fisheries are known to be important contributors to the blue economy, they do not have a significant effect on national shipping. This could be due to the fact that relationships between these sectors have yet been significant. The comparison of sustainable (weighted) ranking and weighted rankings show very significant differences between these. The former is more in favour of countries with a significant maritime industry. The analysis results imply the importance of promoting the relationships between sectors in the blue economy.

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Proceedings

Social Impact

Educating future generations' master mariners: Using visualisation for re-creating, assessing, and learning from prior performance in post-simulation debriefings

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ABSTRACT

This study draws on video recorded data of debriefings in a navigation course to analyse the practical use of visualisation technologies in post-simulation debriefing. The analytical focus is on instructions, i.e. the instructors' use of the playback and interplay with the students. The results show how the playback creates a shared perceptual field to which instructions are directed and navigational problems are elaborated to demonstrate how to coordinate with other ships in confined waters. The meanings of the rules of the sea are hard to teach in abstraction since every decision relies on an infinite number of contingencies that have to be accounted for. The use of visualisations in post-simulation debriefings offers opportunities to portray rules in a context in which their meanings could be tied both to situations as they were actually carried out and to demonstrate more preferable alternatives.

1. INTRODUCTION

A general problem of educating workers in safety-critical domains is to prepare for skilled performance in real work settings. Simulations have been developed to meet these demands in master mariners' educational programs but have also been prominent for decades in healthcare and aviation. An almost universal conclusion in simulation research is that post-simulation debriefing, allowing for feedback and reflection, is a necessary component for participants to learn from their experiences. The rationale is that retrospective analyses of what just happened can form the basis for prospective strategies on how to manage future situations [1]. In order to facilitate feedback and reflection on prior performance, different technologies have been developed to visualise and replay the scenarios during debriefings. In maritime navigation training, visualisations that replay the simulated scenario by taking a birds-eye view of navigation routes is used as means for organising debriefings [2]. Similarly, visualisations are used in aviation training to offer multiple views on the pilots' conduct during debriefings, including video from the cockpit, the pilots' outside view, the instruments involved in steering the plane, and the flight path [3]. In healthcare, in comparison, video recordings of simulated clinical work commonly provide a third-person perspective of what happened [4]. By offering

an outside perspective on the participants' conduct, the use of videos and other visualisations is said to reduce hindsight bias and enable self-reflection [5]. However, studies on the participants' practical use of video in debriefing sessions shows that, while videos of prior performance are central to such reflections, the reflections acquire their work-relevant meaning in and through instructional guidance [2;3;4]. Hence, studies in this tradition emphasise both the role and importance of instructional support and the anchoring role of technologies to visualise and replay the simulation. Moreover, these studies display, in interactional detail, how and why debriefing tools provide the means for re-actualising prior performance, enabling assessments of the participants' conduct, and opening up discussions on what constitutes good work practices [2;3;4].

Given this background, this study investigates a series of simulations in the education of master mariners that teach the rules of the sea in ways that constitutes good seamanship. The analysis was carried out by scrutinising video-data from six post-simulation debriefings in a navigation course for master mariners during their second year [6]. The aim of the study is to present and discuss the practical use of devices for displaying visualisations which is, in this case, a playback of scenarios that reconstruct the events from a birds-eye-view, in order to demonstrate navigational problems and explain how these should be dealt with to be in line with good seamanship.

2. RESEARCH APPROACH, METHOD, AND DATA

This study is part of a tradition that analyses the social and material organisation of learning with technologies [2;3;4;8]. In particular, the analytical focus is put on work-relevant activities and how professional learning is an instructional accomplishment achieved in and through such activities [7]. A number of social and material resources are integrated in such learning processes: a shared perceptual field (for example, a radar display or, as in this case, the playback used in debriefings), the instructor's gestures or inscriptions that highlight relevant aspects of the perceptual field, and instructive talk explaining what there is to be seen [7]. Hence, learning to see and interpret a work-relevant phenomenon, as a professional, is not seen to reside inside the individual brains of students but, rather, by the ways in which instruction is practically accomplished in the technological environment. In this way, the analytical focus is put on how the next generation of professionals are trained through access to one another and the details of the prior activities as played out in the scenario.

In this study, video data from six post-simulation debriefings serves as a basis for conducting a detailed interaction analysis of the instructors' use of visualisation technologies and interplay with the students [6]. The debriefings are part of a larger data corpus, collected in a navigation course for master mariner students during the autumn of 2014. The course took place during the students' second out of four years and consisted of lectures and five simulator-based training sessions. During the scenarios, students trained in teams of two on five different bridges. The focus was on developing students' proficiency in handling instruments on the bridge and applying COLREG in various situations. In the debriefing session under scrutiny in this study, all ten students gathered in a classroom next to the simulator to discuss and reflect upon their recent crossing of the Dover Strait TSS-lane. A crossing of a TSS-lane is a situation where a number of COLREG apply, and, during the debriefing, aspects of keeping a safe

distance to other vessels (Rule 8), the right-hand rule and its exceptions (Rule 9), and showing the intention to cross (Rule 10) are discussed.

3. ANALYSIS AND RESULTS

In the following sections, transcriptions and pictures from the video-recorded data are used in order to show how the playback provides the means for re-creating the students' prior performance (section 3.1). Section 3.2 focuses on how the playback enables assessments of the students' conduct and how alternative actions demonstrate when and how exceptions to the right-hand rule become relevant in the scenario. Finally, in section 3.3. reasonings on what constitutes good work practices, to generalise the lessons learned from this specific situation, are explored.

3.1. RE-CREATING PRIOR PERFORMANCE

In this episode, a playback of the scenario is projected on a whiteboard in the debriefing room. In the following transcription, the instructor's narrative is directed towards the playback and highlighted through his drawings with a black marker on the whiteboard (Figure 1).



Figure 1 "we aim like that"

Instructor: *it's when these gone down... done the turn... eh... then it's this one then... one needs to turn to exactly this course as in that line... because then this vessel might have turned in like this... this vessel is on its way down... or you could say that we aim like that.*

The indexical utterances (the underlined words in the transcription of the instructor's talk, i.e. "these", "this", and "that") are paired with his drawings on the whiteboard (Figure 1). The drawings, in turn, highlight the students' prior actions in a way that creates a concrete and stable ground for the narrative of how the situation unfolded during the scenario [7].

In sum, in this brief instance of instructional talk, it is seen how the playback of the prior scenario is at the core of re-creating its temporal and spatial nature [2;3;4]. Moreover, the drawings, together with the playback, offer a shared perceptual field on which the instructor's narratives are grounded [2;3;4].

4.2. PROVIDING THE MEANS FOR ASSESSMENT

Assessment of a situation requires knowing what actually happened [4]. The continuing talk from the debriefing episode builds on the re-creating of actions taken in the scenario described in 3.1 and starts with a question from the instructor to the students.



Figure 2 "if this one so to say are on the way down" Figure 3 "doing the turn in one move"

Instructor: *n' what intention does one show then... if this one so to say are on the way down here?*

Student: *well then it's a matter of turning in very good time... so we don't turn starboard n' they turn portside*

The question is paired with a new drawing, marking "this one" and the way down with a new line on the playback (Figure 2). The question from the instructor about what intention the students are showing in this particular situation is not answered by the student in a straightforward way. Rather than stating what intentions they show, the student talks about timing the turn. The other vessel's ability to see their intentions in good time is important so as to avoid collision. Next, the instructor provides an evaluation of the student's answer.

Instructor: *Yes, but then when we come like this... n' then one does that turn in one move... n' aim behind directly*

Student: *yees*

The instructor's formulation, "yes, but..." is showing that the instructor treats the student's answer as only partially right. Instead, he moves on by providing the students with an alternative, better solution to the situation, i.e. to make the turn in one turn to portside and go behind the other vessel. The verbal explanation is paired with yet another drawing on the playback, beginning to show what that turn would look like (Figure 3). The student responds to this suggestion with a positive utterance, i.e. "yees", agreeing on the solution as an appropriate alternative. The instructor then follows up on this by providing an account of why making a portside turn is a preferable alternative, that is, why this situation is an exception of Rule 9, i.e. the right-hand rule.



Figure 4 "then you show the intention...". Figure 5 "I can just go on"

Instructor: *then you show the intention to cross... it can't be that one is going in to join... that's confused... one doesn't think like that initially anyways... eh... then this vessel can go on... they don't feel like... yeah I don't need to give way for that one... I can just go on... n' so one can go in and cross later... follow up n' then the vessels that's behind can turn where there are more space and then also more time*

In this part of the transcription, it is seen how the instructor's rationale of his suggested solution is paired with his drawing of the hypothetical crossing on the playback (Figure 4). What is interesting here is also the following reasoning on how other crews might think about the crossing, i.e. "they don't feel like... yeah, I don't need to give way for that one... I can just go on". In this way, the instructor is concretely demonstrating how taking the perspective of other professionals' can be done in a specific situation [7]. Moreover, the statement "I can just go on" is paired with the instructor's drawing on the playback, showing what this would mean in the continuation of the hypothetical scenario (Figure 5).

3.3. GENERALIZING THE LESSONS TO BE LEARNED

The preceding sections showed how the instructional use of visualisation technologies enables the re-creation of prior scenarios and allows for the assessment of the students' actions, as well as the reasoning of alternative solutions. In this section, the instructor's concluding remarks on the situation is presented.

Instructor: *that is... one does a portside turn that doesn't cause a close quarter situation then huh... that someone else need to solve in a hurry like that... so you are allowed to turn portside... but it is with restraint so to say... one should be clear about the consequence so to say.*

While the instructor's previous account of why the specific situation is relevant for an exception to the right-hand rule, the instructor's talk in this transcription is oriented towards more general advice and what to think about in such situations. That is, to turn portside to avoid close quarter situations and avoid putting others in a position where they need to take evasive action, and to do this in an informed manner. Hence, the concluding remark does the work of generalising the lessons from this specific situation by reasoning what the rules mean in practice and what constitutes good seamanship [8].

4. CONCLUSION

In line with research from aviation and healthcare, the results highlight the central role of technologies for visualising prior events and the importance of an instructor to guide the students towards learning objectives during debriefing [3;4]. The results have implications for maritime training, displaying a number of instructional methods for bridging the gap between the application of navigation rules in line with good seamanship and the students' specific actions during the recently performed scenario. A range of different instructional resources were combined in this process: the playback of the scenario, drawings with a black marker to highlight relevant aspects of the scenario, and the students' responses. This, in turn, formed the basis for demonstrating alternative solutions by contrasting what was done and what should be done and by comparing the performed courses of action versus hypothetical ones. In addition, the birds-eye view of the scenario enabled by the playback offered possibilities for seeing others' perspectives on the situation, i.e. of how one's own actions could be perceived by other navigational teams [2;7;8]. In doing this, navigational problems were elaborated to demonstrate how to coordinate with other ships in confined waters. In this way, the application of the rules of the sea were addressed in terms of practical and timely actions in relation to the ever-changing and contingent character of navigation practice.

In summary, the meanings of the rules of the sea are hard to teach in abstraction since every decision relies on an infinite number of contingencies that have to be accounted for. The use of visualisations in post-simulation debriefing offers opportunities to portray rules in context so their meanings could be tied both to real-world situations and to demonstrate more preferable alternatives.

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Maritime education and training system require a change to make a competent seafarer for shipping industry. A case study from an International Maritime institute.

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Keywords: Seafarer's, International shipping industry, Maritime education and training (MET), Competency developments, International maritime training institute.

ABSTRACT

The success of the world's shipping industry ultimately depends on one special group of people: seafarers. These men and women have led humankind in the discovery of the world and changed the global economy. Today, the role of seafarers on board ships has greater importance than ever before and will continue to be key in the coming years. Without motivated, qualified and trained seafarers, the international shipping industry will not thrive. Maritime education and training (MET) is therefore crucial for all parts of the world's maritime community, and particularly for the seafarers of today and tomorrow, as it is the basis of a secure, safe shipping industry. Effective MET for seafarers at various levels provides them with proof of their competence in the particular skills and duties they need to perform on board. However, the effectiveness of MET varies widely, such that having a certificate does not guarantee a seafarer's competency – as demonstrated by the many maritime accidents that continue to occur as a result of human error. Competency must therefore include knowledge and skills, and more importantly, their application in the workplace. This study explores the effectiveness of current MET in developing competency among seafarers. This is achieved by examining and comparing data gathered from interviews with participants with seagoing experience on a competency development course at an international maritime training institute in Australia. The findings of this research show that the participants need more practical studies in their STCW competence development course and different approaches in teaching them. The study concludes by providing a summary of changes to MET on competence developments suggested by the participant interviewees. The findings highlight the importance of teaching practical skills and applying relevant teaching methods to allow seafarers to become competent in the skills they will require in real-life situations. Furthermore, they may serve as an incentive for MET institutions to improve their course content and delivery, as well as for researchers to continue studying this subject further.

1 INTRODUCTION

Shipping is still the most important mode of transport for world trade, and seafarers and ships are therefore vital in terms of improving global trade and the global economy. The economy

of maritime education and training (MET) is linked to the economy of the shipping industry, whose outlook remains bright. ‘We must learn to walk before we can run’ is an old saying that is commonly used in relation to shipping, seafarers and MET. It is a well-known fact that MET has to serve several purposes. Undoubtedly, its main purpose is to produce qualified seafarers for the shipping industry. However, MET today is heavily concentrated on technology rather than on the seafarers themselves. The shipping industry has been developing with the goal of reducing accidents at sea. The aim is that everyone who works on board ships should have proper training and education, not for certification purposes, but for the safety of life and the safety of the environment.

Different countries have their own MET standards within the framework of the single overarching rules and regulations of the International Maritime Organization (IMO). As Koji Sekimizu, Secretary-General of the IMO, said,

“While compliance with standards is essential for those serving on board ships, the skills and competence of seafarers, and indeed, the human element ashore, can only be adequately underpinned, updated and maintained through effective maritime education and training.”

(Sekimizu, 2015)

MET today is guided by the universal Standards in Training, Certification and Watch keeping for Seafarers (STCW) rules. In the 1960s and 1970s, the shipping industry as an active element of global society came under intense pressure following several high-profile shipping accidents that resulted in huge environmental damage (e.g. the Torrey Canyon in 1967). As a result, in 1978 the IMO introduced its first STCW, called STCW78, to set the standards in training for all seafarers. However, this convention proved ineffective (McCarter, 1999), leading to its comprehensive revision on 7 July 1995. Significant amendments introduced in STCW95 include those relating to oversights in training, assessment and certification procedures. Specifically, STCW95 stated that training for seafarers should ensure that they are aware of the hazards of working on a vessel and can respond appropriately in an emergency. However, as noted by Emad and Roth (2008), “after almost two decades of implementation worldwide, the convention was not promoting the changes for which it was initially designed and had not reached its objectives”. In 2010, the IMO adopted new amendments to STCW95 in Manila, called the Manila Amendments. These amendments are necessary to keep training standards in line with new technological and operational requirements that require new on board competencies. IMO also introduced competency-based training as a new method for teaching seafarers.

Despite the introduction of international STCW, many accidents and incidents in the shipping industry are still caused by human error. Modern ships these days are technically very well built and generally well maintained, and so incidents are not generally the result of mechanical malfunction or breakdown, but rather are mainly due to human error. MET therefore has the responsibility of researching the causes of accidents and incidents in shipping industry, thereby creating awareness among seafarers and addressing issues through proper training in their respective competencies. However, despite the introduction of this system, the industry still has problems with human error (Alop, 2004).

This study was designed to find out where there might be problems in MET in the area of competency developments of seafarers. It shows that there are a few contradictions within the

system, whereby seafarers pass their competencies without actually being fully competent in terms of their knowledge and skills.

In this research paper I begin by providing a historical background to problems and changes in MET for competency development training. Following a description of the research method, I report on my case study into different components that affect seafarer competency developments in MET, and then proceed to articulate ways in which those components could be improved in order to raise the competency level of seafarers in the required skills. I conclude with suggestions for overall improvements in the competency development sector of MET.

HISTORICAL BACKGROUND

Seafarers are recognized as competent when they have enough on board experience at a particular competency level to reach the next level of competency. Competency of seafarers is achieved through thorough practice of skills and knowledge, and by attending competency development courses at MET institutions, where they can gain the skills and knowledge they require to perform on board ships. Although merchant shipping and MET are governed by the IMO, actual standards and practices vary widely between countries and between individual MET institutions (Alop, 2004). But the universal fact remains that MET practices needed to be harmonized under a single standard of certification (Emad & Roth, 2008).

Many investigations into accidents at sea have concluded that poor training and lack of competency were the main cause (Bergetal.2013). The lack of enough skills in demanding situations has been shown to be one major contributing factor in various near misses, delays, incidents and accidents (Kim and Nazir 2016). Reform efforts have therefore focused on MET levels. Additionally, accelerating changes in the shipping industry – both technological and regulatory – necessitate the evolution of MET, specifically by further fostering seafarers' practical skills and proficiency to ensure their better performance at sea. MET for competency development is the process that provides seafarers at both the operational and management levels of the shipping industry with the knowledge, attitude and skills they need to perform their various duties. The influence of the human element is paramount, as it is people who carry out almost all operations in shipping companies, both at sea and on shore. Seafarers must therefore be highly competent, well-motivated and stimulated, with qualifications and support in their areas of professional responsibility. It is in this area that organizations providing MET therefore clearly need to focus.

STANDARD OF COMPETENCE

Traditionally, competency among seafarers was achieved by gaining adequate experience and acquiring and demonstrating the skills needed for seagoing employment, simply through serving specified periods of time at sea. Knowledge and understanding of subjects relevant to the work involved could be tested adequately through written examinations. A popular theory suggests that a student passes through five distinct learning stages: novice, competence, proficiency, expertise and mastery (Dreyfus, 2004) these methods worked well over the years. Even today, criticism aimed at seafarers responsible for accidents in the shipping industry imply that their performance at the time of the incident was incompetent, not their overall performance.

Within the standards of the modern shipping industry, seafarers must have a clear indication as to the level of competence required. As the basis to this, the development of competency in seafarers must involve making the desired outcomes of the training explicit, in terms of the standards of each competence level. In addition, the assessment must incorporate the ability to perform to the defined standards and to apply relevant skills and knowledge in practice. Finally, a range of learning opportunities should be open to candidates, which facilitate access to new qualifications and assist their career development and progression. Skills learnt should be tested by both a written examination and an oral exam after the completion of the competency development course in which the seafarer is trained for their next level of competency in preparation for their next role on board. Competence must demonstrate knowledge, skills and the application of these in the workplace. In addition, the decision that someone is competent should mean that a judgement has been made that the person has the ability to continue to perform competently in the future. The standard of competence should ultimately focus on the ability of the candidate to perform effectively. However, effective performance depends on the individual body of knowledge, theory, principles and cognitive skill on which the individual can draw. The ultimate focus on the competency of a seafarer must be effective MET at their particular competency level.

2 METHOD

The project utilized qualitative semi-structured interviews as the method of data collection, whereby the questions asked during the interviews emerged and developed through the advancement the process. The oral interviews were recorded digitally and then transcribed by the researcher. As an integral part of the research process. We aimed to protect both researchers and participants by gaining an ethics approval from the Social Sciences Human Research Ethics Committee.

Project title: The effectiveness of Maritime Education system on competency developments of seafarers.

2.1 RESEARCH OBJECTIVES

This study was designed to reveal any problems in competency-based training within the maritime education system and any contradictions in this system that fail to give seafarers the skills they need. The report initially describes previous systems of learning in the maritime industry and the new requirements that were brought into force by the IMO. The research examines considerable features inside a system designed to improve the education and training of mariners. It does not claim that current MET practices are failing, but highlights potential improvements to the system by better education within the maritime industry. The study reveals the potential for poor competency levels among seafarers, which is the main cause of accidents in the industry. As MET is a vast and continuing development process, the maritime industry itself needs to develop continually in order for the industry to grow.

In this project, mariners who are in the process of attempting to meet their competency levels are asked for their suggestions for improvements to MET. These suggestions and other data gathered, along with the final analysis, are provided in the next two chapters of this research paper. The concept of education in general, and of maritime education in particular, has dramatically and comprehensively changed during the era of globalization. This era is

controlled by technological revolution and the potency of the education pod, or 'herd', where education is no longer provided solely by education institutions during formal study phases, but rather is seen as a continuous process of learning. Education has become the main drive behind the development matrix in general, and the development of maritime transport in particular. It is the effective means to equip humans with experiences and capacities in order to hunt employment opportunities, which is the pillar of development.

This research aims to investigate maritime educational perspectives on seafarer competency development. The study also aims to evaluate the effectiveness of MET for the seafarers of today and tomorrow, as competency development is the basis of a safe and secure shipping industry. Moreover, seafarers' perceptions of their role on board ships, along with their maritime educational background and success criteria, are key in the measurement of effectiveness of maritime education. The research will contribute greatly to the benefit of maritime educational providers internationally. The greater demand of skilled mariners with high levels of knowledge and competency justifies the need for more effective system approaches. Thus, results derived from this study will help these institutions maintain the competency required by mariners working on board ships and in the industry generally. For researchers, the study will help to uncover critical areas in the educational process that they may not have been able to explore.

Specifically, this research is guided by the following questions:

- What is the effectiveness of maritime education and training on the competency development of seafarers?
- How does the competency developed in maritime educational institutions relate to real practices on board?
- What improvements could be made to the maritime education system globally?

2.2 THE RESEARCH SAMPLE

The researcher interviewed students aged between 27-39 years at International Maritime Domain in Australia with both sea experience on engine side and on deck side. The academic and professional backgrounds of the interviewees varied extensively. Often, the students who appear at international maritime domain for their upgrade of competency are current seafarers in the shipping industry. In contrast, the teaching staff (who also constituted part of this study) have long experience at international maritime domain and have various academic backgrounds. In general, the students (seafarers) showed a great interest in participating in the study.

The analysis of the data originated from transcripts of the interviews, which took place between 1 May to 15 May 2017.

2.3 PROCEDURES

The collection of data for the proposed research occurred via face-to-face interviews with individual students. A semi structured formal interview process was utilized to ensure that the research questions were addressed, while also allowing for emerging and unexpected themes to occur. This interview process was implemented so that the interviewer had the freedom to explore areas beyond those covered in the research questions. Potential participants were given

letter of recruitment in their classroom inviting them to take part in the study, along with an information sheet about the project. Interested participants were then asked to respond to the researcher via email. An interview schedule containing open-ended questions was utilized to ensure some consistency in data collection so that comparative data analysis could be carried out. The interview schedule was sent to all 75 participants one week prior to interview and 21 students got interviewed. As the data started repeating from the previous data from the participants, we stopped interviewing participants. The interviews were conducted at the first-choice public place of the participant or, if the participant agreed, in a silent study room. The interview was conducted for approximately 30-45 minutes for each participant depending upon the length and breadth of the topics covered.

The oral interviews were recorded digitally and field notes were taken by the researcher describing the events and his impressions. Thus, the data more likely to be qualitative were used for analysis. The data obtained from the recorded interviews were transcribed by a pseudonymous method.

2.4 DATA ANALYSIS

Coding is an appropriate method to use for analyzing the data collected through this research. It uses a content analysis of written materials from personal expressions by the participants and aims to provide an in-depth understanding of a situation.

Content analysis may be used to analyze data gathered from studies of participants and from interviews, including transcripts of interviews. Content analysis measures the semantic content of a message. Its breadth makes it a flexible and wide-ranging tool that may be used as a stand-alone methodology. It is a research technique for the objective systematic description of the manifest content of the interview. It is the message that conveys a multitude of contents even to a single receiver. Content analysis follows a systematic process for coding and drawing inferences from texts. Each unit type is the basis for coding texts into mutually exclusive categories in a search of the meaning. In this research, referential units of the content analysis are words, phrases and sentences, and may refer to or represent objects, events, persons and so forth.

3 RESULTS AND ANALYSIS

This research study aims to reveal any potential problems in competency-based training within the maritime education system and any contradictions in this system that fail to give seafarers the skills they need. The study reveals that there are two major problems in current the MET system:

- Lack of sufficient attention to the practical training in competency developments of seafarers.
- The shortcomings of the MET system in terms of professional maritime educators and their teaching.

In Section 3.1, based on the data gathered from the participants of the study, I show that there are contradictions in the practical training in competency developments of seafarers at MET institutes in relation to their role on board ships. This chapter reveals that competent seafarers need more practical training that reflects their purpose on board ships. I do not claim that there is no practical training in MET, but that there should be more practical training for a seafarer's

competency. Practical training is restricted to short courses for seafarers, resulting in human error. To eradicate this problem and to maintain safe shipping internationally, more practical training should be incorporated by governments in MET for seafarers at each of their competency levels. The seafarers who participated in this study felt they were not fully competent at their level because of the missing practical aspect in their competency development course. As a way of addressing what is required to make MET more relevant to their competency, study participants were asked for their suggestions and improvements. Some suggested that the certification authorities and government should focus on preparation of new course structures that have a practical component rather than simply continuing with the old theoretical structure. Students should be able to apply the theories they learn in MET practically to reflect their work on board ships. This new change in practical standards will reflect work standards on board. To achieve this, the IMO and the individual country administrators for MET should change the current competency developments course standards to practical challenging competency development.

In Section 3.2, I analyzed two important issues based on data gathered from the participants: that MET should be student centered, not teacher-centered; and that professional MET teachers must be motivated, dedicated and enthusiastic in order to be effective. This study does not claim that existing methods of MET teaching and the quality of professional maritime educators in the sector cause poor levels of competency. Seafarers obtaining competency in MET believe that professional maritime educators are the main resource of MET institutions. As supported by data gathered in this study and by the research of other authors, student centered classrooms are more effective in teaching practical subjects, by which the teacher does less and the students do more. Furthermore, maritime educators need to change their focus to what the students are doing and how they learn, rather than simply delivering lectures as a stream of PowerPoint slides. Practical skills cannot be taught effectively through lectures; they are learnt through experiences, and thus the job of a maritime educator is to create relevant experiences.

3.1 THE IMPORTANCE OF PRACTICAL TRAINING IN COMPETENCY DEVELOPMENT

To achieve competency, seafarers must acquire knowledge and develop skills, both theoretically and practically, at an MET institution. To be awarded with competence, seafarers should be able to have their skills assessed through oral and theoretical examinations by the recognized national administrator of the IMO. In this section, I look at the division of practical knowledge into skills and competency, and the implication for MET institutions in teaching this.

Practical knowledge and theoretical knowledge for seafarers are interwoven. Usually, seafarers add to their knowledge base by learning skills and refine these as they develop related concepts through practical approaches. This is a common type of study in courses that use simulators. There is a lot of memorizing by rote for the examinations, which does not improve competency levels in seafarers. As mentioned previously, many shipping accidents are caused by poor competency levels of seafarers. STCW has been revised to stipulate that adequate and appropriate training should be provided to seafarers in order to eradicate human error as a cause of shipping accidents. Despite efforts from the bodies governing MET,

however, STCW has still not reached its objectives (Chawla, 2006; Wilson, 2007). This study reveals that there is a lack of practical training in STCW competency development courses at MET institutions, and that the study participants were not convinced that the MET they received was of much benefit of them. A typical response to the study question “How do you measure the competency developments in terms of the seafarer’s practical application?” given by the participant, was that:

“The competency development courses are pretty bad. They are not useful because there are no practical’s and they are full of unwanted theory which is not used in ships anymore.”

Another study participant, a certified marine engineer aiming to become a second level engineer, expressed his experience of not being fully competent:

“I am not fully competent because there is no practical training for my competency development course.”

These comments from experienced mariners attending a prerequisite course for the upgrade of their competency level are not common.

According to Sekimizu (International Maritime Organization, 2015), “Effective standards of training remain the bedrock of a safe and secure shipping industry, which needs to preserve the quality, practical skills and competence of qualified human resources”. Of course, it is vitally important to be clear about MET for the competency development of seafarers, for example like concepts as ‘unstable’ and ‘untrustworthy’. The concept ‘unstable’ can be learned from definitions and theory, which most MET institutions provide for competency development courses. But the concept ‘untrustworthy’ must be refined by trial and error, with no certainty at the borderline, and with some sort of ideal type with which to compare each case. A competent is one who has the required skills, developed through adequate practice. Learning a skill by theory alone does not provide practical competency.

At sea, competency is more likely to be defined as a capacity to do a job efficiently in any circumstance that is likely to arise. If we focus on competency in terms of practical training, there would surely be a large measure of agreement about collection of skills and underpinning of technical knowledge at a competent level. The need of a ship to work as an operating unit could be agreed on in a large number of respects, especially relating to safe navigation (from a deck point of view). The two concepts of practical and theoretical knowledge will diverge at some point. The captain of a ship will tend to make some allowance for experience, expecting more or less competence from the seafarers under his command according to their age and background, while the administration simply sets a minimum standard for all. Candidates achieve this minimum standard by gaining the relevant certificate, not by demonstrating their knowledge in a practical way. For example, the administration may set a 50% pass mark. This implies that a certificate of competency can be awarded to someone who gets just 50% of exam questions correct simply by memorizing answers by rote. If a seafarer fails at their first attempt, they can then re-sit for the examinations until they get a pass mark. A captain would take this as evidence, if displayed at sea, that they are not competent. This difference reflects the varied competency levels among seafarers. A certified mariner who participated in this study commented on this issue:

“Can you imagine the knowledge levels of fully competent (first attempt pass) and less competent (second or third attempt pass)... working together on a ship resulting so many mishaps?”

A second concept in competence is the practical aspect, which administrator's state is key to competency development. Competency development courses should therefore assess students equally in both theoretical examinations and practical tests. According to the standards of the competency level, each seafarer needs to demonstrate the competencies prescribed in order to achieve certification. These competencies should be achieved through a combination of education and training, plus practical experience on board ship (International Maritime Organization, 1996). To achieve this, MET generally consists of training of skills through practical short courses, and education of knowledge through theoretical courses. These different types of education and training methods are the most popular in the maritime industry. As discussed previously, maritime administrators set standards of competency at each level, and issue certificates of competency based on the short courses and the theory classes all seafarers must attend and pass exams in. In the following section, I discuss the functions of these short courses and how they affect competency levels.

STCW short courses and STCW competence development courses (practical vs theoretical)

Most of the countries that are party to the IMO's STCW are successfully reaching the organization's objectives in STWC short courses. For every level of certificate of competency there are certain short courses that seafarers must take. These courses, which focus on emergency situations, are mainly hands on and their content is taught by various theoretical and practical methods. Seafarers are generally satisfied with the approach of STCW short courses, where they are assessed by proving their skills. The practical aspect of these courses makes seafarers feel more enthusiastic about their relevancy to practice on board ships. These skills are covered in part by practical training in various types of situations that are encountered on board – for example, firefighting, advanced firefighting, first aid and oil tanker specialization. The IMO stipulates that it is mandatory for all seafarers internationally to be passed as competent in STCW short courses following theoretical and oral examinations.

Although STCW short courses are mandatory for competency assessments, this research study reveals an important aspect of STCW short course structure that needs to be applied to STCW competency development courses for all seafarers. Specifically, STCW competency course examinations and certification criteria are based on the theoretical subject, which students learn during their course and memorize by rote in order to pass their exams: A navigational officer who participated in the study expressed his view about the current situation:

“STCW short courses are really good for seafarers, but the STCW competency development courses for competent seafarers are not up to the mark because of a lack in practical training for competent subjects.”

Seafarers are clearly more motivated by the structure of STCW short courses, and so maritime administrators need to revise STCW competency course structures so that they also contain a practical component, thereby allowing seafarers to become truly competent. STCW competency courses are also long compared with STCW short courses as a certified mariner who took part in the study commented:

“STCW competency development course is a lengthy process where the subject is just 50% used on board ships nowadays.”

Among mariners, STCW short courses are viewed as the best part because of the practical way the courses are taught. Although working on board a ship is a prerequisite under STCW

regulations for anyone looking to gain a certificate of competency, the competency levels change as their job on board changes. For example, a third marine engineer who is mainly responsible for generators on board ship would focus on second engineer responsibilities when he attends a competency development course.

Seafarers who participated in this study were very concerned with the need for a practical component in their STCW competency development courses. Practical teaching of subjects at MET institutes should also be regularly revised in line with technical developments in shipping, so that seafarers can benefit from learning new techniques before going back on board. I conclude this section by quoting from a ship's master who participated in this study, and who felt that:

“More simulators have to be developed, especially due to the upcoming ‘Polar Code’. These new adoptions can be handled only by updating and introducing simulator training methods and practical training for STCW competency development courses.”

3.2 ROLE OF PROFESSIONAL MARITIME EDUCATOR IN COMPETENCY DEVELOPMENT OF A SEAFARER

In the previous section I discussed the need for practical training in competency development courses. This section looks at the importance of the role of maritime professional educators in seafarer competency development.

Because shipping is a transport industry, it takes a special kind of person with certain qualities to be a professional maritime educator (Lloyd, 2012). Seafarers are increasingly being asked to pay for their own shore-based training, and so want efficient tuition that is directed at helping them pass examinations. This will enable them to earn qualifications and associated higher salaries. A certificate from an institute with an established reputation will also enhance their career prospects. The STCW code requires that all seafarers should be properly qualified for each competency they attain at MET institutions. To enable them to achieve these standards, professional maritime educators should teach the required subjects to the level of the standards. Unfortunately, however, data gathered from participants in this research study indicates that not all MET institutions have educators who are necessarily qualified for this task. A chief navigating officer who took part in the study stated:

“Standards of teachers (maritime educators) are not very good. (Ungratified expression).”

There are few countries in which maritime teaching is considered an attractive profession, both in terms salary and image. It is therefore necessary to improve the qualifications of maritime educators. The main qualifications needed by maritime educators are enthusiasm and motivation, which are discussed further below. Even well-qualified maritime educators are not always fully aware of the context in which they operate and what their contribution to safer shipping and cleaner oceans could be. This report aims to give maritime educators a few ideas on how they could improve their performance by updating and upgrading their qualifications. The seafarers who participated in this research study felt that their own competency was based directly on the competency of the maritime educators who teach them. Indeed, one mariner who took part in the study stated:

“People don't come on board qualified because of the poor standards of teachers (maritime educators) who taught them”.

The basic prerequisites for a prospective maritime educator are shipboard experience and the highest certificate of competency in the deck or engine departments or as a dual-purpose officer, provided he/she is not expected to teach mathematics, electronics, English or other subjects, which do not necessarily require certificates of competency or shipboard experience. In the majority of MET institutions maritime educators have additional academic qualifications such as Master of Science degrees or Master of Business Administration degrees in maritime law, maritime economics, and naval architecture and so on. IMO model course 6.10 clearly states that the instructor should have a background or experience in teaching or instructional techniques (IMO 2012, p. 54). Nevertheless, many maritime educators lack training and experience in effective teaching methods, even though they may have vast experience on board ships. As a participant in this research put it:

“More trained maritime educators in teaching are needed in MET for competent seafarers. They have an experience on ships like master or chief engineer but the ability to impart their knowledge to students is missing. It is very difficult to understand them.”

Present maritime educators often do not develop their teaching skills or have a positive attitude to lifelong learning. This is a very important point, as marine educators are key to training seafarers in competency in order to reduce the incidence of accidents at sea. Thus maritime educators should possess a special teaching qualification in order to teach their students effectively.

Maritime educator qualifications – enthusiasm and motivation

Bettencourt et al. (1983) carried out research into the effects of teacher enthusiasm on student engagement. The results showed that students in lectures taken by enthusiastic teachers were more engaged and more focused than those in comparison control classes. The positive effects also seemed to go beyond the classroom. Perry and Penner (1990) found similar results, and it has been suggested that teacher enthusiasm leads to increased student motivation both inside and outside the classroom, improving engagement and learner outcomes. With the requirements of STCW on seafarer competency, maritime educators should take a special interest in cultivating competent seafarers. It takes a special teacher to motivate a student by focusing on their skills and abilities. The problem is actually implicit in the MET system. It starts with the IMO, which prescribes the functions and standards of competence that should be attained. Competency development courses are then constrained by boundaries, beyond which it is not cost effective to provide training. The maritime administration infrastructure is therefore against innovation at the teaching level; yet paradoxically the whole maritime industry is alive in new design ideas and innovations. Unless there is a change in the teaching system, seafarers will always lack competency. The outcome, in the maritime education and training that interests seafarers, is usually seen as the willingness of a maritime educator by showing his/her personal qualifications rather than showing their experiences.

Feedback and assessments

It is not just education and training that rely on the idea of memory. A maritime educator is a source of knowledge, a demonstrator of skill and a judge of standards. It is useful here to recall what we understand about assessment. Rowntree (1985) defined it in the following way

“Assessment is an attempt to get to know about the student and find out the nature and quality of his learning – his strengths and weaknesses, or his interests and aversions, or his style of learning.”

From the above definition it can be concluded that assessment is all about knowledge – specifically knowledge about the student. How can that knowledge be interpreted and used? The main purpose of assessment is to provide feedback for students and teachers. However, this is always given a low priority by maritime educators in MET. Seafarers’ perception of assessments has shaped their approach to learning. “The way that the conventional assessment system in use today is not even achieving its claimed objective: assessing the knowledge an officer needs in board ship to act successfully” (Emad & Roth, 2008). One of the participants in this study stated that:

“Redundant stuff should be omitted and present industry study should be asked in examinations and made to study in course.”

After further discussion with this seafarer about assessments and feedback in the MET system, he said:

“The feedback of delivery and response from students is missing. Teachers should focus more on students. Of course they get feedback from assignments and exams, but there is one more important assessment of students which is missing in MET, i.e. general assessment of students by their skills and ability to focus on subject.”

In some countries, the standards are fully defined and all educators need a special qualification in assessing seafarers before carrying out an oral exam to assess him/her. This process needs to be harmonized across all MET institutes so that all educators give personal feedback to seafarers before they attempt competency examinations. As the seafarer above noted, feedback and general assessment of individual seafarers gives them confidence in their abilities to face the real examination at the first attempt, thereby avoiding a reliance on memorizing information by rote.

Transformation from teacher-centered learning to student-centered learning in MET

According to Halperin (1994), higher education teaching continues to be in the traditional style, whereby “students sit quietly, passively receiving words of wisdom being professed by the lone instructor standing in front of the classes”. As discussed above, professional maritime teachers need to create experiences, which should be delivered in an enthusiastic and motivated way. Felder and Brent (1996) define student-centered learning as a cooperative approach whose pace is dictated by the student and whose content involves active experiences. They stress that students should be given responsibility for their own learning experience, and should be allowed to discuss topics with peers, write essays, and explore different attitudes, values and opinions. This is uncommon in MET, as a chief officer participating in this study noted: “People who teach seafarers are ex seafarers who are not in touch with the new changes in the industry. They may have been teaching for 10 to 20 years but they are not working on ships now. The lessons which they teach are completely different from what is being used currently on board ships.”

