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Transactions on Maritime Science (ToMS) is a scientific journal with international peer review which publishes papers in the following areas:

~ Marine Engineering,
~ Navigation,
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~ Hydrography,
~ Marine Automation and Electronics,
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ToMS aims at presenting major maritime research all over the world, particularly focusing on the Mediterranean area. Articles will be double-blind reviewed by three reviewers. ToMS also promotes scientific collaboration with talented students at a beginning of their scientific careers. These papers also undergo strict peer reviews. Furthermore, the Journal publishes short reviews on significant papers, book reviews and workshops in the fields of maritime science.

The views and opinions expressed in the papers are those of individual authors, and not necessarily those of the ToMS editors. Therefore, each author will take responsibility for his or her contribution as presented in the paper.

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Contents

From Editor-in-Chief

Ivica Kuzmanić

Dear Readers,

I would first like to take the opportunity, on behalf of my most esteemed colleagues and collaborators, as well as in my own name, to say how proud I am due to the publication of the 15th issue of the international scientific journal ToMS ("Transactions on Maritime Science"), published by the Faculty of Maritime Science of the University of Split. As has been the case before, the papers have been submitted to three double-blind reviews, some of them as many as five, of which at least one comes from abroad, i.e. a country different from the one in which the author lives.

This issue is the first one to fully implement the so-called Open Journal System. It was by no means an easy thing to achieve: however, we have finally succeeded, primarily due to enormous efforts of our executive editors and the technical staff.

This issue brings thirteen papers, the largest number so far. Among the authors, apart from the Croatian ones, this issue boasts a cooperation of as many as twenty-one foreign scientists, coming from four continents. We take it as a good omen for our journal to be recognized and to establish a reputation all over the scientific world.

The papers hereby presented deal with topics pertaining to a number of scientific areas and fields, such as marine engineering, navigation, safety systems, hydrography, marine information systems, maritime law, management of marine systems, education, and operation of submarine vessels.

Furthermore, we once again take the opportunity, as we have done before, to present the Croatian cultural heritage by publishing two poems, written in the idiom of the Island of Brač, by the late Ive Marković Kora, poet, painter, and sculptor. This contribution comes in a bilingual form in the inspired translation of Mirna Čudić Žgela, our long-standing collaborator. Readers of the electronic edition will be able to listen to the poems in the striking rendition of Ante Božanić Pepe Kalafot of Komiža, as a special tribute to his late colleague and old friend.

As always, we remain in the hope that the papers we publish will encourage your cooperation.

Effects of Oil Price Shocks and Economic Fluctuations of Trading Partners on Iran's Ports Throughput

Mehdi Mirzaei[a], Hojat Parsa[b]

This study aims to estimate the effects of oil price shocks on seaborne trade in Iran; in particular, port throughput of three leading ports through economic fluctuations of three major trading partners of Iran, based on quarterly data for the period of 1999Q2 to 2018Q1. We apply a standard vector autoregressive (VAR) approach using Cholesky decomposition. The results indicate that with increasing oil revenues in short-run, seaborne trade be further directed towards Shahid Rajaei port while rising oil revenues changes the combination of goods handled in Emam Khomeini and Bushehr ports. In the long run, the share of oil price fluctuations in explaining the variations of Shahid Rajaei port throughput is higher than the other two. In fact, increases in oil revenues cause an increase in the volume of industrial and containerized seaborne cargo trade.

KEY WORDS
~ Oil price shocks
~ Port throughput
~ VAR
~ Vector autoregressive
~ Iran's major ports

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1. INTRODUCTION

With the increasing importance of globalization as well as the acceleration of economic integration among different countries, maritime transportation is playing an important role in facilitating global trade. Ports are the backbones of seaborne trade. According to UNCTAD reports, global trade in 2016 reached 10.3 billion tons after a steady increase during the last seven years. Since 2009, the goods' volume loaded and discharged in ports worldwide has grown by 2.4 billion tons. Mainly, the trade of dry cargo, petroleum products, and gas by sea has increased (UNCTAD, 2017). As stated by the Iran's Ports and Maritime Organization, between 2017Q2 and 2018Q1 over 156.8 million tons of cargo were loaded and discharged in the ports of Iran, which included 47.7 million tons of petroleum products, 4.4 million tons of liquid bulk, 51.2 million tons of dry bulk, 30.8 million tons of containerized cargo, and 4.22 million tons of general cargo. These demonstrate the vital importance of maritime transportation in the foreign trade of Iran (Iran's Port and Maritime Organization, 2018). Therefore, if port authorities wish to establish competitive strategies, and plan and manage logistics as well as transportation infrastructures, they should identify factors affecting port throughput (Kim, 2016).

Undoubtedly, oil price shocks are of the factors affecting the trade volume in different countries, particularly in oil-exporting countries. Economou and Agnolucci (2016) categorized oil price shocks in two major groups: oil supply shocks and oil demand shocks. From the supply perspective, positive and negative shocks of oil prices are caused either by events outside the oil market (exogenous) or as a result of the normal functioning of the oil market (endogenous). Taghizadeh Hesary et al. (2013) stated that when oil prices rise, it is expected to have a direct positive effect on oil exporting countries that are raising oil revenues. On the other hand, for oil-importing countries this price increase is considered as a negative supply shock. As a result, the energy importer's demand is reduced, and this indirect effect is expected to be negative for oil-exporting countries. This adverse effect will increase the energy-exporting country's revenue lower than expected. Also, increasing revenues of oil-exporting countries will enable oil-importing countries to export more goods to these countries, which has a direct positive effect on the foreign trade sector of oil-exporting countries' trading partners.

Furthermore, world seaborne trade continues to be largely determined by developments in the world economy and trade. Although the relationship between economic output and merchandise trade seems to be shifting, with an observed decline in the growth ratio of trade to the gross domestic product over the recent years, the demand for maritime transport services remains heavily dependent on the performance of the world economy. Thus, industrial activity, economic output, merchandise trade, and seaborne trade shipments are positively correlated (UNCTAD, 2017).

Iran is the second largest oil producer in the Organization of the Petroleum Exporting Countries (OPEC, 2005). In such circumstances, any shock in oil markets could have a huge impact on Iran's economic structure. An examination of the structure of foreign trade in OPEC member countries shows that the major share of exports in these countries is dedicated to oil and petroleum products. On the other hand, import in these countries depends heavily on foreign exchange earnings from oil exports. As a result, any change in oil prices will affect imports, production, and economic growth in these countries. Therefore, the analysis of various perspectives of foreign trade in OPEC member countries is important. These countries have similar trading partners. The majority of exports in these countries are to countries such as the United States, Germany, England, France, Italy, China, Japan, Spain, India, South Korea, and the Netherlands. Thus, analyzing the effects of economic fluctuations of OPEC member trading partners is a central issue in the development of foreign trade in these countries.

As stated above, seaborne trade and especially ports are the leading actors in the foreign trade sector in every country. This study aims to investigate the effects of oil price shocks on port throughput in three major ports in Iran through economic fluctuations of its three major trading partners. Some research works have studied the effects of shocks to oil prices on macroeconomic variables in oil-exporting countries (Korhonen and Ledyaeva, 2010; Le and Chang, 2013; Raheem, 2017). Another group of studies estimated the effect of oil price volatilities on terms of trade and real effective exchange rate in oil exporting countries (Dauvin, 2014; Volkov and Yuhn, 2016; Basher et al., 2016; Chen et al., 2016). The results of all these studies indicate that oil price shocks affect the trade sector of oil-exporting countries in the long run and short run, and this impact varies depending on the economic development and dependence of these countries on oil export. Farzanegan and Markwardt (2007) studied the dynamic relationship between oil price shocks and macroeconomic variables in Iran using a VAR approach. The results showed that on the supply side of the economy, rising oil prices would increase terms of trade and the real exchange rate. Furthermore, Hesary et al. (2013) evaluated the impacts of oil price shocks on oil-producing and consuming economies. The results indicated that oil producers (Iran and Russia) benefit from indirect effects through their trading partners. What distinguishes this research from previous studies is that this research is the first attempt to study the impacts of oil price shocks on Iran's seaborne trade through trading partners.

This study uses quarterly data from 1999 Q2 to 2018 Q1, i.e. a period that covers US military strike on Iraq in 2003 and U.S economic sanction against Iran. It analyses the impacts of oil price shocks on the port throughput of three major ports in Iran, i.e. Shahid Rajaei, Emam Khomeini, and Bushehr, through economic fluctuations of Iran's major trading partners. The sample of trading partners consists of three countries: China, South Korea, and Germany. Since the volatility of each port throughput directly and indirectly affects the port's income, the volume of investment in the port, the level of employment, the results of this study can provide policy insights to help port authorities' policymakers to develop seaborne trade policies.

The following sections of the paper are structured as follows: data used in the study is described in Section 2; Section 3 discusses the VAR methodology applied; Section 4 presents the empirical results, and Section 5 summarizes the main results.

2. DATA

In this paper, we use ten variables: seasonal average of Iran's heavy crude oil spot price (LIROP), Gross Domestic Product (GDP) in constant market prices of 2010 for China, Germany, and South Korea (LGDPCH, LGDPGE, LGDPKO) as representative of economic fluctuations of the major trading partners, tonnage of goods loaded and discharged in Shahid Rajaei, Emam Khomeini as well as Bushehr ports (LRALOUN, LEMLOUN, LBULOUN), and the number of vessels handled by sample ports (LRAVH, LEMVH, LBUVH). The tonnage of goods loaded and discharged, and the numbers of vessels handled by ports are used as indicators of port throughput.

The oil price refers to the spot price of the benchmark barrel of different crude oils. The seasonal average of Iran's heavy crude oil price is derived from Iran's heavy oil spot prices ($/B), monthly data of OPEC Reference Basket (ORB), and corresponding components' spot prices (Figure 1). As shown in Figure 1, oil price trend is unpredictable and high volatility is a key characteristic in this market.

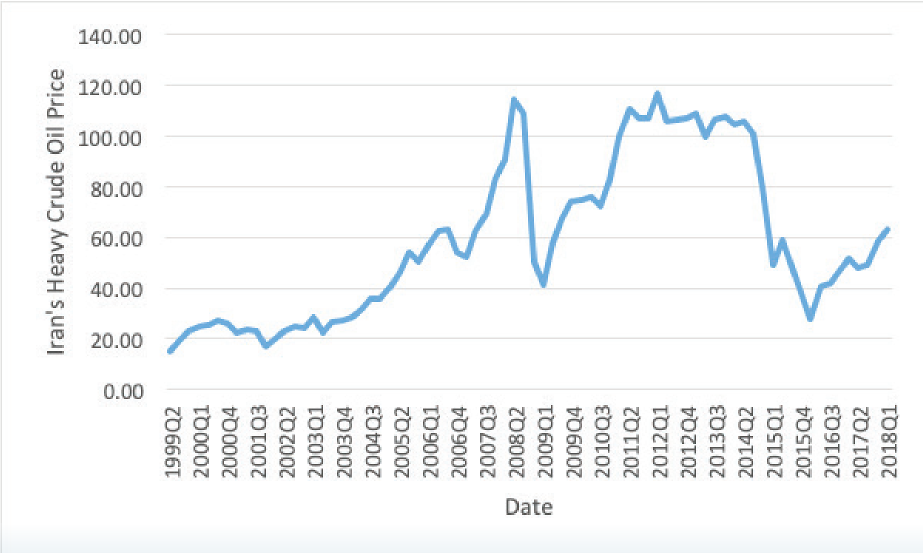

Figure 1.
The Seasonal average of Iran's heavy crude oil price ($/B) (Source: OPEC 2018).