There is a need in MET for learning to change from a teacher-centered system to a student-centered one. Changes in the industry – which are updated on board regularly – will then be shared among all the students, as they are current seafarers who are in regular touch with the system. In order to enable maritime lecturers to make this switch from teacher-centered learning to student-centered learning, they should be given regular professional development in teaching and in up-to-date technical expertise. Professional maritime educators should themselves develop their understanding of how people learn, tools to reflect on their teaching

practice, and skills to use current technology such as simulators to best effect. Grey's (2009) comments are particularly relevant here: "it has become clear that at every level across the industry there is a growing dissatisfaction at education and training... devaluated to the lowest common denominators produced by the need for global qualification". The modern shipping industry, in which crew sizes are being reduced and individual seafarers therefore have greater levels of responsibility, requires an effective MET system. In this critical situation, the institutes providing MET often look to make money by advertising the industry as one that is highly adventurous. This practice contributes to the majority of low crew motivation towards the industry, as seafarers join it in the belief that they can earn good money with no proper skills. The institutes have to address this challenge in order to achieve a reasonable seafarer attention rate.

It has been long been realized that human performance is the overriding factor determining the safety of the shipping industry. Human error has been found to be the main cause of accidents and incidents at sea – indeed, 80% of accidents in shipping are caused by human error (Fotland, 2004). In order to reduce incidents and accidents in shipping, the best approach is proper and effective maritime education and training for all seafarers worldwide.

4 DISCUSSION AND CONCLUSIONS

This research paper reveals considerable contradictions inside the MET system in terms of the competency development of seafarers. The study does not claim that these contradictions cause poor competency levels among seafarers, but suggests that if these contradictions are resolved by maritime administrators internationally then there would be little or no human error caused by poor competency. The findings of this research paper contribute a broad view on the effectiveness of MET for the competency development of seafarers, highlighting the main drawbacks in the system. The findings, in combination with reference to relevant literature, indicate the meanings of these drawbacks, proving the inefficiency of the system. Improvements are suggested in parallel. Moreover, the study raises the importance of MET in competency development by considering the views of the participants.

The quality of MET differs significantly across nations. This study suggests that maritime administrators need to redesign competency development courses and programs, harmonizing worldwide so that seafarers are provided with adequate and proper practical training. As a result, mariners would be able to focus more on how to be truly competent rather than targeting competency certificates. Maritime administrators in all national maritime sectors should focus on the MET system by conducting regular audits with the students by testing their practical knowledge. Specific research into training maritime educators would also be beneficial for the system, to make them more effective in teaching competency development courses to seafarers. As a way to find a solution to the incompleteness of competency development courses, I asked the participants in this study for suggestions and improvements to the system. Almost all of them suggested that improvements should mainly come from the administrators of MET to impart more practical training by introducing more simulators and practical's for better understanding of real-life situations. I conclude this research paper by quoting an experienced mariner who participated in this study:

"Without proper training, the job on board ship cannot be done properly. New training requirements should come to have safe shipping... The competence development courses

should be more standardized by new practical training and teaching methods instead of following the old practices.”

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Opportunities and challenges for seafarers in higher education: A comparative study of the German and the Swedish system.

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ABSTRACT

The paper compares Maritime Education and Training (MET) at undergraduate and postgraduate level at two maritime faculties, one located in Germany and one in Sweden. While undergraduate education in both countries is mostly defined by their adherence to the STCW convention, a different approach is adopted in the provision of postgraduate and lifelong learning programmes. While Chalmers University in Sweden has opted for different on-campus courses, Jade University in Germany aims to further the education of active nautical officers while they still work at sea. Both institutions have identified a clear need for an ongoing MET beyond the bachelor's degree level, given the increasing complexity of the maritime trade. Offering courses to cater to the needs of maritime professionals ensures their progress from a navigational to a more advanced managerial position.

1. INTRODUCTION

The international shipping business transports about 80 percent of the global trade by volume and over 70 percent of the global trade by value. [1] The global maritime industry is one of the world's largest economies and employs, directly or indirectly, more than 200 million people on a worldwide scale [2]. Supplying this industry with a competent and well-educated workforce is a challenge for the international seafaring nations [3, 4, 5]. Maritime companies face an area of tension between a (forecasted) global shortage of seafarers and the higher importance of well-being at sea in terms of an increased work-life-balance. This conflict is reinforced as the shipping profession becomes increasingly sophisticated in terms of social, economic and ecological factors. Therefore, lifelong learning and continuous education pose modern challenges for future trends in maritime education, training and research.

2. METHOD

Following up on this, the present article presents two case studies of German and Swedish IAMU (International Association of Maritime Universities) members. A case study design [6] was chosen and conducted in order to inquire a comprehensive and in-depth insight into the two cases by finding out similarities and dissimilarities as well as addressing questions that ask why, what, and how the cases developed. This has led to a sample (case selection) of

two universities, one from Germany and Sweden each, which includes the status quo of maritime education, both on an undergraduate level in terms of the education of nautical officers and on a postgraduate level in terms of further education in two higher-education institutions. In the further course, a general introduction is given. Afterwards, the two cases of German and Swedish maritime education and training (MET) are introduced (data collection). Data was obtained by information publicly available on the Internet pages of the two universities. Moreover, data is based on intrinsic knowledge of the corresponding authors as they are employed as coordinators of the master programmes discussed. On that basis, a comparative analysis will be conducted to highlight differences and similarities between the German and Swedish system (data analysis). The text closes with a summary, some lessons learned and ways forward (results and discussion). The research is carried out in accordance with the universities' research ethics' regulation.

3. THE ROLE OF SHIPPING AND THE STATUS QUO OF MET

Without shipping the exchange of goods would not be possible, it is thus necessary for the modern world. In other words, the maritime industry constitutes a pillar of our society. For the manpower report 2015 “[t]he world merchant fleet [...] was defined as 68,723 ships” [7] and a global population of 1,647,500 seafarers serving on these ships [ibid.].

In the beginning, the shipping industry traditionally employed a largely unskilled, labour-intensive workforce, which over the years has experienced a massive transformation to the capital-intensive, sophisticated sector we find these days. The same development applies to MET which has also morphed from a highly practical, hands-on approach with an operational education and on-the-job training paradigm to a university-style and tertiary education scheme with a focus on business and analytical skills. We find, for example, an increasing number of tertiary institutions which offer undergraduate as well as postgraduate maritime degree courses not only leading to a certificate of competency but also to a Bachelor's of Science degree. Moreover, this development can be retraced over time by means of established conventions in shipping. It started with the Officers' Competency Convention (ILO C53) of 1936, which was followed by different amendments before the first international shipping convention on education entered into force in 1984. This was the 1978 International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW). This convention was developed further with different amendments, e.g. the Manila Amendments of 2010 [8]. It is not only important for seafarers to learn highly contextualized/situated knowledge of navigation and how to sail a ship safely from the start to the final destination (any more) as MET is far more than this. Officers have to be able to work together in teams. As a starting point, learners are given the chance to learn critical thinking and leadership as well as to apply their knowledge in specific collaborative learning activities such as simulator training which are close to reality [9]. Future officers should have the possibility to experience how people react in practice and in how far they interact with their team (members) [10]. It has been argued that the current MET system, particularly competency-based assessment, does not address students' higher cognitive skills (e.g. comprehension, application, analysis, synthesis and evaluation). These skills are highlighted in the STCW as prerequisite for competent seafarers [11]. Building upon all this, it is now time to shed light on the two cases.

3.1. EXEMPLARY CASE OF JADE UNIVERSITY OF APPLIED SCIENCES

Jade University of Applied Sciences (Jade UAS) is located in north-western Germany. Approximately 700 of the total number of 7,600 students are enrolled at the Faculty of Maritime and Logistics Studies in Elsfleth, which makes it the biggest maritime university in Germany. Its tradition goes back to the year 1832. The undergraduate degree course of Nautical Sciences and Maritime Transport is an eight-semester, full-time degree course which concludes with a Bachelor's of Science (BSc) degree.

The study course includes two seagoing service periods of 26 weeks each in the second and seventh semester in order to fulfil the demands of the STCW convention to issue the certificate of competency. In the first onboard semester, emphasis is placed on seamanship, basics in navigation and basic cargo handling operations. Whereas in the seventh semester, cadets should apply what they have learned by taking on the role of an officer of the watch under supervision. Besides, students sail twice for two weeks on a traditional training sail ship. The lectures cover a wide range of nautical subjects. Building on the basics, specific subjects follow which are related to commanding and loading a ship, subjects related to technical aspects as well as economics. Moreover, elective subjects are included in order to enable students to concentrate on specific areas. In the final semester, extensive exercises in the ship-handling simulator are carried out. The studies conclude with a bachelor's thesis.

3.2. EXEMPLARY CASE OF CHALMERS UNIVERSITY OF TECHNOLOGY

Chalmers University of Technology is located on the west coast of Sweden in the city of Gothenburg. The University was founded in 1829 which makes it one of Sweden's oldest. Out of roughly 10,000 students, 600 are enrolled in shipping related programmes at the Department of Mechanics and Maritime Sciences. Like Jade UAS in Germany, it is also Sweden's largest Maritime University. The education ranges from BSc degrees in nautical sciences (Master mariner), Shipping and logistics and marine engineering to full PhD programmes in marine technology. Chalmers also offers a wider range of continuous education for active seafarers.

The programmes are delivered over three or four years, depending on the programme. The programme leading to a certificate of competence according to the STCW conventions (four years) also includes four periods of onboard training (three months each). The periods of onboard training start with ship knowledge and familiarisation with the tasks of a rating, to then advance to more qualified tasks (those of second mate, chief officer and finally master). The classroom-based education follows different tracks, e.g. communication, leadership, navigation, cargo handling etc. The education also includes extensive training in various types of simulators. In their final year, students also have the possibility to specialize in one of the following categories: Cruise industry, Tanker (oil, gas and chemical) or Offshore industry.

3.3. DISCUSSION

Training to become a master mariner in northern Europe is an education mostly offered by universities or other bodies of higher education. Since the STCW convention regulates the curriculum, there are no major differences in the two examples. Also, the European Maritime

Safety Agency (EMSA) inspects and assesses providers of MET in Europe on a regular basis to safeguard a common standard of training within the European Union.

The differences can mainly be found in details, e.g. the way the onboard training is distributed throughout the years and what kind of specializations and courses can be elected outside the mandatory STCW competencies. Thereby, students are given the opportunity to set the course of their future career at an early stage for both their primary career at sea aboard seagoing ships, as well as in shore-based management positions as a second career.

4. CHANGE AND FUTURE DEMANDS OF MET

Megatrends (i.e. demographic change, digitalisation, climate change, mobility, etc.) will transform and reshape markets, societies and the global order, and they have therefore to be included in this discussion. Such megatrends lead to different developments in shipping: remotely controlled and/or autonomous ships, technology becoming more advanced, cost pressure and bureaucratic burdens rising, etc. All these factors cause an increased workload on board as well as the need for an MET which caters for these requirements. These developments may also cause different types of stressors in an officers' job as well as diverging levels of satisfaction, motivation, demands and resources. Moreover, we find typical stressors which influence seafarers' wellbeing on board as they live and work in one (small) place: these are isolation and loneliness, small crews and their small living spaces, fatigue and occupational health problems [12].

The purpose of this text is to explore future career paths as well as officers' reasons and factors which motivate or demotivate them to stay on board or to leave the sea behind [13]; the initial reasons for choosing a career at sea are not taken into account. Subsequently, the higher importance of an increased work-life-balance has to be considered [7]. Following up on this, the author group of the Aegean University [14] presents three alternative career paths: on board, on shore (which resembles a maritime company) and in port (which resembles a maritime business). Moreover, they present an equation of the ideal maritime industry employee: ideal employee = onboard experience + shore-based job experience. At the same time, persons undergo education on different levels: undergraduate, postgraduate, lifelong learning. In this article, emphasis is placed on the postgraduate level. However, this may also lead to a fluent transition to lifelong learning as graduates should have gained the ability to organise their own lifelong learning process autonomously upon completion of their master's degree studies. Building upon all this, it is now time to shed light on the two cases.

4.1. EXEMPLARY CASE OF JADE UNIVERSITY OF APPLIED SCIENCES

In general, after finishing their undergraduate degree, graduates can either start their professional career (at sea), or they can further their studies with a consecutive master degree course. A third way is to start the professional career and return to the university as "recurrent learners" in order to achieve a further (and usually higher) degree in the context of lifelong learning [15] by enrolling in a cooperative programme of work and distance education studies. Jade UAS offers two post-graduate degree programmes with 90 credit points according to the European Credit Transfer System (ECTS; each point equals 25-30 hours of student workload): Maritime Management (MM, three semesters full-time studies, on-campus) and International Maritime Management (IMM, distance learning). Although the contents of both

degree courses are similar to each other (they include aspects of maritime economy, law and insurance, project work as well as methodological aspects in order to develop problem-solving skills amongst other aspects and lifelong learning), the programmes differ with respect to the target groups they address as well as their concepts.

MM students proceed with their bachelor's studies consecutively at the maritime faculty and pursue their master's studies in Elsfleth. By contrast, IMM students are located around the globe while they study at the maritime faculty. The professionals are mainly junior managers in the maritime and logistics sectors – ashore as well as on board sea-going ships. IMM enables students to achieve a Master of Science (MSc) degree in five semesters' (2.5 years) part-time study without interrupting their work. The time taken may deviate; in case family or professional duties prevail, students can slow down or even pause their studies.

IMM is mainly based on distance learning, which enables students to study in a self-determined manner concerning pace, time and location. Moreover, students' projects and their day-to-day business can be included in the learning modules. IMM includes professional experience into students' studies in order to achieve practical value and mutual benefits: theory and practice go hand in hand. In line with that, the majority of the learning modules ends with a home assignment. However, some on-campus elements are added. The IMM students start in a first attendance phase, which serves mainly for familiarisation purposes. Later, students have to travel to Elsfleth in order to complete three learning modules throughout their studies by means of a written examination, a corporate strategic planning simulation as well as a presentation including a discussion. Studies conclude with a 30 ECTS credit points master's thesis. Moreover, professionally experienced students have prior knowledge acquired outside the sphere of higher education, which could be cross-credited into the studies in order to avoid repetition as well as to save time and costs. Moreover, a possible shortening can, for those with a limited time budget due to professional and/or family responsibilities, even facilitate the decision to study part-time and make it easier to plan this accordingly.

4.2. EXEMPLARY CASE OF CHALMERS UNIVERSITY OF TECHNOLOGY

The career path for the students interested in the maritime cluster varies a bit. The graduates in more practically oriented education areas, such as marine engineers and master mariners, are usually eager to initiate their career at sea. However, some choose to remain on land and continue their education. This also applies to the students attending programmes more oriented towards logistics and supply chain management. Chalmers attaches great importance to lifelong learning and offers a wide range of continuous education for active seafarers as well as two Master of Science programmes (two years, 120 ECTS credit points) aimed towards the student group. The two MSc programmes are Maritime Management and Naval Architecture and Ocean Engineering.

The Maritime Management programme is specifically aimed towards those persons who aspire to become future leaders in the maritime cluster. All persons with a BSc degree relevant to the maritime cluster are eligible to apply. Since the start of Maritime Management in its current form, it has mirrored the industry in being an international market very well. Last year there were over 200 applicants from all over the world.

The programme has a long history at Chalmers (since the mid eighties) and has over the years been delivered in many different forms. It started as a part time Master's programme of 60 ECTS to serve the need of sea-going personnel that wanted to acquire a new skillset to be attractive for onshore positions. The curriculum was later developed to encompass a full two years and was jointly developed by five Scandinavian maritime Universities under the name of Nordic Master in Maritime Management (NOMAR). NOMAR was given as a seminar-style programme with a combination of seminars and home studies. NOMAR was discontinued mainly because of administrative reasons, but the graduation rate of students was also problematic. Since 2013 it has been delivered as a full-time on-campus international Master's programme (time in class is usually 10-20 hours a week). Since it is a management programme by name and content, it is recommended that the students have acquired some work-life experience before entering the programme. Usually, there is a good mixture in the class of both ages and nationalities, which provides a great foundation for a thriving learning environment. Incorporating the more experienced students' experience into the teaching provides good leverage. The curriculum covers varied aspects of management and the programme design rests on three pillars: quality, sustainability and business acumen. The format of the examinations varies throughout the courses from traditional written examinations to home exams and project assignments; emphasis is put on teamwork skills. The programme finishes with a master's thesis worth 30 ECTS credit points, which is usually conducted with an industry partner.

Even if the programme is designed as a full-time on-campus education, some active seafarers try to combine these studies with part-time work, albeit with mixed results. One of the key motivations for persons attending the programme is shifting from a seagoing career to a land-based one but periods of training to achieve such a goal can put a considerable strain on their work-life balance. Usually, this group extends their study period to more than two years. The programme management is aware of the occasional problematic shift from work life to becoming a student again and are looking at possible options to solve this problem.

4.3. DISCUSSION

When it comes to the education at a master's level, the definition of MET undergoes expansion to its application to serve the STCW convention as it is not limited to the education of seafarers any more. The application scope goes beyond the organisation of transport chains in the modern world, which is driven by change, new trends and the need for lifelong learning. It demands the ability to react to all these factors. This is reinforced as the shipping profession is becoming increasingly complex in terms of social, economic and ecological factors. Therefore, lifelong learning and continuous education pose modern challenges for future trends in MET, as shown above.

The career path towards becoming a shipmaster consists of a theoretical and practical part. The theoretical part is covered by the BSc degree in Nautical Sciences (see above). After achieving the licence, the practical part commences with work on board for at least 24 months (without counting holidays) according to STCW. According to Eler et al. [16] the mean duration from achieving the captain's license until the actual promotion to the position of shipmaster amounts to some six years. However, in Germany and Sweden, most seafarers only work on board ships for a few years (in mean approximately some six to seven years),

after which they start a second career in shore-based management positions [17]. The work conditions on board, mainly the long absence phases from home, cause male and female nautical officers to see this work environment as incompatible with raising a family [18]. The active time as seafarers can be combined with further education without the need to give up the position on board [19].

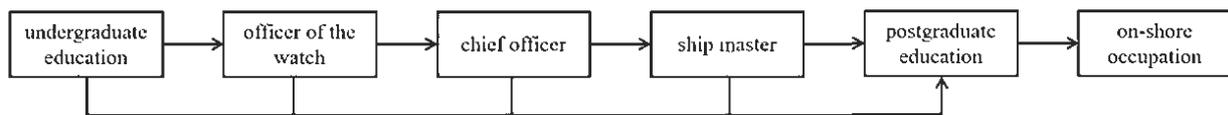
The similar situation sparked the development of postgraduate programmes in Sweden. The situation on board is usually referred to as a driving motivator for a change of career. Fewer crew on board, longer times away from home, increased demands on efficiency and turnaround and increased administrative workload are usually described as contributing factors [13]. As mentioned earlier, Maritime Management has been a postgraduate education programme at Chalmers for a long time and industry, academia and authorities have identified the need for such a training scheme. The aim is to ease the transition from a seagoing career to a shore-based one.

The maritime domain in Sweden employs roughly 150,000 persons while only about 2,000 of those are seagoing personnel. It is, therefore, reasonable to assume that there are several career paths available for persons interested in the maritime industry also after a sea-going career. On a global scale, 10 billion tons of goods are transported every year. The OECD expects the transport need to triple by the year 2050. The cruise industry and other types of passenger traffic are also developing positively, and there are no signs that the industry will decline.

5. SUMMARY AND CONCLUSION

The MET systems in Germany and Sweden have been introduced on both levels, the undergraduate level as well as the postgraduate level. They are quite similar, and the common motivator for students to continue their education is more or less the same. One of the significant differences in this context is that Jade UAS offers IMM as distance learning education, which enables the students to maintain an active seagoing career in combination with studies (see figure 1). There are pros and cons to both systems. One can argue that what one lacks in online education could be made up by the flexibility and adoption possibilities it provides. On the other hand, students may find going without a regular income, and focusing solely on their studies, to be unaffordable. It may also be that family reasons force them to study part-time and independently of time and place, e.g. in the evenings.

1) sequential alignment:



2) increasingly parallel setting:

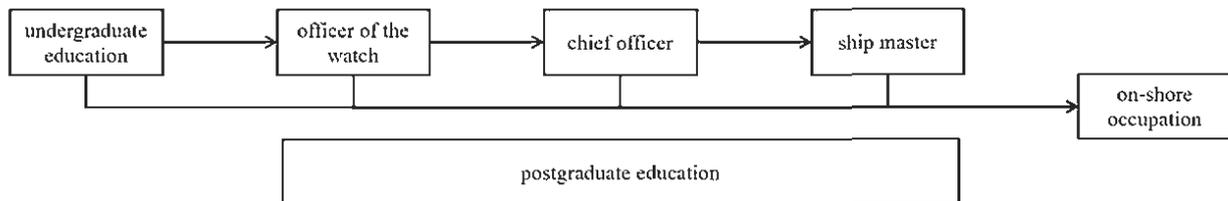


Figure 1: Sequential alignment versus increasingly parallel setting.

Moreover, in the past, we found an idealised understanding of the three phases of life, reaching from education (youth) through to work (middle age) to leisure (old age). Nowadays, this sequential alignment is no longer applicable, and it needs to be replaced by an increasingly parallel setting in terms of lifelong learning [20] as knowledge becomes increasingly out-of-date and obsolete faster and faster and therefore needs to be renewed regularly.

Building up on these results, future research could include a comparative analysis between the institutes from Germany and/or Sweden but also a country from another continent in order to analyse the possible impact of cultural diversity, similarities and differences.

Finally, transportation is one of the four pillars of globalisation [21] and all signs point toward an increase in European and worldwide transportation needs. With an industry employing more people than forestry and logging and air transportation combined, and with a total GDP contribution of € 145 billion [22], there is a clear need to provide a good educational regime for competent managers in the industry to cope with new challenges.

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Maritime Digitisation and Its Impact on Seafarers' Employment from a Career Perspective

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Keywords: maritime digitisation, seafarers' employment, career development, Industry 4.0

ABSTRACT

This paper discusses the potential implications of maritime digitisation and automation on seafarers' careers. While Industry 4.0 implies the modernisation of work in general, it is anticipated that Industry 4.0 will have an impact on seafarers' employment on board contemporary ships. Previous analyses of seafarers' work seem to focus on merely the 'present – future' scenario and overlook seafarers and their career trajectories. Based on an extensive literature review on careers in the global labour market as well as on Industry 4.0, the paper discusses how current career prospects among seafarers may be affected and what alternatives for employment they might have after graduating from maritime education and training (MET) institutions. The paper presents preliminary remarks on career opportunities for seafarers and possible socio-economic implications on future maritime careers in the context of Industry 4.0. It concludes with a set of agendas to support individuals and MET institutions in this transition.

1. INTRODUCTION

Ships have been the main means of delivering goods around the world for hundreds of years [1], and nowadays over 73 per cent of global trade (by volume) is done by sea [2]. Despite the endurance of this industry, roles and skills at sea have changed over the centuries [3, 4]; roles like radio officer and carpenter no longer exist, and roles like administrative officer and electrical technician that did not exist in the past exist now. In the era of digitisation with cyber physical systems, so-called "Industry 4.0", seafarers are increasingly expected to adjust and advance their skills to be more digitally inclined [5].

Industry 4.0 is spreading at a much faster pace in the wider supply chains [6]. In shipping, testing autonomous or unmanned vessels has been driven by the industry, which is creating controversy among various maritime stakeholders; the International Maritime Organization (IMO) is currently undertaking a scoping exercise of 'Maritime Autonomous Surface Ships (MASS)' [7]. If autonomous or unmanned ships are introduced, one of the most affected stakeholders would be seafarers who are responsible for operating ships on board [5]. Current debates tend to focus on the advancement of technologies, which has the potential to replace humans with machines through automation [8]. However, the majority of management practices tend to focus on the effects of organisations on the physical environment while

neglecting the human and social environment for sustainability [9]. This paper argues that the human element, and more specifically seafarers and their career prospects, would help a socio-economic sustainability of maritime industries by planning how to cultivate and utilise maritime talents.

To address these issues, the paper presents a literature review of Industry 4.0 in shipping as a background. The review is followed by a discussion of careers, addressing changes to the nature of careers over the past four decades. Finally, the paper examines the implications of increasing automation and digitisation of processes and roles in the shipping industry and possible implications for maritime education and training (MET).

2. INDUSTRY 4.0 IN SHIPPING

Humans have experienced several industrial revolutions since the late 18th century when water- and steam-powered machineries accelerated manufacturing of goods [10]. Shipping has benefitted directly from such technological developments in terms of improved ship design technology and increased trade across the oceans, followed by mass production during Industry 2.0 in the 19th century. In the 20th century when Industry 3.0 introduced the first computers and automation [10], shipping has significantly increased its volume of cargos and the opportunities of maritime careers, including sea- and shore-based jobs [11].

In every industrial revolution (see Fig. 1), some jobs are created and others lost; in this context, technology and employment often bring controversy in public debates. In the UK, Industry 1.0 resulted in the use of machines abolishing people’s jobs in the textile industry. Similarly, the previous industrial revolutions largely affected a single sector; for example, farmers were replaced by agricultural mechanisation. This is no longer the case with Industry 4.0, which has been moving rapidly across different sectors and at different skill levels. There are already signs of employment polarisation between low- and high-skilled non-routine jobs while jobs at medium skill levels have declined [2].

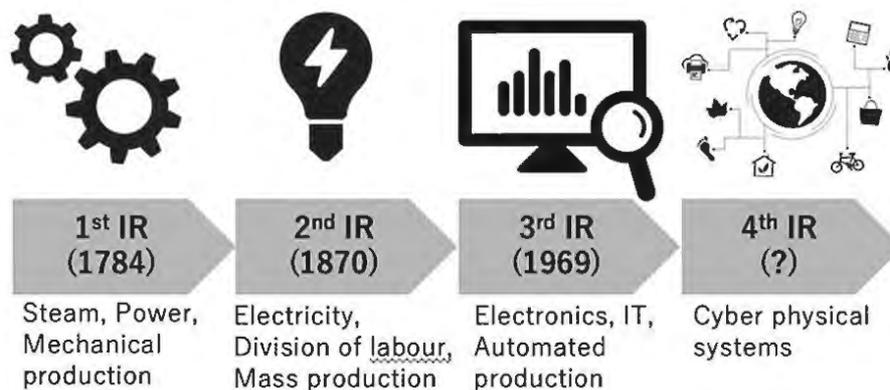


Fig. 1 A glance of Industrial Revolutions (Source: Authors)

Future maritime jobs and skills are becoming a major concern when it comes to implications of Industry 4.0 [5], such as cyber security, absence of regulations, and people’s lack of trust in technology [12, 13]. A recent WMU report identified gaps in new and emerging technology readiness between developed and developing countries as well as the need for training for seafarers to adapt and equip them with the new required skills, such as operations monitoring and system management [5]. Industry 4.0 will bring a paradigm shift whereby seafarers increasingly interact with machines and shore-based personnel. This

highlights the importance of leadership and communication skills in the context of ship operations in Industry 4.0 to facilitate human-machine and human-human coordination [14].

While this technology-driven trend ruling employment is one approach in the adaptation process to digitisation, there may be other ways to support digital transformation with a higher emphasis on humans than technologies. Technology-centred approaches are limited because of the lack of awareness of human potential to understand a whole system of work as well as the limited understanding of individuals' career perspectives/trajectories [15]. Kulikov argues that humans' cognitive skills humans are not merely there to reach abstract thinking but also to reach a deeper understanding of meaning [16]. Such human-centred approaches can be considered as an alternative to the currently dominant technology-centred approaches which attempt to replace humans with machines through automation.

3. CHANGING NOTIONS OF CAREERS

Within the framework of human-centred approaches, this paper focuses on how seafarers' future employment can be supported by career development perspectives. Seafarers' career prospects have changed over time [17] and this needs to be contextualised in wider employment practices across the industries. We begin with a review of the literature relating to careers from a historical perspective. Based on the examination of classical and modern notions of careers, the paper then provides a discussion on seafaring career trajectories and potential implications of digitisation on maritime jobs.

3.1. CLASSICAL THEORIES ON CAREERS

The notion of 'career' is based on the concept of bureaucratisation in organisations, dating back to the 19th century and developments in the industrial revolution [18]. For the purpose of this paper, 'bureaucratic' organisations are those deploying traditional employment practices, where workers retain an uninterrupted career in the same organisation for the duration of their working lives. A 'bureaucratic career' [19], often referred to as 'organisational' [20, 21], or as a 'traditional' [18, 22] career, involves a succession of positions in a strictly defined hierarchy [23], characterised by the logic of linear advancement, usually within a single organisation. Clarke notes how the concept of the bureaucratic career was implicitly present in Max Weber's theory of 'The Ideal Bureaucracy', featuring references to 'promotion based on technical competence' [21]. Additionally, in his book 'The Organisation Man', Whyte notes how workers with bureaucratic careers are not solely employed in a particular organisation but also belong to it [24]. In addition to the above characteristics, Merton indicates how bureaucratic occupations have a 'life-long tenure' and how they maximise 'vocational security' for individuals [25].

Individuals planning a 'career' are likely to make longstanding choices when it comes to the development of their knowledge and skills. Investment in training and skill development can be linked to the idea of the 'bureaucratic career', especially when it comes to an individual's career management. Most decisions relating to the management of bureaucratic careers are generally made by the employer [24], where the 'assignment of roles occurs on the basis of technical qualifications which are ascertained through formalised, impersonal procedures' [21]. In this case, employees would generally follow a mostly hierarchical route for advancement and would receive organisational support in their career development [25].

3.2. CAREERS AND SKILLS IN MODERN ORGANISATIONS

Changes to the classic model of careers started in the 1980s, when worldwide economic factors led to uncertainty and increased competition among international companies [17]. These changes occurred due to different factors, e.g. mass layoffs and the flattening of traditional hierarchies [19, 21, 26] which put pressure on organisations worldwide to ‘push for greater profits and be more flexible in contracting their employees’ [27]. These changes facilitated a greater flexibility in employment [27] and contributed to the rise of a new career model, often referred to as a ‘flexible’ [19, 21], ‘boundaryless’ [28, 29, 30, 31] or ‘portfolio’ [32] career. Unlike the bureaucratic career that is ‘conceived to unfold in a single employment setting’ [33], flexible careers break traditional assumptions about hierarchy and career advancement [34]. Flexible careers emerged as a retort by individuals to the diminishing availability of bureaucratic careers within organisations and to the breakdown of organisational support. Consequently, employees were faced with a ‘new era’ of employment, where they were inescapably responsible for their own fate, and where they could no longer rely on organisational support in the development of their skills and the provision of life-long employment.

It is evident that modern employment practices affected the notions of shore-based careers in terms of bureaucracy and flexibility; however, how can we understand the careers for seafarers? Based on the review of classical and modern notions of “career”, the next section addresses seafarers’ careers in this context.

4. UNDERSTANDING CAREERS FOR SEAFARERS

Seafarers are the main workers in shipping, and there are approximately 1.5 million seafarers operating the world’s fleet [35]. Before presenting the implications of Industry 4.0, we describe some of the changes in the shipping industry that had impacts on the nature of careers in shipping.

4.1. CHANGES TO EMPLOYMENT IN THE SHIPPING INDUSTRY

Several global processes influenced the shipping industry over the years which facilitated the shift to a more flexible work environment. Open registry of vessels is one important process which has impacted different aspects of employment within shipping; e.g. a growing search for economic labour to crew internationally flagged vessels by ship owners [36], an increasing use of third-party manning agencies to recruit seafarers [4], and an upsurge in the number of temporary contracts issued to seafarers [37, 38].

An additional cost-cutting practice that has become commonly used among ship owners is reduced investment in seafarers’ vocational training compared to the past [39]. In the past, training was provided to seafarers by their employers [40, 41, 42]; however, nowadays, most of the costs associated with training are borne by seafarers and their families [4, 39]. In line with the changes described, seafaring careers have become increasingly flexible and casualised, while at the same time maintaining some of the bureaucratic characteristics of employment.

4.2 A CAREER IN SHIPPING – COMBINING BUREAUCRACY AND FLEXIBILITY

Seafaring as an occupation combines some features of bureaucratic employment with

those of flexible employment [17]. Whilst hierarchical advancement is a major component of a seagoing career, presenting the option of a continuous career for some seafarers [43], seafarers are becoming increasingly mobile due to the aforementioned employment practices. Seafarers shift from company to company, vessel to vessel, and voyage to voyage in order to advance their careers [4, 39]. In this respect, seafarers might develop long-term careers at sea based on sporadic, temporary employment contracts as part of a ‘continuous’ employment trajectory.

4.3. AUTOMATION AND DIGITISATION IN SEAFARING CAREERS

We are seeing just the beginning of the effect of Industry 4.0 in the maritime sector. The extreme end of digitisation in shipping is often discussed through the narrative of autonomous ships or unmanned vessels which are slowly entering our lives. The world’s first all-electric container feeder from Norway, YARA Birkeland, will be fully autonomous by the end of 2020 [44]. The Mayflower Autonomous Ship Project is another attempt to cross the Atlantic Ocean by 2020 [45]. While these projects are eye-catching, the majority of existing vessels are still a long way from fully automated operations. Thus, it would seem that the human involvement in shipping is still required in order to operate the world’s fleet; however, seafarers’ skills and qualifications are likely to change in the foreseeable future.

Changing roles and skills required for seafarers in modern shipping are considered to affect seafarers’ career prospects. After a number of years of working at sea, seafarers often shift ashore to take shore-based jobs in areas such as ship survey, port management, maritime lecturing, maritime administrations, ship repair and marine equipment, marine insurance, ship broking and finance, ship classification, maritime law, and offshore work [46]. Faststreams surveyed over 2,000 maritime industry professionals, including 823 serving seafarers, regarding the differences between perception and reality about seafarers’ careers at sea and ashore. The report highlights the challenges experienced by seafarers when shifting to shore-based careers, not only due to the salary drop compared to their earnings at sea, but also abandoning the respect gained from a hierarchical ship work environment and assimilating to a completely different organisation of work from the beginning, and even possibly moving to cities with their families [47].

In addition to these challenges associated with seafarers’ career transition to shore, digitisation is expected to create an increased connectivity between ship and shore and an increased number of shore-based ship operations may become the mainstream [48]. Digital connectivity also opened up the emergence of new business models in maritime operations, for example, in Norway [14]. While new industry players participate in maritime operations, seafarers’ career trajectories may inevitably expand outside the traditional maritime industrial spheres to include work in other industries.

5. CHALLENGES IN MET INSTITUTIONS TO SUPPORT SEAFARERS’ CAREERS

The minimum standards for seafarers’ certifications are internationally regulated under the international convention on Standards of Training, Certification, and Watchkeeping (STCW) [37, 39]. If the industry demands a new set of skills, this is likely to raise questions in MET with respect to training based on the minimum standards sufficient to guarantee seafarers’ employability. Such anticipation by MET institutions is inevitable; however, as long as the

STCW convention remains the same, maritime administrations will not have adequate justification to advise MET institutions to change their curricula. Additionally, even if future maritime skill sets were possible to predict, it would be challenging for educators to ensure their students are appropriately equipped for their maritime careers at sea and ashore.

Furthermore, MET continues to upgrade seafarers' knowledge and renew their certificates regularly while on shore leave. As the costs for maritime education are generally borne by seafarers [4, 17], the general flexibilisation of labour among seafarers working in the global labour market, MET's role in supporting seafarers' careers in Industry 4.0 remains in question.

6. CONCLUSION

The paper reviewed the literature on digitisation and automation within and beyond the maritime industry and identified the limitations of a technology-centred approach, thus suggesting the inclusion of a human-centred approach, including the consideration of seafarers' careers.

While emerging maritime job opportunities require digital skills linked to operations monitoring and system management, there seems to be a gap between the minimum standards of STCW and the advanced digital skills to ensure seafarers' employability. This would pose a new challenge for MET institutions globally. In addition, due to the bureaucratic and flexible careers practised in shipping, the responsibility for career development tends to be carried by individual seafarers. This problem also relates to MET in terms of how MET institutions can support seafarers' career development as life-long learning providers. The paper argues that the responsibility for adaptation to Industry 4.0 should not be placed solely on seafarers but on other stakeholders, including shipowners and other industry players, governments, and MET institutions, in order to strategically design future maritime career opportunities to build capacity for the sustainable maritime industry.

The discussions presented in this paper are limited to literature review only. Future studies can be empirically developed to investigate seafarers' possible career trajectories as well as MET funding issues to support seafarers' career development in the era of Industry 4.0.

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Maritime Innovation Management – A concept of an innovative course for young maritime professionals

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ABSTRACT

Rapid developments in the maritime sector state the need for MET institutions to provide future young maritime professionals with a new set of competencies to enable their participation in innovation processes in the maritime cluster. Four MET institutions took part in a one-year project to tackle this issue and to get an insight into the current situation regarding maritime innovation management and accompanying needs for the future. The results details the educational needs and an educational approach covering a subject and delivery plan, the input from local and global academic and industry experts, and cross-border and cross-sectorial cooperation. The approach incorporates the competencies of students, academia and the maritime sector in a course combining the aspects of e-learning and classroom activities in an international platform.

1. INTRODUCTION

Young maritime professionals entering the labor market in the upcoming years will be part of the rapidly developing maritime industry and will be working with novel solutions throughout their careers. Autonomous ships, "smart" port operations and new environmental and safety considerations are just a few examples that will impact both the individual maritime professional and other maritime industry actors, as well as how they relate.

In response to the growing interest in innovative management and lifelong learning, the idea was born to develop a new blended-learning concept to empower young maritime professionals to be active change agents throughout their careers.

In the light of current developments, it is recognized that the established standards for Maritime Education and Training (MET)[8] do not focus on equipping young maritime professionals with the competencies to be active agents in a context of rapid change where different types of problem-solving strategies and innovation processes are needed.

This manuscript reports on the first results of a project with the objective to develop a university level course in Innovation Management in the maritime sector for young maritime professionals. The course will be based on the assumption that innovation is increasingly driven

in open and dynamic networks of people with complementary competencies, where professionals from industry, academics, and civil servants need to find spaces and approaches to come together - in what can be referred to as a triple helix approach as described in the following section 2. The project explores two questions: what educational topics and what educational approach can build young maritime professionals capacity to participate in maritime innovation?

Section 3 describes the empirical research approach. Section 4 reports on the result of our findings. Section 5 summarizes and describes future directions of the project.

2. RELATED WORK

2.1. A TRIPLE HELIX APPROACH TO INNOVATION

A Triple Helix approach denotes how the interaction among universities, industry, and the government is key to innovation and growth in a knowledge based-economy [1]. Traditionally, industry is a key actor as the locus of production, government provides a base for contractual relations that guarantee stable interactions and exchange, whereas universities are focused on teaching and generation of new knowledge through research. The Triple Helix approach recognizes how these traditional spheres are in flux with e.g. elimination of clear dividing lines between science and business. In this new landscape, the universities play a central role in innovation through an extension of the traditional teaching and research mission in academia into a new focus on economic and social development to identify new spaces for science-based innovation and growth. This includes top-down policy and program development and bottom-up community development, where people find new ways of interacting in their work- and daily life [1] [2]. In this project, students at MET institutes as young maritime professionals are in focus in the triple helix relation and how they can be equipped with competences for maritime innovation management.

2.2. BLOOM'S TAXONOMY

To guide the inquiry of how to develop a university course to address maritime innovation management, the seminal work of Bloom's taxonomy [3] has been referred to. Bloom's taxonomy describes the development of intellectual skills ranging from recalling and understanding basic facts and concepts, to applying and analyzing concepts and information, and finally evaluating and creating new or original work [3]. In guiding the objective of designing a course on innovation management, it was relevant to inquire how the students could acquire a basic understanding of topics such as entrepreneurial skills to participate in open and dynamic innovation networks (e.g. the Industry 4.0 impacts to the maritime industry). Furthermore, it was relevant to inquire about how the students could be empowered to become active agents in applying those concepts and creating new solutions.

2.3. SOCIAL LEARNING AND E-LEARNING

This project, in particular, investigates how different educational approaches of social learning can be used in a course about maritime innovation management. E-Learning is at the top of UNESCO's agenda of re-thinking education for the twenty-first century empowering people

to participate in societal, economical, and environmental change [4]¹. “Online collaborative learning” [7] as one of the established and documented social-learning theories, emphasizes three key aspects related to social learning: Idea generating to collect divergent thinking within a group; Idea organizing where learners compare, analyze and categorize their ideas through discussion and argument; Intellectual convergence with the aim of intellectual synthesis and developing a common understanding.

Social learning, understood in this way, highlights several considerations for a successful outcome, including the need for appropriate technology; clear goals; choice of appropriate topics; defining learners roles and expectations; monitoring participation; regular ongoing instructor presence. These dimensions and others need to be understood in the educational and technical design of, for example, a course or a program.

3. RESEARCH APPROACH

This manuscript reports on the results of a one year project funded by the Swedish Institute with the aim of exploring maritime innovation and growth processes, starting with competence development and life-learning processes from students and young maritime professionals point of view. The project focuses on the capabilities of MET institutes to serve as a central actor in the maritime cluster to support these processes. Four partners have been part of the project: World Maritime University in Sweden, Gdynia Maritime University in Poland, National University "Odessa Maritime Academy" in Ukraine, and Estonian Maritime Academy in Estonia. The project relates the European Union ERASMUS program framework of Strategic Partnerships in the field of Education, Training, and Youth. The analysis of three project activities constitute the empirical results that are reported in the following section:

- **An industry and student surveys** were carried out in the early stage of the project to understand the issues and the potential of maritime innovation from the perspective of the maritime cluster surrounding the partner universities and students. The results of the survey were used as an input to the partner workshops and the design of the student participatory workshop.
- **Partner workshops** were organized at each of the partner universities to localize the understanding of issues and potential solutions. As a result, potential educational topics and approaches from both the individual universities perspective as well as ideas of joint collaboration were established;
- **A student participatory workshop** with representatives from participating institutions aimed to gain students perspective on maritime innovation management. The students were asked to analyze the Strengths, Weaknesses, Opportunities, and Threats (SWOT) of Maritime Innovation Management from the perspective of their competence development, as well as come up with possible solutions.

4. RESULTS

¹ Of relevance to this stud a connection can be made between triple helix approach to innovation and sustainable development [5]

This section reports the results of the main project activities about the educational needs and how to design a university course to build young maritime professionals' capacity in maritime innovation management.

4.1. EDUCATIONAL NEEDS

The initial survey results indicated that a course on maritime innovation management is found relevant. It is taken as a high-level indication on current issues and needs the maritime industry and students are facing with respect to maritime innovation management. The results from the student participatory workshop provided a ground perspective about what educational topics are needed and how they should be taught. Figure 1 shows the outcome of the SWOT analysis and rich mapping that the students used to present their results.



Figure 1. Results from the students' workshop. SWOT Analysis, Risk Matrix and Lifelong learning perspectives in MET.

The key findings can be understood in three parts: In the first part, the students were asked to critically explore how they as young maritime professionals were equipped with competences to participate in the rapid development of the maritime industry that they will face throughout their careers. The students sensed opportunities with the development of the maritime industry, but perceived that it was a threat that they were not equipped with the competencies to participate in that development, ranging from the lack of topics to outdated teaching approaches and platforms (where for example e-learning was still a novel occurrence). In the second part, the students were asked to prioritize the outcome of the SWOT analysis in regard to consequences and probability. The result furthermore detailed how the students at the end of their studies lacked competencies for professional skills like teamwork, self-presentation, problem-solving, especially given the international nature of the maritime industry. They also lacked a systematic understanding of e.g. new trends in the maritime industry and the impacts of new technologies. In the third part, the students were asked to create a rich-picture exploring

an educational solution to the prioritized issues. Combined with the outcome of the partner workshops, the result gives evidence to how the MET institutes, generally, are well positioned to provide competence development relevant for maritime innovation management, e.g. through having good contact with shipping companies and with graduates. Potentially this could enable the students to learn from each other via experience-sharing and real-life examples, beyond textbook examples and hypothetical cases. However, it was perceived that the MET universities were not taking advantage of this possibility very often.

In summary, the MET institutes could do more to equip their students with the necessary competencies to participate in the rapid development of the maritime industry, and seize the opportunities available to them. At the same time, it is important to note the necessity to be sensitive to the differences between the MET institutions and the room for improvements.

4.2. EDUCATIONAL APPROACH

The design of an educational approach is the outcome of the partner workshops and is based on the outcomes of section 4.1. This section describes the current educational approaches, the potential of new collaborative educational approaches between the MET institutions and the provisions of new educational techniques. Figure 2 summarizes the results, combining the educational approach, subject and delivery plan.

<p>Module 3 – Blended-learning (Evaluate, Create)</p> <p>Students evaluate their local cases together with students and professionals from other universities and organizations. Creation of new solutions and insights</p> <p>Students upload their local cases in the distance-learning platform for joint reflection and feedback thorough forums and webinars</p>
<p>Module 2 – Classroom learning (Apply, Analyze)</p> <p>Apply conceptual knowledge in relation to local cases and students own challenges and opportunities</p> <p>Students work with local instructors</p>
<p>Module 1 – Distance-Learning (Remember, Understand)</p> <p>Conceptual understanding of Maritime Innovation Management, theories, frameworks, and cases</p> <p>Distance-learning: recorded lectures and e-lessons with Global and local industry and academic experts</p>

Figure 2. Blended-learning delivery approach

4.2.1. SUBJECT AND DELIVERY PLAN

A subject and delivery plan was designed to combine the educational needs highlighted in the previous section with the educational approach. The partner workshops indicated how a course structure in three sections may be foreseen. First, a fully distance-learning part where students collaborate in transnational teams around basic concepts and theories as well as practical aspects of Maritime Innovation Management using an e-learning platform. This is followed by students working in local innovation teams in collaboration with a local maritime company. Finally, the course will once again move into the e-learning platform and a blended-learning format where the student teams present the results of the innovation processes online and evaluate each other's outcomes. This subject and delivery plan concept is innovative in the sense that no similar syllabus or course concept for Maritime Innovation Management exist already.

4.2.2. LOCAL AND GLOBAL ACADEMIC AND INDUSTRY EXPERTS INPUT

Although the results from the project indicated the existence of capable instructors in MET institutions, it was also highlighted how their capacity needs to be developed to cater to a new innovative subject as Maritime Innovation. The innovative design of the proposed course develops the teaching capacity of local instructors with global academic and industry experts. The core part of the digital section of the course will be the e-lessons presented by global and local academic, as well as industry experts. A platform containing materials like video lectures, reading materials, etc. enable students from different geographical locations to take part of the same lectures on their own time and they may also return to any lectures as they need during the course.

4.2.3. CROSS-BORDER AND CROSS-SECTORIAL COOPERATION

Taking into account the international nature of the maritime sector (as also stated in 4.1) it is important to provide the students with opportunities for cross-border, as well as cross-sectoral collaboration experience already during the studies. To enhance the quality of offered courses the cooperation between different MET institutions is considered the key aspect in the stage of development and delivery of the innovation management course. Engaging students, academia, the maritime industry, and the private sector in the real-life innovation processes at an international level could be an effective solution to stimulate sectoral development. Incorporating different relevant stakeholders in the educational process and innovation management increases the competitiveness of young maritime professionals in the labor market.

5. CONCLUSION AND FUTURE DIRECTIONS

The results of the project show the educational needs and an educational approach for a joint transnational course on Maritime Innovation Management. The outcome shows that students see potential with the developments of the maritime industry, but at the same are concerned that they lack the competences to participate in this development. The outcome of the surveys and student participatory workshops show that the students would like better education in current trends and the impact of e.g. the rapid technology development facing the maritime industry. They furthermore called for better possibilities to develop their problem-solving skills, team-working, and self-presentation in an international context, given the inherently international nature of the maritime industry. The results showed how there was a call for developing these competencies through collaboration: collaboration between students at different maritime universities, and collaboration with the maritime industry. The partner workshops gave an understanding of how a blended-learning educational approach could be developed to meet these educational needs. The educational approach is based on social learning and an online collaborative learning approach where the students both get to improve their understanding of concurrent topics through e-lesson by academic and industry experts, but apply their knowledge on local cases relevant to them and work together to analyze the results and create new solutions. This constructionist approach is innovative in MET as well the transnational and digital dimensions of the course.

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Current trends in the maritime profession and their implications for the maritime education

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Keywords: maritime education, trend survey, transformation processes, optimization

Abstract: The paper presents the current trends in the seafaring profession and their educational dimensions. The initial thesis is that different maritime specialists perceive and interpret trends in different perspectives. The study presents an overview of trends in the maritime professional sphere in order to classify them regarding their origin and possible consequences. The research includes a survey on already formulated trends, causes and consequences. Based on the empirical research the results are analyzed in order to define which trends and areas are characterized by more consensus and which trends and processes are characterized by differences in the opinions of the evaluated target groups. The study provides recommendations for adapting the maritime education to the current trends.

1. AIM OF THE STUDY AND METHODOLOGY

The **aim** of this study is to identify current trends and motivations in the maritime profession, such as working onboard a ship as well as working in a shipping company, and the differences in these trends depending on the working experience of the respondents.

1.1. SURVEY RESPONDENTS

The survey includes 132 participants who live in Bulgaria between 25 and 40 years old. Of these, 57 work on a ship (as a crew in a shipping company or on a Navy ship) and the rest are engaged in maritime jobs on the shore or in academic institution (Fig.1 and Fig.2). 123 respondents state that they know the trends in the maritime profession well and very well, and the rest believe they know them poorly according their work experience (Fig.3).

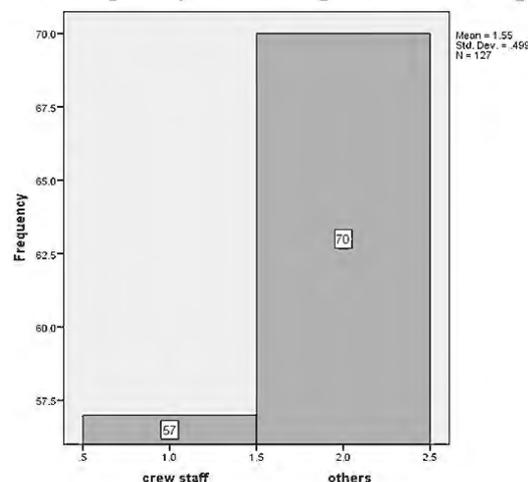


Fig.1. Job occupation

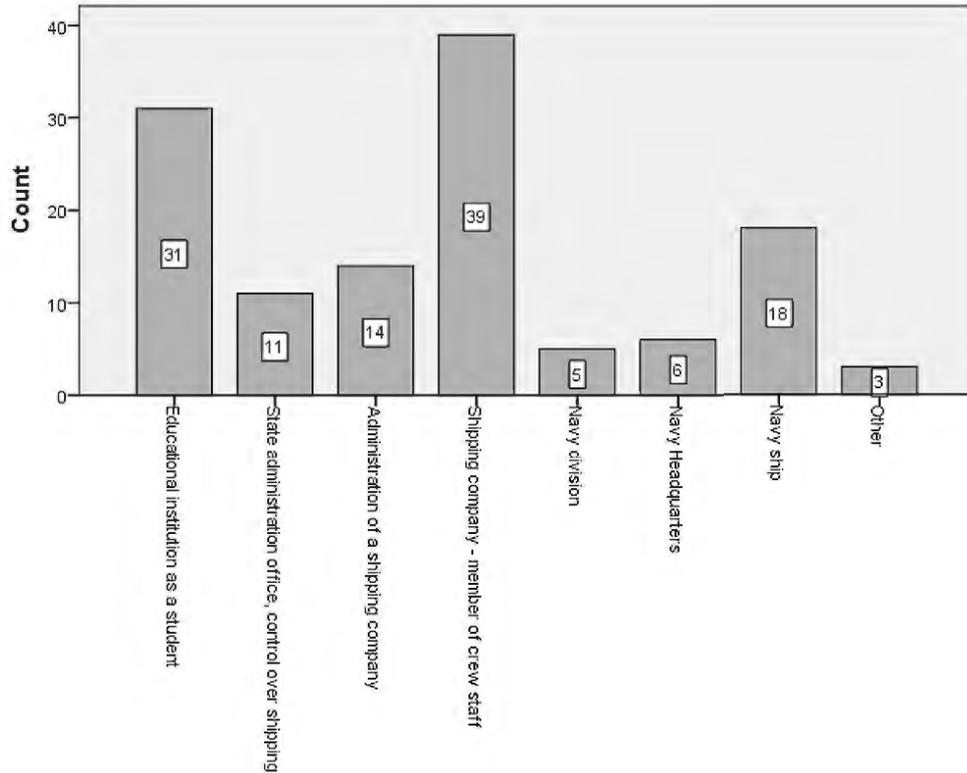


Fig.2. Job position

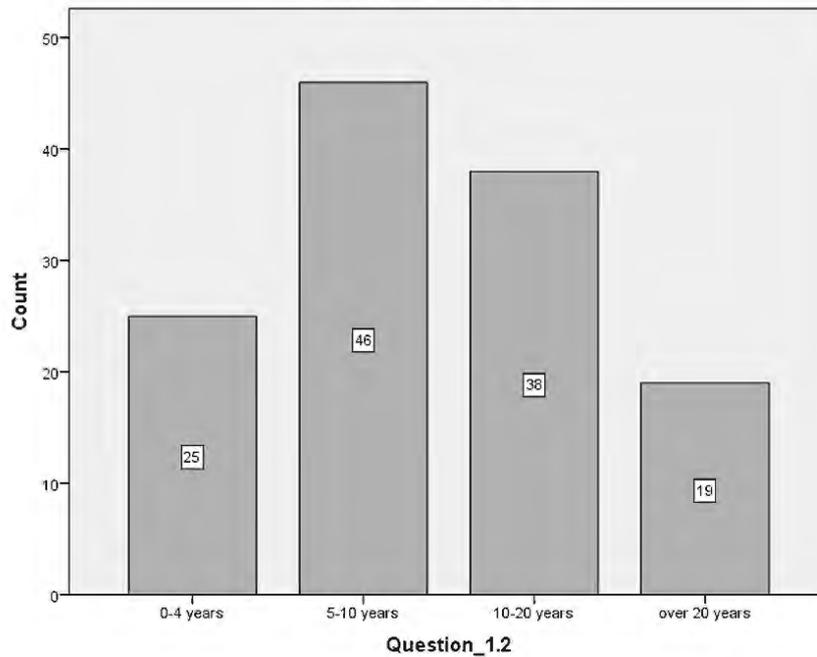


Fig.3. Job experience

Respondents answered to five sociodemographic questions, to 22 questions studying the trends in the seafaring professions according to the Likert 5-point scale, and 5 questions according the Likert's 5-point scale related to ship's motivations for work. The data were collected during the first six months of 2019. The anonymity of the surveyed persons is preserved.

1.2 STUDY DESIGN AND CONDUCT

In order to research whether the 22 questions from the scale of trends in different maritime occupations for ship work formed a reliable scale [1], the Cronbach coefficient alpha was measured. The reliability of the trend scale is $\alpha = 0.855$ for the entire sample $N = 132$. In statistics, it is assumed that the Cronbach alpha α ratio greater than 0.7 is reliable. Therefore, the presented questionnaire is reliable for the surveyed sample.

In studying whether the five issues related to changes in motivation of the seafaring profession onboard a ship form a reliable scale, the Cronbach's coefficient alpha is $\alpha = 0.796$ for the entire sample $N = 132$, ie. The scale that explores the motivation is reliable.

In order to check the constructive validity of the two scales for the analyzed sample, a confirmatory factual analysis of the issues related to trends in the seafaring profession and questions concerning the motivation of the maritime professions was carried out. The data were analyzed by the Varimax (Varimax) rotation method with Kaiser normalization.

The survey also explores the change in motives for practicing maritime jobs onboard a ship. The main factors motivating the work are investigated:

1. Financial motivation;
2. Good career perspectives;
3. Opportunity to visit foreign countries;
4. Motivation stemming from the "passion and romance of the sea";
5. Prestige of the profession in society.

In order to verify the hypothesis that the arithmetic value of the responses to the trend survey [2] for the two groups: onboard and offshore is equal, independent-samples t-test of Student and one-factor ANOVA dispersion analysis were carried out.

The study consists of two scales that analyze the trends and motivations in the maritime professions onboard a ship and on the shore. In the course of its conduct the differences in the attitudes of respondents to the questions depend on the maritime profession they exercise and the period in which they have the impression and experience of the seafaring profession.

On the basis of the conducted statistical study, the following main trends were highlighted using Varimax's rotation method with Kaiser normalization:

1. *Increased development and implementation of information technology.*
2. *Leadership and team management skills.*
3. *Diversity management skills and project development know-how.*
4. *Standardization of the seafaring profession and related qualification training.*
5. *Administrative, economic, legal know-how and stratification of the maritime profession.*
6. *Integration of the maritime transport and involvement of specialists with different „not maritime" education.*
7. *Image decrease of the maritime profession in the well-developed countries and remote management of the activities from the shore.*

The obtained results show that the applied methodology for determining the trends in the seafaring profession is reliable and constructively valid for the given sample. This allows further statistical analysis.

2. RESULTS

2.1. RESULTS OF THE COMPARATIVE STUDY ANALYSIS OF TRENDS IN THE MARITIME OCCUPATIONS ONBOARD A SHIP AND ONSHORE

With regard to **Trend 1 „Increased development and implementation of information technology”** it was found that there was no statistically significant difference between the arithmetic mean values for ship’s occupations ($M = 4.42$, $SD = 0.865$) and onshore occupations ($M = 4.29$, $SD = 0.806$), $t(124) = 0.88$, $p = 0.892$. The magnitude of the difference in the arithmetic mean ($d = 0.156$) is less than the typical magnitude of the effect, according to Cohen [3]. Both groups of respondents consider that IT skills take an increasingly important role in maritime professions (Fig.4). The weak difference between the two groups of respondents leads to the conclusion that all have already realized the need to use modern information technologies, both in the maritime professions onshore and for the ship occupations.

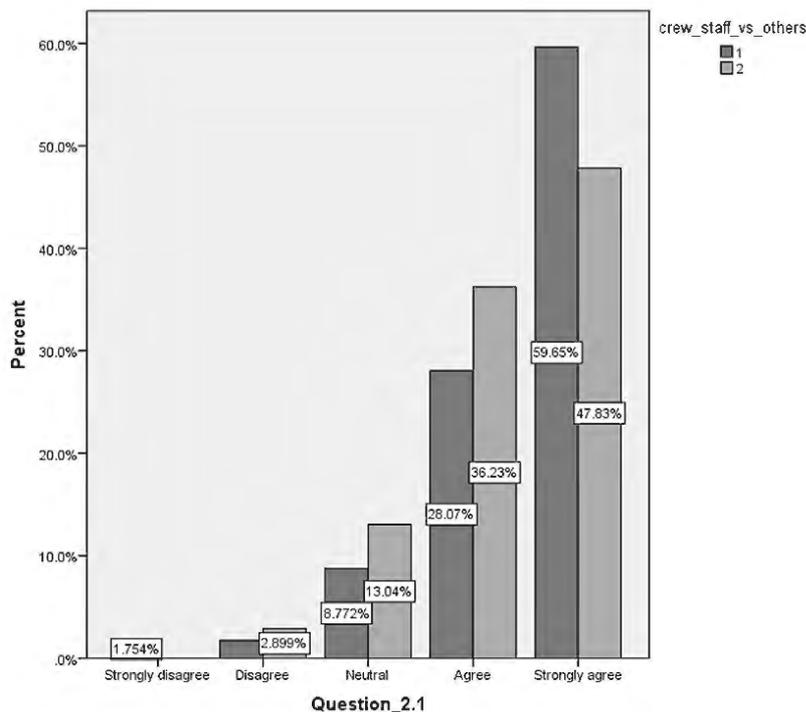


Fig.4. Trend 1 answers of crew staff and others

In the one-factor analysis of the issues related to **Trend 2 „Leadership and team management skills”**, no statistically significant difference was found in the answers to the questions. Both groups – working on a ship ($M = 4.61$, $SD = 0.648$) and on the shore ($M = 4.60$, $SD = 0.602$) are on the same opinion that teamwork is increasingly important in the seafaring profession. The requirement to have leadership skills at the present stage also increases, according to the two groups surveyed, for the occupation on a ship ($M = 4.54$, $SD = 0.683$), and on the shore – ($M = 4.31$, $SD = 0.778$). Small-team management skills have also been reported to have been rising recently for shipboard naval professions ($M = 4.51$, $SD = 0.658$) and on shore – ($M = 4.43$, $SD = 0.719$). Respondents believe that the development of maritime transport is becoming more and more important in solving complex problems for shipboard occupations ($M = 4.58$, $SD = 0.755$) and on shore – ($M = 4.50$, $SD = 0.680$). They consider

that communication skills in maritime professions are increasingly important – for the naval professions on a ship ($M = 4.44$, $SD = 0.780$) and on the shore – ($M = 4.44$, $SD = 0.799$). Nowadays, it is recognized that the role of the human factor is increasing. This fact requires from the relevant academic institutions to train staff with leadership skills, good communication and teamwork skills.

One-factor analysis of **Trend 3 issues „Diversity management skills and project development know-how”** did not provide a statistically significant difference in respondents' answers. They consider that there is a growing need to have the skills to handle cultural diversity – for maritime personnel on a ship ($M = 4.00$, $SD = 0.991$), and on shore – ($M = 4.23$, $SD = 0.843$). In the context of increasing numbers of women who have chosen maritime professions, according to respondents, there is a growing need for skills to deal with gender differences ($M = 3.64$, $SD = 1.135$) and on shore ($M = 3.71$, $SD = 1.177$). They report that there is a growing need for critical thinking among all maritime professions – for shipboard naval professions ($M = 4.43$, $SD = 0.710$) and on shore – ($M = 4.28$, $SD = 0.899$).

The survey shows neutral opinion about the need for project management skills both for onboard personnel ($M = 3.43$, $SD = 1.059$), and on the shore – ($M = 3.30$, $SD = 0.960$). An increasing number of ship crew and onshore companies are required to work in a multicultural environment, which creates communication challenges. It is inevitable that conflicts and specific problematic issues may arise in an working environment with cultural diversity. The increasing number of women in the maritime professions requires training and additional gender management skills as well. It is a fact that crews consist for the most part of different nationalities, religions and gender. The need for diversity tolerance is recognized by almost all respondents.

The one-factor analysis of **Trend 4 „Standardization of the Seafaring Profession and Related Qualification Training”** also did not show a statistically significant difference in the responses of the surveyed groups. Naval staff on a ship ($M = 4.14$, $SD = 1.034$) and on the shore ($M = 4.34$, $SD = 0.683$) believe that the dynamics of technical development and the standardization of professional requirements increasingly require courses to update training. The two groups of respondents consider that the standardization of the profession is increasing in the modern times – for the naval professions on a ship ($M = 3.71$, $SD = 1.004$) and on the shore – ($M = 3.72$, $SD = 0.774$). The maritime professions follow the dynamics of the technical development of maritime transport and there is no doubt that it is necessary to attend courses to update professional knowledge.

The analysis of **Trend 5 „Administrative, economic, legal know-how and stratification of the maritime profession”** again did not show a statistically significant difference in respondents' answers. They consider that administrative activities occupy an increasing part of working time for the staff on a ship ($M = 4.45$, $SD = 0.592$), and on the shore – ($M = 4.29$, $SD = 0.799$). The growing need for economic knowledge of commercial processes has also been reported by all surveyed practitioners onboard ($M = 3.63$, $SD = 0.885$) and on shore – ($M = 3.46$, $SD = 0.919$). The two groups of respondents agree that at the present stage the legal knowledge is increasingly important for the ship's naval professions ($M = 3.63$, $SD = 1.071$) and on the shore – ($M = 3.64$, $SD = 1.017$).

Onboard ($M = 3.00$, $SD = 1.307$) and shore personnel ($M = 2.94$, $SD = 1.299$) expressed a neutral view of the statement that seafaring is highly segmented and new jobs occur in

addition to traditional ones. Neutral opinion is given by the respondents from the two groups also regarding the claim that there is a „stratification” of the seafaring professions – for the maritime professions on a ship ($M = 3.25$, $SD = 1.148$), and on the shore – ($M = 3.14$, $SD = 1.149$). In the current transport developments, it is increasingly necessary for maritime professionals to have broad knowledge in the area of economics, administrative activities and law. Respondents believe that maritime professions should have the necessary training to cope with these new requirements that are being currently imposed on them. The survey showed that there is no need for opening new positions or maritime professions, and that qualified seafarers need to acquire the necessary knowledge in these fields during their education.

The one-factor analysis of respondents’ answers to questions related to **Trend 6 „Integration of maritime transport and involvement of specialists with different „non maritime” education”** showed no statistically significant difference. They expressed a neutral view of the assumption that in the maritime business staff with non-maritime education is increasing – for seafaring naval professions ($M = 2.91$, $SD = 1.299$) and on shore – ($M = 3.09$, $SD = 1.276$). This is also their opinion with regard to the statement that transport is getting more and more integrated and the segregation of maritime and other kinds of transport is diminishing – for shipboard naval professions ($M = 2.82$, $SD = 1.136$) and on shore – ($M = 3.06$, $SD = 1.113$). The respondents do not appreciate the existence of this trend in the development of maritime transport.

No statistically significant difference was found for the two surveyed groups in the answers to the questions related to **Trend 7 „Image decrease of the maritime profession in the well-developed countries and remote control of maritime operations”**. They consider that the prestige of seafaring professions is declining in developed economies – for the naval professions on a ship ($M = 3.55$, $SD = 1.292$), and on the coast – ($M = 3.55$, $SD = 1.388$). Respondents from both groups expressed a neutral opinion regarding the statement that an increasing number of management and maintenance processes and control of technical parameters are carried out remotely from the shore – for the maritime staff on a ship ($M = 2.79$, $SD = 1.155$), and on shore – ($M = 3.16$, $SD = 1.134$).

The trend survey among ship and onshore professionals showed that the two groups of respondents had no differences in terms of the considered trends.

2.2. RESULT OF THE COMPARATIVE STUDY ANALYSIS STUDY OF THE TRENDS IN THE MARITIME PROFESSIONS ACCORDING TO THE TIME OF WORKING EXPERIENCE

A one-factor analysis of the trends in the maritime profession for staff on a ship is carried out for three groups according to their experience in the seafaring profession. The first group has an experience of 0 to 4 years. It mainly includes students. The second group has an working experience of 5 to 10 years and the third is with experience of more than 10 years.

In the analysis of **Trend 1 „Increased development and implementation of information technology”**, a statistically significant difference was not found between the three groups – for the first group ($M = 4.35$, $SD = 0.847$), for the second group ($M = 4.38$, $SD = 0.871$), and for the third one – ($M = 4.23$, $SD = 0.297$), $F(2, 113) = 0.136$, $p = 0.873 > 0.05$. All respondents, regardless of their working experience, believe that the use of modern information technology is necessary, both in the maritime professions onshore and onboard the ship.

A one-factor analysis of the issues related to **Trend 2 „Leadership and team management skills”** found a statistically significant difference in respondents from the three groups on the need for leadership skills $F(2,112) = 3,442, p = 0.035 < 0.05$. The magnitude of the effect $n = 0.24$, which is calculated using the coefficient e , is average or typical, according to the interpretation made by Cohen [3]. A Tukey HSD post-hoc test was used to show that the arithmetic mean for the third group ($M = 3.92, SD = 0.76$) was statistically significantly different from the arithmetic mean of the first group ($M = 4.49, SD = 0.697$) ($M = 4.47, SD = 0.671$).

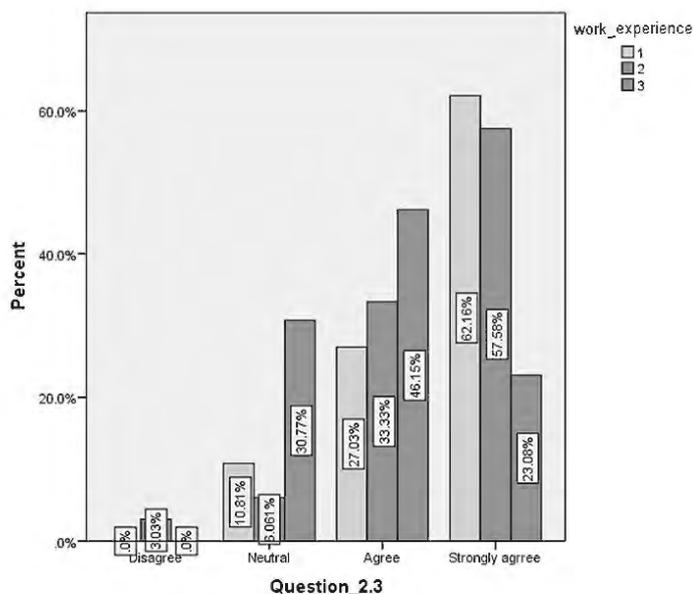


Fig.5. Trend 2 answers according work experience

This fact has a logical explanation because the third group includes maritime personnel with more than 10 years of experience who hold management positions and definitely understand and practice leadership skills. The first two groups have only indirect observations on the question. For this reason, it was statistically confirmed that there is no difference in their attitude on this issue (Fig.5).

After analyzing the answers to questions related to **Trend 3 „Diversity management skills and project development know-how”** there were no statistically significant differences for the three groups.

In analyzing the answers to the questions of the respondents concerning **Trend 4 „Standardization of the seafaring profession and related qualification training”**, a statistically significant difference was found between the three groups regarding the need to attend qualification courses for training update $F(2,111) = 3,870, p = 0.024 < 0.05$. The magnitude of the effect $n = 0.255$, which is calculated using the coefficient e , is average or typical, according to the interpretation made by Cohen [3]. A Tukey HSD post-hoc test was used to show that the arithmetic mean for the third group ($M = 3.62, SD = 1.121$) was statistically significantly different from the arithmetic mean of the first group ($M = 4.29, SD = 0.801$) ($M = 4.35, SD = 0.839$).

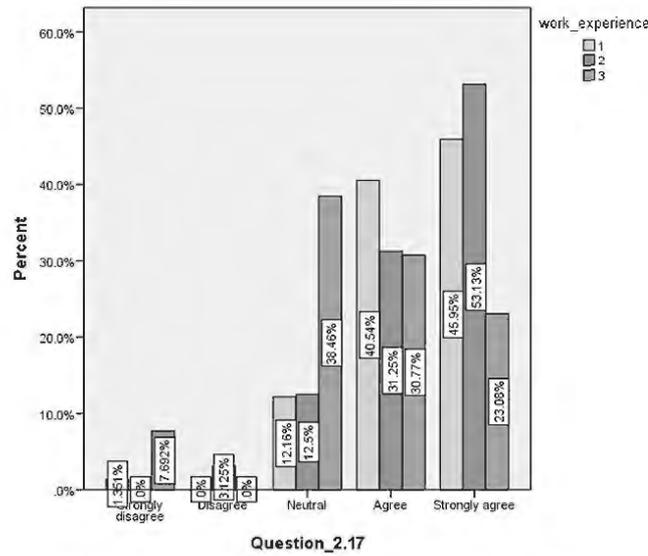


Fig.6. Trend 4 answers according work experience

The results can be interpreted in two assumptions.

- Respondents with more than 10 years of experience believe they have attended enough such courses and have gained practical experience and therefore the need to update their training decreases (Fig.6).
- The reason for the differences with regard to this issue can be found in the frequency of conducting qualification courses and the higher requirements of the experienced people regarding the quality of the conducted courses.

The one-factor analysis of **Trend 5 „Administrative, economic, legal know-how and stratification of the maritime profession”** showed no statistically significant difference in respondents from the three groups, but the PostHocTests test showed a statistically significant difference between the second (M = 3.23, SD = 1.309) and the third group (M = 2.38, SD = 0.870) according to the Games-Howell test in addition to the traditional F (2.110) = 2.033, p = 0.136.

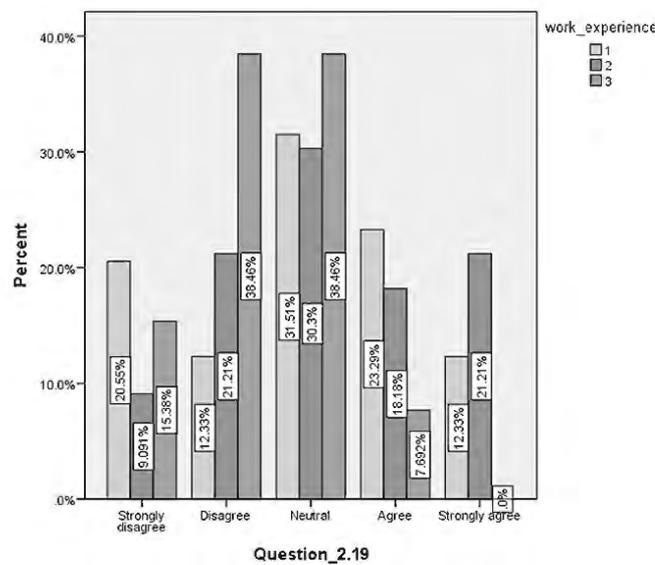


Fig. 7. Trend 5 answers according work experience

Respondents from the third group, with more than 10 years experience in the profession, do not accept the segregation of the seafaring profession, while the second group for the most part express a neutral opinion (Fig.7). This fact can be explained by skepticism and routine accumulations of experienced maritime personnel in terms of the current changes that take place in the maritime profession and the developments in this business.

After analyzing the responses to the questions related to **Trend 6 „Integration of maritime transport and involvement of specialists with different „non maritime” education”**, there were no statistically significant differences for the three groups.

In analyzing the responses to the questions of the respondents on **Trend 7 „Image decrease of the maritime profession in the well-developed countries and remote control of maritime operations”** a statistically significant difference between the arithmetic mean values of the three groups’ responses was found regarding the views that the prestige of the maritime professions declined in the developed economies $F(2,112) = 0.632, p = 0.003 < 0.05$. The magnitude of the effect $\eta = 0.106$, which is calculated using the coefficient e , is less than the typical, according to the interpretation made by Cohen [3]. For the first group ($M = 3.56, SD = 1.281$), for the second one – ($M = 3.44, SD = 1.523$), and for the third group ($M = 3.92, SD = 0.862$). The third group stated more convinced than the first one, while the second group has a rather neutral opinion (Fig.8).

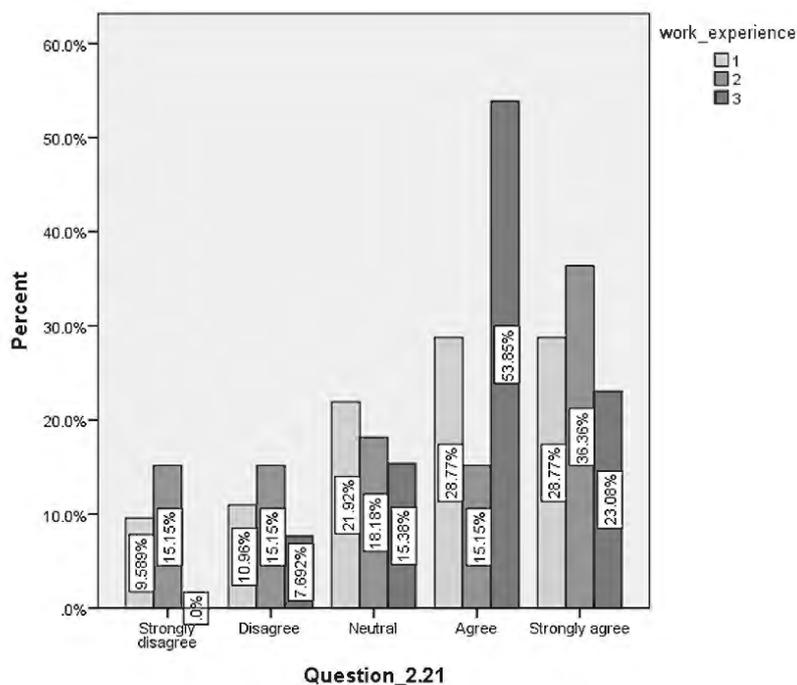


Fig. 8. Trend 7 answers according work experience

2.3. RESULTS OF THE COMPARATIVE ANALYSIS OF THE STUDY OF MOTIVATIONS IN THE ONBOARD MARITIME OCCUPATIONS FOR BOTH ONBOARD AND ON SHORE PERSONNEL

A statistically significant difference was found, $F(1,116) = 0,307, p = 0,024 < 0,05$ for the answers to the question of **Motivation 1 "Financial motivation"** for onboard and onshore personnel. The majority of onboard staff ($M = 3.45, SD = 1.564$) expressed a neutral opinion

on this issue, while onshore personnel ($M = 3.60$, $SD = 1.321$) considered that financial motivation was important for occupation onboard a ship. The magnitude of the effect $\eta = 0.051$, which was calculated using the coefficient *ema* is less than the average or less than the typical Cohen interpretation [3].