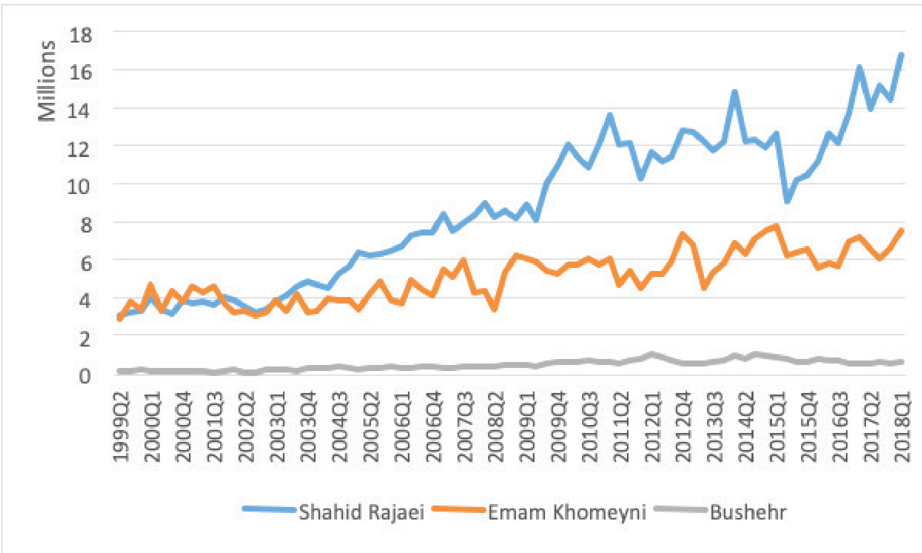

Figure 2.
Tonnage of goods loaded and discharged in Iran's major ports (tons) (Source: Iran's Port and Maritime Organization 2018).

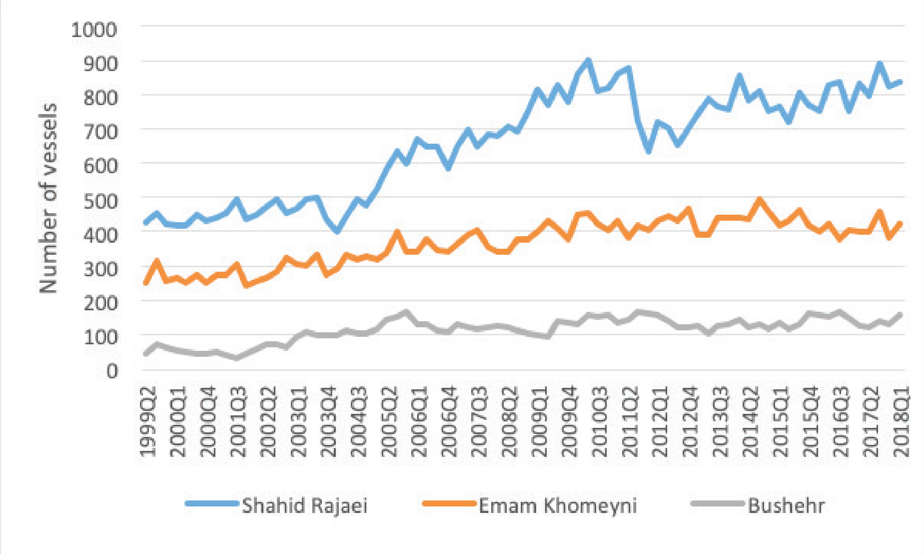

Figure 3.
Number of vessels handled by Iran's major ports (Source: Iran's Port and Maritime Organization 2018).

GDP in constant prices of 2010 is the sum of gross value added by all the resident producers in the economy, plus any product taxes, and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or depletion and degradation of natural resources. Data are in constant 2010 U.S. dollars. Dollar figures for GDP are converted from domestic currencies using 2010 official exchange rates.

The United States Bureau of Transportation (2017) defines port throughput as the amount of cargo or number of vessels a port handles over time. The tonnage of goods loaded and discharged for each port is the loading and unloading tonnage of non-oil cargoes including dry bulk, liquid bulk, containerized, and general cargoes. In addition, the number of vessels handled by each port includes vessels whose deadweight tonnage[1] is greater than or equal to 1,000 tons. For this research, data for the throughput of each port were obtained from Iran's Port and Maritime Organization data portal (Figures 3 and 4).

In order to take into account the effects of the Joint Comprehensive Plan of Action (JCPOA), we have employed a dummy variable (D1)[2]. After 2010, when sanctions became more comprehensive, and oil price decreased to 60 dollars per barrel in 2009, the exports reduced dramatically to about 20 billion dollars in 2010. Besides, oil export was reduced to 1 million barrels per day. After the removal of sanctions in the first half of 2017, the exports were increased to an average of 50 billion dollars, and the imports reached 40 billion dollars. Also, during the same period oil exports rose from 1 million barrels per day to nearly 2.5 million barrels per day (Mehdi-Zadeh, 2018).

3. METHODOLOGY

In order to investigate the response of Iran's major ports throughput to changes in Iran's crude oil prices and economic fluctuations of Iran's three major trading partners, we apply a standard vector autoregressive approach. The VAR approach provides us with a framework in which changes in a variable are related to changes in its own lags and changes in other variables plus the lags of those variables (Farzanegan and Markwardt, 2017). This approach emphasizes that in modelling, and especially in determining the endogenous and exogenous variables, all variables should be considered as endogenous. In the analysis of VAR models and the use of their results, Forecast Error Variance Decomposition and Impulse Response Functions (IRF) are usually used. Less attention is paid to criteria such as the significance of the coefficients using t statistic; since in VAR models the explanatory variables usually have strong multicollinearity, t statistics cannot be a reliable criterion for the suitability of variables. Our standard VAR model of order p is presented in Equation 1:

1. *It is a measure of how much a vessel can carry.*
2. *The JCPOA or the Iran Nuclear deal was signed on July 14, 2015 by Iran and five permanent members of the UN Security Council plus Germany. It officially went into effect in January 2016.*

in which z_t is the vector of exogenous variables, y_t is the vector of endogenous variables, ε_t is the innovation process, A_i and B are coefficient matrices, and p is the lag length. In the present study, the vector of endogenous variables for each

$$y_t = A_1 y_t + ... + A_p y_{t-p} + Bz_t + \varepsilon_t \quad (1)$$

VAR model, according to Cholesky decomposition, includes the seasonal average of Iran's heavy crude oil price (LIROP), GDP in the constant market prices of 2010 for China, Germany, and South Korea (LGDPCH, LGDPGE, LGDPKO), number of vessels handled by each port (LRAVH, LEMVH, LBUVH), and tonnage of goods loaded and discharged in each port (LRALOUN, LEMLOUN, LBULOUN). Given the optimal lag length of one, VAR models can be presented as the matrix forms below:

$$\begin{bmatrix} LRAVH_t \\ LRALOUN_t \\ LIROP_t \\ LGDPCH_t \\ LGDPGE_t \\ LGDPKO_t \end{bmatrix} = \begin{bmatrix} V_1 \\ V_2 \\ V_3 \\ V_4 \\ V_5 \\ V_6 \end{bmatrix} + \begin{bmatrix} A_{11} & A_{12} & A_{13} & A_{14} & A_{15} & A_{16} \\ A_{21} & A_{22} & A_{23} & A_{24} & A_{25} & A_{26} \\ A_{31} & A_{32} & A_{33} & A_{34} & A_{35} & A_{36} \\ A_{41} & A_{42} & A_{43} & A_{44} & A_{45} & A_{46} \\ A_{51} & A_{52} & A_{53} & A_{54} & A_{55} & A_{56} \\ A_{61} & A_{62} & A_{63} & A_{64} & A_{65} & A_{66} \end{bmatrix} \begin{bmatrix} LRAVH_{t-1} \\ LRALOUN_{t-1} \\ LIROP_{t-1} \\ LGDPCH_{t-1} \\ LGDPGE_{t-1} \\ LGDPKO_{t-1} \end{bmatrix} + \begin{bmatrix} u_{1t} \\ u_{2t} \\ u_{3t} \\ u_{4t} \\ u_{5t} \\ u_{6t} \end{bmatrix}$$

$$\begin{bmatrix} LEMVH_t \\ LEMLOUN_t \\ LIROP_t \\ LGDPCH_t \\ LGDPGE_t \\ LGDPKO_t \end{bmatrix} = \begin{bmatrix} V_1 \\ V_2 \\ V_3 \\ V_4 \\ V_5 \\ V_6 \end{bmatrix} + \begin{bmatrix} A_{11} & A_{12} & A_{13} & A_{14} & A_{15} & A_{16} \\ A_{21} & A_{22} & A_{23} & A_{24} & A_{25} & A_{26} \\ A_{31} & A_{32} & A_{33} & A_{34} & A_{35} & A_{36} \\ A_{41} & A_{42} & A_{43} & A_{44} & A_{45} & A_{46} \\ A_{51} & A_{52} & A_{53} & A_{54} & A_{55} & A_{56} \\ A_{61} & A_{62} & A_{63} & A_{64} & A_{65} & A_{66} \end{bmatrix} \begin{bmatrix} LRAVH_{t-1} \\ LRALOUN_{t-1} \\ LIROP_{t-1} \\ LGDPCH_{t-1} \\ LGDPGE_{t-1} \\ LGDPKO_{t-1} \end{bmatrix} + \begin{bmatrix} u_{1t} \\ u_{2t} \\ u_{3t} \\ u_{4t} \\ u_{5t} \\ u_{6t} \end{bmatrix} \quad (2)$$

$$\begin{bmatrix} LBUVH_t \\ LBULOUN_t \\ LIROP_t \\ LGDPCH_t \\ LGDPGE_t \\ LGDPKO_t \end{bmatrix} = \begin{bmatrix} V_1 \\ V_2 \\ V_3 \\ V_4 \\ V_5 \\ V_6 \end{bmatrix} + \begin{bmatrix} A_{11} & A_{12} & A_{13} & A_{14} & A_{15} & A_{16} \\ A_{21} & A_{22} & A_{23} & A_{24} & A_{25} & A_{26} \\ A_{31} & A_{32} & A_{33} & A_{34} & A_{35} & A_{36} \\ A_{41} & A_{42} & A_{43} & A_{44} & A_{45} & A_{46} \\ A_{51} & A_{52} & A_{53} & A_{54} & A_{55} & A_{56} \\ A_{61} & A_{62} & A_{63} & A_{64} & A_{65} & A_{66} \end{bmatrix} \begin{bmatrix} LRAVH_{t-1} \\ LRALOUN_{t-1} \\ LIROP_{t-1} \\ LGDPCH_{t-1} \\ LGDPGE_{t-1} \\ LGDPKO_{t-1} \end{bmatrix} + \begin{bmatrix} u_{1t} \\ u_{2t} \\ u_{3t} \\ u_{4t} \\ u_{5t} \\ u_{6t} \end{bmatrix}$$

We assume that the first variable in the pre-specified ordering of variables has a significant impact on the dynamics of VAR models. In the ordering of all three equations, oil price shocks are considered as the most important endogenous variables. Since Iran is one of the main suppliers of crude oil in the world, and crude oil is the main source of government revenues, many macroeconomic variables such as terms of trade and real exchange rates are affected by oil price fluctuations, which as a result affects the trade sector of the country and trade relationships with major trading partners.

It is argued that if variables follow a I(1) process, we should not use their first differences because in VAR models the aim is to determine the correlation between the variables, not the estimation of the parameters. Moreover, Sims (1980) stated that differencing might cause losing information when there are co-integration vectors in a model.

In the first step, we need to check the order of integration of our variables and the existence of cointegrating vectors. Augmented Dickey-Fuller (1979) and Philips-Perron (1983) tests have been applied to examine the order of integration. The results are shown in Table 1. The results for both tests indicate that all the variables follow I (1) process. Considering that all the variables are stationary after first differencing, we analyze the existence of a relationship among the variables in the long run. Johansen cointegration tests (see Johansen, 1991, 1995) with considering all the five deterministic trend models are used. The number of cointegrating relations is shown in Tables 2 to 4. The results indicate the existence of a long-run relationship between variables. The optimal lag length is determined based on the Schwarz information criterion (SC), and Hannan-Quinn information criterion (HQ) for each VAR model is 1. The details of lag length selection are presented in Tables A1 to A3 in Appendix

A. The results of Impulse-Response Functions and Forecast Error Variance Decomposition tables for each VAR model are presented in the next section.

4. EMPIRICAL RESULTS

4.1. Unit Root Tests

As stated by Granger and Newbold (1974), if all the variables in a model have a unit root, the model will encounter spurious regression. In this study, both Augmented Dickey-Fuller and Philips-Perron tests have been applied to specify the integration order for each variable. Table 1 presents the results. Each test has been applied with and without trend. At 5 per cent significant level, the null hypothesis of a unit root test has been rejected in both tests. Referring to the results, the variables are stationary after the first differencing. Since all the variables have unit root, OLS[3] regressions cannot be used. If all variables are stationary after the first differencing, we can apply VAR econometric approach.

4.2. Johansen Cointegration Test

Considering that the variables of the models follow a I(1) process, in a second step we analyze the existence of long-run relationships among these variables. In the present article, Johansen cointegration test is accomplished in order to determine long-run relationships between the seasonal average of Iran's heavy crude oil price, Gross Domestic Product in the constant market prices of 2010 for three Iran's major trading partners, and Iran's major ports throughput. The number of cointegrating relations for each VAR model is shown in Tables 2 to 4, at a 5 per cent significance level and using trace as well as maximal eigenvalue statistics. In order to specify the lag

Table 1.
Unit Root tests.

		ADF		PP		Integration degree
		Without trend	With trend	Without trend	With trend	
LIROP	Level 1st diff.	-2.18 -7.45*	-1.77 -7.46*	-2.20 -7.40*	-1.86-7.43*	I(1)
LGDPCH	Level 1st diff.	-3.19* -5.55*	1.37 -6.17*	-2.28 -5.44*	0.61 -6.17*	I(1)
LGDPGE	Level 1st diff.	-0.35 -5.50*	-2.95 -5.48*	-0.41 -5.46*	-2.53 -5.44*	I(1)
LGDPKO	Level 1st diff.	-3.23* -6.89*	-2.97 -7.31*	-3.08* -6.84*	-2.96 -7.25*	I(1)
LRAVH	Level 1st diff.	-1.58 -10.91*	-2.81 -10.84*	-1.33 -11.81*	-2.66 -11.79*	I(1)
LRALOUN	Level 1st diff.	-1.01 -11.35	-2.71 -11.29	-0.98 -12.06	-2.51 -12.01	I(1)
LEMVH	Level 1st diff.	-1.55 -9.68*	-4.80* -9.67*	-2.24 -19.64*	-4.95* -20.97*	I(1)
LEMLOUN	Level 1st diff.	-3.10* -13.09*	-6.12* -12.98*	-2.91 -48.83*	-6.20* -49.44*	I(1)
LBUVH	Level 1st diff.	-2.19 -9.24*	-2.62 -9.14*	-2.11 -9.34*	-2.61 -9.22*	I(1)
LBULOUN	Level 1st diff.	-2.19 -9.98*	-3.48* -7.27*	-2.03 -14.21*	-3.51* -16.71*	I(1)

***indicates the rejection of the null hypothesis of a unit root test at 5 per cent significance level.**

3. *Ordinary Least Squares.*

length needed for Johansen cointegration test, variables are entered into a VAR model. The lag length is determined based on the Schwarz information criterion (SC) and Hannan-Quinn information criterion (HQ). According to the results, there are strong long-run relationships among the variables. Therefore, we can evaluate the dynamics of the models over the long run using Forecast Error Variance Decomposition.

Table 2.
Johansen cointegration test for VAR model of Shahid Rajaei Port.

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept	Intercept	Intercept	Intercept	Intercept
	No Trend	No Trend	No Trend	Trend	Trend
Trace	3	3	2	2	1
Max-Eig	3	3	1	1	1

Table 3.
Johansen cointegration test for VAR model of Emam Khomeyni Port

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept	Intercept	Intercept	Intercept	Intercept
	No Trend	No Trend	No Trend	Trend	Trend
Trace	4	4	4	3	3
Max-Eig	4	4	3	3	3

Table 4.
Johansen cointegration test for VAR model of Bushehr Port.

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept	Intercept	Intercept	Intercept	Intercept
	No Trend	No Trend	No Trend	Trend	Trend
Trace	5	5	6	3	3
Max-Eig	5	4	3	1	1

4.3. Impulse Response Functions

Impulse response functions indicate how each variable in a VAR model responds to the shocks. We trace the effects of a one-time shock to the seasonal average of Iran's heavy crude oil price as well as the real GDP of China, Germany, and South Korea on short-run values of the number of vessels handled by ports and the tonnage of goods loaded and discharged in Iran's major ports. The following subsections illustrate and explain IRFs for the VAR model of each port.

Shahid Rajaei Port

As shown in Figure 4, the IRFs for Shahid Rajaei Port's throughput VAR model indicate that the initial shock in oil prices significantly increases both the number of vessels handled plus the tonnage of goods loaded and discharged in this port, which hits a peak after the third period. This implies increasing the seaborne trade of this port both regionally and internationally. Since this port is Iran's largest commercial port, such an impact is expected. Shocks to GDPs of China and South Korea increase Shahid Rajaei's port throughput marginally, while a shock to Germany's GDP decreases it in the short-run.

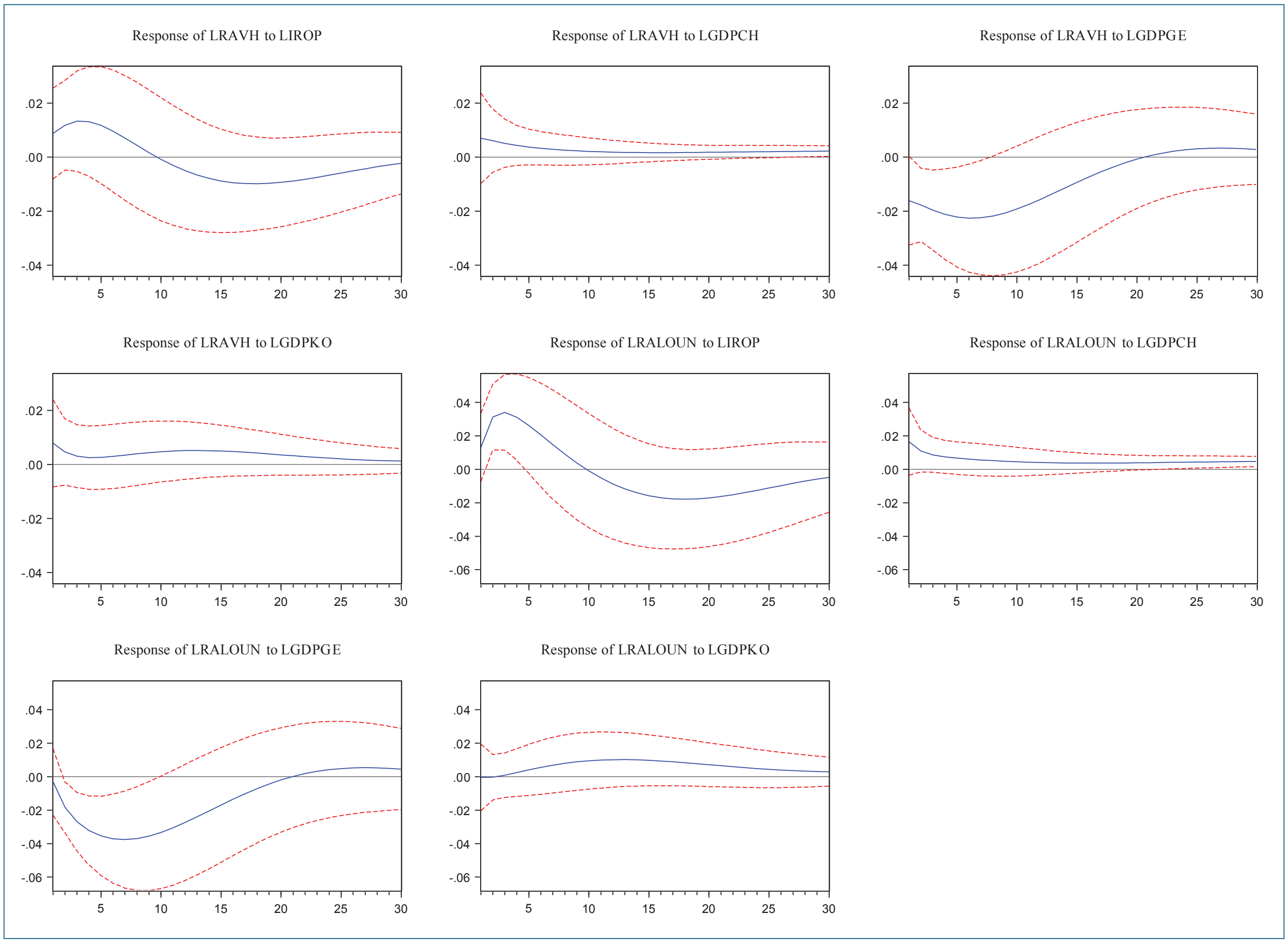

Figure 4.
IRFs for Shahid Rajaei port VAR model.

Emam Khomeini Port

Based on IRFs for Emam Khomeini port throughput shown in Figure 5, it can be seen that an increase in oil prices will increase the number of vessels handled by Emam Khomeini port; however, at the same time the tonnage of goods loaded and discharged in this port significantly decreases. This means that vessels calling at this port despite the larger number have lower deadweight tonnage. Since vessels with lower DWT are generally used in regional trade, it can be concluded that rising of oil prices in the short term will strengthen the seaborne trade of this port at the regional level. It can also be concluded that the imported goods at the time of rising oil prices are mainly industrial and expensive cargoes that have less volume than bulk commodities. Only an increase in China's GDP will increase the port throughput of Emam Khomeini port marginally, and the increase in the GDP of Korea and Germany reduces the throughput of the port in the short term.

Bushehr Port

Similar to the results for Emam Khomeini's port model, rising oil prices will increase the number of vessels handled by Bushehr port, but at the same time it reduces the tonnage of goods loaded and discharged in this port. Moreover, in this case it can be concluded that vessels calling at this port have a lower DWT; thus, seaborne trade of this port increases at the regional level. In addition, it can be determined that imported goods at the time of rising oil prices are mainly industrial and expensive cargoes. Initial shock to Germany's GDP increases the throughput of this port insignificantly in the first and second periods. The impact of China's and South Korea's GDP growth on the throughput of the Bushehr port is almost the same. In the short run, an increase in the GDPs of China and South Korea will increase the number of vessels handled by this port and slightly reduce the tonnage of goods loaded and discharged in this port. The results are shown in Figure 6.