Difference was seen in onboard and onshore personnel' responses to **Motivation 2 "Good career perspectives"** - $F(1,116) = 0.289$, $p = 0.029 < 0.05$. Onboard staff ($M = 3.36$, $SD = 1.331$) expressed a neutral opinion on this issue, while onshore personnel ($M = 3.85$, $SD = 1.062$) agree that this is important for choosing the seafaring profession. The magnitude of the effect $\eta = 0.05$, which is calculated using the coefficient *ema*, is small or less than the typical Cohen interpretation [3].

The statistics made on the responses to **Motivation 3 "Opportunity to visit foreign countries"** showed differences in onboard and onshore-working place based opinions - $F(1,116) = 1,854$, $p = 0,012 < 0,05$. The ship staff ($M = 2.58$, $SD = 1.42$) believe that the opportunity to visit foreign countries for the most part does not affect their motivation them while onshore personnel ($M = 2.91$, $SD = 1.155$) has different opinion on this issue. The magnitude of the effect $n = 0.125$, which is calculated using the coefficient *ema*, is small or less than the typical Cohen interpretation [3].

In the analysis of **Motivation 4 "Motivation stemming from the" passion and romance of the sea"** there was no statistically significant difference between the responses of onboard ($M = 1.89$, $SD = 1.103$) and onshore personnel ($M = 2.22$, $SD = 1.281$), $F(1,116) = 2.173$, $p = 0.154 > 0.05$. Both groups do not accept that love for the sea can motivate a person to choose a seafaring profession onboard a ship.

Concerning **Motivation 5 "Prestige of the profession in society"**, there was also no statistically significant difference in the responses of onboard ($M = 2.49$, $SD = 1.325$) and onshore staff ($M = 2.54$, $SD = 1.292$) $F(1,116) = 0.154$, $p = 0.701 > 0.05$. Ship and onshore personnel rather believe that the seafaring profession onboard a ship is not sufficiently prestigious in society to motivate young people to choose it.

2.4. RESULTS OF THE STUDY COMPARATIVE ANALYSIS OF MOTIVATIONS OF THE ONBOARD SEAFARING PROFESSIONS OF A SHIP ACCORDING TO THE WORKING EXPERIENCE OF THE RESPONDENTS

The one-factor analysis of **Motivation 1 "Financial motivation"** did not show a statistically significant difference between the responses of the three groups according to their years of experience. For the first group ($M = 3.60$, $SD = 1.426$), for the second - ($M = 3.25$, $SD = 1.602$), and the third group ($M = 3.92$, $SD = 1.379$) $F(2,105) = 1.002$, $p = 0.326 > 0.05$. The three groups do not think that enough financial motivation can influence the choice of an occupation onboard a ship.

In the analysis of **Motivation 2 "Good career perspectives"**, there was also no statistically significant difference in the responses of the three groups. For the first group ($M = 3.53$, $SD = 1.165$), for the second one ($M = 3.11$, $SD = 1.315$) and for the third one ($M = 3.25$, $SD = 0.965$) $F(2,105) = 1.348$, $p = 0.403 > 0.05$. The three groups expressed a neutral view of the fact that „climbing the ladder” could be a motive for choosing a seafaring profession.

No statistically significant difference was found in the one-factor analysis of **Motivation 3 "Opportunity to visit foreign countries"** for the three groups. For the first group ($M = 2.87$,

SD = 1.292), for the second one - (M = 2.54, SD = 1.29) and for the third (M=2.58,SD=1.311) $F(2,105)=0.765$, $p=0.978>0.05$. The three groups did not consider the opportunity of visiting foreign countries motivating enough for the choice of a seafaring profession onboard a ship.

Statistically significant difference was found in the one-factor analysis of **Motivation 4 "Motivation stemming from the" passion and romance of the sea"** for the three groups. For the first group (M = 1.94, SD = 1.105), for the second one (M = 2.32, SD = 1.492) and for the third group M = 1.92, SD = 0.9, $F(2,105) < 0.05$. The magnitude of the effect $\eta = 0.14$, which is calculated using the coefficient *ema*, is less than the typical, according to the interpretation made by Cohen (Cohen, 1988). The first and third group of respondents are convinced that passion for the sea can not serve as a motivation for choosing an onboard occupation, while the second group is less of the same opinion.

For the **Motivation 5 "Prestige of the profession in the society"** in the one-factor analysis no statistically significant difference in the answers of the three groups of respondents was found. For the first group (M = 2.66, SD = 1.253), for the second one (M = 2.29, SD = 1.436) and for the third (M=2.33,SD=0.985) $F(2,105)=1.014$, $p=0.189>0.05$. The three groups do not agree that the prestige of the seafaring profession in society motivates the choice of an onboard position.

3. SUMMARY OF THE RESULTS AND CONCLUSION

The maritime industry is changing very fast. The great challenges facing the seafaring professions and the outflow of them especially in the well-developed countries require research and analyzes of the current trends during their development. Research results outline the most important of them. The scales used to measure the attitudes of respondents find their reflection in the factors that build up the factorial analysis. The results show that for the most part the participants confirmed the validity of the previously outlined trends.

Regarding the seven trends the research confirms their validity with a slightly new aspects, f.ex. the need for obtaining more knowledge of experienced personnel in the project management that is closely connected with the new economic reality in the maritime business. This is once again confirmed by the neutral view of the respondents to new economic processes like „stratification” of the profession, increase of non-maritime educated personnel, transport integration, remote management and control of operations etc. Neutral answers mean in the most cases lack of enough information about the asked trend. It can be assumed that a debate on understanding the overall economic framework of the processes is definitely needed.

Regarding the factor analyses one factor seem to be leading for the formation of ones understanding of the asked processes - the age and the respective length of working experience. This means that routine accumulations can change the perception and the acceptance of some new tendencies. In some cases we can divide maritime personnel in the so called „old school” and new one.

Differences are confirmed between onboard and onshore personnel regarding the motivation for choosing an onboard position. Onshore personnel are more active in commenting career and financial perspectives whereas onboard personnel show more neutralness. Both groups do not accept that „love for the sea” can motivate a person to choose a seafaring profession onboard a ship as well as both groups agree that the prestige of the

profession decreases. There is a kind of an „abstinent” perception of the profession with a slightly difference in the age of experience between 5 and 10 years.

To conclude, recommendations can be developed in the direction of changing training models. At least several directions seem to be correct based on the conducted statistical research. First of all, it seems reasonable to emphasize the preparation of so-called „soft skills”. Obviously, in general this training has been neglected in previous practice. Next, the training for an active work in advanced informational product environment should be enhanced, focusing on software packages use skills.

Last but not least, it is appropriate to bring the following idea to discussion. As a result of the dynamics of technology development, new technical means should be expected to become more rapid. This will inevitably lead to a decrease of staff competence to work with specific technical systems. Obvious we will face the need for additional skills. First of all, this is to build a long life learning system for seafarers to regularly update their competencies.

Another aspect is the necessity for these specialists to have the skills to learn and to train. This approach should be specifically emphasised during the whole process of the training of maritime specialists. In this context we can study, suggest, apply and test the implementation of some principles from the adult learning theories (Alexander Kapp, Eugen Rosenstock-Huessy, Shepherd Knowles, etc.), to change the learner’s attitudes in teaching the mentioned topics and to include reasonable aspects of the transformative learning in the teaching methods.

The results of the study could be used as a basis for further research which will be presented and discussed in subsequent surveys and scientific forums.

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Female leaders in maritime professions – Finnish educational aspect

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ABSTRACT

It has been generally stated that investing in women is the utmost effective way to lift societies, businesses, and even nations. The more there is a gender equality- the more the economic is growing. In the companies which have more female leaders acting, are the achievements better. [1]

The purpose of this paper is to examine the current status of women leadership in maritime sector. What kind of preconditions the leadership education according to STCW requirements and education in master level in maritime institutions (MET), gives for female seafarers in Finland? What kind of managerial skills and knowledge should female mariners gain to success in male dominated industry?

For this paper, I have interviewed Finnish women, who are currently working in managerial level positions in maritime sector. The subjects of the interview were connected to the leadership and managerial skills.

1. INTRODUCTION

Nowadays, there are globally approximately 1,2 million seafarers sailing at sea, but only 2 per cent of them are women. Most of the female seafarers, up to 94 per cent, are working in the cruise industry. Generally, majority of women are working in cruise ships as hotel staff, but the picture varies significantly worldwide.

The right to receive education and possibilities to work equally haven't been obvious and many barriers have an influence for women seeking into maritime sector. Obstacles can be related to cultural and social matters and to traditional family and practical issues, such as how to combine motherhood with career at sea. [2]

Many international organizations, governmental agencies and private organizations have promoted the progress of women in maritime industry for several decades. A gender equality has been an ambition of the United Nations (UN) and its specialized agencies. The importance of networking platforms and demand for the development of a new strategies to bolster role of the female in the maritime industry has been understood. [2] International Maritime Organization (IMO) started in 1988 a gender programme called "*Women in maritime*". A strategic approach of IMO programme is targeted towards enhancing the contribution of

women as key maritime stakeholders. One of the policy objectives has been improving women's access to maritime training and technology and increasing the percentage of women at the senior-management level within the maritime sector. The theme for annual World Maritime Day for year 2019 was selected to be "*Empowering Women in the Maritime Community*". Awareness of the significance of gender equality in line with the United Nations' development Goals (SDGs) are promoted through this selected theme and also to raise the essential contribution of women globally to the maritime sector. [1]

The women's participation in the leadership roles and managerial positions is a global challenge and a great field of fight to equality. It is estimated that 47 per cent of the total work force consists of women but according to recent research of S&P 500 companies indicated that female represent less than 5 per cent of CEO positions [3]. A gender gap in leadership positions is still a major issue to fight for in all business sectors, also in male dominated domain, like maritime industry.

2. MARITIME EDUCATION AND LEADERSHIP

Leadership skills need to be applied by seafarers; not only the master and chief engineer but also by officers on deck and engine room who will prepare themselves to the future higher positions of responsibility. In certain occasions, anyone on board a vessel can be in situation where leadership skills are required in addition to technical skills. Anyhow, many seafarers are continuing their maritime career ashore, often in managerial or leading positions. So, what kind of qualifications are mariners expected to have in respect to leadership skills?

Educational systems differ between countries and possible career paths in maritime sector vary due to these differences. [2]. Educational minimum requirements for seafarers were set in 1978 when International Convention on Standards on Training, Certification and Watchkeeping for Seafarers (STCW) Convention was first established. Before that standards and procedures of training varied widely between countries even more despite of the fact that shipping is the most international of all industries. Manila amendments to STCW Convention and Code were made in 2010 which meant major changes to seafarers' education. One of those revisions among the others concerned new requirements on training in leadership, teamwork and resource management on operational and management levels. [3]. Currently there are various courses in MET-institutions for leadership training to meet this STCW demand.

Management level shore-based positions often require a higher educational degree which means that mariners are often motivated to continue their studies to broaden their possibilities in labor market. In Finland, Satakunta University of Applied Sciences (SAMK) has offered a Master of Maritime Management programme since 2006 which has been specifically tailored to meet women's demand for a work in land-based organization. One of the main goals of the programme has been to generate equality of female seeking into maritime professions and offer further education which is built on existing STCW based education so that there would be a visible "career-bridge" from ship to shore based managerial professions. [2]

2.1 Leadership onboard

One definition for leadership according to IMO model course on leadership and teamwork: "a process whereby an individual influences a group of individuals to achieve a common goal" and "leaders carry on this process by applying their leadership knowledge and skills" [4]

According to Devitt and Holford (2010), maritime industry has exceptional characteristics which make it challenging to apply the concept of leadership training in other industries into maritime context. The reasons for this are for example;

- Ships' teams change in certain intervals and are augmented as required. This does not normally occur outside the maritime industry. The duration of the working relationship has an impact on leadership and teamwork
- Ships' teams can vary culturally so that there is less utilization of standard communication phrases. Communication as well as use of interventions and challenges varies due to cultural issues.
- National cross-cultural, organizational, professional and departmental issues associated with the globalization of the maritime industry are affecting on leadership
- Dynamic workload matters on a ship which is operating routinely and affected by external environmental factors, commercial operations, duration of the voyage, administration requirements and supportive mechanism available. [5]

Other factors that differ from shore-based organizations are the fact that seafarers are working long periods of time away from home and their families and in addition the ship is continuously moving working environment that can exposure to various risks during the sea voyage and cargo operations.

3. FEMALE LEADERS IN MARITIME SECTOR

Like earlier mentioned, women are minority in the maritime sector and due to that the remarkable majority of leaders in the maritime industry are men even though proportion of female mariners is growing. HR Consulting published in 2017 a report about women employment in shipping. According to this report over 76 per cent of the female labor force works at administrative, junior and professional level roles and only few are reaching managerial levels or higher. This report also reveals that only 0.17 per cent of women have places on executive leadership teams.

The importance of identifying possible barriers that can hinder women in applying for maritime education and profession is generally paid attention. Stereotyping gender can be one reason why men and women are unequally assessed. It has been also shown that stereotypes have an influence on self-confidence and how the different genders are expected to act in male / female dominated vacancies. One noted obstacle is women's self-evaluation of their competences and leadership skills which is important for any person that would like to seek into a job that requires a certain competences and skills. In another words, person with a lesser belief in themselves would probably not submit an application for a vacancy for which they felt they are not competent enough. According to Ortega, Øvergård and Henden's (2015) research

female maritime officers tend to underestimate their own leadership skills which is opposite effect compared to male maritime officers. [6]

Differences in the leadership styles of female and male have been found to be relatively small due to the pressure towards similarity of men and women leaders. Studies about gender affecting in leadership have shown that leadership styles of female can be more effective and productive nowadays when organizations are less hierarchical. In addition, female leaders are participatory and cooperative by character. [7]

4. INTERVIEW OF FINNISH WOMEN IN MARITIME INDUSTRY

For this paper, there have been interviewed Finnish women seafarers' and their subjective experiences of women leadership in maritime industry. Data was collected during Spring 2019 by in-depth interviews from 3 participants who were selected from SAMK alumni or they were invited by using professionals contacts. Interviews were conducted by email or personal interview.

Background of these women were bachelor's degree of sea captain program or master's degree in maritime management and they all have also seafaring experience. All participants had quite long working history from the industry and currently their vacancies are in leading managerial positions in maritime sector either at sea or ashore. Details of background in this paper are wanted to keep very limited due to protection of participants identities.

The author of this paper acknowledges that data collected to this paper is very limited and exposes only objective views of a few female from a one country. The purpose of this paper has only been to bring out a small sample of a present view among women leaders in maritime industry.

The interview consisted of five questions which were presented to the participants in English:

1. What kind of preconditions for leadership in maritime sector the sea captain's education gave to you?
2. In your opinion, what kind of characters is needed for a good leader?
3. Does gender influence on leadership?
4. In your opinion, what factors could promote the position of women as a leader?
5. What should be taken into consideration in the maritime leadership education?

4.1. Results of the interview

Each participant was graduated from bachelor level sea captain programme already a time ago when their curriculums were according to STCW 95. According to the interviews, women felt that the leadership training was hardly paid attention at that time in Met institutions and they have got support afterwards from superior onboard or their leadership skills have developed in working life.

The second question concerned the characters of a good leader. Women in this interview described that a good leader should have understanding of different types of personalities and

ability to communicate effectively with subordinates. A good leader is approachable, available for support as needed and accept suggestions from the subordinates. The leader needs to know where the organization is heading and direct the others to that goal. The subordinates should be encouraged to grow in their positions and allowed to complete their tasks on their own without micromanaging unless support is required. Other charters of a good leader were described to be; fairness, skills to listen to others and capabilities for effective teamwork.

To question, does gender influence on a leadership, the participants said that depending of a culture a gender may have effect on a leadership. In this sentence a culture can mean either organizational culture or culture of people from different countries. According to women, in cultures where male dominance is seen as a norm, women in leading positions might need to work harder and adjust their style of a leadership in addition, expectation towards female leader can be different as towards men. If it is considered as a normal to have women in the management there might be less pressure for them to conform, and the community probably would not expect them to, at least to same extent if all the other leaders were male. It is not a question of gender alone, in workplaces with a lot of diversity different leadership styles are probably more accepted if the leader demonstrates the skills needed for the job. Also, the gender experience and cultural background of the personnel you need to lead have an influence on the leading style.

Factors that could promote the position of a women as a leader were diversity embracing, condemning any inappropriate behavior or speech, whether it is a gender related, racial or anything else inconvenient. Giving the possibility for women to try their wings, like men can grow as a leader and the same way women will grow in their positions if given a chance and assistance. According to experiences of these interviewed Finnish women, female leaders are better listeners and can be therefore seen more approachable. Also, patience was said to be the benefit of women which can be important character in situations where careful consideration is needed.

The last question was about the issues that should be taken into consideration in the maritime leadership education. The answers received from interviews were strongly related to cultural awareness and good intercommunication between people.

According to one participant, the leadership onboard was seen like this: *“Leaders onboard a ship have a common goal: to make everything run smoothly, safely and cost-effectively, in that way leaders in the maritime sector are not different from their counterparts in any office shoreside. However, the cultural diversity onboard (up to 40-50 different nationalities) combined with widely varied levels of education and training the crew members have, can pose a problem and the leader needs to be able to adjust their style depending on the situation. It would be good if awareness of cultural differences could be incorporated in the maritime leadership education. Normally the majority onboard sets the norm for the leadership style, e.g. having East Europeans as the majority of leaders is quite different to having Swedish, although naturally there are individual differences between leaders as well. Sometimes a leader can unintentionally offend their subordinates, and if that person is the only one onboard*

from that particular culture they often just need to adjust to the situation, as the majority sees their way of doing things as correct and are unaware that their way of behaving is offensive to somebody. Especially senior management should be able to pick up on this and show a good example how to create a good atmosphere.”

The leadership style that works onboard a vessel and ashore are seen different. The working environment itself makes a difference in the leadership.

5. CONCLUSIONS

The Manila amendments to the STCW Convention 1978 brought the requirements of leadership training to become compulsory for all seafarers at the operational and management levels. MET institutions are providing this education with varying ways. However, it seems that there is room for development and improvement. To develop of good leader, you need to receive leadership training and education but also experience from real world. According to Mori (2014), jurisdiction and context should be taken into account when leadership training in Met institutions are tailored. Also, leadership education should bear in mind trainees personal progress over the long term. [8] Cultural awareness and good communicational skills were highlighted among the interviewed women and the importance of these skills should be emphasized in the maritime education.

Women working in maritime professions are acting in environment where models of leadership are formulated by rules of male-dominated domain and female working in that industry are adapting to that style. The organizational structures and work force are traditionally considered to meet the needs of male gender. Certain qualifications are connected to the men and preferred for a leader, such as independence, determination and assertiveness. Behavior of gender can be seen with different eyes, self-confidence or assertiveness of men can be seen as arrogant or abrasive conduct in women. On the other hand, qualities female or feminine style of leading are not necessarily respected similar way than stereotypical male leading style.

In Finland, those women who have continued to SAMK Master of Maritime Management studies have been highly motivated, more efficient and percentage of graduation has been higher than among the male students. Almost 100 percent of female who have been accepted to the programme have completed their studies and have also changed their jobs to land base organization during the next year after graduation [2]. It seems that women are wanted work force also in shore side leading professions and the higher degree in maritime management have improved their possibilities in labor market.

It can be seen that women starting to break the “glass ceilings” in man dominated industry and the progress is assisted by the maritime educational possibilities.

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From Sailor to Scientist – Reaching Out to Researching Professionals on Doctorate Level

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Keywords: researching professionals, doctoral education, professional doctorate, online doctorate

ABSTRACT

Doctoral programmes are usually offered in full-time and part-time form, with latter mainly chosen by working professionals whose drop-out rate is significant. In order to keep these part-time doctoral students at doctoral programmes, universities must reach out to them and help them overcome the obstacles in their path to postgraduate diploma. This paper discusses two possible approaches in handling this problem, which can quite easily be incorporated together. One possible solution, rarely used in maritime sector, is offering a professional doctorate (EngD) over classical research doctorate (PhD). Another possible solution would be addressing the needs of working professionals in maritime sector by composing adequate online curriculum of postgraduate programme. Principles to be considered in order to successfully produce professional and online doctorate are given in the paper and applicability of the concept in the maritime sector is discussed.

1. INTRODUCTION

Doctoral degree represents the highest academic qualification awarded to student upon successful completion of a course of study in higher education that is usually preceded by bachelor's and master's degree. It takes a giant leap to advance from master's to doctoral degree, a leap that only a few are ready to take. According to 2018 survey [1] in the USA, the number of people age 25 and over whose highest degree was a master's is 21 million, while the number of doctoral degree holders is just 4.5 million. There are no precise data for students educating in the maritime sector, but given the nature of the mentioned sector, it can roughly be assumed that only a small portion of the finished master's students is ready to advance to doctoral level and most of them coming after some years of service at the sea.

To cater for different needs, doctoral programmes are usually offered in full-time and part-time form. Part-time doctoral programmes are mainly chosen by working professionals – those who opt for pursuing doctoral degree along with their regular full-time job. These part-time doctoral students often carry substantial practical experience in industry and business, experience that can significantly contribute in detecting actual challenges that need to be confronted by new scientific methods. However, practical-solving approach of these working professionals often collides with somewhat rigid academic mindset so, quite often, their full potential is not recognized and universities miss on prospering from this unique academic and professional blend [2]. The problem is even more specific in maritime sector where professionals working

at seas are separated from universities for prolonged periods. In Fig. 1 numbers of full-time and part-time PhD students at Croatian PhD maritime programmes for the last nine enrolment cycles is given. It is obvious that, at maritime sector, students in majority opt for part-time doctorate.

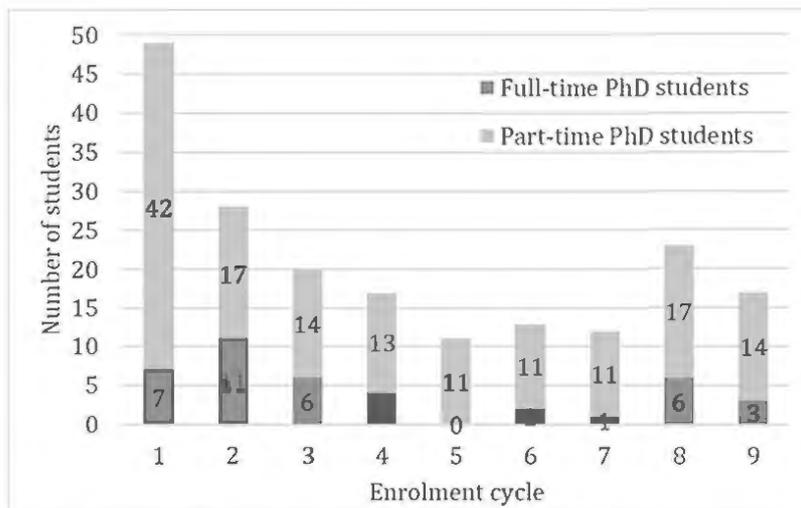


Fig. 1. Full-time and part-time PhD students at Croatian PhD maritime programmes for the last nine enrolment cycles (2006. – 2018.).

Obviously, in order to attract and keep them at doctoral programmes, universities must reach out to them and help them overcome the obstacles in their path to postgraduate diploma. This paper discusses two possible approaches in handling this problem, which can quite easily be incorporated together. One possible solution, rarely used in maritime sector, is offering a professional doctorate (Doctor of Engineering, EngD) over classical research doctorate (Doctor of Philosophy, PhD). In brief, PhD is intended to develop “professional researchers” and EngD is designed to develop “researching professionals” [3]. EngD combines foundational and theoretical knowledge of a discipline (or, sometimes, more than one discipline) with knowledge of research in its context. EngD should be considered as it could suit the needs of working professionals more adequately than PhD. Another possible solution would be addressing the needs of working professionals in maritime sector by composing adequate online curriculum. These ideas are more thoroughly presented and discussed in the next section of the paper where they are emphasized in six points that should represent strongholds of every professional doctorate. These strongholds are put together by authors after extensive review of available literature and doctoral programmes in the engineering field of study, with whom maritime sector coincides.

2. SIX STRONGHOLDS OF A PROFESSIONAL DOCTORATE

A question commonly asked and, at the same time, difficult to answer is how does the professional doctorate differ from the classical research doctorate? Variations in professional doctorates exist not only across institutions and across subjects, but also within subjects. The same conclusion can, however, be drawn for classical research doctorate as there is no clear consensus on what is “the right path” to PhD title. Still, some features shared by the majority of professional doctorates programmes can be highlighted as strongholds on which an EngD programme can be built. They are identified by careful investigation of the leading doctorates

curricula available online and available literature. These strongholds are presented in the following subsections.

2.1. CAREER FOCUS

The traditional PhD is generally not adequately suited to the needs of professionals pursuing a career outside research in academia environment or an industrial laboratory [4]. PhD is open for apprentice researchers who generally may have no or little experience of the subject beyond the knowledge obtained at the BSc and MSc level in the proposed field of study. Moreover, PhD is intended to be available as a pre-service training in research, while EngD is intended to be a form of in-service professional development.

This career focus is what sets PhD and EngD apart. EngD is usually aimed at experienced professionals who wish to extend their professional expertise and undertake advanced research, while not intending to become career researchers. The professional doctorate is intended for experienced practitioners within a profession and prospective candidates for a professional doctorate programme are usually required to carry 3 years of professional experience and relevant employment.

“Professional researchers” vs. “researching professionals” is a term that maybe most adequately describes the difference in career focus of PhD vs. EngD.

2.2. RESEARCH TYPE AND FOCUS

“Research and experimental development (R&D) comprise creative and systematic work undertaken in order to increase the stock of knowledge - including knowledge of humankind, culture and society - and to devise new applications of available knowledge” [5]. The term R&D covers activity such as: basic research, applied research and experimental development. The latter is of interest here, because it defines work directed to producing new or improved products or processes, drawing on previously gained knowledge. Former is of interest because it defines the difference in type of research that is to be performed in PhD and EngD.

“Basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view” [5]. This description can fit reasonably well for most PhDs. “Applied research is original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific, practical aim or objective” [5]. Definition of applied research is what adequately describes professional doctorates.

As for the research focus, most PhD candidates aim to make a significant original contribution to knowledge by focusing their efforts on a perceived gap in the literature in a subject discipline. PhD candidate is normally expected to undertake a preliminary literature research and review to identify that existing gap and start their work from what is already known.

By contrast, EngD candidate starts from what is not known, a perceived problem in professional practice that needs investigation and resolution. Professional research deals with a topic that relates to a candidate’s own field of professional practice.

2.3. LEARNING OUTCOMES

At the end of their PhD course, students should become independent scientists capable of performing and critically evaluating research using current techniques and methodologies and

developing new ones. They should have a thorough knowledge of the literature and a comprehensive understanding of scientific methods and techniques applicable to their own research. They should be able to understand how well their research fits in their field in terms of novelty and scientific significance. The intended learning outcome of the PhD is to develop the capacity to make a significant original contribution to knowledge in a particular discipline through research.

Learning outcomes of professional doctorates include the capacity to make a significant original contribution to knowledge of professional practice through research. EngD students should demonstrate the knowledge to create and interpret new knowledge, through original research, of a quality to satisfy peer review, extend the forefront of the discipline, and merit publication. They should, in general, be able to systematically acquire and understand a substantial body of knowledge and applicable techniques for research that are at the forefront of their area of professional practice. EngD students should, in particular, be able to conceptualise, design and implement a project that is intended to generate new knowledge and its application to professional practice.

2.4. MODE OF STUDY

Professional doctorate students are expected to spend their working time in industry and therefore most of the professional doctorate programmes are designed to be studied only by part-time attendance. However, some programmes state that the candidates are registered as full-time students with the understanding that most of their time will be spent working in an industrial or professional organisation. If the blend between professional work and academic duties is performed seamlessly, it is hard to distinguish between part-time and full-time mode of study.

2.5. BLENDING OF WORK AND STUDY, PRACTICE AND THEORY

As previously stated, most professional doctorates try to integrate the professional work of candidates into their doctoral studies as much as possible. Harmonizing the extent to which the scientific research will penetrate everyday professional practice of an EngD student seems crucial in attracting prospective candidate to EngD programmes and helping them to cope with two difficult tasks: delivering optimal performance at work place and, in the same time, fulfilling academic requirements. Hence, professional doctorates can, in a way, be viewed as a type of work-based learning and life-long learning. This implies acceptance of alternate means of teaching and mentoring at the PhD level of education; a significant step in breaking the rigid frames of academic environment.

Besides blending work and study, a proper combination of theory and practice seems just as much important. Once again, PhD is concerned with contributing to scientific theory while EngD should be concerned with making a research-based contribution to professional practice. It is inevitable to use theory in teaching and mentoring EngD student, but it must be made in a way that clearly opens the path to practical implementation of theory to practice.

Setting the professional work of candidates into their doctoral studies can be done directly or indirectly. Directly, when students deal with a problem that is an integral part of their professional practice and indirectly when students deal with a problem that is not an integral part of their professional practice. Indirect setting is primarily used for students that wish to

gain a broader knowledge about their professional sector. There is a possibility of not setting the dissertation in practice, of course, but this approach is most likely to discourage the students from professional doctorate.

2.6. DISTANT LEARNING

Students enrolled in the PhD programmes are expected to study on-site, at university campus, committing themselves to full-time programme attendance. As for the EngD students, it is expected for them to continue working while taking courses. Moreover, in some specific industries, it is almost impossible to account for students' regular visits to campus. Professionals that are tied to transport industry, military industry, civil engineering or large multinational companies can rarely expect that they will spend prolonged periods at a single place.

A possible solution for their problems would be addressing the needs of working professionals by composing adequate online curriculum of postgraduate programme. This programme should adhere to same academic rigour as ones taking place on campus ground. Academic rigour means that students are challenged to think, perform and grow to a level that they were not at previously [6]. Standards of the course must be set in a way that they challenge the students, not frustrate him. Academic rigour commonly consists of three different phases: setting the standard for students; equipping students through instructional and supportive methods; student demonstration of achievement [7]. At distant learning, it is often challenging to maintain academic rigour due to the nature of the study, but failing to do so can lead to deficient results of the research and dissertation itself.

3. CONCLUSION

Classical doctorate programmes dedicated to maritime affairs are rare, professional doctorate programmes almost non-existent. Out of 64 regular members of International Association of Maritime Universities (IAMU), only 25 offer some kind of PhD programme (data available by browsing web pages of institutions), Fig. 2.

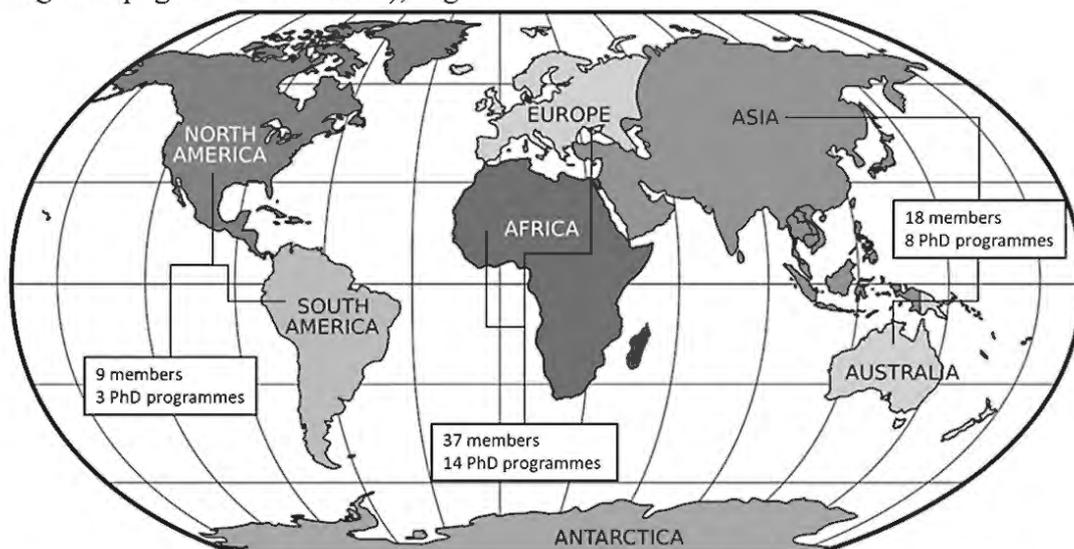


Fig. 2. Number of IAMU members across continents and PhD programmes offered (as of June 2019).

Given the extreme applicability of the research in the maritime domain, it is obvious that there is a place for EngD programmes. Nevertheless, some problems exist. They are often underappreciated both by academia and industry with the PhD still seen as the “gold standard” of doctoral qualification [8]. This can be one of the reasons for the lack of professional doctorate programmes in maritime sector in spite the fact that that they are a tougher test than the PhD as research takes place in an environment with less support and findings must have an impact on a professional setting as well as making a contribution to knowledge [9]. However, if enough efforts are put in proper design of professional doctorate programmes and dissemination of the idea behind them to working professionals’ community, maritime sector has the most serious potential to implement this type of postgraduate advancement.

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Proceedings

Policy Impact

Marine Engineering Education Program development due to CDIO concept

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Keywords: Education development, CDIO, Integrated learning, General skills, Quality Assurance

ABSTRACT

The paper describes and analyses the education development process of the BSc Marine Engineering Program at Chalmers University of Technology. The goal has been to advance to both fulfil the STCW Manila Amendments [1] as well as to implement the CDIO (Conceive-Design-Implement-Operate) approach for engineering education [2]. The aim was to develop a program with emphasis on fundamentals in the context of marine engineering with integrated learning of general engineering skills that support the students' development of knowledge, skills and understanding for their future careers. External and internal evaluation as well as feedback from stakeholders give much credit to the developments and verify that the developments are in line with the aims as well as the expectations of an up-to-date marine engineering education.

INTRODUCTION

We argue that program development is a long-term process and that the success lies in the ability to sustain an enduring long-term process as well as using a continuous improvement philosophy with the ability to set new goals. The development process of the Marine Engineering program started already in 2010 with a renewed program plan that was evaluated and updated in 2014 after the graduation of the first cohort. The program has since then been continuously updated and refined with the focus on the professional role while using the CDIO approach and toolbox to form an integrated up-to-date Marine engineering education. In this process special attention has been put on satisfying the IMO regulations [3] and the Swedish Degree Ordinance [4] as well as the Local Qualifications Framework for Chalmers University of Technology [5].

The program's aim, idea and learning outcomes together with a design matrix connecting learning outcomes to the courses are stated in the program description. The development of the program description is the most important tool for the unification of the program as well as for the design of courses and teaching activities. It generates a common terminology and helps to shift the emphasis on program development discussion from specific courses towards high-level issues such as program outcomes, idea and the teaching/learning of general skills. Moreover, the program quality assurance system comprised a set of planning and evaluation tools including the agreement between the program and the departments on course delivery. Finally, input from various evaluations as self-evaluation, benchmarking as well as student and faculty are taken into account in a systematic manner.

To conclude, the paper aims to

- Provide a detailed description of the long-term development process of the Marine Engineering program at Chalmers with focus on aims, goals, quality assurance, success factors, etc.
- Evaluate the results, in what way is the different and better compared to ten years ago? How are achievements measured? How do the different stakeholders view the results?
- Identify critical success factors for a long-term education development process.

RESEARCH APPROACH

The general aim of this paper is to forward the experience and knowledge that we have found during the development process of the Marine Engineering program. To give a good view of the development we start with revisiting 2009 when most part of the courses were revised due to the fact that a new program structure was suggested by the Chalmers leadership for education. We then account for the process of development up to the current date and also summarize the further plan for the program. The background data of the process are from different quality evaluations as, for example, the Swedish National of Higher Educations evaluations, course evaluation, alumni surveys, peer assisted activities and study social reviews. In the conclusion we will also list the most critical factors that we have found in this development process. We will also make it clear that the authors have a central role in the development process as head of program and dean of education. Due to this there is a risk that the findings are seen in positive direction.

DRIVERS FOR THE EDUCATIONAL PROGRAM CHANGES

Education is like most of us know not a static process and there are a many different reasons for that, just to mention a few reasons we have rapid development of technology, changes in environment and culture. Obviously, educations (courses as well as programs) need to be continuously developed and improved to meet the needs of a rapidly changing world. In practice, this is not easy to achieve in universities that are highly hierarchically organized in disciplines with a variety of bureaucratic obstacles and an inherent slowness of change.

Most educational programs are traditionally taught through disciplinary courses and the link between courses are weak due to “stand alone courses”. Due to this we experienced a lack of overhearing and cooperation among teachers in the program. One obvious example of this shortcoming was the teaching and learning of communication. The communication was almost limited to a single course without any interaction with other courses or the program as a whole. Students and stakeholders asked for more active and experiential learning activities. To meet this a more active connection to the demands of the professional career of marine engineering was demanded by the industry, in particular regarding general skills as leadership, project management, communication as well as ethics and sustainability. Moreover, due to globalization, there is an obvious need to prepare to students for global cooperation and competition as well as prepare students and courses for exchanges.

THE CDIO (Conceive Design Integrate Operate) INITIATIVE

The CDIO approach to engineering education was introduced in the early 2000's. It started as a cooperation between Chalmers University of Technology, The Royal Institute of Technology (KTH), Linköping University in Sweden and Massachusetts Institute of Technology to reform engineering educations. The cooperation has now grown to an international network with about 150 educational institutions from all parts of the world.

In short, CDIO consists of two main parts: a description of the professional role together with general goal descriptions and a systematic way of working to develop and implement educational programs to achieve the goals. The former contains important components in order to be able to apply the fundamental disciplinary knowledge to develop new products, processes and systems. The other main part is about creating conditions for progression and how general engineering skills such as communication, teamwork and project management can be actively trained through integration into courses and projects. CDIO is also about building learning environments that support the students to work in a practical and collaborative way. The CDIO framework contains a model for evaluation and continuous improvement that includes self-evaluation and benchmarking. CDIO further features a systematic approach for designing and continuously improving educations [2].