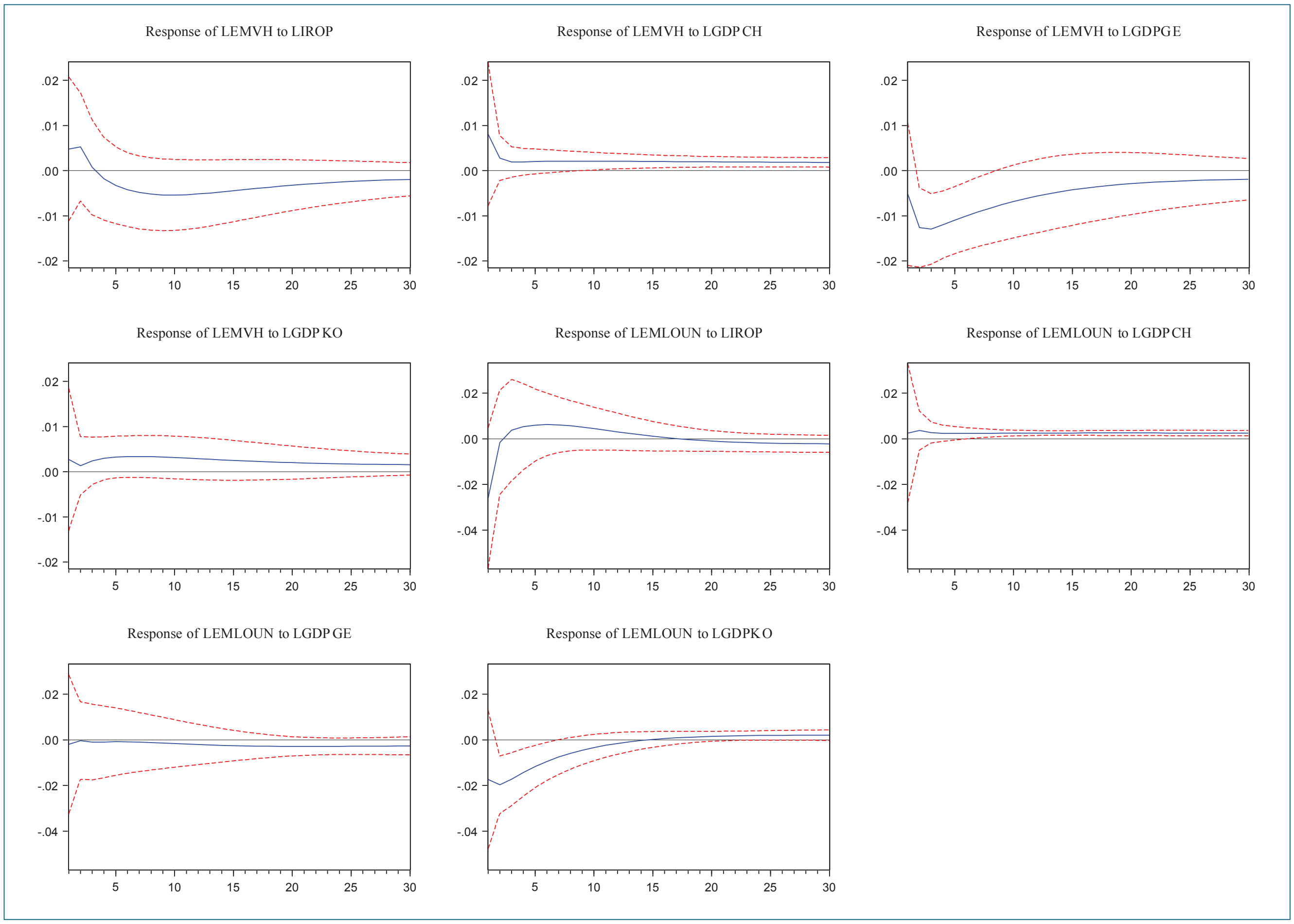

Figure 5.
IRFs for Emam Khomeyni port VAR model.

4.4. Forecast Error Variance Decomposition

Forecast Error Variance Decomposition is a method for evaluating a VAR model's dynamics. This method examines the variations of dependent variables due to the shocks applied to a variable against the shocks applied to other variables. In this study, shocks applied to oil price variable transfer to other variables. Forecast Error Variance Decomposition specifies how much the effect of shocks is due to various factors. Furthermore, forecast error variance decomposition enables us to determine which variable is stronger in explaining the variability in the dependent variables over time. It also indicates how much of the future uncertainty of a time series is due to future shocks in other time series in the VAR system. The following subsections explain Forecast Error Variance Decomposition for each VAR model.

Shahid Rajaei Port

As shown in Table 5, the share of oil price fluctuations in explaining variations in the number of vessels handled by this port is low, which increases in the early periods, but decreases in the long run. The share of oil price volatility in explaining the variations in the tonnage of goods loaded and unloaded in Shahid Rajaei port is low in the early periods, but then after several periods, it increases significantly. In explaining the variations in Shahid Rajaei port throughput, fluctuations in Germany's GDP have a stronger short- and long-run role compared to fluctuations in China's and South Korea's GDPs. The share of Germany's GDP in explaining changes in the tonnage of goods loaded and discharged in this port is remarkable in the long run. Since Germany has always been the largest trade partner of Iran among the industrialized economies, it can be concluded that this port is affected by technology and investment spillovers, which in the long run contribute to the country's economic development and will increase the throughput of this port.

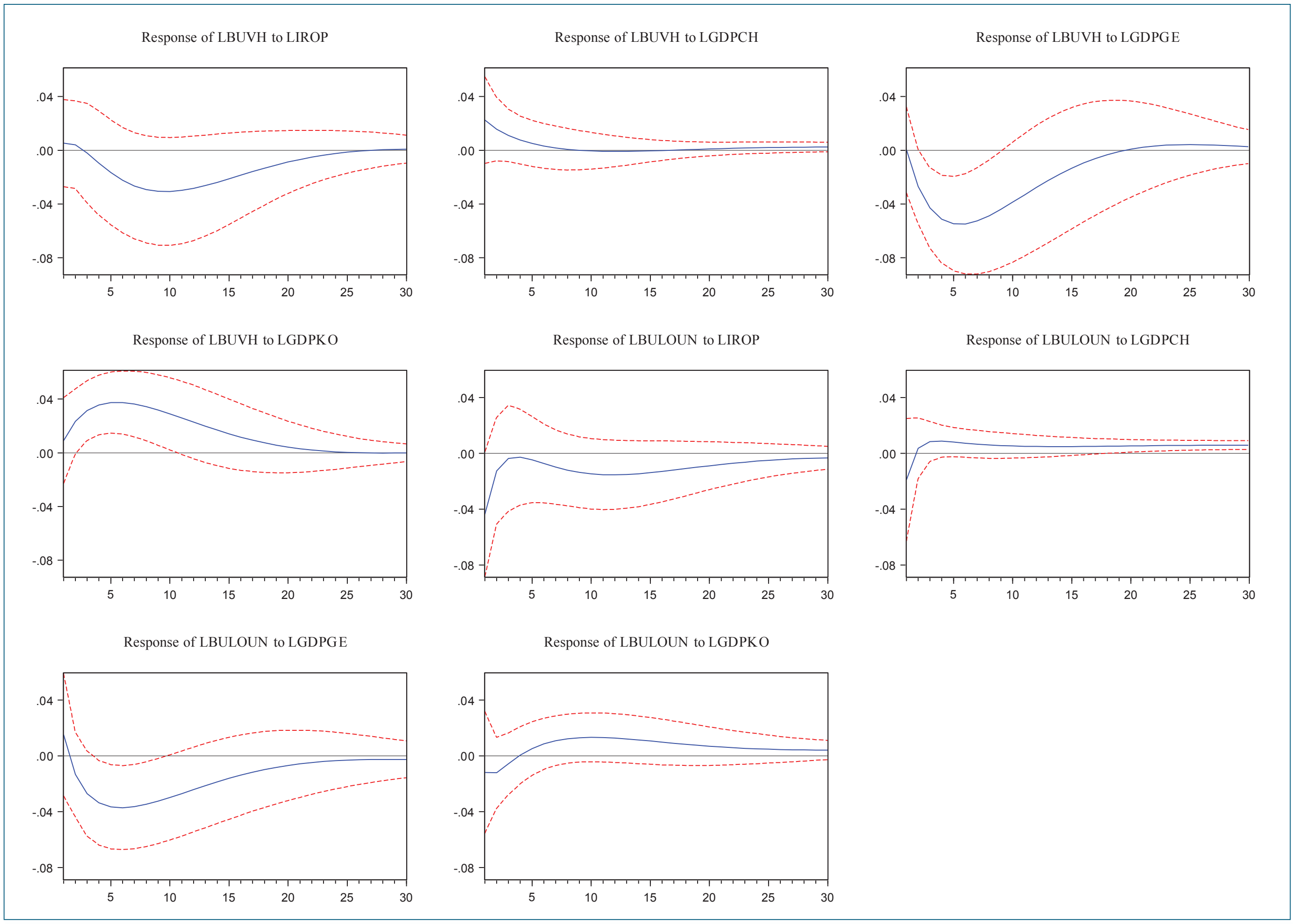

Figure 6.
IRFs for Bushehr port VAR model.

Table 5.
Variance Decomposition of LRAVH and LRALOUN.

Quarter	LIROP	LGDPCH	LGDPGE	LGDPKO	LRAVH	LRALOUN
Variance Decomposition of LRAVH:						
1	1.45	0.93	4.95	1.16	91.48	0.00
4	5.37	1.24	13.41	0.93	77.13	1.89
8	6.50	1.27	25.56	1.05	63.45	2.14
12	6.07	1.25	31.93	1.57	56.91	2.24
Variance Decomposition of LRALOUN:						
1	2.19	3.51	0.12	0.001	7.33	86.82
4	18.90	2.99	12.12	0.03	5.53	60.40
8	18.68	2.62	29.98	0.65	4.25	43.79
12	16.08	2.47	38.76	1.79	3.67	37.21

Table 6.
Variance Decomposition of LEMVH and LEMLOUN.

Quarter	LIROP	LGDPCH	LGDPGE	LGDPKO	LEMVH	LEMLOUN
Variance Decomposition of LEMVH:						
1	0.48	1.39	0.57	0.15	97.39	0.00
4	0.99	1.47	9.05	0.43	83.83	4.20
8	2.22	1.62	14.48	1.13	76.64	3.88
12	3.88	1.80	16.41	1.66	72.46	3.76
Variance Decomposition of LEMLOUN:						
1	3.78	0.03	0.021	1.68	30.38	64.07
4	3.69	0.16	0.029	6.10	30.69	59.31
8	4.32	0.27	0.04	7.53	29.94	58.87
12	4.63	0.39	0.10	7.67	29.72	57.46

Table 7.
Variance Decomposition of LBUVH and LBULOUN.

Quarter	LIROP	LGDPCH	LGDPGE	LGDPKO	LBUVH	LBULOUN
Variance Decomposition of LBUVH:						
1	0.14	2.59	0.00	0.42	96.83	0.00
4	0.35	2.32	12.99	7.19	76.83	0.29
8	4.16	1.63	27.54	13.75	52.57	0.32
12	8.30	1.33	29.73	15.38	44.96	.026
Variance Decomposition of LBULOUN:						
1	5.02	0.95	0.61	0.37	13.66	79.38
4	4.21	1.05	4.59	0.64	21.29	68.18
8	4.29	1.28	13.45	1.23	19.35	60.38
12	5.35	1.35	17.63	2.24	18.15	55.24

Emam Khomeini Port

Table 6 shows the results of Forecast Error Variance Decomposition for the VAR model of Emam Khomeini port. Although the share of oil price fluctuations in explaining changes in the throughput of Emam Khomeini port increases over time, it is much lower in comparison with Shahid Rajaei port. The share of Germany's GDP in the explanation of changes in the number of vessels handled by the port increases dramatically, but this share is very low and below 1 per cent in explaining the variations in the tonnage of goods loaded and discharged in this port. Besides, the share of China's and South Korea's GDPs, although rising are not significant. Indeed, most of the fluctuations of Emam Khomeini port throughput are explained by their own past shocks. The reason is that raw materials and agricultural commodities, which are the primary requirements of the country, account for the highest share of the goods loaded and discharged in this port, while the share of industrial goods and containers is much lower. Therefore, regardless of the changes in oil prices and the increase or decrease in oil revenues, raw materials and agricultural commodities have always been imported to the extent required in all circumstances.

Bushehr Port

Similar to the port of Emam Khomeini, the share of oil price fluctuations in the explanation of changes in the throughput of Bushehr port increases over time; however, in the long run this increase is much lower compared to Shahid Rajaei port. In the long run, the share of South Korea's GDP in explaining the fluctuations of the number of vessels handled by Bushehr port increases rapidly, but this share is modest in explaining the variations of the tonnage of goods loaded and discharged in this port and does not change considerably over time. Like Shahid Rajaei port, the share of fluctuations in Germany's GDP in explaining the changes in the throughput of Bushehr port is low in the early periods, but increases considerably in the long run. Consequently, Bushehr port benefits from the technology and investment spillovers over time. The share of China's GDP is marginal in both the short and long run, and does not change significantly over time. The results are shown in Table 7.

5. CONCLUSIONS AND POLICY DISCUSSION

In the present research, an attempt was made to estimate the effects of oil price shocks on port throughput in the three major ports in Iran, i.e. Shahid Rajaei, Emam Khomeini, and Bushehr, through economic fluctuations of the three major trading partners. The number of vessels handled by each port and the tonnage of goods loaded and discharged in each port were chosen as indicators of port throughput. Besides, the seasonal average of Iran's heavy crude oil price was selected as the indicator of oil price shocks, and GDP in constant prices of 2010 was chosen as the indicator of economic fluctuations of Iran's major trading partners. The sample of trading partners consists of three countries: China, South Korea, and Germany. The data used in this study was quarterly, covering the period from 1999 Q2 to 2018 Q1. We applied the vector autoregressive (VAR) approach using Cholesky decomposition.

Analysis of the Impulse Response functions for each VAR model shows that in the short run and with increasing oil revenues, seaborne trade will be further directed towards Shahid Rajaei Port as the largest commercial port in Iran. Rising oil revenues in the short term will change the combination of goods loaded and discharged in the ports of Emam Khomeini and Bushehr. Furthermore, the results of forecast error variance decomposition tables show that in the long run the share of oil price fluctuations in explaining the variations of Shahid Rajaei port throughput is higher than the other two ports. In addition, these tables show that fluctuations in Emam Khomeini port throughput are also explained by changes in the past values of the dependent variables. Besides, the results of forecast error variance decomposition indicated that the share of China's and South Korea's GDP fluctuations in explaining the changes in the throughput of Iran ports in the short and long term are low and do not change considerably over time. However, the share of Germany's GDP fluctuations in explaining the variations in the port throughput of Shahid Rajaei and Bushehr ports are low in the short run, but in the long run will increase dramatically. Indeed, the results of the research prove the fact that by increasing GDP the macroeconomic system tends to be more open. On the other hand, increasing oil revenues results in GDP growth. There is a close relationship between GDP, containerized cargo trade, and open macroeconomic systems. Consequently, increases in oil revenues cause an increase in the volume of industrial and containerized seaborne cargo trade. Actually, economic growth deceleration causes a decline in merchandise trade, increased trade policy uncertainty, and the negative impact of low-price commodities trade on export earnings. According to the results of the models, the policy suggestions include:

- Permanent monitoring of fluctuations in oil prices and prospects in this market.
- Ports specialization is one of the prerequisites for the attainment of the fourth generation of ports. Considering the need of the country to attain the fourth generation of ports, the specialization of Shahid Rajaei and Bushehr ports in handling industrial commodities and containers, and the specialization of Emam Khomeini port in handling bulk commodities as well as raw materials are proposed in order to increase the throughput of these ports.
- Increasing the seaborne trade volume with industrial economies.

APPENDIX A. LAG LENGTH SELECTION

The optimal lag length for each VAR model is determined based on the Schwarz information criterion (SC) and Hannan-Quinn information criterion (HQ). The results are reported in Tables A.1 to A.3.

Table A.1
Optimal lag length for VAR model of Shahid Rajaei Port.

Lag	SC	HQ
0	-13.28907	-24.88955*
1	-23.86283	-22.40962
2	-21.12502	-13.52347
3	-25.82712*	-25.50358
4	-24.75356	-24.17214

Table A.2
Optimal lag length for VAR model of Emam Khomeyni Port.

lag	SC	HQ
0	-13.88260	-24.48683*
1	-23.60555	-22.33395
2	-21.04975	-14.11699
3	-25.42440*	-25.24630
4	-24.67788	-24.09686

Table A.3
Optimal lag length for VAR model of Bushehr Port.

lag	SC	HQ
0	-10.90809	-22.21277*
1	-21.48239	-19.87927
2	-18.64248	-11.14248
3	-23.15035*	-23.12315
4	-22.22320	-21.68959

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Control of Unmanned Underwater Vehicle as a Member of Vehicles Team Performing a Given Task

Andrzej Zak

The article presents the control system of a single underwater vehicle which is a member of the underwater vehicles team. The application of the multi-agent system concept for modelling and controlling a team of homogeneous underwater vehicles is discussed. Issues relating to cooperation actions in the team of underwater vehicles are described and solved using the theory of games and vector quality index. The process of negotiations between the vehicles is modelled as a multiplayer cooperative game. Finally, the water region search tasks performed by a team of cooperating underwater vehicles are presented and discussed taking into account possible vehicle failures happening during task realization.

KEY WORDS

~ Unmanned underwater vehicles
~ Control
~ Team of vehicles
~ Cooperation

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1. INTRODUCTION

Currently, in the underwater robotics concepts are developed in which a team of unmanned underwater vehicles performs specific tasks. Among these tasks, the most common ones are: search, inspection, and recognition, which can be performed by a single robot, whereby a team of vehicles can perform them faster and more efficiently. The team of cooperating underwater vehicles has many advantages, such as high resistance to damage that allows the task to be performed in the event of failure of one of the robots, or the possibility of using vehicles with a much simpler structure due to the decomposition of the task. However, the problem of controlling a team of cooperating underwater vehicles is a more difficult issue than controlling a single vehicle. In this case, it is required to consider for example: communication between vehicles, coordination of activities, or conducting negotiations.

In the computer sciences, multi-agent systems are widely used in solving problems of a distributed or computationally complex nature. The multi-agent system includes communicating and cooperating agents whose task is to achieve common goals. The mechanism of multi-agent systems can be easily used to control a team of cooperating underwater vehicles, treating each of them as a separate agent.

The main goal of the research is to develop methods and algorithms for controlling an autonomous underwater vehicle that performs tasks as a member of a vehicle team.

The article consist of two main parts. The first part describes the methods and algorithms of operation of a single, autonomous underwater vehicle treated as an agent in a multi-agent system. The second part presents selected results of researches carried out in simulation conditions for the task of searching water region by a team of homogenous underwater vehicles. In the summary, the research is briefly discussed.

2. METHOD DESCRIPTION

2.1. Unmanned Underwater Vehicle as an Agent

Let $S=\{s_1, s_2, \ldots\}$ mean possible environmental conditions and $A=\{a_1, a_2, \ldots\}$ possible agent actions. While making a formal description of the agent's operation, it can be noted that the action can be treated as a function (Gnatowski, 2005; Weiss, 1999; Zak, 2013a):

$$action: S^* \rightarrow A \tag{1}$$

where S^* – selected sequence of environmental states.

The environment can be defined as a function:

$$environment: S \times A \rightarrow S \tag{2}$$

The above means that the action taken results from the state of the environment, and the environment under the influence of the agent changes its state.

It is also necessary to define a function which allows to read the input signals by the agent, called perception. It can be written as a function:

$$perception: S \rightarrow P \tag{3}$$

which maps the state of the environment into perception P. In connection with the above, the action function will take the following form:

$$action: P^* \rightarrow A \tag{4}$$

where P^* – sequence of perception.

The agent's interactions with the environment can be treated as a game with Nature, meaning a two-person game with zero payout, which has the following assumptions (Ameljańczyk, 1984):

- one player is an agent and the other is Nature as a hypothetical opponent of the agent;
- nature is a passive opponent, so it does not depend on winning;
- the agent's strategies are defined by ways of acting, and the strategies of Nature are its states;
- Nature realizes its states according to a specific random mechanism, about which an agent can have or obtain certain information.

Nature has a set of states that will be numbered with a natural number, $n \in \{1,2,\ldots,k\}$, $n, k \in N$, and the agent will have a set of decisions X. The result of the agent taking a certain decision $x \in X$ and realizing a particular state of Nature $n \in N$ is in some way assessed by the agent. Let this assessment having a fixed interpretation be a real number representing the loss that we will denote by the symbol $F_n(x)$.

At the beginning, let us assume that the agent has no information about the probability distribution of the states of Nature, so choosing the decision doesn't know what its assessment will be, because it doesn't know which state Nature will take. Any decision $x \in X$ can be evaluated with k numbers $F_n(x)$, $n \in N$ (Ameljańczyk, 1984). The agent will try to choose such a decision x that all of its grades $F_n(x)$, i.e. loss values, will be as low as possible. It will ensure that regardless of the state n which will be realized, his losses will be as small as possible. Formally, the above decision-making task can be treated as a multi-criteria type optimization task

$$(X, F, R) \tag{5}$$

where R – dominance relation.

In this case, it is interesting to determine the form of the dominance relationship $R \subset F(X) \times F(X)$. Naturally, the suggestion is a relationship ≥ generated by a cone (Ameljańczyk, 1984):

$$\Lambda=\{\lambda \in R^k \,|\, \lambda \geq 0\} \tag{6}$$

In the set $Y = F(X)$ we will get a set of Pareto-optimal results. So, the agent will probably choose one of the decisions leading to the set $Y_k^{\leq}$.

A pessimistic agent can use the following dominance relationship R_p (Ameljańczyk, 1984):

$$\max_{n \in N} y_n \leq \max_{n \in N} w_n \tag{7}$$

where $y, w \in Y$ and $(y,w) \in R_p$.

This means that the result y is considered better than the result of w if the maximum conditional loss is lower than or equal to the maximum conditional loss in the case of w result.

In the case of a decision, this means that the decision *x* such that *F(x) = y* is better than the decision *z* such that *F(z) = w* if it guarantees a loss equal to or lower than the decision *z*. The dominant result of z will be such a result that (Ameljańczyk, 1984):

$$\max_{n \in N} y_n^p \leq \max_{n \in N} w_n \tag{8}$$

for every $w \in Y - \{y\}$.

If the player is an optimistic agent, he will value the results in a different way. Let $y, w \in Y$ and $(y,w) \in R_o$ when

$$\min_{n \in N} y_n \leq \min_{n \in N} w_n \tag{9}$$

This means that the agent will prefer decision *x* such that *F(x) = y* over the decision *z* such that *F(z) = w* if the loss is lower than or equal to the corresponding loss in the case of a decision *z*.