EDUCATIONAL DEVELOPMENT MANAGEMENT

Education development is often a slow process with many bureaucratic obstacles as well as a faculty that often are constantly counteracting every change that may affect their courses. To overcome this, we used an Agile approach of management and leadership. In this approach we begun with the vision and acknowledged that the detailed specifications become the goal. Thus, we focused on early incremental developments that were continuously improved. We put continuous attention to new findings regarding curriculum and course design and if found suitable they were implemented. Motivated faculty interested in developments were identified and invited to take part and the developments were then build around them. The head of program practiced collegial and inclusive leadership that promoted flexibility, transparency, collaboration and incremental developments and implementations realized by focusing on small steps.

To give a view of this we explain the “Chalmers” management model for undergraduate and graduate education” briefly. All programs at Chalmers are organized under a school and the ME program is a part of the “School of MATS (Mechanical, Automation & mechatronics, Design and Marine Engineering including shipping)” that are led by a dean of education. The schools bear solely the responsibility for the programs, “purchasing” courses from departments. This to avoid conflicts of interest where departments would strive to develop courses for the interests of their teachers and form programs for the needs of the department rather than the society. Program heads “buy” courses from the departments in an annual process including evaluation of last years’ delivery, developments of contents and pedagogics, start and put down courses and budgeting. In this process departments, faculty and program heads can propose new courses, new programs and course developments, study environments developments etc. We would argue that this organizational form is suitable for changes and to ensure that the programs are well composed to meet the requirements of the society.

PROGRAM BOARD AND INDUSTRIAL CONTACTS

The program head’s major body for developments and implementations is the advisory board with representatives from industry, students, faculty and administration. All strategic decisions are raised and discussed in the board. Another important part within the concept of CDIO at Chalmers is work life interaction and the connections with the industry. In the ME program there are strong links the industry due to the onboard training courses, guest lectures and field trips as well as student projects and theses with assignments from industry.

QUALITY ASSURANCE

The quality assurance work at Chalmers for the education is carried out within a process-oriented work method in which the student's path through the education is at the center. The student's path is divided into the four parts Attractiveness, Recruitment/Beginners, Student-Centered Learning and Alumni. In addition, the quality system encompasses the educational conditions such as learning environment, teacher competence, societal relevance as well as goals, management processes and program design [7].

In the system, the most important indicators for internal follow-up and external evaluation are clarified, and measurements and follow-ups are carried-out in the various parts of the system. The quality of courses and programs, the quality of students' support and the quality of learning environments are planned, implemented, followed up and developed in, e.g., course evaluations, external program evaluations and benchmark with universities world-wide, advisory board meetings, study social and safety reviews, and agreement meetings with the departments regarding course offerings and delivery.

To the develop and execute the education the interaction between teachers responsible for the different courses and projects is crucial to understand differences and possibilities for cooperation and developments. The ME program has a very ambitious annual agenda for this. Each academic year starts with an all-teachers meeting with the program management to discuss pros and cons with the past year and what will be the drivers and possibilities for the coming year. Example of agenda items is, course evaluations, follow up on students result, self-assessment, new rules and regulations and the agreements with the departments. During the academic year there is another three planned meetings to follow up and develop. In addition, there is several meetings with specific teachers or group of teachers as needed based on current issues and developments.

Much of the daily quality work is carried out in the program team. The program team consists of a director of studies and a study guidance counselor and is lead by the head of program. The program team focus on daily operations, guiding and well-being of the students as well as administration and planning of the education.

MARINE ENGINEERING PROGRAM OF TODAY

This section will give a view of the program of today including the aim, idea, curriculum, learning environment and how the management process works at Chalmers.

PROGRAM AIM

Chalmers marine engineer program aims to educate marine engineers with the knowledge and skills required for work as an engineer on board a merchant vessel in an international environment or within industry that is linked to shipping, energy and mechanical engineering.

THE IDEA WITH THE PROGRAM

The vision of the marine engineer program is to be an internationally sought after, high quality and stimulating marine engineering education, with a focus on professionalism and sustainable shipping and operation of energy plants. The program educates marine engineers who will mainly work in the shipping industry but also in related industries such as energy plants and mechanical manufacturing industries. The graduates must have knowledge, skills and attitudes that enable effective use of today's and tomorrow's technology.

When planning the program, the following ideas are of central importance:

- The program educates marine engineers who are well prepared to work in a global labor market
- The program meets the requirements of the Swedish Transport Agency, Swedish and international authorities.
- The program has a base in mechanical engineering subjects in which students develop understanding and knowledge of complex machine systems
- The program uses Learning-centered teaching planning (Constructive alignment) and there is a clear link between learning outcomes, teaching and assessment.
- Communication is a central part of the program to prepare for the professional role.
- The program has teaching in Swedish and in English which are integrated into the program's courses with clear progression
- The program uses guest lecturers with special competencies related to technical systems of shipping.
- The students' knowledge and skills about operating and optimizing of energy systems create the back bone for sustainable shipping.
- The program's elective courses aim to give the student the opportunity to gain a deeper understanding of ship technology, and mechanical engineering and / or broadening within the subjects of law / economics, nautical and human factors.
- The program is continuously developed in collaboration with students, program teachers, administrators, Chalmers management and program advisory board with representatives from the business community

THE PROGRAM STRUCTURE OF TODAY

The Marine engineering program is a four years education divide into two general parts. Due to this the program is not in accordance with the Bologna structure [4]. The four academic years are structured as follows,

- Bachelor of Science in Marine engineering through three academic years of theoretical and practical studies in campus environment with access to workshop, labs and simulators. In total 180 ECTS.
- Unlimited certification to serve as second engineer, one year including one summer course of onboard training courses and workshop skills. In total 90 ECTS.

The reason for the deviation from the Bologna 3 +2 structure is that the program also must fulfill the requirement of Swedish Transport Agency, Standards of Training Certification and Watchkeeping (STCW) in addition to the Swedish Higher education Authority and the Local Qualifications Framework for Chalmers University of Technology. All examination of courses either theoretical or training courses are executed at Chalmers, but the time onboard the merchant vessel is reported to the Swedish Transport agency so there is a clear distinction of the Bachelor of Science in Marine Engineering degree and the unlimited license to serve as sea farer. With this system of incorporated theoretical studies and onboard training the students will be able to serv as second engineer unlimited after completed all the courses during a time span of approximately four years. To be noted here is that the BSc degree is a part of the education at Chalmers and it is possible for the student to fulfill that without the onboard time

as cadet. The onboard time is carried out as voluntary courses that most student traditionally take.

In the upcoming section we will discuss the program plan for all four years including the onboard courses. (The study year is divided into two semesters and each semester consists of two study periods). All of the courses will be viewed in matrix with links to what program level learning outcomes they cover. Complete course descriptions are found in the Chalmers study portal)

THE PROGRAM CURRICULUM

The program description is the essential tool for the quality assurance system and for developing and executing the educational programs at Chalmers. The program description captures program vision/aim, idea, program level learning outcomes, program plan and a program design matrix showing in what courses the program learning outcomes are introduced, taught and assessed, and utilized to satisfy other, higher level, outcomes. The development of the program description is the most important tool for the unification of the program as well as for the design of courses and teaching activities. It generates a common terminology and helps to shift the emphasis on program development discussion from specific courses towards high-level issues such as program vision, goals, idea and the teaching/learning of generic skills. Suggested changes can be put in relation to the goals of the program. All learning outcomes are student-active formulated with inspiration from Bloom's taxonomy and constructive alignment, linking assessment, teaching activities and learning outcomes, is used as the common course design strategy.

Since 2010, the program plan for the Marine Engineer Program has been built mainly on courses of 7.5 ECTS (1.5 ECTS corresponds to one week of full time studies and, thus, one academic year is equivalent to 60 ECTS) with a structure of theoretical and practical courses, and onboard training courses of 15 ECTS. The program ends with a BSc thesis of 15 ECTS and two elective courses of 7.5 ECTS each. The last year (year 4) of program is entirely taught in English. The reason for this is to give the student good opportunities to prepare themselves for their coming work life and to be able to cater for incoming international students. There is four elective onboard training courses and two applied workshop and electrical systems courses. Over 90% of the students choose to attend these.

First year

The first semester prepares the students for the first onboard training course. The students also develop their knowledge base in mathematics and physics as well as in marine, and electrical engineering. In the courses Marine engineering and Marine engineering systems the students begin with their first design task in terms of a shaft with couplings that they will manufacture during the second year. The courses in marine engineering also contain laboratory work in engine room simulator and Standard Maritime Communication Phrases (SMCP) that is a requirement according to the STCW code and the Swedish Transport Agency.

Second year

The starts with courses in applied physics and communication and leadership. The course in flow science and thermodynamics is the first course in which mathematical knowledge is applied and deepened. Furthermore, the course is prior knowledge for the course Steam and refrigeration's techniques. Both courses have integrated exercises in the engine room simulator. Furthermore, communication teaching and training are vital parts of the Steam and Quality courses. During semester two the practical and applied parts focus on electrical engineering

and workshop skills together with combustion engineering. In both courses the students must use their knowledge and shaft design drawing from the first year.

Third year

During the third year, the program is broadened with courses and projects in Automatic control, Mechanics, Maintenance and Maritime law and economics. This prepares for the future role of commander and manager. The course Ship maintenance includes communication in English with an example of an authentic report task for a marine engineer. Within the courses of Mechanics and strength of materials, and Ship stability the knowledge of design of vessels and the needs for safe use of are strengthened.

Fourth year

The fourth year is taught fully in English. Laboratory work in the engine room simulator is practiced in Combustion engine engineering and Marine engineering project. Parallel to this there is two other courses in Maritime Environment and Computer based control systems. The Maritime Environment course includes both laboratory experiments with bilge water separators and a written assignment in the subject. Computer based control systems involves a project in programming of a complex elevator system. During the spring semester, the students complete their BSc thesis. In parallel with thesis work two elective courses are offered.

The BSc thesis work is carried out individually or in pairs (with individual assessment). The thesis project has a central role in the education and confirms that the students meet the requirements set for the Marine Engineer degree. The students show that they have not only learned facts, but also can apply and further develop their knowledge, skills and attitudes obtained during their studies.

Master program

After completion of the four years ME program, the students can continue studying at master's level at Chalmers. They possess sufficient prior knowledge to enter the master's program Maritime Management while they need to deepen their knowledge in Math, Energy, Fluids and Mechanics to enter the master's program in Sustainable energy systems and Naval architecture and ocean engineering.

THE ENVIRONMENT FOR LEARNING AT CAMPUS

The ME program has access to modern engine room simulators, combustion lab, electrical and mechanical workshop.

Engine room simulator (ERS)

The ERS is a simulator with 17 desktop stations, and full mission simulators, one with touch screens and one with traditional hardware equipment. The facilities are open for students to use all days of the week in scheduled sessions as well as for own training.

The workshop is fully equipped with, latches, welds, CNCs, electrical and logic control equipment. Also, to high-light, there is real high voltage equipment including the shore connection. The learning environment is also suitable for flipped classroom with video screens, spaces for face-to-face learning and team work.

At campus there is a main library that was transformed in to a learning common during 2016 with study as well as social spaces. It has been a very successful environment for the students and it is heavily used both for own studies, lectures and open workshops for communication and team work.

INTERNATIONAL BENCHMARKING

Chalmers has for long time been involved in peer evaluations with the CDIO community [10] and the Nordic five tech (an alliance of the leading Nordic Tech univ. [11])

In particular the Marine engineering program has teamed up with Frederica Maskinmester Skole (FMS) [12] to evaluate and compare the programs including identifying best practices and possibilities for improvements. In this work templates and experiences from CDIO and Nordic five tech were used. The new peer program was named Nordic Marine Engineering peer evaluation (N2ME) and it was performed during 2017-2018. The main findings will be presented under the further development.

EVALUATION OF MARINE ENGINEERING EDUCATION/ SWEDISH HIGHER EDUCATION AUTHORITY (UKÄ)

In 2016 the Maritime educations in Sweden were evaluated and accredited by the UKÄ, the Swedish authority reviewing Higher Education Institutions (HEIs) [7]. The ME program came out well in the evaluation with clearly identified strengths and minor suggestions of areas to further develop.

Strengths

- The scientific basis of the education and the connection to research
- The systematic procedure to ensure the quality of the thesis projects
- Laboratory and simulator exercises in up-to-date simulators and workshops
- Integrated project work including reporting, teamwork and systematic assessments.
- Integrated teaching and training of written and oral communication.
-

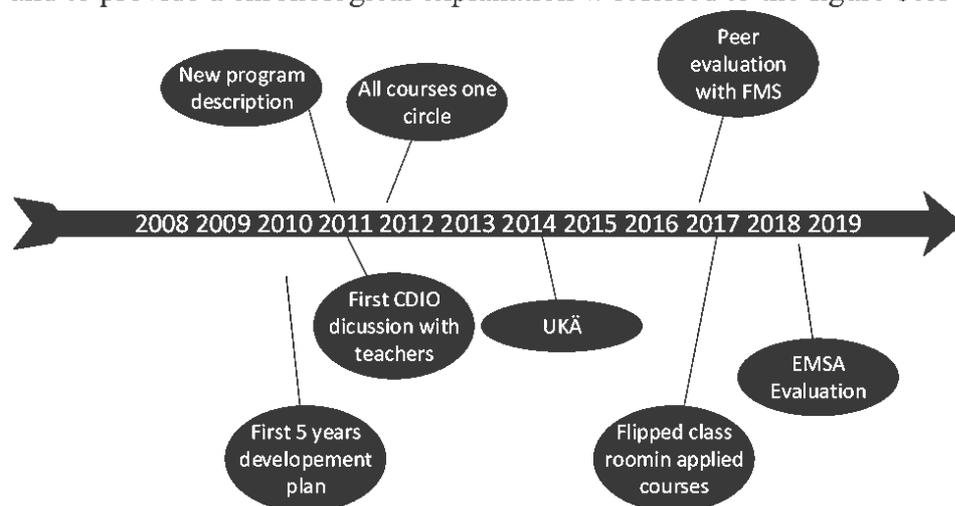
Areas to develop

- Maritime engineering, in particular fire safety
- Teaching, learning and assessment of work Ethics

Educations in Ethics and Fire safety have now been developed, implemented and approved.

THE TIMELINE OF IMPLEMENTATION

The program structure of today has its roots in 2008 with further development. To view this and to provide a chronological explanation we referred to the figure below.



Time line of program developments carried out during ten years. Own copyright

SUCSESSES FACTORS

When working with long-term development of an education program with the respect of implementation of the CDIO approach and Swedish Transport Agency and EMSA accreditations accreditation we have found some factors that we like to share as success factors. The teachers and administrators that are affected must be involved, acknowledged and get the time for own reflections due to the changes. Time is also an important factor and not try to change all parts in a short time span but use an agile incremental developments strategy. Education is a slow process and it is impossible to foresee all effects of changes as well as the rapid changes in technology and the society which call for an adaptive strategy. The program needs clear aims but also the ability to continuously revising goals and set new goals. The ME program has a clear aim in educating future marine engineers that can take leading roles in operations onboard as well as in onshore industry. The program has also showed the ability to set new goals including, e.g., integrated curriculum, ethics, sustainability, authentic problem-based learning, the use of simulators and practical electrical and mechanical work.

The education management structure needs to be suitable for changes an able to handle conflicts of interests that appear in a multidisciplinary education. To meet this a strong program level is crucial with clear mandate and responsibilities. The program head needs support from university management to drive the changes. Developments will need some investments. Allocating money to investments in education development is a key responsibility of university management.

A purposeful quality assurance system that monitors and guides the development of the program is essential. The system needs to be designed so that it measures the intended development and includes the views of the stakeholders. Further, it needs to be easy to implement and accepted by teachers, managements and stakeholders to avoid that it does not merely become a “paper product”.

Finally, active participation from stakeholders, in particular, students and employers, are crucial for a sustained educational reform aiming at an education that is attractive for students and in harmony the present as well as the anticipated needs of the industry. The major body for this in ME program is the advisory board with active participation by industry and students. The key to make this function is to have active participants. The way to get them active in the developments is to show that they have impact and that the changes are implemented.

FUTURE DEVELOPMENT

To have a clear direction of the coming development the program has a five years plan. The plan includes the following quality assurance activities and developments

- Continue and develop the Peer assessment with FMS,
- Actively work with recruitment of motivated students,
- Development and implement an educational track of maintenance engineering,
- Be an active part in the development of teaching and learning of generic competences at Chalmers and implement relevant findings in the ME program,
- Develop the database for STCW outcomes,
- General information about the STCW code among the teaching staff would give the teachers a better understanding of it as well as provide assurance that the learning goals are achieved.

- Take an active part in the develop the learning and social environment at Campus, and
- Strengthen information to teachers about the whole program, in particular, including a mentor program for new teachers,

CONCLUSION

With this paper we have summarized and, in some parts, evaluated Chalmers' Marine engineering program's developments during a time line of ten-years. During this 10 year there has been a lot of changes in the program and a large number of new educational innovations has been introduced. Some of the changes have been stated from the beginning but most of them have evolved during the journey as it is impossible to foresee what is needed and the rapidly changes during a ten-years period. Internal and external evaluations involving stakeholders as well as peer evaluations with international partners have gained the most input and inspiration to the developments.

The CDIO concept is found to be applicable and very useful for the ME program although the program is not a traditional academic engineering program. The CDIO approach has provided the program with a number of strategies and tools that have been essential for the developments this include a clear vision and strategy as well as a toolbox to form an integrated curriculum and to use quality assurance processes to develop, implement an execute the educational program.

Finally, the Chalmers educational management structure with a strong program level have proven to be a key circumstance to implement changes. A strong program level is found to be essential for implementing changes as, e.g., integrating general engineering skills, and for resolving conflicts between different disciplinary interests A strong program level is also found to be crucial for monitoring and evaluating the program as a whole.

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A Review of Technology, Infrastructure and Human Competence of Maritime Stakeholders on the Path Towards Autonomous Short Sea Shipping

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ABSTRACT

Shipping is fast moving towards digitalisation and minimising human intervention in its processes. This article intends to explore the implications of such changes in human element competencies across core-stakeholders such as Ports, Vessel Traffic Services (VTS) and Information and Communication Technology (ICT) providers. It is apparent from the findings of this article that digitalisation is assisting stakeholders to be efficient and competitive. This trend is complementing the implementation of autonomous ships that depends on stakeholders for safe and efficient operations. However, as stakeholders continue to automate the processes previously performed by humans, the required physical and manual skills of employees would decline. Alternatively, future employees would require multitasking and cross-functional competence at all levels. It is also evident that future employees of these stakeholders would require to have a degree of technological competence to be to perform their jobs.

1. INTRODUCTION

Autonomous ships without seafarers' on-board is the inevitable future. Thus, it is important to understand how the stakeholders involved in shipbuilding to ship operation would complement the transition [1] [2]. Automation is not a new concept in shipping [3]. More than a decade ago, a Radio officer was mandatory on-board all trading ships. However, Global Maritime Distress and Safety System (GMDSS) made the Radio officer's job redundant as deck officers were allocated the task of operating the GMDSS equipment [4]. As the result the radio officers needed to upskill to be able to work in other capacities such as electrical engineers with different functional competence [4]. The GMDSS system made it easy for Search and Rescue (SAR) teams ashore to quickly assess the ships situation with regard to casualty and exact position with a click of a button.

Currently, on board ships human is the final decision maker. In future, as the automation of systems progresses, autonomous ships would operate by Artificial Intelligence without human assistance. Thus, it is important to comprehend how the transformation from conventional to smart ships (Automated Functions with Crew on-board) and from Smart ships to Remote Controlled ships (Without crew on-board. Crew embark in port area to carry out critical functions such as mooring) to finally autonomous ships with human operator (at a remote Shore Control Centre (SCC)) to only convene in case of an emergency would take place.

In this process it is important to understand that shipping is multi-faceted and involves multiple stakeholders [2]. Thus, to operate an autonomous MASS safely and efficiently, cooperation and partnership with stakeholders are critical.

2. METHODOLOGY

In this study, Integrative Literature Review method was utilized (Torraco, 2016). In this method, relevant bodies of literature were synthesized to propose a competence framework for the human element required for the autonomous operation of a MASS. In addition, stakeholders career webpages were analysed. This helped to find the competence of the employees who were being recruited.

3. FINDINGS

This paper studied the type of services that would require to be provided by stakeholders to successfully complete a MASS voyage both safely and efficiently. The findings of this study show that the stakeholders' involvement with shipping can be categorized into Operational, Technical, Commercial, Regulatory, Legal and Financial aspects. The following sections present findings of this study regarding possible future technology, infrastructure and competence of the stakeholders that would complement autonomous shipping.

3.1 OPERATIONAL

3.1.1 Terminals and Ports (Technology, Infrastructure & Competence)

Future ports are expected to be interconnected with ships, other ports and other modes of transport such as trains and trucks. Thus, most of the port logistics functions would be automated and almost all stakeholder data would be on the cloud [5]. This would also complement Just in Time arrival that is part of port call optimisation [6]. Also, technology such as automated mooring solutions without human involvement and fast charging for battery powered MASS would be available for autonomous ships [5].

It is expected that the demand for employees with competence in cloud computing and networking would increase, as most logistics functions would be carried out autonomously using AI [7]. Port employees who are delegated the maintenance of equipment in port and managing repairs of MASS would have to undergo further training to be competent in handling 3D printing or maintenance of MASS equipment. Port employees responsible for the maintenance function are presently being trained using advanced Augmented Reality (AR) to swiftly troubleshoot autonomous machinery failures. They would require cross-functional competence in electro technological, mechanical and IT functions to complete most port jobs successfully as further digitisation and interconnectivity between port and other stakeholders takes place [5].

3.1.2 VTS (Technology, Infrastructure & Competence)

The future VTS operation would be affected by autonomous shipping. As a matter of fact, the changes are already started to happen. For example, MONALISA 2.0 is a project that carried out to enhance Sea Traffic Management (STM). In this project ships entering the VTS area would upload their passage plan into the VTS server where a VTS operator would advise on the limitations and precautions. Further, a comparison of all ships in the operational area

would be analysed for assessing safety of transit [8]. Porathe et al (2014) suggests a different perspective where the VTS operator should only warn the Shore Control Centre (SCC) operator as in the case of conventional ships. The ship should decide how to utilize the resources on-board especially in case of emergency. Further, the current communication medium requires improvement. Instead of communication over VHF, it is suggested to use messages that would prompt on the SCC operator's screen [9]. Thus, VTS would complement autonomous shipping by providing their core-competence that is reliable navigational assistance for MASS.

As VTS transforms to being a STM, the responsibility of managing the ships safely and efficiently would be vested more on the STM operators. Further responsibility would be vested if VTS operator were given the task of MASS navigation. In that scenario, VTS operators would require complete understanding of MASS navigation including the technology and its limitations [10]. As in the present VTS, STM could employ a navigator who has experience navigating a MASS, as the competence would be almost similar. However, the STM operator would require higher cognitive skills such as critical thinking and decision-making more than the present day VTS operators have [8].

3.1.3 Equipment Suppliers (Technology, Infrastructure & Competence)

The MUNIN has proposed IEC 61162-460 standard, which assures persistent communication with cyber security capability even in case of worst weather conditions [11]. Hoyhtya et al (2017) suggest a resilient communication architecture, which comprised of terrestrial and satellite components as well as High Altitude Platforms (HAP) system. Also for ships on intercontinental voyages the European Space Agency (ESA) is developing a 5G-satellite network that would help the implementation of autonomous shipping [12]. Thus, communication technology providers would complement autonomous shipping by providing their core-competence that is reliable with cyber security enabled data communication.

Future workforce would require competence in machine learning or artificial intelligence as the 5G satellites would not only be communicating between earth stations but also among themselves [12]. Therefore knowledge of tidal patterns, current and seismographic data analysis would be required for HAP or similar marine communication systems in place [13].

Big Data storage and analytics companies would be commonplace in maritime transport domain as stakeholders become more connected and share information [14]. Technology companies such as StormGeo have commenced to provide shipping companies with services such as real time updating of route planning [15]. Thus a SCC operator would have to only follow the route provided by the route planning company to safely and efficiently navigate between destinations.

3.1.4 Search and Rescue Coordination Centre (Technology, Infrastructure & Competence)

UK Maritime & Coastguard Agency (MCA) recently commenced testing the use of drones for SAR missions. Thus Unmanned Aerial Vehicles (UAV) would initially be sent to assess the situation before sending human rescue teams [16]. Also, international maritime consultancy and software company Qinetiq is constructing an autonomous fire fighting crafts that would continuously be deployed in ports and offshore area. Thus, human SAR teams would

not have to risk their lives [17]. As the result, SAR would complement autonomous shipping by providing their core-competence that is salvage and assistance in safe operation of MASS.

The SAR team would require licenced UAV pilots as well as licensed USV operators for navigating and operating the autonomous or remote controlled fire fighting crafts [18]. Also SAR teams would require upgrading their competence to salvage a MASS as design and on-board features are peculiar to a conventional ship.

3.2 TECHNICAL

3.2.1 Classification Society (Technology, Infrastructure & Competence)

Future Classification Societies would assume a central role in relation to verification and certification of MASS [19]. It is expected that the MASS would continuously be remotely monitored from Shore unlike present day where Classification Society surveyors board the ship for inspection [20]. Further Classification Societies would be liable to third party claims levied directly against them [19]. Thus, classification societies would be legally responsible for maintaining safety of MASS. Classification Society surveyors would require advanced IT skills, as system verification on a MASS would be mostly on software such as Artificial Intelligence systems [21].

3.2.2 Insurance (Technology, Infrastructure & Competence)

The Original Equipment Manufacturers (OEM) of critical equipment of MASS such as Navigation would be held liable in case of a collision or grounding instead of the ship owner [1]. The Insurance company staff would need to be proficient on the maritime law for MASS [22].

3.3 LEGAL—Arbitrators (Technology, Infrastructure & Competence)

Maritime lawyers would require having knowledge of amendments to law such as Hague Visby rules [22].

3.4 REGULATORY—Flag State (Technology, Infrastructure & Competence)

Many of the present regulations would require to be amended upon introduction of MASS [22]. Regulations pertaining to IMO regulations such as SOLAS, COLREG, STCW and Load Lines would be affected [23]. Thus, staff of flag states such as Australian Maritime Safety Authority would require having knowledge of amendments to National Law Act 2012 [22].

3.5 FINANCIAL—Ship construction (Technology, Infrastructure & Competence)

Ship manufacturers' are looking for innovative business models as present ship construction business market has saturated [14]. Thus innovative business models such, as MASS renting similar to the UBER Autonomous Vehicle (AV) fleet business model would be common among the ship builders [14]. Staff of ship Construction Companies would require having technological skills as the business would be operating on a software platform [14].

3.6 COMMERCIAL—Freight Forwarders and agents (Technology, Infrastructure & Competence)

Recently Container shipping companies such as Maersk has digitalised maritime transactions amalgamating with IBM block-chain technology [24]. Thus the middlemen such as Freight Forwarders or agents would become obsolete as more companies adapt the technology and become connected [24].

4. DISCUSSION

It is evident from the findings that present day ports, VTS, shipyards and other stakeholders are fast embracing digitization to improve productivity and competitiveness. Inadvertently, this transition is aiding conventional ship to smoothly transform towards autonomous shipping. Presently, most of the responsibility in assuring seaworthiness of a ship including maintenance and repair function is all done by ship staff. However, as the transition from shipboard to SCC takes place most functions carried out by shipboard staff is expected to be delegated. For instance, maintenance staff of MASS would be designated at Ports. It is also apparent that few stakeholders would become obsolete as digitalisation and connectivity between stakeholders improve. It is also expected that new regulations would make all stakeholders responsible for the part they play in ship operation. As per Australian Consumer Law (ACL), the product manufacturer is liable for any casualty arising by using a product [25]. Such a regulation would enhance relationship and coordination among the stakeholders. This would further assist in making all stakeholders interconnected through technology such as cloud computing [26]. It was also identified that new companies and new jobs would be created as the transition of seafarers takes place from shipboard to SCC. Many new start-up companies with competence in specialization of digital service solutions such as vessel performance monitoring or vessel tracking that are presently being performed manually by many ship operators are on the rise. Thus, employees with technological competence in big data analytics, software development, robotics and AI would be in demand.

5. CONCLUSION

This digitization trend is paving the path towards autonomous shipping. Even presently many of ship operational functions are delegated to stakeholders. In the near future the stakeholders need to possess core-competence that would complement autonomous shipping functions without seafarers onboard. The industry would evidence more employees with competence in AI and advanced technological skill is joining the workforce. The current physical and manual activities for instance in places such, as ports will be replaced with robotics and automation. It is evident that the future workforce in shipping apart from their core competence e.g. mechanical engineering would need to be digitally savvy. We are in a transition period so, as in the past, the current employees would have to upskill their competence to suit the future job profiles.

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Gender equality policies for the incorporation of the gender perspective in maritime studies: a case study

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ABSTRACT

This paper aims to determine the effectiveness and impact of current gender equality policies, regulations and programmes in the maritime educational sector. To this end, the specific policies and programmes applied at Universitat Politècnica de Catalunya·BarcelonaTech (UPC) have been considered. More specifically, a pilot project implemented at the UPC that tries to incorporate the gender perspective in engineering university degrees, has been studied. The outcomes of such a plan on maritime studies have been analysed in order to determine the impact of its implementation. The preliminary results confirm the gender gap in maritime education, which is then transferred to the professional sector, and the need to foster more inclusive gender policies in MET institutions. Finally, some conclusions have been drawn up to provide some recommendations based on the evidence gathered with the final aim of assisting maritime institutions in making informed decisions on future gender equality actions.

1. INTRODUCTION

Although the number of female students enrolled in Maritime Education and Training (MET) institutions has shown an increase since their incorporation into maritime studies, female figures are still far from the desirable gender balance expectations. In line with other present findings and observations in the MET space, a recent study [1] shows that between 2009 and 2018, there is no significant raising tendency concerning female figures in any of the European MET universities analysed. This gender imbalance seems to be a widespread problem and becomes worse in developing countries where women have even more difficulties for enrolling in maritime programs. Besides, the same study concludes that gender equality promotion policies are still scarce or inexistent in the MET institutions studied and have had a limited effect on female enrolment figures. Hence, in spite of a raising awareness of the need to foster policies and programmes for the incorporation of female students in maritime education, there is still a lot of work to be done to guarantee the success of gender equality in MET. In line with this, considerations of gender discourse or pedagogy in maritime studies may also constitute an important

asset to reduce the present gender imbalance in this male-dominated maritime educational sector and to incorporate a new and necessary gender perspective.

2. MARITIME EDUCATIONAL POLICIES ON GENDER EQUALITY

Tertiary education institutions play an important role to address gender equality issues in MET as they transmit not only knowledge but also societal norms and values [2], to this end, they may promote of gender equality and cultural awareness [3]. In line with this, a research study carried out in 2015 [4] explored how gender equality was addressed in the curricula of maritime education, examining official study plans and curricula from eight maritime universities in Finland, Norway, Sweden and the Philippines; all countries ranked in the top five in the Global Gender Gap Index. Contrarily to the expectations, the study concluded that gender issues were not a visibly integrated part of curricula in any of the eight universities analysed. In order to bridge this gap, most institutions are developing their own policies to integrate gender issues in higher education. For example, the Swedish World Maritime University (WMU) has developed and implemented its own policies to achieve gender equality and women's empowerment in the maritime transport sector and within the institution itself [4, 5] with quite successful results as the policies adopted for increasing the number of female graduates resulted in an augmented female student body, the policies adopted for reaching gender parity opened doors to female academics and the gender perspective was integrated in sections of the curriculum [6]. In Europe, education policy issues on gender equality are considered since the applicability of the new European Higher Education Area (EHEA). European legislation provides guidance and support to higher education institutions concerning the promotion of gender equality, political and religious tolerance, and democratic and civic values as anti-discrimination measures regarding the appointment and promotion of staff, and equal access to education and learning [7].

At national level, numerous examples of laws passed to promote a culture of gender equality in education can also be found. In Spain, there is a law for the quality of education that fosters anti-discrimination and gender equality in educational centres [8]. In line with this, in order to foster a culture of equity and equality of opportunities for women in all Catalan Universities, the Catalan University Quality Assurance Agency (AQU) is promoting a regulation for the incorporation of the gender perspective in the all the bachelor's degrees in tertiary education in Catalonia by 2021 [9].

2.2. THE GENDER DIMENSION IN TEACHING: A UPC PROJECT

The Universitat Politècnica de Catalunya · BarcelonaTech (UPC) is a public institution of research and higher education in the fields of engineering, architecture, sciences and technology, and one of the leading technical universities in Europe positioned in the main international rankings. The UPC promotes equality within the university community and in the society it serves. This is the reason why up to the present, this institution has implemented three different Equal Opportunities Master Plans with the general aim of promoting a culture of equity and equality of opportunities for women [10, 11, 12]. These plans also intend to overcome the present gender imbalance between female and male students in the different UPC engineering studies (25.8% of enrolled female students over

the last decade). The I and II Plan were implemented during the periods 2007-2011 and 2013-2015 respectively and since 2016, the III Plan for Gender Equality is in place. The results of the implementation of the I and II Plan show a slight increase in female student enrolment at degree level and a stabilisation of the falling tendency at master and doctoral level. Thus, these plans may constitute a first step to overcome the gender gap in engineering studies but the results reveal that there is still a lot of work to be done in this direction. Concerning Barcelona School of Nautica Studies, although these plans are not particularly addressed to Maritime studies, the school also benefited from these promotion policies and slightly increased the number of female student enrolment when the II Plan was launched.

In addition, in order to comply with the AQU regulation for the incorporation of the gender perspective in the all the bachelor's degrees in tertiary education in Catalonia by 2021, the UPC launched a pilot project to integrate the gender dimension in teaching. The *Gender dimension in teaching and GEECCO project* receives funding from the European Union's Horizon 2020 Research and Innovation programme, which also includes gender equality as a transversal issue in all its work programmes, thus ensuring a more integrated approach to research and innovation. In the first implementation of this pilot project, eight teams from different UPC engineering degrees participated with a view to introducing the gender perspective in teaching in some of their courses. The participating teachers volunteered to incorporate some activities in their courses to make students work and reflect on different gender issues. The outcomes of the project were analysed in order to determine the impact of its implementation and its transferability to other engineering courses and degrees. Likewise, as the present research is mainly addressed to MET, its main focus is on the applicability of such policies and proposals on maritime education and its transferability to different maritime courses and degrees.

3. METHODOLOGY

This paper focuses on the implementation of the UPC Gender dimension in teaching project at Barcelona School of Nautical Studies and analyses its impact on maritime studies. One hundred students from Marine Engineering and Nautical Studies & Maritime Transport bachelor's degrees participated in this pilot project. The selection of courses chosen to implement the proposed guidelines was based on the willingness of the teaching staff wishing to contribute to the project. The participating courses were *Maritime Technical English, Mechanics Technology, Marine Pollution Prevention and Sustainability and Ship Stability*. These four different courses followed an agreed methodology to incorporate the gender perspective in teaching together with the other participating UPC engineering courses.

The applied methodology consisted of a pre-test, different activities to incorporate the gender dimension in teaching, a post-test and a pre- and post-test analysis. All these steps were carried out during one semester. The pre- and post-test were developed to help gather information on knowledge, attitudes, opinions and behaviours on gender issues. The pre-test was passed at the beginning of the semester and comprised five different sections. The first one included some general information and the second incorporated questions on professional references in the maritime and naval sector. The third asked

participants about their perceptions as UPC university students on different gender issues. Section four comprised some questions relative to women figures in Barcelona School of Nautical Studies and the maritime professional sector. Finally, section five included different questions for the different participating courses depending on the activities to be undertaken in class. The activities incorporating the gender dimension were designed, developed and implemented by the teachers in line with the contents of their courses. At the end of the semester, the same questionnaire was passed and the responses obtained were analysed to determine any significant difference between the pre- and post-test results. These results were analysed individually for each course and then the mean values for all the common sections of the maritime courses were calculated to discover any common tendency in maritime studies. It should be noted that as this is the first edition of this pilot project there is still room for improvement regarding the methodology applied and that subsequent editions will be enhanced according to the weaknesses detected.

4. RESULTS AND DISCUSSION

Some preliminary results show that the gender distribution among the participating students (20% of female students and 80% of male students) corresponds to the present figures of student enrolment in Barcelona School of Nautical Studies. After analysing their replies to the pre- and post-test questions, it can be observed that students' perceptions as for the number of female students enrolled and graduated at Barcelona School of Nautical Studies, which is of 20% over the last decade, is quite accurate (see Figures 1 and 2). However, the number of correct answers slightly increases in the post-test after students were informed about the actual figures during the course.

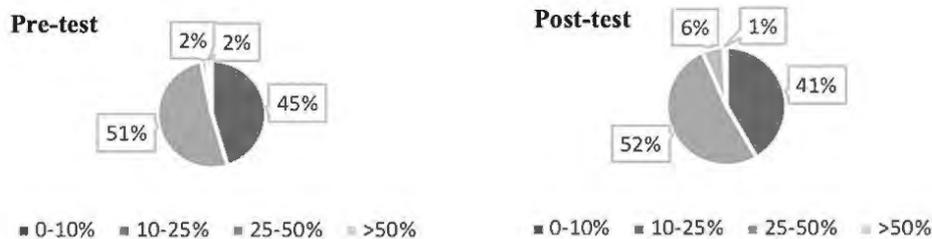


Figure 1. Student responses on female student enrolment figures at Barcelona School of Nautical Studies



Figure 2. Student responses on female student graduation figures at Barcelona School of Nautical Studies

Similarly, when being asked about the number of women obtaining Master Certificates of Competency (CoC) issued by the Spanish Maritime Administration, which is 15% over the last decade, students realize that their expectations in the first test were not very exact and the number of right answers increases in the post-test (see Figure 3). Nevertheless, with respect to the percentage of women earning Chief Engineer Certificates of

Competency (CoC), participants rightly guess in the first test that this is not higher than 10% (it is in fact only 5%) and this percentage remains the same in the post-test (see Figure 4).