Suppose that the agent knows the Nature state probability distribution. Let p_n be the probability that the *n*-th state of Nature will occur. Of course, the following relationships take place:

$$\sum_{n \in N} p_n = 1 \text{ i } p_n \geq 0, n \in N \tag{10}$$

In this case, it seems advisable to use the method of compromise hierarchical solutions in which the order of criteria can be determined using the p_n values. The dominance relationship can be defined using the expected loss value. Let $y, w \in Y$, then $(y,w) \in R_p$ when (Ameljańczyk, 1984)

$$\sum_{n \in N} p_n y_n \leq \sum_{n \in N} p_n w_n \tag{11}$$

The set of dominating solutions, with such a dominance relationship, is a set of such decisions $\tilde{x} \in X$, that (Ameljańczyk, 1984)

$$\sum_{n \in N} p_n F_n(\tilde{x}) = \inf_{x \in X} \sum_{n \in N} p_n F_n(x) \tag{12}$$

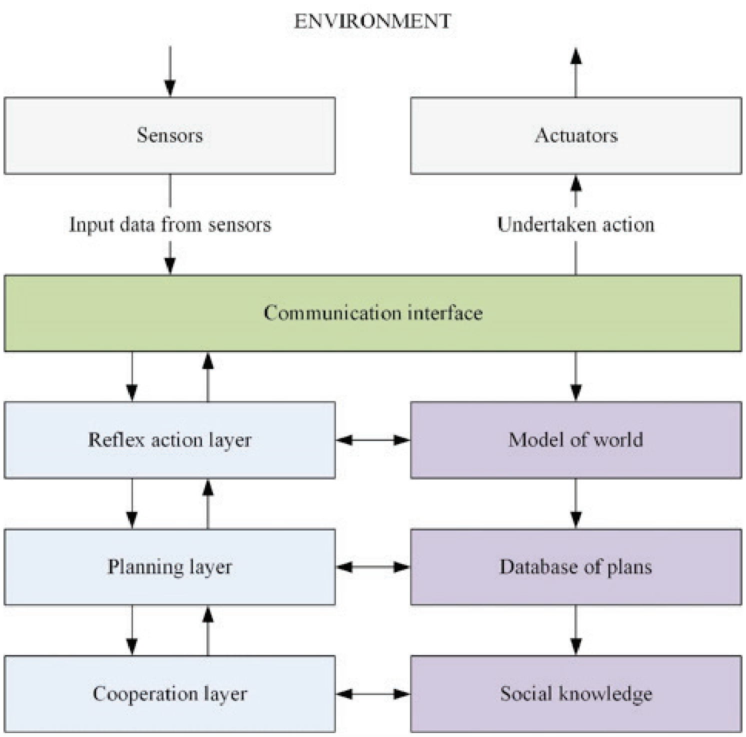

Figure 1.
Agent architecture and control flow (Gnatowski, 2005).

So far, we have treated the agent as an abstract concept. Giving it the autonomy function consists in defining the action function to take depending on the input signals that make up the perception. The proposed solution adopts a layered, hierarchical architecture (Figure 1) (Zak, 2013b). Its advantage is the lack of the need to define the decision mechanism and the simplicity of operation. This architecture will consist of layers, where the lowest layer is responsible for reflex behavior, the middle one for planning, and the highest for cooperation with other agents (Gnatowski, 2005; Maza & Ollero; Mukkerm 1996). Each of the layers has a corresponding database which represents the state of the environment corresponding to the given layer. The control flow in this architecture takes place in two directions. First, the control signal is sent from the lower to the higher layers, and then from the higher to the lower layers. If the lower layer using its database is unable to take appropriate action, it sends the signal to the upper layer. From this it follows that the higher the layer, the less frequently it is activated (Gnatowski, 2005).

2.2. Algorithm of Agent Behavior

It was assumed that the team consists of heterogeneous vehicles, i.e. that their hardware and software layers, including operation algorithms are the same. It was also assumed that the team's goal is to search the set water region. The vehicle's operation algorithm should ensure that the goal set for each

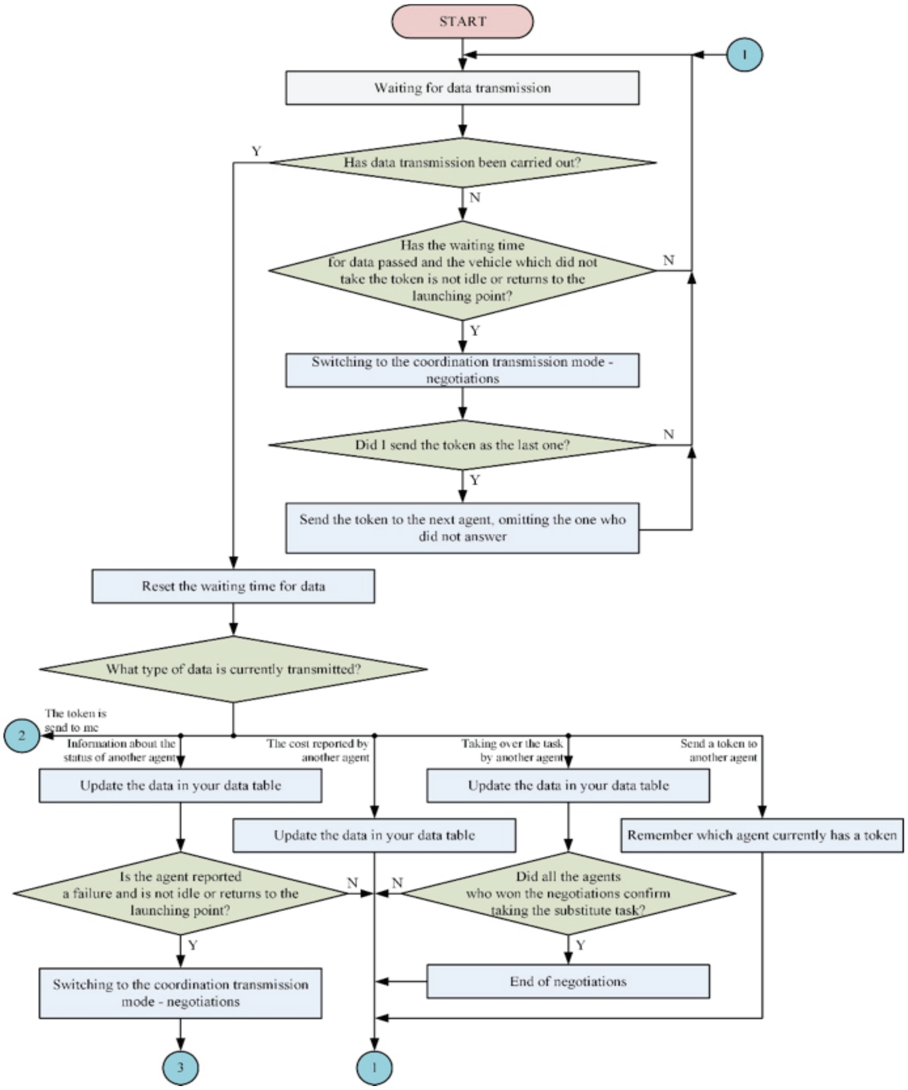

Figure 2.
The operation algorithm of a single agent - an underwater vehicle, Part 1, a continuation is shown in Figure 3.

agent is achieved, as well as the cooperation between the agents. According to the adopted structure, the algorithms related to detecting obstacles are implemented in the layer of reflex action as well as algorithms related to maintaining the course and speed of movement (Garus & Zak, 2010; Zak, 2016). The planning layer implements algorithms related to driving the vehicle along a set trajectory, including determining the trajectory of obstacle avoiding (Lisowski, 2016; Zak 2013a). At the level of cooperation, the vehicle exchanges data with other team members and also conducts negotiations in the event of damage to any of the vehicles and the need to undertake a substitute task (Lisowski, 2013). For this purpose, information about the condition of a given vehicle is sent between vehicles, as well as in the case of negotiations also the costs of performing replacement tasks by individual vehicles. Since communication between vehicles is most often carried out in water using hydro-modems, in the situation of a common transmission media token ring mechanism can be used. In the case of winning negotiation by a given agent, its trajectory is automatically extended by a part that was taken over as a substitute task (Zak, 2013a).

Figures 2 and 3 present the algorithm of operation of a single agent in the scope of cooperative activities, which should ensure the performance of the task in cooperation with other agents, i.e. to achieve a common goal – the search a given water region.

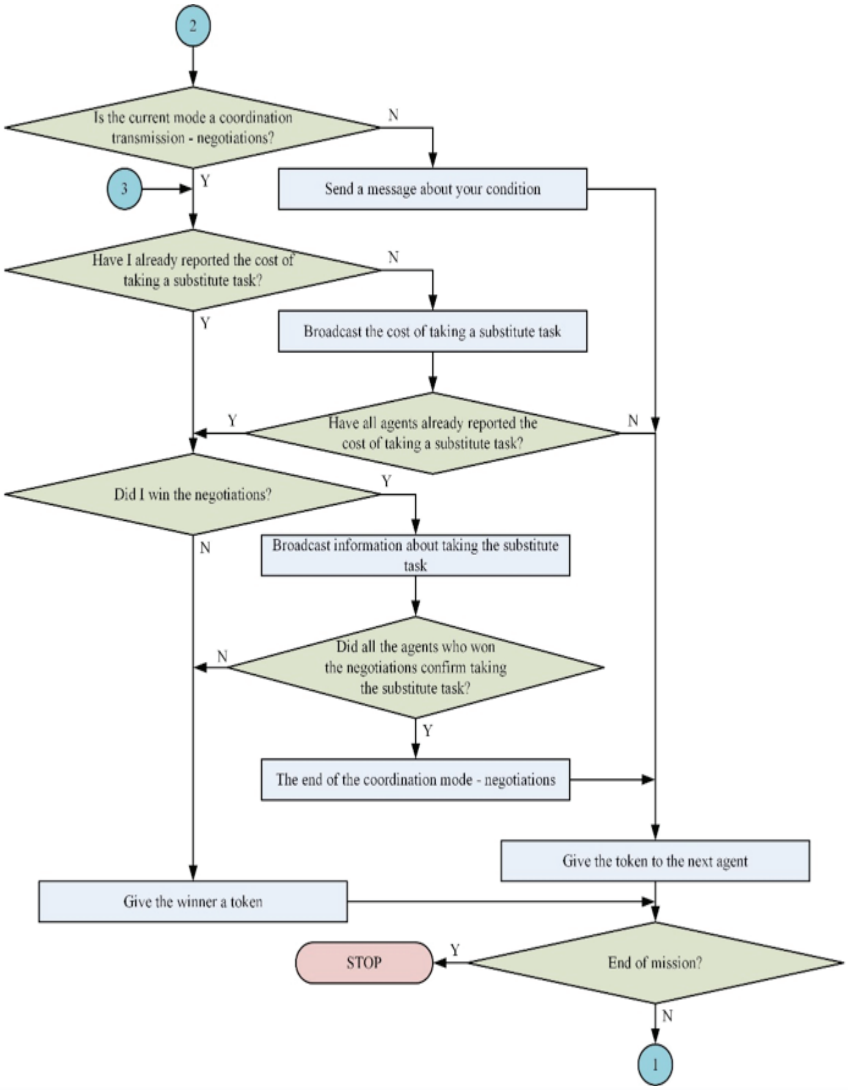

Figure 3.
Algorithm for the operation of a single agent - an underwater vehicle, Part 2

3. RESULTS OF RESEARCH

The correctness of the adopted solutions has been verified on the basis of simulation tests carried out in the Matlab environment. The research assumes that a set of heterogeneous autonomous underwater vehicles performs the task of searching a given water region. A single autonomous underwater vehicle is an agent who, together with the other vehicles in team, has to pursue the main objective. Each of the vehicles has a specific purpose, which is to search the indicated part of the water region. The environment is the water into which the underwater vehicle interacts with the thrusters allowing it to move. The task of perception is primarily fulfilled by navigation devices that are necessary for the vehicle to move on a given trajectory. In addition, technical observation devices are used, for example to detect obstacles. Perception functions can also be met by technical observation devices through which the vehicle can detect the objects sought if the task requires it; otherwise, they are not important from the point of view of the agent's implementation. During the task performance, the vehicle cooperates with other vehicles in the team; in particular, it exchanges data coordinating the work. Each vehicle also has low-level control algorithms that allow it to travel along the trajectories. Before starting the mission, each vehicle acquires the following data from the supervision system (mission planner):

- number of vehicles participating in the task;
- description of the reference system common to all vehicles;
- description of the shape of the water region in the form of a contour defined by a set of points with coordinates (x,y) in the assumed reference system;
- the trajectory on which a given vehicle is to move, as defined in the adopted reference system;
- trajectories of other vehicles involved in the task.