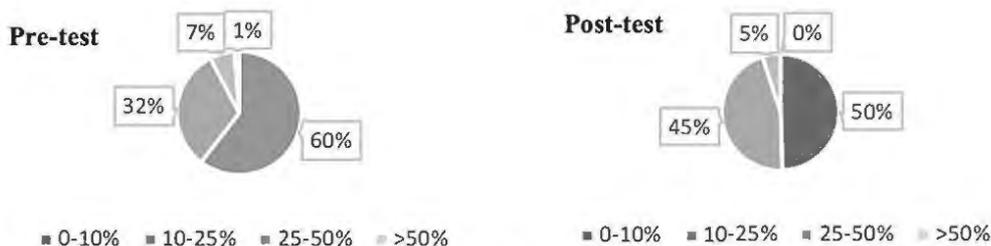


Figure 3. Student responses on women obtaining Master Certificates of Competency (CoC) in Spain

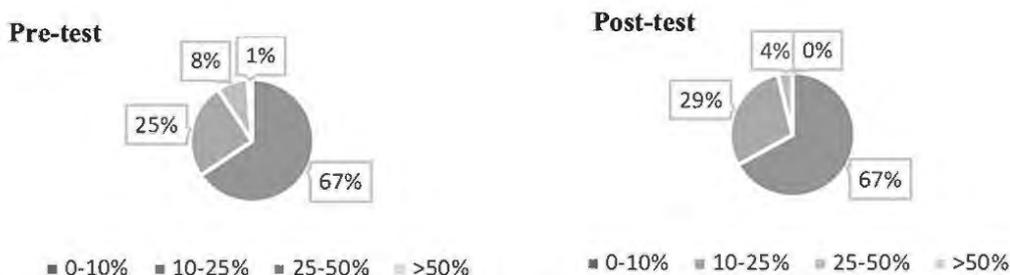


Figure 4. Student responses on women obtaining Chief Engineer Certificates of Competency (CoC) in Spain

Also, when asked about their knowledge of male and female references in the maritime and naval sector at the beginning of the course, 32% of students identify some male reference in the maritime sector in front of an only 14% that identify a female reference. However, their knowledge of female references increases up to 34% by the end of the semester although only 16% believe that there is visibility of female professionals in the maritime sector. Another section of the questionnaire asked students about their perceptions on different gender issues. Although 59% of students have never experienced a differential treatment among female and male students on the part of teaching staff, 19% of students believe that such a differential treatment exists and 16% of them consider that girls encounter more difficulties throughout their studies due to gender issues. Merely 23% of students have observed the use of sexist language in class whereas a broad 44% of them recognise an effort on the part of some teaching staff members to use a more gender-inclusive language. Concerning the use of stereotypes in teaching materials, only 8% of participants have occasionally detected some stereotyped images in presentations, course notes and books. As for classroom management, 86% of students have never noticed any significant gender pattern in the distribution of tasks in cooperative learning activities. However, those that have worked in mixed groups agree that usually girls are the ones who make decisions (94%), take notes (80%) and manage groups (75%). On the contrary, 53% of participants believe that male students intervene much more frequently than female ones in classroom interactions with the whole group. Finally, 88% of students consider the existence of gender projects like the one presented in this study really necessary.

5. CONCLUSIONS

The results of the present study show that the implementation of this pilot project for the incorporation of the gender perspective in maritime teaching has brought about some changes in students' knowledge and perceptions concerning gender issues. First of all, students become more aware of the gender gap in the maritime and naval sector and even in their own studies after participating in all the proposed activities. Furthermore, after the analysis of the results, it becomes clear that the gender dimension should be considered at different levels, namely course contents, methodology, classroom management and assessment. With respect to course contents, these should incorporate a gender-inclusive language, avoid stereotypes in the examples and make use of female references as models for students. On the other hand, including women in the bibliographic references and writing their full names may also help to give them more visibility. Concerning methodology, this should cater for different learning styles and should also allow students to reflect on social and gender issues. Classroom management should contemplate the assignments of tasks and roles in classroom interaction in order not to fall into gender-biased patterns, foster a balanced participation and offer a wide variety of experiences and topics to suit the different gender needs. Finally, although it was out of the scope of the present project, assessment should also be revised in terms of exam and question types, teacher intervention, interaction and student response as it has been demonstrated that all these aspects also affect student response depending on gender. Finally, as drawn from the results of the test and students' own perceptions, the incorporation of the gender perspective in teaching becomes crucial if we are to bridge the gender gap and offer a more inclusive training in maritime studies. This requires a joint effort from university administrators, teaching staff and students. University administrators should incorporate the necessary changes in the curricula and provide lecturers with the necessary tools to modify their teaching pedagogy and course contents accordingly. These joint efforts, together with the raising awareness of students on social and gender issues, may favour a change towards the desired direction.

To conclude, it should be noted that these conclusions obtained from the implementation of the pilot project at Barcelona School of Nautical studies are mostly based on students' answers to the different questionnaires. It will be interesting to widen this research in the future in order to gather additional support for these initial findings and observations with a view to improve the implementation of further editions of this UPC gender dimension in teaching project and to refine the results for the maritime domain. For example, the analysis of similar studies carried out in other institutions can be one of the aspects to examine in future research. In addition, the effects that gender policies may have in the maritime industry should also be considered as MET and the professional sector cross-feed each other. Besides, it is well-known that different international organisations, namely the International Maritime Organisation or the European Commission, also aim at addressing this gender imbalance in the blue economy and encourage women to step into traditionally male-dominated work areas.

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Process approach for determining competencies

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ABSTRACT

The competencies, as defined in the STCW Convention, are in most part based on traditional shipboard organization, related to common shipboard departments and traditional levels of responsibilities (i.e. management, operational and support levels). Their descriptions mostly refer to the certain task, and are not interconnected with other jobs and tasks. In the future, the strict division between departments and tasks is expected to disappear, or at least to significantly diminish.

In the paper, the results of the two-year research activity are presented. The main goal of the research was to interrelate the on-board processes with competencies required to control and accomplish those processes. Consequently, it requires a process approach implying identification and analysis of critical processes, sub processes, activities, decisions, tasks, and executors. The work processes of the Masters and Chief officers on board LNG carriers and cruise ships have been analysed, and compared with competencies as stipulated in the STCW Code A and B, Model Courses, study programs of the Croatian higher MET institutions, and continuous professional development programs. Results indicate that presently used competence descriptors do not describe competencies up to the required level, particularly as expected in the future working environments.

1. INTRODUCTION

A rapid development of technologies used on board ships changes the way the ships are controlled and operated. Anticipated developing trends include further increase of decision-making capabilities in various control units (AI), increased number of different measuring sensors, extensive redundancy of critical systems on board, remote-controlled vessels, and finally gradual introduction of autonomous vessels. Consequently, the concurrent operations of autonomous vessels, remotely controlled vessels and manually controlled vessels are highly probable.

These changes are creating new tasks and challenges for human operators on board. It is beyond any doubt that humans, participating in the shipboard processes, will have to master additional competencies. Presently, the most notable developments are those related to onboard decision-making processes. Rapid development of new technologies and AI-based systems on board ships are followed by continuous reduction of the ships' crews. This causes increased workload, despite the increased level of ships' automation. Finally, these developments change the roles

and responsibilities of ships' crews as well as those ashore. At the end, these new forms of control and supervision functions will require respective changes in the legal framework.

Transition to new technologies and ever-increasing complexity of the conventional technologies seems to be a rapid process rather than the gradual one. For example, new MARPOL requirements for sulphur content in marine fuels resulted in increased use of liquefied natural gas (LNG) as fuel. Consequently, new competencies turn out to be required, new certificates are introduced as well as new IMO Model Courses (IMO, HTW 6, 2019).

The most challenging transition will be the introduction of the Marine Autonomous Surface Ships (MASS). According to the present understanding of the capabilities of the autonomous marine systems, IMO divided these ships into four categories (IMO, MSC 99/5/n, 2018):

- Degree one: Ship with automated processes and decision support. Seafarers are on board to operate and control shipboard systems and functions. Some operations may be automated and at times be unsupervised, but with seafarers on board ready to assume control.
- Degree two: Remotely controlled ship with seafarers on board. The ship is controlled and operated from another location. Seafarers are available on board to take control and to operate the shipboard systems and functions.
- Degree three: Remotely controlled ship without seafarers on board. The ship is controlled and operated from another location.
- Degree four: Fully autonomous ship. The operating system of the ship is able to make decisions and determine actions by itself.

It is quite clear that new competencies will be required for crew members (on the MASS vessels of degree one and two) and for shore-based operators who will remotely monitoring and control MASS vessels. The MASS operators will need new competencies, mostly related to control and supervisory systems they will use, but also will need a support from the team members with traditional maritime competencies (Yemao, et al, 2015). At present, regulatory framework as defined by the STCW convention is applicable only to the crewmembers on board and not to operators working in shore-based control centres (Komianos, 2018).

Considering all these factors, it seems that the main role of the ship management in the future will be much more supervision-oriented; decision-making and action execution will be expected only in extraordinary circumstances. The same applies to operators ashore. New roles will require new competencies to be developed, some existing ones to be upgraded, while some presently required will become obsolete.

2. NEW TECHNOLOGIES AND EFFECTS ON REQUIRED HUMAN SKILLS

New technologies implemented and used on modern ships have and will have substantial effects on human competencies.

One of the most easily noticed change is a significant increase of quality and reliability of information. The term "information" here refers to raw information, including raw data generated by the increased number of sensors, metadata (data about data), as well as to real time data (video and audio streams), either requiring human interpretation or not. In general, the quality and reliability of different data streams is constantly improving. Unfortunately, extended availability of information increases the number of correspondents (data users) interacting with the vessel. It is quite common these days that nearly every stakeholder in the

transport process wants to have real time information about ship's movement instead of just using already processed information.

In addition, new types of sensors and measuring equipment offer information previously not available. Consequently, additional competencies are required to process multitude of information and data. In some cases, expert knowledge and experience are required to process the available data and to react as required. Sometimes, there are multitudes of ways to analyse available data. To ease the burden, the AI based systems are eventually introduced. In some cases, the implementation of AI helps, in some cases it only increases the ambiguity, particularly when crewmembers must decide which information is sufficiently reliable and relevant for further actions. In most of the cases, only a part of the available information is needed for the crew to react (Maglic et al, 2016).

In addition, the whole process has become more complex by involving new stakeholders with different legal interests.

As a final point, the main consequences are:

- 1) significantly increased quantity and quality of information, requiring new competencies, some requiring the knowledge and understanding quite beyond the level of knowledge commonly delivered at traditional MET institutions;
- 2) transition from individual to collective decision making (teamwork!), as a rule increasing the quality of decisions made, but also requiring much longer time to reach a conclusion (it is particularly emphasized when decision making is shared between ship and shore management);
- 3) shared responsibilities, mostly because of the extended number of stakeholders (decision-makers), sometimes up to the level that actual responsibility is cluttered;
- 4) increased dependencies on team members, particularly because increased number of highly complex operation requires the increased number of executors, thus increased probability of underperformance.

It seems that gap between required and actual competencies is recognized by many shipping companies particularly those operating highly sophisticated ships (Gundić et al, 2015). Knowing that digitalization as a process is clearly getting momentum, the remedial actions in respect of missing competencies must be considered at the STCW level. It is important to note that these remedial actions will have to consider also the missing competencies of those ashore, not only shipboard personnel.

3. COMPETENCIES

The concept of competencies (as ability to do something successfully or efficiently) was introduced in the 1950s (Mulder, 2014). The main cause was a recognized difference between abilities gained at educational institutions and those needed to perform a job. There is no universally accepted definition of competencies (Dragoo and Barrows, 2016). According to some authors, the competence is a dynamic combination of knowledge, understanding and skills (Caena, 2011). Almost the same definition is used in the STCW Convention according to which a competence consists of associated knowledge, understanding and skills. However, some authors believe that competencies are more than just knowledge and skills. As the competence concept was developing, so were the assigned definitions. For example, (Nanzhao, 2005) considered the idea that competence is a combination of one's capabilities, temper, and

talent. That is, a competence consists not only of one's ability to perform demanding tasks, but of one's attitudes too (DeSeCo, O.E.C.D., 2005). Every individual must be able to use, apply and show awareness, knowledge, skills, and attitude to perform a job effectively (Wahba, 2013). In other words, a competency refers to every distinctive trait, knowledge, skills, and all other qualities of an individual needed to perform a job effectively (University of California, 2012). In a larger sense, a competence represents a combination of cognitive and practical skills, knowledge, motivation, values and ethics, attitudes, emotions, and behaviour that lead to a successfully performed job (Nanzhao, 2005, according to Rychen, Tiana, 2004). It can be summarized that common features for all definitions of competencies are knowledge, skills, and attitudes.

In the STCW Convention competencies are determined according to ship operations (functions) at operational and management level. That led to the classification of competencies that are not clear and precise enough to refer clearly to the unique shipboard process. Another problem is that competencies, as identified in the STCW Convention, are mostly those required on ships commonly trading at the time of the Convention development. At the time technological differences among various ship types and trades were relatively narrow, competencies were relatively easily transferrable, and social relations were relatively simple. Maintaining and upgrading required competencies was relatively simple, usually by attending few short courses or a specific on-board training. In addition, the competencies were mostly perceived as static; working environments were not considered.

Nowadays, technological differences among various ship types and trades are significantly more distant. Because of that, competencies are not easily transferrable, and short courses are not enough, especially for technologically advanced ships (e.g. LNG ships).

As a result, today one can easily recognize obsolete competencies (celestial navigation, still taught in many MET institutions!), but also missing competencies, particularly if highly sophisticated ships are considered (numerous short courses required by companies operating such ships). The list of missing competencies includes especially those associated with the social arena, like those referring to social networks, cyber security, high-tech control, etc. Finally, competencies, as defined in the STCW Convention, refer only to a person, without analysing his/her surroundings.

Based on the mentioned, it is quite clear that competencies should be linked with working processes on board ships as well as with the tools and devices mandatory (or commonly) used aboard.

4. FORMALIZATION OF THE COMPETENCIES USING PROCESS APPROACH

Processes on board ships are complex and consist of many system elements. These elements are shipboard organizational units, tools, and devices. An organizational unit¹ can participate in many different processes and vice versa, more organizational units can participate in only one process. In other words, various combinations of organizational units, equipment and processes are possible and existing on modern ships.

¹ An organizational unit implies a person, or a group of people who participate in a process, as it may be appropriate.

Every process on board ships has its measurable goals and objectives, and it can be assigned with appropriate priorities. These objectives refer differently to the main objective of a ship, that is, to its transport function. All processes, together, affect the realization of the main objective of a ship.

No matter how complex a ship may be, there are several clearly recognized processes on every merchant ship, including (but not limited to):

- 1) navigation,
- 2) loading, care for, and unloading of cargo, including embarkation, care for, and disembarkation of passengers
- 3) safeguarding safety, security, and environmental standards in respect of the vessel, passengers, and cargo
- 4) maintenance of ship's functionality (propulsion, power management, different services).

Rapid development of technology has changed the crewmembers' role in processes and the way in which the processes are carried out. In addition, new actions and tasks have been developing whereas some actions and tasks are becoming obsolete. As a result, the already existing competencies must be adjusted. Therefore, it is important to:

- 1) determine how competencies defined in the STCW Convention relate to identified shipboard processes, and
- 2) redefine competencies to be implementable in different working environments.

To achieve the above mentioned it was necessary to:

- 1) determine the appropriate method to analyse processes and tasks taking place on ships under investigation,
- 2) analyse competencies required for most demanding tasks on sophisticated ships,
- 3) identify commonalities, and
- 4) compare them with competencies defined in the STCW Convention.

The process analysis (Figure 1) implies the recognition of subprocesses (if they are a part of the process), participating organizational units, decisions to be made within the process, as well as their executors. The number of subprocesses, organizational units, actions, decisions, and their executors within a process determines the complexity of a process.

Most of the shipboard processes take place simultaneously. Some processes contain easily recognizable sequences (subprocesses), repeating from time to time.

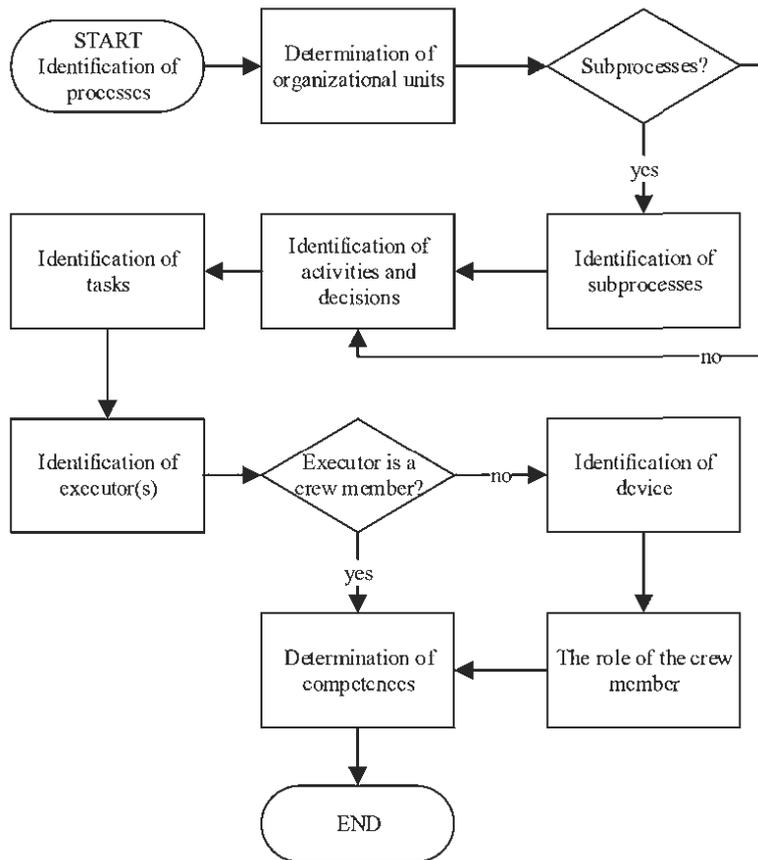


Figure 1 Analysis of a process

The impact of the new technologies can be analysed through their influences on:

- 1) executors,
- 2) actions and tasks,
- 3) decision-making.

Executors of an action within a process can be divided in two groups: crewmembers and devices. Sometimes new solutions will require the same number of executors, sometimes the number of executors might be minimized, or human executors can be completely removed from the loop. In later case, it might mean fewer seafarers, or a significantly changed task list assigned to the crewmember.

Furthermore, the implementation of new technologies can affect the actions within the process. That is, the number of actions (or tasks within an action) may be reduced, the actions and tasks within an action can be done more precisely, time needed to perform an action or a task may be reduced, or new actions may be introduced as well. Finally, the implementation of new technologies can also affect decision-making processes.

The existing determination of required competencies refers only to a person without analysing his/her surroundings or the devices and tools he or she use in the processes. To determine more precisely required competencies, it is necessary to analyse the working environment. Taking into account that decision-making but also execution is often carried out by the teams, the term “competence” should refer not only to the individual but also to the group of people that work together, perform a task together or decide together. That is, the group of people may have its

own competencies. Basic difference between the competence of a group of people and the competence of an individual lies in the fact that knowledge, understanding and skills can be differently distributed within a group, depending on the task they must accomplish.

The analysis of sophisticated ships and their equipment and operations (LNG and cruise ships) revealed a need for more precise descriptions of required generic competencies, too. Generic competencies are defined as transferable, multipurpose knowledge, understanding and skills that an individual acquires and develops in different ways and in different situations (Fung et al, 2007). Today's crew should be able to work in a team, solve problems, analyse more information simultaneously, learn and evaluate, think critically, etc. The results of the two-year research on generic competencies are presented hereafter.

The main goal of the research was to determine to what extent various competencies are present in the STCW Convention, in associated study programs, and in programs of non-formal education. Furthermore, the presence of professional, generic, and other competencies has been estimated. In addition, the analysis includes also sector-specific competencies (those important for various professions within one sector), and cross-sectoral competencies (those used in different sectors according to the European Skill, Competencies, Qualifications and Occupations).

Competencies have been identified estimated according to the total number of topics in a particular STCW table that refer to a certain type of competency. Approach used is shown in Table 1.

Table 1 Example of competence classification

Competence classification in IMO Model Course²			
Topic	Professional	Generic	Other
Shifting of bulk cargo by reducing an excessively high GM.	X		
Appropriate action to take in emergency and medical first aid situations involving dangerous goods			X
Effective communication with the port authority		X	
Competence classification in a study program³			
Topic	Professional	Generic	Other
Ship's pharmacy	X		
Composition and texture of the human body			X
Competence classification in non-formal programs⁴			
Topic	Professional	Generic	Other
Team development		X	
Bridge watch keeping	X		

The analysis of competencies, determined in the STCW Convention, has been based on the analysis of the respective IMO Model Courses. The IMO Model Courses specify topics that are

² Competence classification in IMO Model Courses has been shown on the example of topics that refer to Carriage of dangerous, hazardous, and harmful cargo.

³ Competence classification in a study programme has been shown on the example of the course called Medicine for seafarers.

⁴ Competence classification in non-formal programs of education has been shown on the example of a programme called SMS Bridge Resource management. The program is a part of the non-formal programs required on LNG carriers.

supposed to be a part of the curricula for a particular competence. The results are shown in Figure 2.

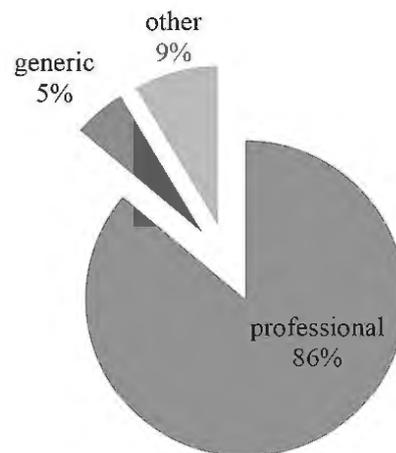


Figure 2 Presence of various competencies in IMO Model Courses

To determine the presence of different competencies, the undergraduate study program “Nautical Studies and Maritime Transport Technology”, delivered in Croatia, has been analysed. The program is based on the IMO Model Course, and it includes all topics needed for jobs at management level. Figure 2 shows the participation of different competencies for the undergraduate program under considerations.

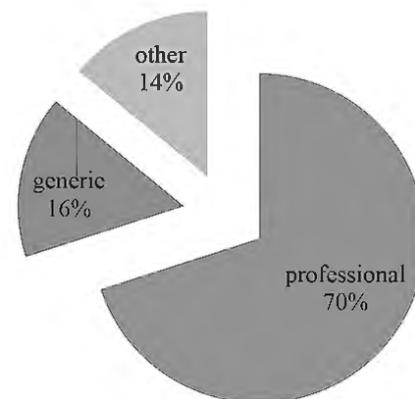


Figure 3 Presence of various competencies in undergraduate program

It has been already emphasized that study programs often do not include all the competencies needed for the job market (Carron, Carr-Hill, 1991), and in many cases are not in accordance with rapid technological development. It is almost impossible to acquire all the competencies needed to perform an on-board job through study programs. It might be assumed that this is the main reason for noticed development of the non-formal education. Non-formal education refers to all programs leading to competencies needed for a working environment (Ainsworth, Eaton, 2010). In maritime education and training, these additional programs may be divided according to their source, i.e. those prescribed by the STCW Convention, and those required by the shipping companies (Gundić et al., 2015). The analysis presented here considered programs required for crewmembers sailing on LNG carriers and cruise ships. These two types of vessels have been chosen because of the specialised equipment and high rate of implementation of the new systems, needed for the safe operations.

The research was divided in two phases. In the first phase, 57 programs required by companies managing 188 LNG carriers, and 41 programs on 12 companies managing 161 cruise ships have been analysed. Since there are no agreed international standards, programs differ in duration, content, and reasons why shipping companies require them.

The second phase focused on duties and responsibilities of masters and officers on board LNG carriers and on-board cruise ships as defined in the available Safety Management Systems.



Figure 4 Presence of various competencies in non-formal programs for LNG carriers

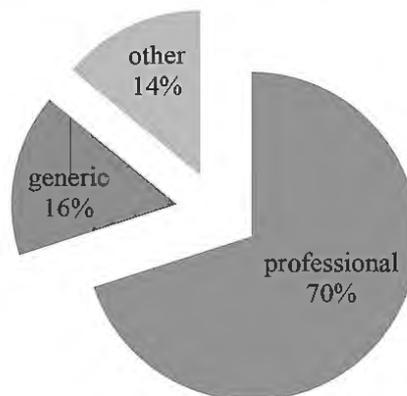


Figure 5 Presence of various competencies in non-formal programs for cruise ships

Research results indicate that IMO Model Courses and the STCW Convention significantly emphasizes topics providing professional competencies. Generic competencies needed to perform a job on board are only partially included. Among those, the mostly present and required competencies are those referring to teamwork and team management.

The analysed study program is based on the respective IMO Model Course, and it includes all topics prescribed by it. The ones that are mostly present in the analysed study program are those that refer to effective communication.

Analysis of non-formal programs revealed again strong focus on professional competencies. Generic competencies mostly present in these programs are teamwork, team management and decision-making.

After being compared with results of analysis of duties and responsibilities of management staff on LNG carriers and cruise ships, it seems that there is a noticeable deficit of several generic competencies. These competencies include teamwork, team management, time management,

decision-making, problem solving, and effective communication, collaboration in multidisciplinary and multicultural teams, critical thinking, teaching and evaluation.

Research revealed generic competencies as a highly important part of the required set of competencies for management level. At the same time, these competencies are not clearly recognized in the STCW Convention and related documents (although several generic competencies are mentioned). In order to ensure the uniform education, at least in part dealing with critical processes, these competencies have to be more precisely described, including the methods of delivering and assessment.

CONCLUSION

New technologies change the way processes are carried out on board ships. They affect the actions within a process, executors of an action and decision-making processes. Consequently, existing competencies must be upgraded, and new must be developed. It may be concluded that competencies as drafted in the present STCW Convention are not robust enough to be used reliably on high-tech ships.

Moreover, presently drafted competencies do not comply with many working processes on board modern ships, and they are not clear enough. Therefore, new technologies imply development of new competencies and/or the upgrade of the already existing ones, while some traditional competencies may be omitted from curricula.

Traditionally, competencies are tied with an old-style department organization on board. Thanks to the new technologies, these shipboard organization models are not implemented as strictly as they were, with many variations, mostly depending on applied technology and area of trade. Consequently, the so-called process approach for determining competencies has been suggested in this paper.

According to the research results, it is necessary to interrelate competencies with associated processes more strictly. In addition to personal competencies, it will be necessary to define more precisely the collective competencies (in the present STCW Convention the collective competencies, i.e. competencies required and executed by the group of people, are already recognized as teamwork competencies, although not precisely described).

The research results indicate a need for thorough revision of the STCW Convention and related documents; it must ensure precise descriptions of required competencies. In particular, generic competencies are missing, above all those dealing with critical thinking, problem solving, teaching and evaluation, etc. Considering the complexity of the task, it is not reasonable to expect that it can be done only by IMO and maritime administrations. The process needs extensive participation of all involved parties, particularly those providing maritime education and training. In that respect, IAMU, as the most important association of the prominent MET institutions is expected to participate in the process.

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Team Resilience in Maritime Emergency Response: Analytical Framework and Implications from Accident Report Analysis

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ABSTRACT

Maritime accidents keep a rate of 3,200 p.a. with some two-thirds involving damage/loss to ships and/or crew, according to EMSA (2018). This study develops an analytical framework to identify the factors influential to team resilience in maritime accidents. The framework is then applied to evaluate team resilience and performance in two ship accidents. The analysis found communication and coordination are some of the critical factors in onboard teams' emergency response. This is traced back to bridge resources management (BRM) training and its effectiveness in improving onboard team performance and leadership. The effect of team-related factors such as unity and culture, on team resilience is also highlighted.

1. INTRODUCTION

The maritime sector is subject to high risks because of the nature, sea perils, human errors, unexpected events and operational complexity. Despite technological developments in shipbuilding and navigation, as well as improvements in maritime education and training (MET), maritime accidents remain a huge challenge for the maritime industry, causing loss of life and property, and damage to the environment.

The ability of the onboard crew to survive accidents is critical especially when the challenge and the adverse impact are high, difficult to control, and require immediate action with no time to plan adequate response. Teamwork is necessary for the onboard crew because not only teams bring synergy, but ship operations require coordination and communication between crew members to achieve common goals. The International Convention on Standards of Training, Certification and Watchkeeping (STCW) requires that all seafarers must have training, and demonstrate competence in BRM that covers: shared mental model, situational awareness,

error management, contingency planning, challenge and response, and distractions and interruptions (ATSB 2015).

Little attention is given to improve the resilience of the onboard team. To date, only limited research has been conducted on team resilience and emergency response (Morgan et al. 2017; Linthicum 2012). Existing studies tends to overlook factors, such as leadership, coordination, communication, and organisational culture that are critical to the performance of a team. For example, team performance and resilience depend on leadership, which depends on other factors such as influence, inspirational motivation, intellectual stimulation, individualised consideration. Intellectual stimulation promotes intelligence, problem-solving ability, while individualised consideration allows each member to contribute his/her best to the team or weakness to be considered and supported by other members (Bass and Avolio, 1994).

The last four decades have seen extensive research on resilience of employees in workplace. Focus has been given on resilience of teams, organisations and even broader communities in challenging and emergency situations, such as natural disasters, epidemics, crises and accidents. Research was carried out mainly in non-maritime sectors, such as defence, health, social care and sport (Chapman et al, 2018). This opens potential benefits as well as necessity to study the Resilience of Teams in Maritime Emergency Response (ROTIMER).

This paper reviews the role of team performance and resilience in emergency response in the maritime domain. We aim to test what the influential factors in team resilience are and how team performance is being considered in maritime accident investigation. We conduct a literature review and also analyze several maritime accident reports. We check the latter against the team resilience factors to reveal the gaps in accident investigation and improve MET, especially BRM training.

2. REVIEW OF THE LITERATURE ON TEAM RESILIENCE

Teams are also social entities composed of members with high task interdependency and shared and valued common goals (Dyer, 1984). A common theme running throughout research on teamwork is that team members do not exist in isolation. They are usually organised hierarchically and sometimes dispersed geographically. They must integrate, synthesise, and share information to coordinate and cooperate as task demands shift throughout a performance episode to accomplish their mission.

Unlike individual work that concerns the work carried out by person, teamwork requires interactions and interdependence between team members. More importantly, teamwork is not a static process and rather it is a dynamic process (Stachowski et al., 2009). As such, team resilience is also a dynamic, temporal process (Morgan et al., 2017). Teamwork typically involves interaction with varying patterns. The level of interaction is important for team performance (Stachowski et al., 2009).

Another important factor in teamwork is communication or information exchange. Several studies suggest effective communication in emergencies not necessarily greater in quantity Stout et al. (1999). Through effective communication, shared mental allows team members to anticipate needs and provide information needed for the given situation. Existing studies have

also shown that newly composed teams tend to exhibit more flexible interaction patterns and respond more effectively than teams that had been together longer (Dionne et al., 2004).

Information sharing shows how teams adapt their performance processes under varying task conditions (Entin and Serfaty, 1999). It helps improve team cognition and collective orientation as an important attribute of teamwork. Team members who are high in collective orientation are more likely to gain collective intelligence and will predict team performance. They will listen to team members and built a strong association between collective intelligence and team performance in League and Legends (Kim et al., 2017).

Leadership as another factor influential to team performance pertains to many aspects of team work, including decision making, inspirational motivation, intellectual stimulation and influence. Inspirational motivation means a leader's ability to empower team members and promotion of confidence in achievement and execution of goals and tasks (Bass and Avolio, 1994). Intellectual stimulation promotes intelligence, problem-solving ability and or seeking a different perspective when solving problems etc. (Bass and Avolio, 1994). Good leadership positively impacts team cohesion and enhance the team's resilience to withstand stressors (Dionne et al., 2004, Rodríguez-Sánchez and Vera Perea, 2015, van der Beek and Schraagen, 2015).

According to Morgan et al. (2017), team resilience refers to the capacity of a team to overcome crises and difficulties. It is the ability to "either thrive under high liability situations, improvise, and adapt to significant change or stress, or simply recover from the negative experience".

Based on their literature review Alliger et al. (2015) found a consensus about team resilience as a team's ability to "withstand", "resist" and "overcome" stressors. Moreover, team resilience is 'not synonymous' with individual resilience. Team work's focus is on collectivism, not individualism. It is based on the concept that the whole is greater than the sum. Disciplined groups tend to make better decisions than individuals (Page, 2008). Existing studies have different views and approaches to the constructs of team resilience, especially in emergency response. No research has been found on team resilience in maritime emergency response, where onboard teamwork is critical when the ship is exposed to high operational risks and sea perils and it is difficult to get immediate support.

3. ANALYTICAL FRAMEWORK

This section proposes a framework to present the key factors or attributes of team resilience in emergency response. The four factors identified for the literature are: *Leadership* (Morgan et al., 2015, Dimas et al., 2018, Sommer et al., 2016); *Communication/interaction* (Gomes et al., 2014, Gucciardi et al., 2018, Lionel, 2015); *Coordination* (Gomes et al., 2014, Amaral et al., 2015); and *Sharing/cohesion/trust*, (Amaral et al., 2015, Stephens et al., 2013, Lionel, 2015, Kennedy et al., 2016)

Due to the dynamic nature of resilience especially in emergency response (Gucciardi et al., 2018), it is essential to consider the emergency response process, where team resilience takes place and emerges from. In this regards, various existing models were developed but did not consider team resilience factors. For example, Lundberg and Johansson (2015) developed a

systemic resilience model (Figure 1) that considers various aspects of the process, including functional dependencies, constraints, ability to adjust or adapt, and strategies. In operational terms, the process is divided into five stages, namely ‘Anticipate’, ‘Monitor’, ‘Control’, ‘Recover’, and ‘Learn’ (Johansson et al., 2018).

As an alternative to Lundberg and Johansson (2015), US military strategist and Air Force Colonel Boyd (1996) developed the ‘OODA Loop’ framework for the emergency response process with four stages: ‘Observe’, ‘Orient’, ‘Decide’, and ‘Act’ adapted from the military combat operation process (Figure 2). Note that OODA Loops allows for the co-existence of an ‘implicit guidance and control’ procedure and the ‘feed forward’ process.

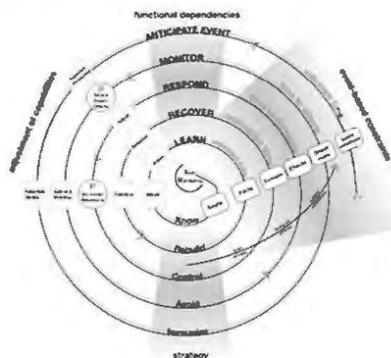


Figure 1: The Systemic Resilience Model (Lundberg and Johansson, 2015)

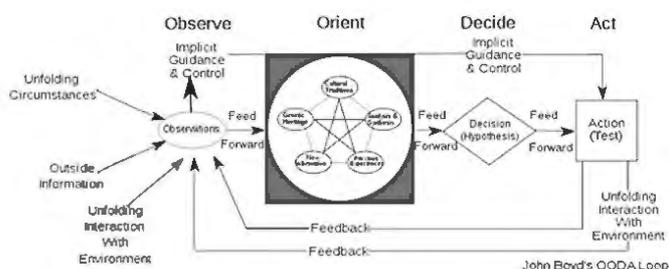


Figure 2: OODA Loop (Source: Wikipedia (2018))

Despite of its popularity and applications in various fields (Evertsz et al., 2019, Byus, 2018), OODA Loop is not suitable for teamwork because it is lack of team factors. Therefore, we propose an analytical framework for team resilience in emergency response that integrates the above team resilience attributes and emergency response process. The response process can be modified or extended. For example, the four components in OODA Loop, ‘Observe’, ‘Orient’, ‘Decide’ and ‘Act’ can be replaced with ‘Respond’, ‘Engage’, ‘Act’, ‘Communicate’ and ‘Transition’ components from the REACT framework (Linthicum, 2012). These components will be analysed along the emergency response process in tandem with the respective models such as the OODA (Boyd, 1996) or REACT (Linthicum, 2012) frameworks.

4. CASE STUDIES

We analyze two case studies of maritime accidents using data from the Marine Accident Investigation Branch (MAIB 2014) and Ministry of Infrastructures and Transports (MIT 2019).

The first deals with the collision of the container vessel CMA CGM Florida and the bulk carrier Chou Shan in open water 140 miles east of Shanghai on 19 March 2013. They collided in the East China Sea resulting in both vessels sustaining serious damage, and approximately 610 tonnes of heavy fuel oil being spilled from CMA CGM Florida. CMA CGM Florida left China heading to Korea. Chou Shan left China heading to Australia.