The developed algorithms were tested during a research in which the task was to search the Szczecin harbor by a team consisting of five autonomous underwater vehicles. In the first test, it was assumed that none of the vehicles failed during the task. Table 1 summarizes the data that numerically characterizes the water region and the performed task. Figure 4 presents the route of passage of each underwater vehicle in the test No. 1, on the background of the electronic water map.

Table 1.
Convolution results of discrete functions x(n) and ψ(n) for different N.

Port area [m2]:	405,296.7	The number of vehicles in the team [pcs.]:		5
The length of the shoreline [m]:	6,228.2	Vehicle no. 1:	the length of the route [m]:	4,653.9
			execution time [min]:	38.8
The depth of the harbor [m]:	13.0	Vehicle no. 2:	the length of the route [m]:	4,725.3
			execution time [min]:	39.4
Distance from the bottom when performing the task [m]:	9.0	Vehicle no. 3:	the length of the route [m]:	4,576.9
			execution time [min]:	38.2
Width of the observation [m]:	38.6	Vehicle no. 4:	the length of the route [m]:	4,639.8
			execution time [min]:	38.7
Distance between the survey lines [m]:	36.7	Vehicle no. 5:	the length of the route [m]:	4,531.6
			execution time [min]:	37.8
The course of the survey lines:	61°			
The total length of the route [m]:	15,503.9			
The total time of completing the task by a single vehicle [min]:	129.2			

As a result of this test, the vehicle team should complete the search task after 39.4 min., which is a shorter time by about 1/3 compared to the time necessary for a single vehicle to perform this task.

In the second test, it was assumed that the underwater vehicle No. 2 had failed after passing 1,975 m of the route assigned to it. According to the adopted solutions, other vehicles undertook negotiations to determine which of the vehicles,

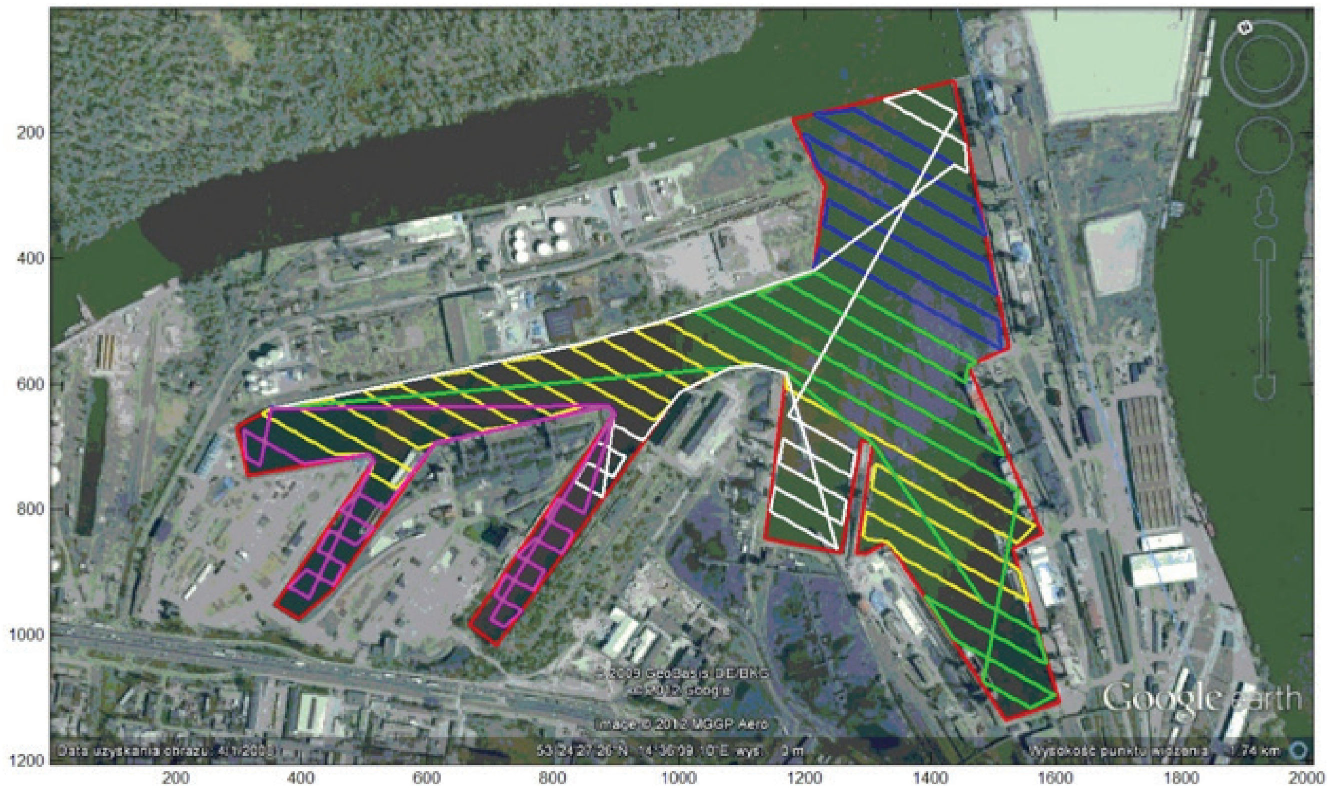

Figure 4.
Routes of passage realized by each of the underwater vehicles forming a team of vehicles performing the task of searching the Szczecin harbor. Assignment of the color line to each vehicle: yellow line – vehicle No. 1, green line – vehicle No. 2, blue line – vehicle No. 3, white line – vehicle No. 4, magenta line – vehicle No. 5.

possibly a vehicle coalition, would complete the task for vehicle No. 2. As a result of the negotiations, the vehicles reported the costs of the substitute task and determined the profits from individual coalitions as well as the basis on which the solution was chosen. The optimal solution should ensure the highest profit and the lowest costs. In the proposed solution, it was assumed that the priority was to minimize the time to perform the task of searching the given water region. Accordingly, the cost will be the route that the vehicle undertaking the substitute task has to travel (the sum of the route to reach the starting point of substitute task and the route of performing the substitute task). The profit will be the difference between the maximum cost of performing the substitute task by a single vehicle with the longest route of access to the starting point of the substitute task and the reported costs by particular coalitions of vehicles. In the search for an optimal solution, some restrictions were also adopted. Firstly, a coalition that performs a substitute task must be as large as possible. Secondly, the profit to be obtained as a result of the formation of a given coalition is to be at least L times greater than the maximum profit of all coalition partners, where L is the number of coalitions. In addition, each of the coalition members must have an assigned trajectory on which he will perform a search of a length greater than or equal to the two lengths of the route to the starting point of the substitute task. Based on this, it was determined that the most cost-effective solution would be taken over the task for vehicle No. 2 by a coalition of agents consisting of vehicles No. 3 and No. 5. As a result of realizing the substitute task, the routes of vehicles 3 and 5 will be extended respectively to 6,848.4 m and 6,470.4 m. This meant that the entire task would be completed in the time of 54.3 min., i.e. 14.9 min. longer than in the absence of a vehicle No. 2 breakdown.

4. SUMMARY

On the basis of the conducted research, it can be concluded that the use of many cooperating vehicles for the task of searching a given water region has two basic advantages. It allows to significantly reduce the time necessary to complete the task, and also ensures that the mission will finish successfully even in the event of failure of any of the vehicles. However, it should be noted that the time required to complete the task does not decrease in proportion to the number of vehicles used. This effect results from the need to take into account the time needed to reach the area of operation by each vehicle in the team. The research carried out indicates that the use of five vehicles allows to shorten the task execution time just over three times.

In the solution proposed, a single vehicle is treated as an agent in a multi-agent system. A single agent was modeled as a player with Nature, which allowed to describe his actions mathematically. Adoption of the hierarchical structure of the agent's operation enables a practical application of control algorithms, including controlling its behavior as a member of team. Communication between the vehicles working as a team in one water region is a serious problem, which is particularly difficult in underwater conditions. A proper data exchange allows the coordination of vehicles' activities and cooperation at the time of damage to one of the team members. The results of the tests indicate that the adopted solutions related to the control of a single vehicle being a member of the vehicle team are correct and give a satisfactory result in the case of searching tasks. It should be noted here that in the case of a mission of a different nature, it may be necessary to modify the adopted solutions and adapt them to the specific requirements.

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Diffusion of Innovation Assessment of Adoption of the Dry Port Concept

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Dry ports, when implemented effectively, reduce seaport congestion, improve seaport throughput and, due to the movement of containers from road to rail, reduce harmful emissions. This study investigates the implementation of dry ports at five U.S. seaports, which is then analysed considering the diffusion of innovation attributes. Data for the study was collected through face-to-face interviews at US East Coast seaports of Miami, Everglades, Jacksonville, Savannah and Charleston. To ensure validity, the triangulation of data sources was performed; i.e. a number of secondary sources were used, such as reports, internal and external documents, as well as site visits to the facilities. Three components have been recognized as key to the successful dry port concept: on/near-dock rail, reliable inland rail connection and a functional inland intermodal facility. These three components have a diverse group of stakeholders, many of whom are unknown to one another; however, when coordinated, they create the innovation of the dry port concept. If the attributes of successful innovations are understood, with respect to their influence specifically on dry ports, then they can be managed to contribute to the successful implementation of dry ports. The novelty of the research lies in its approach of using the diffusion of innovation attributes that have been historically proven to impact the adoption rates of innovations to provide insight into the adoption of the dry port concept.

KEY WORDS
~ Dry port
~ Seaport
~ Inland access
~ Diffusion of innovation
~ USA

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1. INTRODUCTION

The concept and the reality of dry ports have evolved in the past decade in response to growing global trade and the resultant increased demand for port logistics services. Dry ports have been established to reduce seaport congestion and improve throughput rates (e.g. Roso, 2007; Hanaoka and Regmi; 2011). When used in conjunction with on-dock rail, dry ports also reduce the negative effects on the environment because the containers are moved directly from road to rail, reducing harmful emissions from motor carrier vehicles (Roso, 2007; Henttu and Hilmola, 2011, Khaslavskaya and Roso, 2019).

One contributor to the growing demand for port logistics services in the U.S. is the Panama Canal expansion, which, in June 2016, began allowing vessels as large as 14,000 TEUs to traverse the canal and reach the East Coast of the U.S. directly, bypassing the heretofore heavily used land bridge option of entering the U.S. via LA/Long Beach ports and using rail to reach the densely populated markets of the U.S. East Coast. This creates significant opportunity and challenges for seaports on the U.S. East

Coast, such as the seaports of Miami, Everglades, Jacksonville, Savannah, and Charleston. While larger vessels help carriers to reduce voyage cost, these savings are increasingly outweighed by higher port and landside costs (WCN, 2016a). Ports spend heavily on projects aiming to handle large vessels, with little guarantee of a return on their investments. There is fear that every region will likely see the number of ports reduced to just a few larger transshipment hubs, which will trigger "fantastic" competition between them. The challenge facing these ports is to increase their capacity and improve their inland access via dry ports to meet the new demand.