Table 1: Collision of CMA CGM Florida and Chou Shan

Team	Response process			
	Observe	Orient	Decide	Act
Sharing: sharing team value and work, allocating resources, caring each other safety, etc.	Florida: failed to identify priorities during hand over; poor interpretation of equipment (AIS/Radar) Chou Shan: failed to identify priorities during hand over	Florida: engaged in minor issues; big picture was not clear to them; tried to achieve impossible tasks (requesting F.V to alter course – not common) Chou Shan: big picture was not clear. ColRegs were not given a priority; poor judgement of safety; late actions	Florida: relied on F.V. to take action; relied on AIS information; Chou Shan: did minimum alterations; expected other vessel to follow her instructions; agreed to the course change (red to red) after request from Florida; decided to head towards Florida and reduce stbd. turn	Florida: priority given to stay clear of F.V.; changed Radar range to 6 Nm. a/co to stbd. side several times Chou Shan: continued to work around Fishing vessels; a/co to stbd.; reduced the stbd.; turn and turn to stbd. again
Communication: exchanging information, verbally, using technologies, etc.	Florida: failed to establish common ground between Chinese 2/O and OOW; tried to establish un wanted communications with F.V.; used different languages to communicate not common to team members; Chou Shan: change of plan (a/co) request from Florida confused OOW and was a too late request:	Florida: different opinion about Chou Shan's movement confused the handling of the ship; confused over the communications; Use of different languages made poor situation awareness; Chou Shan: unaware of the danger; Failed to establish common ground with Florida; wanted to clear fishing vessels first;	Florida: decided use VHF communication for collision avoidance; decided to call Fishing vessel; initially unaware of movement of Chou Shan decided to clear F.Vs.; Chou Shan: agreed to go red to red; later decided not to do a large alteration to stbd.; agreed with AB to continue with stbd. alteration;	Florida: a/co to stbd. several times. Chou Shan: a/co to stbd.; reduced the rate of turn and head towards Florida; continued to turn towards stbd. again
Leadership: Vision, decision making process, participation of team members, etc.	Florida: worries about the movement of F.Vs.; OOW advised to engage in unsuccessful communication with F.V; big picture was not clear to OOW; Chou Shan: worries about the movement of F.Vs.; did not take early action to avoid situation;	Florida: did minimum course alterations; wanted to influence fishing vessels to a/co; did not want to take early and large alterations to stay away from the Fishing vessels; Chou Shan: did minimum alterations; lack of appreciation of developing situation;	Florida: tried to clear F.Vs.; to maintain course between F.Vs. and Monte Pascoal; Chou Shan: tried to clear fishing vessels due to unawareness of developing danger situation;	Florida: A/co to stbd. several times; Chou Shan: did minimum alterations;
Coordination: Planning, timing, organising, monitoring the progress, etc.	Florida: unaware of standard seamanship practices; Chinese 2/o was not aware of the stbd. alteration of the Chou Shan; Chou Shan: unaware of standard seamanship practices; requested to a/co to pass stern of the Florida (this was against rules); VHF communication under 2 miles and CPA od 0.3 nm;	Florida: did minimum alterations; came to a point where the bridge team was unaware of the movement of the vessel Chou Shan; Chou Shan: did minimum alterations; unaware of the problems faced by Florida; final VHF communications create confusions at the last moment;	Florida: decided to maintain course between fishing vessels and Monte Pascoal; reduction of turning rate of Chou Shan and concerns of Chinese 2/o prompted OOW to stop stbd. alteration; decided to a/co to port as well – feedback from the Chinese 2/O; decided to go back to original plan (a/co to stbd.); Chou Shan: clear the fishing vessels first; agreed to pass red to red. did not call to master; Reduce the stbd. turn by ordering to head towards Florida;	Florida: continued with small alterations to stbd.; a/co to port; again a/co to stbd.; Chou Shan: continued to concentrate on movement od F.Vs.; a/co to stbd.; head towards Florida; again, agreed to AB to turn further to stbd.;

The second case study deals with the passenger vessel Costa Concordia, which on 13 January 2012, whilst in navigation in the Mediterranean Sea with 4229 persons on board (3206

passengers and 1023 crewmembers), in favourable meteo-marine conditions, collided with the “Scole Rocks” at the Giglio Island.

Table 2: Grounding of Costa Concordia

Team	Response process			
	Observe	Orient	Decide	Act
Sharing: sharing team value and work, allocating resources, caring each other safety, etc.	Vessel manoeuvred in poorly lit area and shallow waters; Factors of risk in navigation neglected or underestimated; Captain did not share reasons to take over navigation; Danger realized late; Master distracted during manoeuvres due to inadmissible activities; Bridge Team not paying required attention during manoeuvres;	Speed of navigation kept high for this manoeuvre; Cartography not appropriate; Bridge design did not allow verifying clear outlook in night-time; Master provided the helmsman the compass course to be followed instead of the rudder angle;	Master took full command of navigation with no obvious reason Vessel navigated in high speed in shallow waters and poorly lit area Attempt to avoid grounding; Emergency Generator Power switched on after black-out;	Efforts to avoid grounding came too late; Understanding of risks and dangers for ship considered too late to avoid the grounding; EGP failed to supply utilities to handle the emergency; Realization of severity of situation came only due to vessel heeling violently and speed sharply decreased;
Communication: exchanging information, verbally, using technologies, etc.	Master steering on own initiative; Master did not share need to navigate the vessel on his own and in this particular conditions and speed; Bridge Team demonstrating disconnect and passiveness;	Dangers of navigation overlooked; Decision on navigation approaches poorly shared with crew and passengers; Damage inspection identified 5 watertight compartments flooded; Wireless communication system not functional under emergency power	Decision to send distress signal delayed; Communication to authorities delayed; Master conducted analysis under his direct coordination; SAR actions had to be conducted in isolation to information from Master	Master did not warn the SAR Authority of his own initiative; Master informed Authorities about a breach, launching the related distress with delay; SAR involved resources on its own initiative; General Emergency Alarm not activated immediately;
Leadership: Vision, decision making process, participation of team members, etc.	Master took over navigation without indicating reasons for his decision; Master did not warn the SAR Authority of his own initiative; Bridge Team passive and seemed not to have urged the Master to notice dangers of navigation;	Usage of inappropriate cartography; Manoeuvring under risky conditions with no visible purpose and reason; Navigation plan not properly assessed and shared;	Master took over from Chief Mate without proper reason; Master decided on a risky manoeuvre; Master provides information to authorities with delays; Abandon ship message issued with delays Abandon ship message issued a bit over 2 hours after grounding not preceded by general emergency alarm;	Handover from Chief Mate to Master did not concretely occur; Plan of navigation unreasonably risky; Master failed to provide timely information to authorities; Rescue operations delayed; Distress signal issues only by insistence of Livorno SAR; Abandon ship message did not reach many people on ship.
Coordination: Planning, timing, organising, monitoring the progress, etc.	Poor assessment of navigation plan by Master; Damage assessment gave full reports only after several days; Rescue operations continued several days; Environment operations by authorities immediately took place recovering oil spill of 2042.5mc	Poor coordination and communication prior to grounding with passive Bridge Team; Coordination with authorities suffering substantial delays; Delays in most processes surrounding emergency situations on board;	Initial inspection of damage commanded directly by Master; Lack of direct orders from Bridge to safety operation crew team; Coordination of activities imposed by initiative of authorities; One officer remained on bridge to coordinate abandon ship; Lack of orders on the base of the Master List for this specific emergency;	Rescue operation continued under authority supervision for several days; Master’s review of initial navigation plan carried loosely; Inconsistencies in the assignment of duties to crew members; Basic training of crew played negative role in the emergency response of the crew;

5. CONCLUSION

The paper discussed maritime accidents from the perspective of team resilience and its role in the efficient and effective handling of such emergency situations at sea. We proposed an analytical framework to identify the factors influential to team resilience in maritime accidents utilizing and improving prior developments in this domain. We then utilized the framework to discuss and assess the team resilience and performance in two ship accidents – the collision of container vessel CMA CGM Florida and the bulk carrier Chou Shan in East China Sea, and the grounding of Costa Concordia at Giglio Island (Italy). The analysis of the cases demonstrated clearly that communication and coordination are some of the critical factors in onboard teams' emergency response and it is what causes severity in the consequences from marine accidents in many instances. We were able to follow that back to training standards and quality and its effectiveness in improving onboard team performance and leadership.

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Proceedings

Student Session

USE OF ANALYTIC GEOMETRY FOR TASK SOLUTION ON MANEUVERING BOARD

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ABSTRACT

Nowadays, **maneuvering board** is still taught in maritime institutions. This aid to navigation provides a **graphical solution** for determining true-motion and relative-motion factors of vessels.

The project of the author is focused on the method of navigation task solution at maritime academic institutions. Besides using graphical solution as an initial step of training, **analytic geometry** can be used as a secondary or control method.

In navigation, a navigational polar coordinate system is used to determine an object position with a bearing (*BRG*, in degrees) and a range (*RNG*, in nautical miles). A position can be converted into a point in a Cartesian coordinate system, i.e. with two axes *x* and *y*.

Analytic geometry is used to make up some formulas to determine those movement factors of other targets, e.g. *CPA* (closest point of approach, in nautical miles), *TCPA* (time to *CPA*, in minutes), heading/course (in degrees), speed (in knots), etc.

1. THE BRIEF HISTORY

The table below shows the brief history of the radar and its use:

Table 1. The brief history

Time	Event
In the 1880s and the 1890s	There were first experiments of many famous physicists from all over the world, using radio wave to detect objects.
World War I and World War II	There were the first versions of modern radar developed.
*	
In the 1960s	The first versions of ARPA (<i>Automatic radar plotting aid</i>) were developed and applied in shipping industry.

The **gap period** in the table, which is marked by an asterisk, is a big question to the author. In that period, **maneuvering board** was used to rapidly determine motion factors.

2. CONVERTING BETWEEN NAVIGATIONAL POLAR AND CARTESIAN COORDINATES

In order to convert a position from one coordinate system to another, some trigonometric functions are applied.

For the purpose of this project, the navigational polar and Cartesian coordinate systems are mentioned.

The concentric circles with equal intervals of distance can be used to rapidly determine the range for the purpose of navigation.

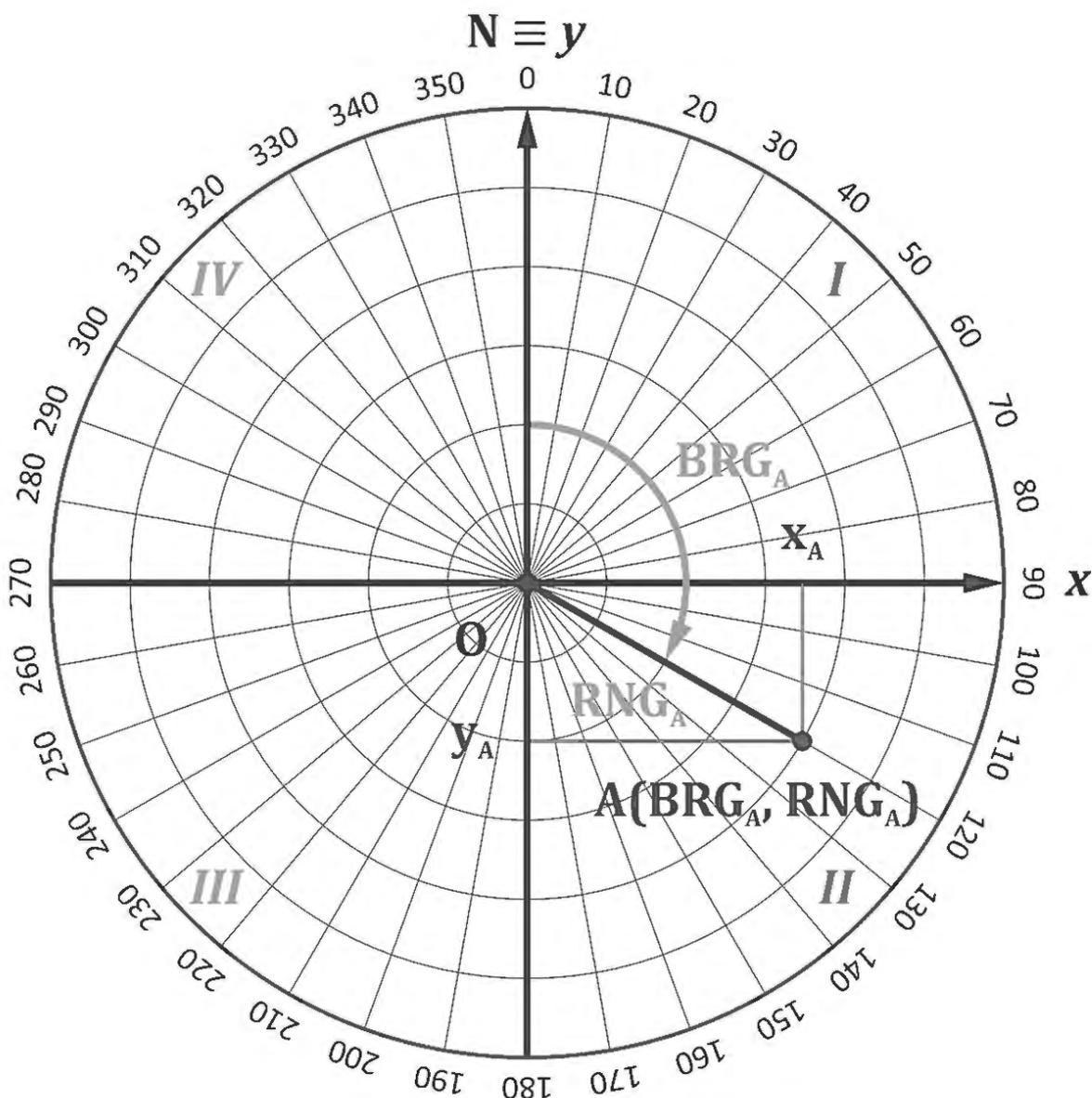


Figure 1. Converting between navigational polar and Cartesian coordinates

The vertical axis Oy and the north axis ON are coincident, which point to a direction of $BRG = 0^\circ$. Consequently, the horizontal axis Ox points to a direction of $BRG = 90^\circ$.

As to the conversion formulas mentioned in this case, there is a change in the applied trigonometric functions sine and cosine, because of the main differences from the ordinary polar coordinate system (i.e. the north axis position and the direction of the bearing angle).

The table below shows the main basic formulas used to convert between navigational polar and Cartesian coordinates.

Table 2. Converting formulas

Navigational polar coordinate	Cartesian coordinate
$RNG = r = \sqrt{x^2 + y^2}$ $BRG = \arctan\left(\frac{x}{y}\right) = \arcsin\left(\frac{x}{RNG}\right) = \arccos\left(\frac{y}{RNG}\right)$ <i>(with defined conditions)</i>	$x = RNG \cdot \sin BRG$ $y = RNG \cdot \cos BRG$

“The defined conditions” mean the definition for quadrant determination, which depends on the signs of the coordinates x and y :

Tables 3. Quadrants

Quadrant	<i>I</i>	<i>II</i>	<i>III</i>	<i>IV</i>
x	$x \geq 0$	$x \geq 0$	$x \leq 0$	$x \leq 0$
y	$y \geq 0$	$y < 0$	$y < 0$	$y \geq 0$
<i>BRG</i>	$\arcsin z$ $\arccos z$ $\arctan z$	$\arcsin z + 90^\circ$ $\arccos z$ $\arctan z + 180^\circ$	$180^\circ - \arcsin z$ $360^\circ - \arccos z$ $\arctan z + 180^\circ$	$\arcsin z + 360^\circ$ $360^\circ - \arccos z$ $\arctan z + 360^\circ$

where: z – respective trigonometric functions of BRG

3. MANUAL GRAPHICAL SOLUTION ^[1]

The figure and the table show an example of manual graphical solution on manoeuvring board and its description.

For the purpose of this project, the central point $O(0,0)$ represents the own vessel, and the points with alphabetical names, e.g. $A(BRG_A, RNG_A)$, show the other objects or vessels (in general, targets).

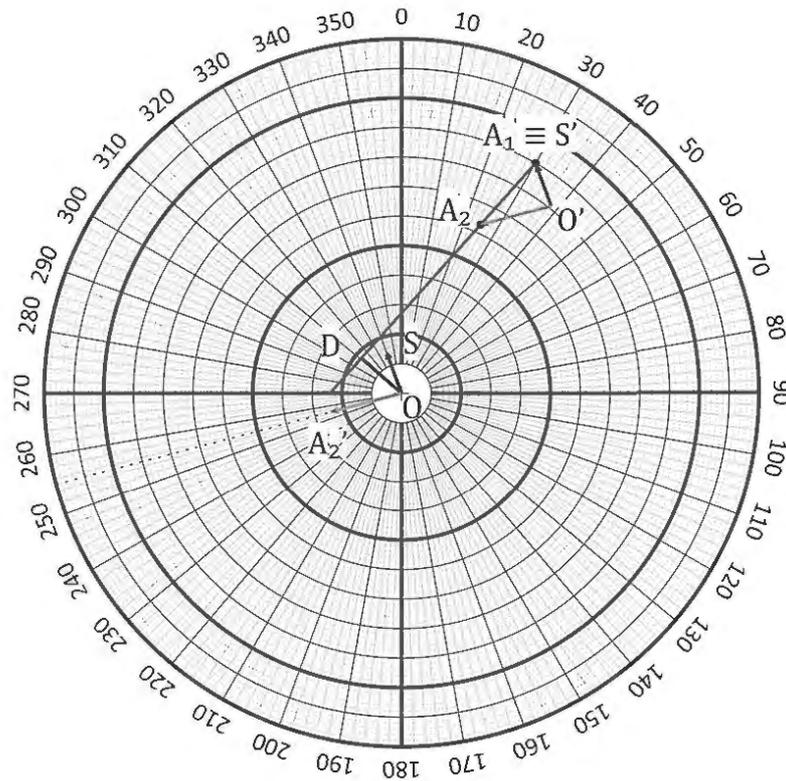


Figure 2. An example of manual graphical solution on manoeuvring board

Table 4. Manual graphical solution description

Step	Description	Remark
1	Situation	
	<p>The own ship data (heading/ course and speed): $HDG = CSE = 340^\circ$ $SPD = 15 (kn)$</p> <p>The target A data: At moment t_1 $\{t_1 = 00:00:00$ $\{A_1(030^\circ, 9.0')$</p> <p>At moment t_2 $\{t_2 = 00:06:00$ $\{A_2(025^\circ, 6.3')$</p> <p>Interval of time between moments $\Delta t = 6 (min)$</p> <p>Required movement factors: $A(CPA, TCPA, CSE_A, SPD_A) = ?$</p>	

2	Plotting the own ship vector	
	$Scale = \frac{\Delta t}{60} = \frac{6}{60} = 1:10$ $\overrightarrow{OS} = (360^\circ, 15 \text{ kn}) \rightarrow \overrightarrow{OS} = (360^\circ, 1.5 \text{ nm})$	
3	Plotting the target relative vector	
	$A_1(030^\circ, 9.0')$ $A_2(025^\circ, 6.3')$ <p>The target relative vector is $\overrightarrow{A_1A_2}$ vector.</p>	
4	Determining the target CPA	
	CPA = OD ≈ 1.8 (nm)	
5	Determining the target TCPA	
	$TCPA = \frac{A_2D}{A_1A_2/\Delta t} = \frac{6}{2.7/6} \approx 13.3 \text{ (min)}$	
6	Determining the target true vector	
	CSE_A ≈ 252.5° SPD_A ≈ 25 kn	

4. APPLICATION OF ANALYTIC GEOMETRY ON MANEUVERING BOARD

The initial analytic geometry formulas for determining movement factors are converted into final formulas, which depend only on input data, without any other intermediate factors.

Initial formulas:

$$CPA = OD = |\overrightarrow{OD}| = \sqrt{x_D^2 + y_D^2}$$

$$TCPA = \frac{A_2D}{A_1A_2} \cdot \Delta t$$

$$SPD_A = 10 \cdot \sqrt{x_2'^2 + y_2'^2}$$

$$CSE_A = \left(Oy, \overrightarrow{OA_2'} \right) = \arctan \frac{x_2'}{y_2'} = \arcsin \frac{x_2'}{V_A/10} = \arccos \frac{y_2'}{V_A/10}$$

(with defined condition)

Final formulas:

$$CPA = \frac{|R_1 \cdot R_2 \cdot \sin(B_1 - B_2)|}{\sqrt{R_1^2 + R_2^2 - 2 \cdot R_1 \cdot R_2 \cdot \cos(B_1 - B_2)}}$$

$$TCPA = \frac{\sqrt{R_2^2 - \frac{[R_1 \cdot R_2 \cdot \sin(B_1 - B_2)]^2}{R_1^2 + R_2^2 - 2 \cdot R_1 \cdot R_2 \cdot \cos(B_1 - B_2)}}}{\sqrt{R_1^2 + R_2^2 - 2 \cdot R_1 \cdot R_2 \cdot \cos(B_1 - B_2)}} \cdot \Delta t$$

$$SPD_A = 10 \cdot \sqrt{\left(R_2 \cdot \sin B_2 - R_1 \cdot \sin B_1 + \frac{V}{10} \cdot \sin H \right)^2 + \left(R_2 \cdot \cos B_2 - R_1 \cdot \cos B_1 + \frac{V}{10} \cdot \cos H \right)^2}$$

$$CSE_A = \arctan \frac{R_2 \cdot \sin B_2 - R_1 \cdot \sin B_1 + \frac{V}{10} \cdot \sin H}{R_2 \cdot \cos B_2 - R_1 \cdot \cos B_1 + \frac{V}{10} \cdot \cos H}$$

(with defined condition)

where: R – range, B – bearing, V – the own ship's speed, H – the own ship's heading

Table 5. The comparison

Value	Manual graphical solution	Analytic geometry
CPA	1.8 (nm)	1.780 (nm)
TCPA	13.3 (min)	13.049 (min)
CSE	252.5°	254°
SPD	25 (kn)	24.457 (kn)

5. IMPLEMENTATION OF A COMPUTING APPLICATION

INPUT DATA			OUTPUT DATA				
The own ship	HDG	SPD	The target A	From the initial formulas			
	340.0	18.0		CPA	TCPA	CSE	SPD
(degrees)	(knots)	1.7783926		13.049946	253.97871	24.455212	
		From the final formulas					
The target A	BRG	RNG		CPA	TCPA	CSE	SPD
	Moment t_1	0		150.0	9.00	1.7783926	13.049946
Moment t_2	6	125.0	6.30	1.7783926	13.049946	253.97871	24.455212
(minutes)	(degrees)	(nm)	(nm)	(minutes)	(degrees)	(knots)	

Figure 3. Implementation of a computing application

A computing application (e.g. spreadsheet *Excel*) is applied as an example of quick determination of movement factors, with input data entered and output data received almost simultaneously.

This implementation opens another ability in application of programming language for automatic calculation.

6. COMPARISON: ANALYTIC GEOMETRY VS ARPA

There were sequences of observations of targets' movement factors during the author's shipboard training. The comparison below is between the author's method and the output data from ARPA.

Table 6. Input data

The own ship		The target A	Moment t_1	Moment t_2
<i>HDG</i>	240.6°	<i>BRG</i>	240.4°	237.4°
<i>SPD</i>	12.4 (kn)	<i>RNG</i>	9.63 (nm)	9.58 (nm)

Output data from the computing application applied analytic geometry:

INPUT DATA			OUTPUT DATA				
The own ship	HDG	SPD	The target A	From the initial formulas			
	240.6	12.4		CPA	TCPA	CSE	SPD
(degrees)	(knots)	9.5545608		8.2838204	217.50316	12.775235	
		From the final formulas					
The target A	BRG	RNG		CPA	TCPA	CSE	SPD
	Moment t_1	0		240.4	9.63	9.5545608	8.2838204
Moment t_2	6	237.4	9.58	9.5545608	8.2838204	217.50316	12.775235
(minutes)	(degrees)	(nm)	(nm)	(minutes)	(degrees)	(knots)	

Figure 4. Output data

Table 7. Comparison

Value	ARPA	Analytic geometry
CPA	9.56 (nm)	9.554 (nm)
TCPA	8.1 (min)	8.284 (min)
CSE	217.4°	217.503°
SPD	12.9 (kn)	12.775 (kn)

7. CONCLUSIONS

Recalling the gap period (*) mentioned above, what if the author's method of solution on maneuvering board using analytic geometry had been thought up and developed before ARPA, i.e. before the 1960s?

As to the future, hopefully, the author's method can somehow improve the way radar/ ARPA works, for instance, in shipping.

There are some aspects, which are taken into account during the project development:

1. Calculation of **leeway angle** and **drift angle**
2. The effects from **wind** and **current**
3. Manoeuvring **prediction** and **suggestion**
4. **Collision avoidance** with many targets
5. Calculation of **BCT** (bow crossing time) and **BCR** (bow crossing range)

As to the implementation of the author's method for the future, it can be suggested that, together with AI (Artificial Intelligence), "a manoeuvring advisor" can be developed. The AI, with all input data of the own vessel and the vicinity information (i.e. meteorological condition, traffic density, etc.), can rapidly calculate and display the suggested manoeuvres to the navigator. The aftermath of the suggested manoeuvres can also be predicted and presented.

It is completely obvious that, the computer and algorithm can comply with the regulations (such as the International Regulations for Preventing Collisions at Sea 1972 - COLREGs), more precisely, with very quick suggested solutions.

It is an honour and a pride for the author that the thesis has been successful proved, as per initial stage, from the slightest idea, which suddenly appeared in the author's mind two years ago (i.e. in the spring semester, 2017), during a class period of the "Maneuvering board" course, after many observations and calculations, up to now.

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The Future Competences of the Marine Engineer

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Keywords: Marine Engineer, Competences, Future-proof Educations

ABSTRACT

The maritime industry is undergoing a transformation and it seems that there are different perspectives within the field regarding important future scenarios. Consequently, it is likely that the competence profile of the marine engineer will also transform in order to meet future demands. This study finds that, in the future, the maritime industry will be in need of a marine engineer who is a practice-oriented problem-solver with advanced competences in management, innovation, process understanding, maintenance and digitalisation. Furthermore, personal competences such as curiosity, independence and resilience will be in demand. In order to accommodate the prospective competence demand of the maritime industry, three suggestions have been made:

1. *An increased focus on the areas of digitalisation and innovation;*
2. *Utilisation of continuing education to enhance the competences of the marine engineer;*
3. *Regulatory efforts to maintain and expand the flexibility of the educational system, to support the changing demands.*

1 INTRODUCTION

Since the Viking era, the Danish people have associated the maritime industry with economic growth. As technological development changes the field, the necessary competences of the crew is bound to change as well. In 2017, Danish Shipping (trade and employer organisation) conducted their half-yearly status report, which also included questions concerning future competences in seafaring. The report asked 26 leaders, representing 79 % of the Danish merchant fleet, which competences would be in particularly demand within the next five years [1]. Tradesmanship and commercial understanding rated high on the list, while more traditional competences in management and technical understanding were rated lower, despite it being at the core of the skills of the marine engineer education today. The point of departure in this study is to explore, whether the current mandatory requirements are in alignment with the maritime stakeholders and their scenarios of the future demand for competences. The maritime field is a global industry, influenced by rapid technological development and there are many qualified notions as to which competences a marine engineer must possess in the future. The competition in the field is fierce and companies are cutting costs to survive. The provision of a proper pool of maritime competences and skill-set is a vital part of successful maritime business. This study explores the fit between the prospective competence need as viewed by the industry and the requirements in the current Danish Ministerial Order no. 1348 of Bachelor in Technology Management and Marine Engineering.

In the following section, a detailed description of the methods and materials are presented. In section 3, the observations are outlined followed by a discussion in section 4. Finally, section 5 contains recommendations based on the findings.

2 METHODS AND DATA

In the study, we apply the SOLO-taxonomic requirements (Structure of the Observed Learning Outcome) for each subject area in the current Ministerial order of the Danish bachelor's degree in marine engineering. The SOLO taxonomy structures and separates levels of understanding and learning outcome into cumulative degrees of complexity [2]. This allows for a comparative analysis of the fit between the current educational competences and prospective expectations of the competence demand in marine engineering held by the maritime industry.

The Ministerial order no. 1348 of Bachelor in Technology Management and Marine Engineering uses *knowledge*, *skills* and *competences* to segregate the levels of understanding. The table shows the eight subject areas defined in the current Ministerial order and the required level of understanding according to the SOLO taxonomy.

Table 1. Ministerial order no. 1348 – SOLO classification of subjects

Level	Ministerial order – Subject areas	Verb from SOLO
0 Pre-structural	Incompetence	Fail, miss point
1 Uni-structural	<p>“Account for principles of the composition of machine- process and electrical plants[...].”</p> <ul style="list-style-type: none"> • <i>Innovation</i> 	Identify, name, follow simple procedure
2 Multi-structural	<p>“Conduct measurements on machine-process and electrical plants.”</p> <ul style="list-style-type: none"> • <i>Craftsmanship</i> 	Combine, describe, perform serial skills, list
3 Relational	<p>“Fault-finding on machine- process and electrical plants”</p> <ul style="list-style-type: none"> • <i>Management</i> • <i>Communication</i> • <i>Maintenance</i> • <i>Business Economics</i> • <i>Automation</i> • <i>Process Understanding</i> 	Analyse, apply, argue, compare, contrast, relate
4 Extended abstraction	Generalised in new domain	Create, formulate, generate, reflect, theorise

Generally, *knowledge* demands are at a uni-structural level, while *skills* are at a multi-structural level. Lastly, *competences* are at a relational level. The Bachelor in Technology Management and Marine Engineering is at the sixth level of the Danish Qualification Framework for Higher Education, with Masters and PhD degrees at levels seven and eight. Hence, no subject area requirements for marine engineering are found at the extended abstraction level.

In order to get a richer understanding of the complex nature of the maritime industry's prospective competence demand we chose a qualitative strategy and performed interviews with maritime stakeholders. The Danish maritime industry was sorted into the following three segments:

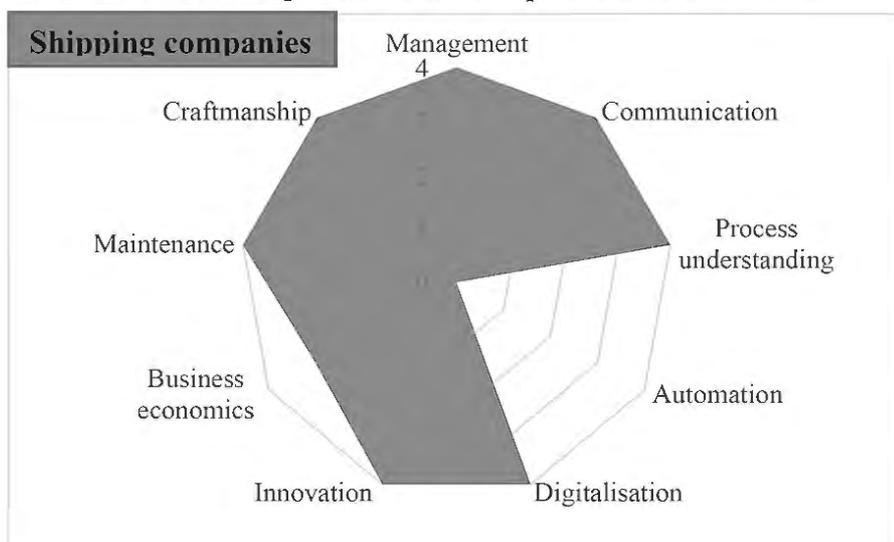
1. Companies which directly operate at sea, such as shipping companies or offshore companies;
2. Support companies such as engine builders, ship agencies or development companies;
3. Regulatory institutions, unions and educational institutions.

Danish harbours, shipyards and drilling was excluded in the study, due to the timeframe of the study. In order to explore the maritime stakeholders' beliefs about the competence demand in 10 years' time, a total of 20 executives from the three segments was selected and invited to participate as informants in the study. Out of the 20 executives, 14 accepted the invitation. The informants were selected based on their leading position in the Danish maritime industry. Prior to participation, an informant analysis was performed stating the informant's role in answering the research question, and their background or possible personal agenda [2]. The data was collected via interviews during the fourth quarter of 2018.

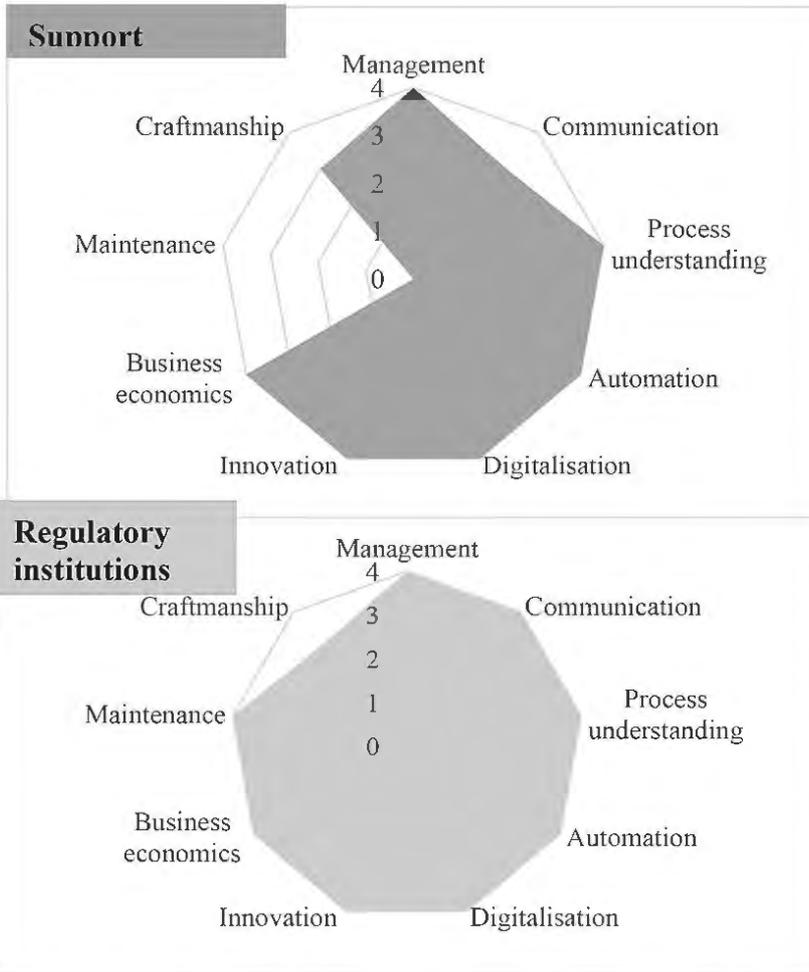
The interviews were transcribed and all statements of significance were coded and categorised, ensuring that all conclusions drawn from the gathered material were empirically founded. Thus, all interviews have been coded against all categories, including subcategories. To analyse the interviews, five categories were established: The background of the informant, future maritime engineer competences, the informant's motivation for mentioning a competence, the external conditions of the Danish maritime industry and personal qualifications. In order to classify at what level the informant believed a specific competence would be required, the SOLO taxonomy was applied. After finalising the rating of the competence requirement for each informant, the rating results were validated by the informants.

3 FINDINGS – THE MARITIME STAKEHOLDER'S EXPECTATIONS

The competence radar is based on the informant's competence demand, which is analysed using SOLO. It is illustrated as a radar with the subject areas from the Ministerial order. Digitalisation has been added even though it is not a mandatory requirement in the Ministerial order today, but many informants have requested future competences in that field.



The informants from the shipping companies, valued craftsmanship more than the other segments of the maritime industry in Denmark. Furthermore, none of the five informants from the shipping companies mentioned automation, which is surprising given the global discussion on autonomous vessels.

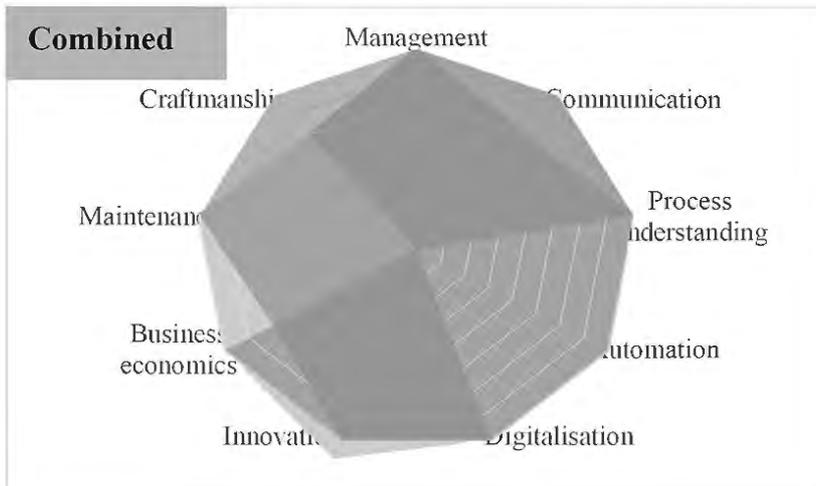


In contrast, the support companies all mention automation, but none of them focussed on maintenance. Where the shipping companies requested that the marine engineers were able to use craftsmanship to solve problems of a practical nature, the support companies have requested craftsmanship at a multi-structural level, which is lower than the shipping companies.

The regulatory institutions generally request a more advanced level of understanding in all the subject areas, especially innovation. Two out of six informants requested innovation at an extended abstraction level as they requested that marine engineers be able to create new solutions using innovation.

When all the competence radars are combined,

it becomes clear that the maritime industry in Denmark requests competences at a relational level within all subject areas. The marine engineer should have a wide range of competences relevant for several maritime functions - both onshore and offshore, in the future as well.



The subject areas where most informants have requested competences at the relational level are **management, innovation, process understanding and maintenance**. Innovation is requested at a higher level than required according to the current Ministerial order. Furthermore, 8 out of 14 informants requested competences outside the subject areas of the ministerial order: competences such as curiosity, independence and maturity.

4 DISCUSSION

In the following section, the results from the competence radars will be compared with the informant's position in the Danish maritime industry, and the differences will be explored to elaborate on the competence requirement throughout the field.

In order to fully understand the competence requirements, it is essential to also know which reality the informants are exposed to – what scenarios they see in the future. Generally, there are two scenarios: a traditional future, where ship designs won't change. The ships that were built ten years ago will need to be operated ten years from today. A reality where the market leaders are the companies who can bring the running costs down. The shipping companies are the primary proponents of this scenario. The other scenario is the technological, where the important factor is being first with new technology. It is mostly the support companies and a couple of the regulatory institutions which propose a future where technological development and legislative changes will shape the need for a different mix of competences. The stakeholders' beliefs about the future is especially important when it comes to the question of whether the marine engineer should be a craftsman or an academic, or somewhere in between.

The shipping company's orientation towards a practice-oriented marine engineer is supported by the assumption that the operation and maintenance of the ship will not change much in 10 years' time. The general direction for the shipping companies also leans towards more green innovation, and process optimisation because the modern world, and especially the shipping industry, have a significant focus on that area, and the assumption for the group shows that this focus will only grow in the future.

The group of support companies' assumption for the future revolves around being the first with new solutions and products. They need to develop and implement new technology which requires the ability to innovate. This relates to this group's demand for a higher level of digitalisation and automation, but also a high demand for business understanding at a multi-structural level. In this segment the marine engineer is perceived as an academic, broadly speaking. The informants conceptualise innovation in two different ways. Either as optimisation in the everyday operation of the vessel, or as the creation of new products or solutions. Either way, all informants request that marine engineers apply competence in innovation at a day-to-day basis.

To sum up, all of the future competences required by the informants are included in the current Ministerial order of the Bachelor in Technology Management and Marine Engineering, apart from the areas of innovation and digitalisation, and personal competences. The informants request a higher level of understanding within the subject of innovation than the ministerial order is securing today. Digitalisation as a subject area is not included in the current ministerial order, which makes it optional for educational institutions to include it in their curriculum. Furthermore, it was observed that, despite the word digitalisation was used frequently, the meaning of the word differed. Some believe that digitalisation will bring insight to the operation of ships, while others speak of digitalisation as knowing how to set up workstations. Either way, competences in digitalisation were mentioned by 8 out of 14 informants which suggest that in some shape or form, digital competence will be of relevance in any future scenario. Other competences mentioned are the personal competences which are difficult to place under a subject area in the current ministerial order. These competences were mostly requested by employers who sought curiosity and

independence in their marine engineers. The wanted personal competences are not specifically secured in the ministerial order, which means that they, too, are left in the hands of the educational institutions.

The marine engineer education is legislated by the Danish government and in accordance with the international STCW Convention. It is an advantage that the education is partly legislated by an international convention, due to comparability, but it also means that changes cannot be implemented as fast. Whether the informants believe that their business model will operate with traditional or the technological ships in the future, many believe that the future will be more complex than it is today. This may warrant a change in the content of the education. If changing the education system is a slow process, the change in the demand of future competences, will need to be provided by continuing education. In 2006, the marine engineer education became a Bachelor's degree, which then opened the door for further education. Despite this, there is no culture of further education within the marine engineer field, nor many options for further education. If the future competences requirements are to be met, there must be an increased focus on flexibility in the educational system.

5 CONCLUSION

The maritime industry is undergoing a transformation which influences the demand for specific competences as well. The study suggests that management, innovation, process understanding, maintenance and digitalisation are competences which will be in demand in the future. These five subjects are the areas which most informants have requested competences in. Based on the informants' beliefs about the future – traditional or technological - the marine engineer needs to be competent as a craftsman and a manager and be able to innovate through optimisation or by creating new solutions. In order to accommodate these demands, the following three suggestions are proposed:

1. *An increased focus on the areas of digitalisation and innovation;*
2. *Utilisation of continuing education to enhance the competences of the marine engineer;*
3. *Regulatory efforts to maintain and expand the flexibility of the educational system, to support the changing demands.*

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Comparative Analysis of Different Current Turbine Designs Based on Relevant Conditions of the Nile River of Egypt

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2. Keywords: Current Energy; Nile River; Savonius, Turbine; Darrius Turbine; CFD simulation

1. ABSTRACT

Egypt is regarded as a developing country looking for increasing its renewable energy share to meet its sustainable development goal through utilizing as many renewable energy resources as possible and develop new technologies to harvest this energy at a maximum efficiency. One of these resources is water current present of the Nile. Hydrokinetic turbines can be used to harvest the kinetic energy. Vertical Axis hydrokinetic (Water) turbines (VAWTs) are gaining popularity nowadays in the market of hydrogenated renewable energy. The purpose of the present work is to investigate the performance of two different hydrokinetic turbines types: Savonius; and Darrius relative to local conditions of Egypt by conducting a 2D simulation for Darrius and Savonius turbines Using ANSYS fluent 19.1. The study yields a 47% increase in Coefficient of power of Darrius turbine relative to that of the Savonius turbine.

2. INTRODUCTION

2.1 GENERAL

The global energy demand continues to increase with the majority of this demand coming from developing countries. Such ongoing increase is mainly met by consumption of fossil fuels - which are already accounting for the majority of global energy consumption- resulting in an environmental degradation due to the accompanied emissions [1]. Also being finite energy sources promotes renewable energy sources to be the major energy supplier worldwide in the near future due to being environmentally friendly and guaranteeing sustainability. As a result, all sectors has been urged to adopt renewable energy sources and cut down emissions with the maritime sector being no exception. The maritime sector answer to this was adopting new approaches to cut down emissions and exploitation opportunities for offshore wind, water tides and water currents.

Since Egypt is regarded as a developing country [2], so developing reliable, efficient energy production techniques for potential renewable sources shall cut down the country fossil fuels dependence by a considerable margin in the years to come. One of the most promising renewable sources within the country is the water current in the vast network of 40,000 km of channels branching from the Nile River through hierarchically classified canals: principal

(water directly from the Nile), main branches and distributary canals [3]. In addition, there are also mesqas, private ditches distributing water to the field. The preceding implies that Current energy from flowing water in open channels has the potential to support local electricity needs with lower regulatory or capital investment than impounding water with more conventional means.

The theory of current stream power is similar to wind power but advantageous in being more predictable in velocities and direction of the fluid and hence more predictable power generation, adds to this water density is more than 800 times that of air, hence smaller scale hydrokinetic turbines are needed to extract the same power at even lower velocities if compared to wind turbines.

Hydrokinetic turbines are a flowing water energy converters which can be classified into horizontal axis water (hydrokinetic) turbines (HAWTs) and vertical axis water turbines (VAWTs). Both turbines have advantages and disadvantages. In comparison to the high power Coefficients of HAWTs, VAWTs can harvest energy from the flowing water from any direction [4] which means that a yaw mechanism is not necessary [5]. Vertical axis water turbines can be mainly categorized into lift-based Darrieus turbines and drag-based Savonius turbines [6].

2.2 DARRIEUS TURBINE

Darrieus have been receiving much attention in recent years for being able to be used in stand-alone applications [7]. Ease of maintenance, simple blade fabrication, and low noise level, and its high efficiency in turbulent flow fields are just some advantages of Darrieus water turbines [8]. A great deal of research was carried out in the recent years by researchers to study the performance of Darrieus turbines. A study made by Mohamed [9] on the performance of Darrieus turbine with different shapes of airfoils investigated that the S-1046 shows a maximum power Coefficient of 0.4. An experimental investigation on the effect of different parameters on the performance of Darrieus turbine such as water flow velocity, and number of blades are carried out by shiono [10] which concluded that two bladed turbine is more efficient than three bladed turbine. A study carried out by Mahdi [11] on the startup characteristics of the H-Darrieus turbine concluded that the combined use of cambered airfoil NACA-2418 and the outward pitch angle of 1.5 degree resulted in a reduction of 27% of the starting time.

2.3 SAVONIUS TURBINE

Savonius turbine is characterized by its low efficiency and high self-starting capabilities if compared to Darrieus turbine. A great deal of research has been carried out in recent years to improve the performance of Savonius turbine. A study made by Mohamed [12] proved that two bladed rotor have better performance than three bladed rotor. Regarding the effect of blade profile, Nur [13] studied the effect of Semicircular and elliptic shapes concluding that semicircular showed a better performance that elliptic shape. Khan [14] studied the performance of one stage, two stage, and three stage Savonius rotor to determine the most suitable rotor for micro sea floor power system concluding that two stage rotor gives a maximum power Coefficient of 0.049.

2.4 OBJECTIVE OF THE STUDY

Due to the lack of research on the Darrieus and Savonius turbines under the Conditions relative to Nile River, a study needs to be performed to investigate the performance of both turbines to attain the optimum tip speed ratio, maximum power coefficient, starting torque and the

behavior of power coefficient of the range of water speeds in Nile River. This was achieved by 2D simulation of both turbines using ANSYS software.

3. PRINCIPLES OF OPERATION

The basic shape of a Darrieus turbine is an 'H' shape type, having two, three or four airfoils attached the central shaft with struts. According to the standard airfoil theory, if an airfoil is positioned with an angle of attack (α) in a fluid flow, a lift force (F_L) will be generated perpendicular to the direction of the free stream with a drag force (F_D) in the direction of the free stream as Shown in Fig. (1). The resultant of the lift and drag force can be resolved into an axial force normal to airfoil cord and a tangential force in the direction of rotation which is responsible for the torque and power output of the turbine. So Darrieus Turbine is a lift dependent turbine [9].

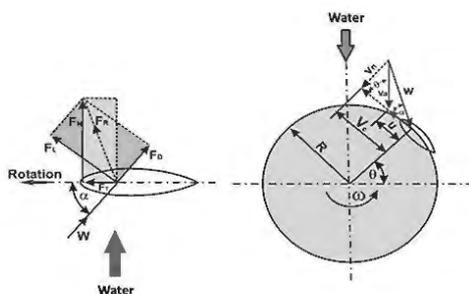


Fig. (1): Darrieus turbine illustration and Force analysis

On the other hand, a Savonius turbine is mainly a drag dependent turbine. The basic shape of a Savonius turbine is an 'S' shape type, having two semicircular blades attached to the central shaft. The operation principle of a Savonius turbine mainly depends on the difference of the drag force between the concave and convex blades of the turbine as Shown in Fig. (2). the drag coefficient of the concave side is much higher than the convex side. This difference create a moment around the central shaft of the turbine to which the blades are attached. This moment is responsible for the torque and power output of the turbine [15].

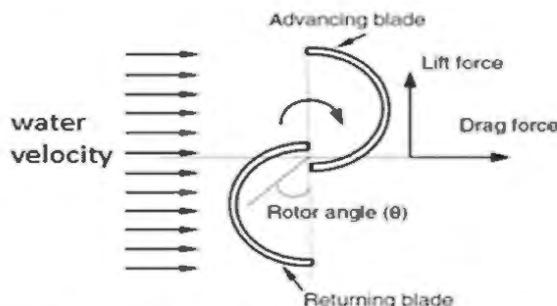


Fig. (2): Savonius turbine illustration and force analysis

For a Darrieus and Savonius turbine of height H and Incoming Flow velocity V , the maximum power output can be written as follows
$$P = \frac{1}{2} \rho A V^3 \quad \text{(Eq.1)}$$

According to Betz's limit [16], a fraction of the kinetic energy crossing the turbine can be captured, this fraction can be expressed by power Coefficient (C_p).

$$C_p = \lambda C_T \quad \text{(Eq.2)}$$

Where C_T is the Coefficient of torque and λ is the tip speed ratio.

$$C_T = \frac{T}{\frac{1}{2}\rho ARV^3} \quad (\text{Eq.3})$$

$$\lambda = \frac{\omega r}{V} \quad (\text{Eq.4})$$

4. GOVERNING EQUATIONS

Three assumptions were used during modelling which are:

- 1- Flow is incompressible.
- 2- Flow exhibits turbulent unsteady behavior.
- 3- Forced rotation of the rotor since the sliding mesh technique has been used. [17].

ANSYS Fluent 19.1 has been used to solve the Unsteady Reynolds averaged Navier-Stocks Equations (URANS) Formulated by the Eq.5 and Eq.6 coupled with the $k - \varepsilon$ turbulence model expressed by Eq.7 and Eq.8.

1 - Continuity and conservation of mass:

Mass conservation principle presented by the continuity equation is expressed Eq.5 [18].

$$\frac{\partial \rho}{\partial t} + \nabla \cdot \rho \mathbf{u} = 0 \quad (\text{Eq.5})$$

2 - Momentum balance Equation:

The momentum balance equation can be expressed by Eq.6.

$$\frac{\partial \rho \mathbf{u}}{\partial t} + \nabla \cdot (\rho \mathbf{u} \mathbf{u}) = -\nabla P + \nabla \tau + \rho \mathbf{f} \quad (\text{Eq.6})$$

3 - Transport equation for turbulent kinetic energy K [19]

$$\frac{\partial \rho k}{\partial t} + \frac{\partial \rho k u_i}{\partial x_i} = \frac{\partial \left(\Gamma_k \frac{\partial k}{\partial x_j} \right)}{\partial x_j} + \tilde{G}_k - Y_k + S_k \quad (\text{Eq.7})$$

4 - Transport equation for dissipation of the specific energy ω [20]

$$\frac{\partial \rho \omega}{\partial t} + \frac{\partial \rho \omega u_i}{\partial x_i} = \frac{\partial \left(\Gamma_\omega \frac{\partial \omega}{\partial x_j} \right)}{\partial x_j} + \tilde{G}_\omega - Y_\omega + D_\omega + S_\omega \quad (\text{Eq.8})$$

5. CFD MODEL SETUP

5.1 Model Geometry

Many researches on Darrieus turbines has employed different airfoil series; NACA 0012 was studied and shows a better operation in specific ranges of Reynolds numbers, after that focus goes to NACA0015, NACA0018, and NACA0022. Also a research on the Symmetric and non-symmetric blades based on five different series of the profile (NACA 00XX, NACA 63XXX, S-series, A-series and FX-series) have been made by M.H.Mohamed [9] concluded that S-1046 shows the maximum power coefficient among the considered series. In the present study, the S-1046 airfoil with a cord length (c) of 150 mm have been used as a purpose of validation.

Based on a review made by Kumar. [15] On Savonius turbine on the different parameters affecting turbine performance and a study made by Nur. [13] On Different blade profiles. In the present study, a two bladed Savonius turbine of semicircular profile with a Zero overlap ratio has been used for the purpose of validation.

In this study, the computational domain for Darrieus turbine was divided into five regions: a circular rotating Hub, a rectangular stationary far field and three rotating Control Circuits (CC) around the blades as shown below in Fig. (3). For Savonius turbine the domain -as in Fig. (4)- Is divided into two regions: a circular rotating hub, and a rectangular stationary far field.

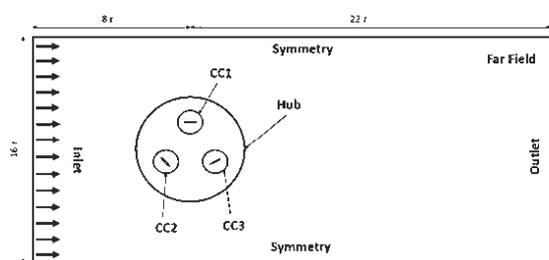


Fig. (3): Darrieus turbine Computational Domain.

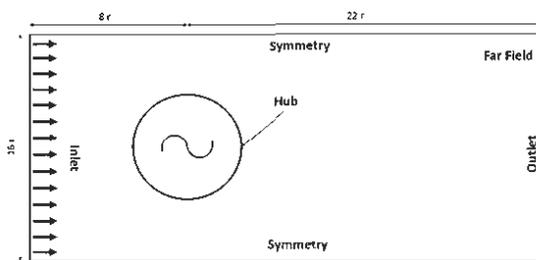


Fig. (4): Savonius turbine Computational Domain.

In order to avoid any blockage effect and reach a fully developed state of the turbine a research is conducted to find the optimum dimensions of the computational domain. Based on the well-referenced sensitivity analysis made by Mahdi [11]. A domain with a dimensions of 30 r and 16 r in the directions parallel and perpendicular to the flow direction respectively. The turbine was located at 8 r from the inlet. Tables (1) and (2) below give a detailed description of the turbine design prepared by AutoCAD for Darrieus and Savonius Respectively.

Parameter	Value
Diameter [mm]	1000
Air foil	S – 1046
Cord length [mm]	150
Number of blades	3
Solidity	0.45
TSR range	1 – 3.5

Table 1: Darrieus turbine Specifications

Parameter	Value
Diameter [mm]	300
Blade profile	Semicircle
Overlap	zero
Number of blades	2
TSR range	0.4 – 1.2

Table 2: Savonius turbine Specifications

5.2 Meshing Topology

The quality and the method of the grid has a great effect on model accuracy and validity. Some techniques were used during the grid generation process to assure the accuracy and quality of the mesh. Unstructured grid is used, giving flexibility for an Automatic generation of grid. Attention paid to the modeling the boundary layer near walls which enhances the turbulence allowing it to reach its calibrated performance and give a better prediction of the fluid flow behavior near walls [21]. The quality of the mesh on the turbine blades is governed by the dimensionless y^+ which is equal to 1 in the present study as suggested by other studies [24]. The

grid used has 15 layers of quadrilateral cells near airfoil wall, with the first cell height of about 5×10^{-2} mm (= 0.033% c) and 16×10^{-2} for Darrieus and Savonius respectively with a growth rate of 1.1. Adaption has been applied for the cells near the wall as Shown in Fig (5)

For increasing the mesh refinement and hence the results. A combination of Body sizing for hub, control circuits and far field, edge sizing for blades and interfaces has been used as seen in table (3) and (4) for Darrieus and Savonius Respectively.

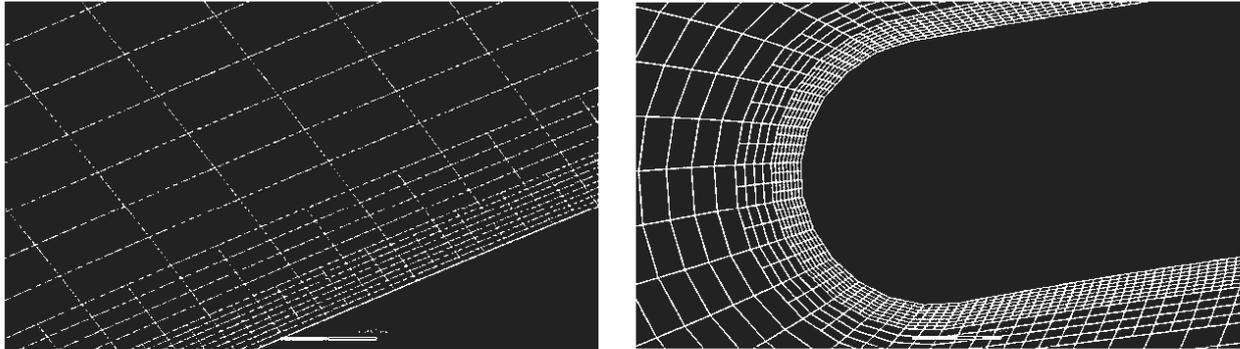


Fig. (5): Adaption for Darrieus turbine airfoil –left- & Savonius turbine blade –Right.

Item	Refinement levels			
	Level 1	Level 2	Level 3	Level 4
Far Field [mm]	50	47	44	41
Hub sizing [mm]	10	9	8	7
CC sizing [mm]	8	7	6	5
Edge sizing for CC	500	700	900	1100
Edge sizing for Hub	1000	1200	1400	1600
Edge sizing for blades [mm]	1	0.8	0.6	0.4
Number of cells	289391	358725	393901	572556

Table 3: Mesh Specification for Darrius turbine

Item	Refinement levels			
	Level 1	Level 2	Level 3	Level 4
Far Field [mm]	50	47	44	41
Hub sizing [mm]	5	4	3	2
Edge sizing for Hub	800	1000	1200	1400
Edge sizing for blades [mm]	0.6	0.5	0.4	0.3
Number of cells	220212	260350	313237	463405

Table 4: Mesh Specifications for Savonius turbine

5.3 Boundary Condition

For the present study, a velocity inlet was placed at the left of the computational domain with a uniform velocity profile of 2 m/s for the steady simulations. A pressure outlet was applied for the outlet at the right of the domain with a zero relative pressure representing an open condition. Further, the turbulent Intensity and turbulent viscosity ratio are 5% and 10 respectively and they are kept constant. For sides, a symmetry boundary condition is applied to avoid any side blockage effect. A no-slip wall boundary condition is assigned for the blades. Since there were no reported data regarding the effect of surface roughness in the validation set, it is neglected in the present study and will be studied in further research.

As shown in Fig. (6) For Darrieus turbine, Four interfaces – to insure continuity in the flow – have been created; three of them between the control circuits and the Hub and a large interface between the Hub and the Fairfield. For Savonius turbine, only one interface is created between the Hub and the far field as shown in Fig. (7).

For the transient simulation, Sliding mesh technique has been used for the rotating Hub at constant speed. The three control circuits and the blades were set to be rotating relative to the hub at constant velocity.

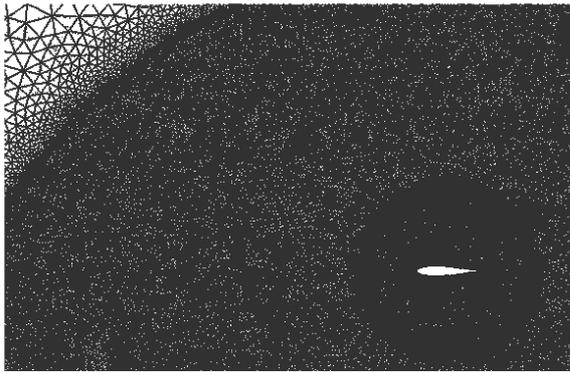


Fig. (6): Darrius turbine grid interfaces –portion.

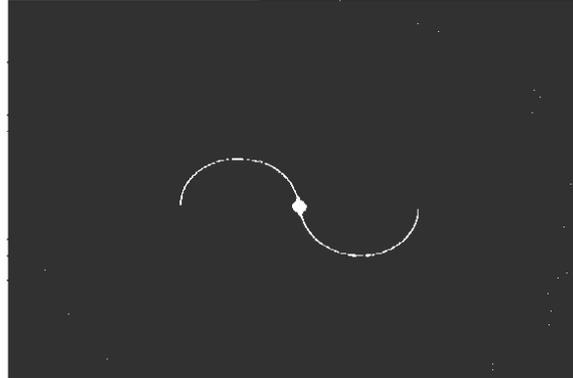


Fig. (7): Savonius turbine grid interfaces.

5.4 Turbulence Modeling

The turbulence model is a key parameter in any CFD Simulations as affects the resultant flow field and the computational resources as well. For complex simulation such as VAWTs, it is essential to choose appropriately the turbulence model especially for operation at low TSR values. Therefore, a particular attention was paid to the turbulence modeling.

In present study, the two equation realizable $k - \varepsilon$ turbulence model with a scalable wall function – for wall treatment – was used as recommended by earlier studies [9] [22]. The realizable $k - \varepsilon$ turbulence model is different form the standard $k - \varepsilon$ turbulence model as it provides better performance in flows involving flow separation, recirculation, and rotation with a slight increase in computational resources [22]. The term 'realizable' means the model is consistent with turbulent flows and satisfies certain mathematical constraints on Reynolds stresses [21].

The transport equations for k and ε in the realizable $k - \varepsilon$ turbulence model are given by the following equations [23].

$$\frac{\partial}{\partial t}(\rho k) + \frac{\partial}{\partial x_j}(\rho k u_j) = \frac{\partial}{\partial x_j} \left[\left(\mu + \frac{\mu_t}{\sigma_k} \right) \frac{\partial k}{\partial x_j} \right] + G_k + G_b - \rho \varepsilon - Y_M + S_k \quad (\text{Eq.9})$$

$$\frac{\partial}{\partial t}(\rho \varepsilon) + \frac{\partial}{\partial x_j}(\rho \varepsilon u_j) = \frac{\partial}{\partial x_j} \left[\left(\mu + \frac{\mu_t}{\sigma_k} \right) \frac{\partial \varepsilon}{\partial x_j} \right] + \rho C_1 S_\varepsilon - \rho C_2 \frac{\varepsilon^2}{k + \sqrt{\nu \varepsilon}} - C_{1\varepsilon} \frac{\varepsilon}{k} C_{3\varepsilon} G_b + S_\varepsilon \quad (\text{Eq.10})$$

5.5 Mesh Independence study

In this study, a grid independence study was made for the purpose of verification that the solution is grid independent. The verification process was started by running a steady simulation for both Darrius and Savonius Turbine with a variation in the level of refinement for the mesh. Various levels of mesh have been created by changing the element size inside far field, Hub, Control circuits (CC), blade edge sizing, and number of division for interfaces at a fixed steps for all levels. Four different levels of refinement were tested for the present study and finally, 3rd level of refinement for both Darrius and Savonius were selected to complete the Analysis.

Coefficient of pressure for the 1st air foil is plotted for the four levels of refinement to determine the mesh convergence limit. 3rd level of refinement having 393901 element number for Darrius and 313237 element number for Savonius were selected. For this level of refinement, the average values of Orthogonal Quality, aspect ratio, and Skewness for Darrius turbines were found as 0.963, 1.20, and 0.062 respectively. Whereas that of the Savonius turbine were found 0.967, 1.188, 0.059 respectively. These values comes within the acceptable limits that represents a very good quality level [23]. Fig. (8) and (9) shows the variation of pressure coefficient of the air foil and the Semicircular blades respectively.

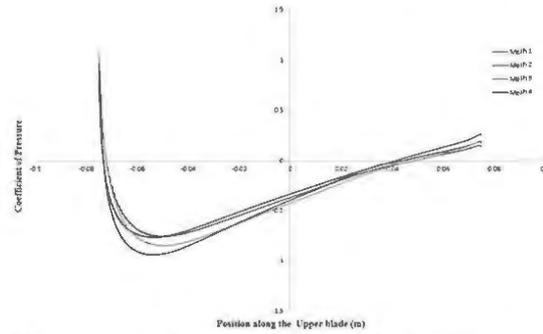


Fig. (8): pressure Coeff. along upper airfoil of Darrius turbine.

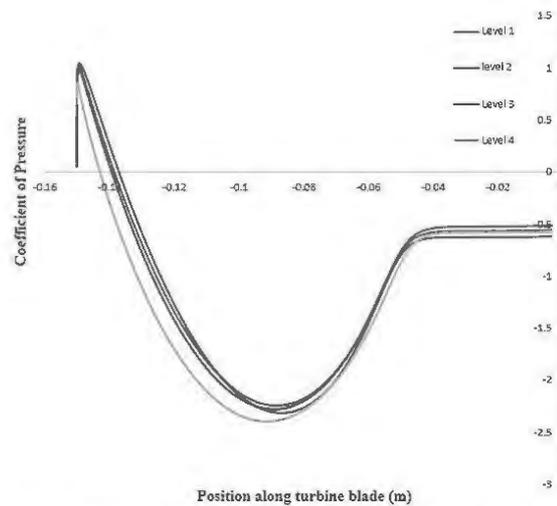


Fig. (9): Pressure Coeff. Along the upper blade of Savonius turbine.

5.6 Simulation Parameters

For Darrius and Savonius - the Steady and Transient simulations - the water density and viscosity were set to 998.2 kg/m^3 and $1.003 \times 10^{-3} \text{ kg/m.s}$ respectively. The reference values used in the present analysis is given in table (5) [18]. The SIMPLE (Semi-Implicit Method for pressure - linked equations) method is used for higher accuracy and to couple the pressure and velocity equations [9] [21] [24]. Gradient is spatial discretization of least square cell-based algorithm is used to insure accurate results. The second order upwind scheme is applied for pressure, momentum, turbulent kinetic energy, and turbulent dissipation rate. Residuals of momentum, continuity, and turbulence equations are set with a convergence criteria of 1×10^{-5} [21].

Reference parameter	Value	
	Darrieus	Savonius
Area [m ²]	1	0.3
Density [Kg/m ³]		998.2
Depth [m]		1
Enthalpy [j/Kg]		0
Length [m] ' rotor radius '	0.5	0.15
Pressure [Pa]		0
Temperature [K]		288.16
Velocity [m/s]	2 verification and validation 0.5 – 2.5 for analysis	
Ratio of specific heats		1.4
Reference zone		Hub

Table 5: Reference values for Both turbines

Transient simulation numerical results depends on the size and number of time steps, however it requires high computational time. Accordingly, in the present study, a 4 degree rotation per time step was applied in order to maintain the accuracy and computational time. In order to reach a steady state, 8 complete revolutions for rotor were simulated [25] and a total of 720 time steps were applied for 50 iteration per each time step.

The coefficient of torque (C_T) was monitored to obtain the mean moment on turbines surface. The C_T of the last revolution was used to calculate the power coefficient. The variation of C_T is studied over the entire range of azimuth positions to evaluate the starting moment and its fluctuations for each turbine.

7. RESULTS AND DISCUSSION

7.1 Model Validation

The entire domain was initialized using Standard initialization method. Each turbine was simulated at constant flow speed of 2 m/s over for a range of TSR for the Purpose of validation .Table (6) and (7) give the range of tip speed ratio (TSR), power coefficient (C_p) and time step calculations for Darrieus and Savonius turbines respectively. Simulation ran until both turbines reached a steady state. Coefficient of torque (C_T) was monitored to obtain the mean moment on turbines surface.

Flow Velocity v (m/s)	TSR	ω (rad/sec)	Simulation time step, Δt (sec)	Number of revolutions simulated
2	1	4	0.017444444	8
	1.5	6	0.011629630	
	2	8	0.008722222	
	2.5	10	0.006977778	
	3	12	0.005814815	
	3.5	14	0.004984127	

Table 6: Validation transient calculations for Darrieus turbine

Flow Velocity v (m/s)	TSR	ω (rad/sec)	Simulation time step, Δt (sec)	Number of revolutions simulated
2	0.4	5.33333	0.013083333	8
	0.6	8	0.008722222	
	0.8	10.6667	0.006541667	
	1	13.3333	0.005233333	
	1.2	16	0.004361111	

Table 7: Validation transient calculations for Savonius turbine

For the purpose of results validity, the Validation of Darrieus turbine computational model obtained results was performed for a small 3-bladed H-Darrieus water turbine tested experimentally and 2D simulated by Maitre [24], a 3-bladed H-Darrieus water turbine 2D and 3D simulated by Stefania [26]. The average Error with Maitre 2D model was 5.1% with a Max. Of 7.1% and with Stefania 2D model was 9.2 % with a Max. Of 18%. Fig. (10) Shows a comparison between the numerically predicted and experimentally measured Power Coefficients (C_p) verses tip speed ratio (TSR).

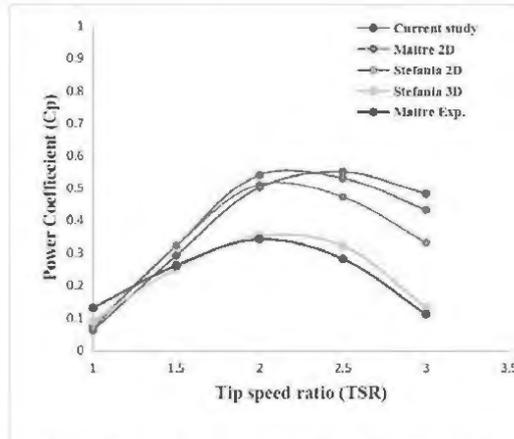


Fig. (10): C_p vs. TSR for Different studies of Darrieus turbine.

Savonius turbine Computational model obtained results was performed for a small 2 – bladed semicircular shaped Savonius water turbine tested experimentally and 2D simulated by Parag [27]. Fig. (11) Shows the comparison between the numerically predicted and the experimentally measured power coefficient (C_p) Verses Tip speed ratio (TSR).

It can be noticed that for a Darrieus and Savonius turbine that numerically obtained results overestimated the experimentally obtained results. However, the trend of the Power Coefficient (C_p) over the tip speed ratio (TSR) range is the same for 2D, 3D and experimental data. The reason is that Vortices occurred in the of the Blade ends in 3D simulation and experiment Causes energy losses which is called the 3D effect, where water flows with different velocities (velocity gradient) at the top and bottom of the blades generating a pressure difference pushing water at the end of the blades from high-pressure region to low-pressure region enhancing vortices to be generated [28].

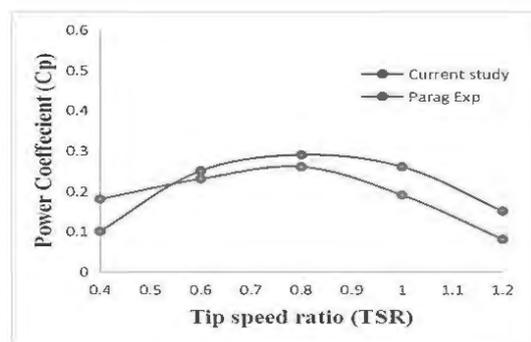


Fig. (11): C_p vs. TSR for Different studies of Savonius turbine.

7.2 Savonius and Darrius Results

As a result of validation process, the maximum power coefficient (C_p) occurred an optimum tip speed ration of 2.55 as shown Fig (10). Using the obtained optimum tip speed ratio, an analysis for the turbine performance over the range of water speed in the Nile River from 0.5 to 2.5 m/s to was carried to study the variation of the turbine power coefficient (C_p). Fig (12) shows the different values of Power coefficient (C_p) over the desired velocity range. At a flow velocity of 0.5 m/s, C_p has a value 0.5 then it experienced a slight increase over the velocity range till it reaches a maximum of 0.55 at the Nile nominal speed of 2 m/s with a constant behavior a flow velocity of 2.5 m/s.

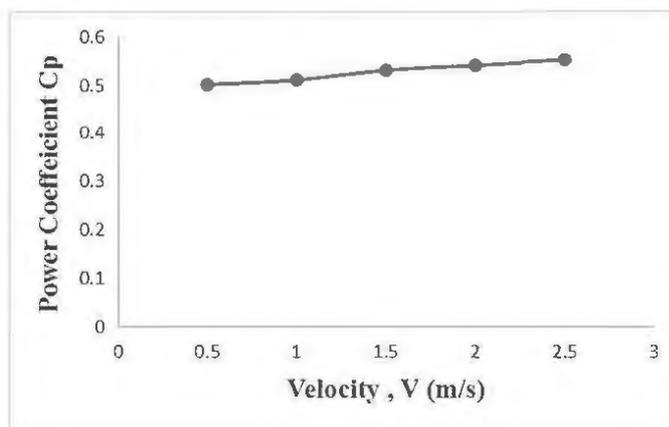


Fig. (12): C_p for a velocity range for a Darrius turbine.

For the Savonius turbine, a maximum power coefficient (C_p) of 0.29 occurred at an optimum tip speed ratio of 0.8 as shown in Fig (11). Using the optimum tip speed ratio, an analysis for the turbine performance over the range of water speed in the Nile River was carried to study the variation of the turbine power coefficient. Fig (13) gives the different values of power coefficient (C_p) over the desired velocity range. At a flow velocity of 0.5 m/s, C_p has a value of 0.23 then it experienced an increasing behavior reaching a maximum value of 0.29 at a speed of 1.5 m/s then it stayed constant for the rest of the range.

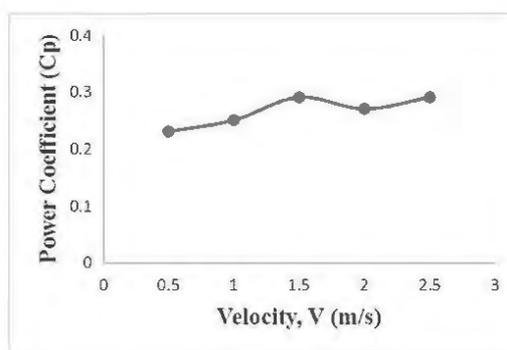


Fig. (13): C_p for a velocity range for a Savonius turbine.

Tables (8) & (9) give the time step calculations and results for Darrius and Savonius turbines analyses respectively.

Flow Velocity ,v (m/s)	TSR	ω (rad/sec)	Simulation time step, Δt (sec)	Number of revolutions simulated
0.5	2.55	2.55	0.027363834	8
1		5.1	0.013681917	
1.5		7.65	0.009121278	
2		10.2	0.006840959	
2.5		12.75	0.005472767	

Table 8: transient analysis calculation for Darrius turbine.

Flow Velocity ,v (m/s)	TSR	ω (rad/sec)	Simulation time step, Δt (sec)	Number of revolutions simulated
0.5	0.8	2.666667	0.026166667	8
1		5.333333	0.013083333	
1.5		8	0.008722222	
2		10.66667	0.006541667	
2.5		13.33333	0.005233333	

Table 9: Transient analysis calculations for Savonius turbine.

Both Turbines were tested in order to investigate the starting torque at the first two revolutions. The coefficient of torque (C_T) is monitored at every time step and the variation of C_T with respect to azimuthal angle is plotted in Fig (14). It can be seen from Fig (14) that the Instantaneous values of C_T at the first two revolutions for Savonius turbine is much higher than Darrius turbine by two to three times.

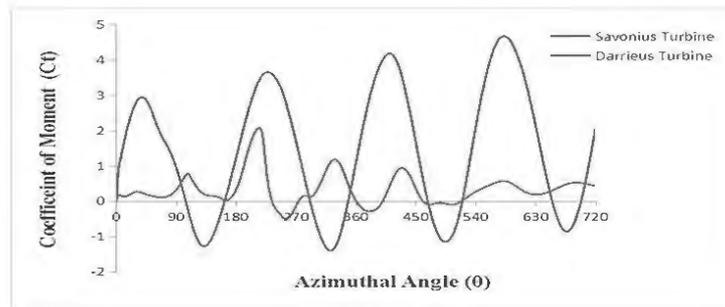


Fig. (14): Starting torque for both Darrius and Savonius Turbines

8. CONCLUSION

A study of the performance of the 3-bladed Darrius and 2-bladed semicircular shaped Savonius turbine -with respect to the velocity conditions in the Nile River- was carried out by using 2D simulation analysis of ANSYS CFD module, fluent 19.1. A mesh independence study was carried out to find the optimal mesh quality to assure accurate results. The $k - \epsilon$ turbulence model was used with a y^+ value equals 1. Validation for Darrius and Savonius turbines are made by comparing 2D numerical results obtained with previous validated studies of Maitre [24] & Stefania [26] for Darrius and Parag [27] for Savonius. For all simulation cases, all initial conditions, boundary conditions and numerical methodology were kept the same.

A maximum power coefficient of 0.55 at a tip speed ratio of 2.55 and flow velocity of 2 m/s for Darrius turbine and a maximum power coefficient of 0.29 at a tip speed ratio of 0.8 and flow velocity of 1.5 m/s for Savonius turbine was obtained. For the velocity analysis at the

optimum tip speed ratio over a range of velocities from 0.5 m/s to 2.5 m/s, power coefficient starts to increase the behaves constantly over the rest of the range for both turbines.

Future work will comprise a 3D Computational and Experimental analysis of present designs of both the Darrius and Savonius Turbines to obtain even more accurate results of different parameters

Also, an analysis of the performance of a Darrius-Savonius hybrid turbine can be performed using 2D and 3D models to investigate the extent by which the starting torque of the Darrius turbine can be improved while maintaining a high power coefficient (C_p) characteristics.

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10. APPENDICES

Nomenclature			
A	Swept area (m^2)	Γ_k, Γ_ω	Effective diffusivity for k and ω
c	Chord (mm)	$\tilde{G}_k, \tilde{G}_\omega$	Generation of turbulence kinetic energy k and ω
C_T	Coefficient of torque	Y_k, Y_ω	Represents the dissipation of k and ω
C_p	Power Coefficient	S_k, S_ω	Source term
\vec{f}	Force density [N/m^3]	D_ω	Cross diffusion
k	Kinetic energy (%)	ε	Dissipation rate of turbulent kinetic energy
$t, \Delta t$	Time, time step (s)	σ_k	constant of standard $k - \varepsilon$ turbulence model
\vec{u}	Velocity (m/s)	G_k	represents the generation of turbulence kinetic energy due to mean velocity gradients
ρ	Density (Kg/m^3)		
τ	Viscous shear stress (Pa)	G_b	Represents the generation of turbulence kinetic energy due to buoyancy.
θ	Rotation Angle (rad)		
λ	Tip speed ratio	Y_M	represents the contribution of the fluctuating dilatation incompressible turbulence to overall dissipation rate
ω	Rotation speed (rad/s)		
u_j	velocity component	$C_2, C_{1\varepsilon}$	Constants
x_j	Cartesian coordinate	$\alpha_k, \alpha_\varepsilon$	the turbulent prandtl numbers for k and ε respectively
μ	Viscosity	S_k, S_ε	The user defined source terms.
μ_t	Turbulent viscosity	CFD	Computational Fluid dynamics

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