The term dry port in this study is used to refer to an inland intermodal terminal directly connected to seaport(s) by rail, where customers can leave/pick up their standardized units, as if directly at/from the seaport (Roso et al, 2009). Three components have been recognized as key to the successful dry port concept: (1) on-dock rail, (2) reliable inland connection and (3) a functional inland intermodal facility (Black et al, 2013, Roso et al 2009). These three components, taken together, make-up the innovation of the dry port concept (Roso et al, 2009). The concept has the potential to generate benefits for the ecological environment and the quality of life of residents by shifting freight routes from road to rail (Black et al, 2018; Roso et al, 2009). It mainly offers seaports the possibility to secure a market in the hinterland and increase the throughput without physical port expansion (Black et al, 2018). In this scenario, seaport cities and the seaports themselves benefit from less road congestion and a reduced need for infrastructure investment. Increasing seaport capacity without improving inland access leads to supply chain bottlenecks inland. With a growing demand for containerized freight transportation, efficiency of rail and flexibility of road are increasingly needed for inland access to and from the seaports.

The dry port concept involves an eclectic group of stakeholders, many of whom are unknown to one another. It is a challenge, when adopting the dry port concept, to create understanding and motivation across all stakeholders, regardless of their position in the inland access transport system. However, this challenge must be overcome to achieve the capacity growth and operational efficiency promised by dry ports that operate effectively in conjunction with their partner seaports.

Accordingly, the study investigates the influences on the adoption of dry ports through the lens of diffusion of innovation. The real innovation of the dry port are the three dry port components working together as a single innovation, i.e., (1) on-dock rail, (2) reliable inland connection and (3) a functional inland intermodal facility working in a coordinated fashion as one innovation. If the influences on adoption can be understood, with respect to the three components working together, then the proven diffusion attributes can be managed to improve adoption rates, positively affecting port throughput, congestion and environmental impact.

The research questions in this study are:

- How does the diffusion of innovation attributes affect the adoption of dry ports?
- What are the challenges of diffusion of this dry port innovation?

In pursuit of these research questions, the remainder of this paper includes an explanation of the competitive importance of the dry port concept in Section 2. Section 3 discusses the port attributes of the five U.S. East Coast ports explored in this study: Miami, Everglades, Jacksonville, Savannah and Charleston. Section 4 of this paper explains the research approach and the diffusion of innovation, and presents the influence of diffusion attributes on our dry port concept of study. Section 5 presents our findings, including a theoretical diffusion model of dry ports, which details the specific impact of attributes on the three dry port components: (1) on-dock rail, (2) reliable rail connection and (3) a functional inland intermodal facility. Finally, Section 6 presents the conclusions, including contributions to research and managerial implications.

2. COMPETITIVE IMPORTANCE OF THE DRY PORT CONCEPT

Growth in ocean container freight traffic manifests itself in increased container port traffic volumes and demand for port services that require seaports to expand not only the capacity, but also the functionality of their services. However, due to the constrained supply of land available for seaport expansion, congestion, notably at major container ports, has intensified. With growing container transports, the efficiency of rail and the flexibility of road are increasingly needed for inland access to and from the ports. Competition requires ports to focus on their inland access (Roso et al, 2015; Rodrigue et al, 2010), on the demand for services in their traditional hinterland (Bask et al, 2014, Andersson and Roso, 2016), as well as on the development in areas outside their immediate market (Rodrigue et al, 2010). Many container ports around the world are implementing and developing dry ports, i.e. inland intermodal terminals directly connected to seaport(s) by rail, where customers can leave/pick up their standardized units, as if directly at/from the seaport (Roso et al, 2009). One of the aims of dry port implementation is to improve seaport inland access to increase competitive advantage, terminal capacity and consequently productivity. Such developments have been observed in China (Beresford et al., 2012), Australia and New Zealand (Roso, 2013; Black et al, 2018).), India (Ng and Gujar, 2009), the United States (Rodrigue et al, 2010, Roso et al., 2015), Asia (Hanaoka and Regmi, 2011; Black et al, 2013), Russia (Korovyakovsky and Panova, 2011), and Europe (Flämig and Hesse, 2011; Henttu and Hilmola, 2011; Monios, 2011, Bask et al, 2014, Khaslavskaya and Roso, 2019). To meet the increased demand on the East Coast due to the Panama

Canal expansion, some of the seaports are extending their docks and acquiring new equipment to handle larger vessels. However, increasing capacity only at the seaport entry point, without improvements in inland connections, is insufficient for the proper functioning of the entire container transport chain. Hinterland connections beyond the seaport, where congested roads and inadequate connections cause delays and raise transportation costs, could well be the weakest link in the transportation chain of seaports experiencing this exponential increase in demand. To gain competitive advantage, seaports need to focus on their inland access, on the demand for services in their traditional hinterland, as well as on the development in areas outside their immediate market. One strategic approach to resolving economic and environmental issues is the expansion of intermodal (road and rail) transport through dry ports/inland ports.

Sustainable inland access is a key element in maintaining competitive seaport capacity and operational efficiency levels. Seaports have replaced their earlier narrow focus on cargo handling with a wide range of logistic activities, giving them a more active role of offering door-to-door rather than port-to-port transport solutions (Paixão and Marlow, 2003). This trend has expanded the seaports' hinterland, creating a competition between neighboring seaports. That competition requires the seaports to focus not only on improvements within the seaport area but also on their inland access via functional inland intermodal terminals. Although inland intermodal terminals connected to seaports by rail have emerged around the world, there is no definitive consensus on which term to use; terms such as dry port are being advocated by some researchers (Rodrigue et al, 2010). The term dry port in this study refers to an inland intermodal terminal directly connected to seaport(s) by rail, where customers can leave/pick up their standardized units, as if directly at/from the seaport (Roso et al, 2009). Dry ports act as seaports' inland interface, offering services such as transshipment, value-added services such as storage, consolidation, depot, track and trace, container maintenance, and customs clearance that are usually available at seaports (Roso et al, 2009). As such, the concept emphasizes a higher level of integration with seaports. Port related transport processes along the transport chain should be seamless and the idea behind the dry port concept is to facilitate smooth transport flow (Roso and Rosa, 2012). In other words, the flow should not stop in the nodes; all node activities should be part of a seamless transport flow.

According to Roso (2013), dry port implementation brings competitive advantage to the seaport since it might expand the seaport's hinterland by improving the seaport's access to areas outside its traditional hinterland. Dry port implementation is not the only factor in relieving seaport congestion (Henttu and Hilmola, 2011) or improving seaport inland access (Hanaoka and Regmi, 2011); however, it is a significant component when it comes to improving seaport productivity. Dry port implementation should decrease CO_2 emissions since rail service maximizes tonnage moved per gallon of fuel for shippers, helping them save costs and lower their environmental impact (Henttu and Hilmola, 2011; Roso, 2013), congestion at seaport terminals and seaport city roads should be avoided, and the risk of road accidents reduced (Roso et al, 2009). Apart from the general benefits of the shift from road to rail for the environment, inland ports offer seaports the possibility to increase their throughput without physical expansion at the seaport site (Roso et al, 2009). Furthermore, market-driven Outside-In development of inland intermodal terminals that generates higher level of integration with the seaports (Wilmsmeier et al, 2011) has been seen as very successful and very likely contributes to the viability of rail at short distances (Roso, 2013). The concept of the dry port has gained a lot of attention from researchers around the world who have studied the phenomenon from different perspectives. Many have identified success factors for dry ports for their specific cases. Black et al's (2013) study on dry port implementation in Asia summarizes the factors that influence dry ports' implementation and operations and, consequently, their success. However, as a part of intermodal transport solutions the dry port concept has issues with multiple transshipments that might increase costs, reliability and speed (Wiegmans et al, 2007).

3. PORT ATTRIBUTES

To inform our understanding of seaports, dry port activities and their level of implementation, data were collected from five U.S. East Coast Ports: Miami, Everglades, Jacksonville, Savannah and Charleston. These seaports have been chosen geographically, i.e. all five are situated very close to each other on the East Coast and all handle containers, approximately 1 million TEU or more in 2017. Face-to-face semi-structured interviews with seaport managers were conducted since this type of interview allows the interviewees to introduce new issues and the interviewer to follow up on topics more fully (Stuart et al, 2002). The interviewees were given a list of topics and discussion questions in advance. Triangulation with multiple means of data collection was used to ensure validity (Stuart et al. 2002). In addition to face-to-face interviews and site visits at seaports' terminals, secondary data were obtained from companies' websites, internal company reports, newspaper articles and presentations. Some additional e-mail correspondence was also conducted to clarify and fill the gaps in the data, as well as to validate the findings from the interviews.

3.1. Port of Miami

The Port of Miami is the US container port closest to the Panama Canal. In the year 2017 it handled 1,024,335 TEU, with imports mostly from Latin America and the Caribbean (Port

Miami, 2018). The landlord port leases 520 acres to cargo terminal operators: Seaboard Marine, POMTOC and SFCT (ibid). The port handles a wide range of cargo, such as waste, machinery, textiles, apparel, furniture and fruit/vegetables. The port is a point of entry/departure for cargo and relies on its connections with other intermodal facilities, such as the Miami International Airport (MIA), the Florida East Coast Hialeah Intermodal Facility, and the West Dade trade-related, freight forwarding and consolidation warehouses (Port Miami, 2018). At the port, landside access has been improved by the Port of Miami Tunnel that feeds truck traffic directly into the major interstate highway; and the Intermodal and Rail Service reconnection project - the port has on-dock rail (9,000 ft. of tracks on 3 sidings) which links the container terminals to the national rail system that connects the port to 70 % of the U.S. population in four days or less (Port Miami, 2016). However, only 10-12 % of total container volumes are transported by rail to/from the port. Additional dredging has deepened the port to 50 feet to prepare for Panama Canal opening, but despite the massive dredge project that was completed in 2015, some areas of the port are still not wide enough to accommodate 14000 TEU vessels, with even vessels of 11,000TEUs struggling (Miami Herald, 2018).

3.2. Port of Everglades

The port leases its 500 acres of land area to various private entities providing cargo and cruise services. In 2014, the Port of Everglades broke the one million TEU mark, ranking as one of the leading container ports in the United States and the top port in Florida, serving more than 150 ports and 70 countries (Port Everglades, 2015). The port handled 1,076,912 TEUs in 2017 and kept its position as the first container port in Florida (Port Everglades, 2018). The port is conveniently located just across the international airport that brings additional cargo and cruise passengers, but also limits the stacking of containers for safety reasons. Dredging at Port Everglades has upgraded the channel, turning basin, and berthing while near-dock intermodal container transfer and highway and rail access have improved connectivity. The port has 12 container terminal operators handling fruit, vegetables, automobiles and apparel, mostly to and from Central America, the Caribbean, South America, Europe and even the Far East. Exports and imports are rather balanced, roughly 40 and 60 percent respectively. Florida East Coast Railroad (FEC) has a 42.5-acre near-dock intermodal container transfer facility that transfers international and domestic containers between ships and rail (Port Everglades, 2015), which currently accounts for approx. 10-15 % of the total container volumes handled. The Intermodal Container Transfer Facility (ICTF) should reduce congestion on interstate highways and local roadways and reduce air emissions by diverting an estimated 180,000 trucks from the roads by the year 2027 (ibid).

3.3. Port of Jacksonville

The port is a landlord port handling 1 million TEU on a 1,500 acre site, offering worldwide direct cargo service, as well as cruise services in 2017. The port terminals are serviced by three U.S. interstates and the city has 36 daily trains via three railroads: CSX, Norfolk Southern, and Florida East Coast Railway. The port has an equal number of imports and exports, and is the number 1 US port for Puerto Rico (JAXPORT, 2017). There are three cargo/container terminals that handle every type of general and project cargo: Blount Island Marine Terminal, Dames Point Marine Terminal and Talleyrand Terminal. The terminals have near-dock and on-dock rail, however, the on-dock one is not in use due to operational space shortages. The port has an internationally ranked Foreign Trade Zone (No. 64) that streamlines custom clearance (JAXPORT, 2017).

Although the channel is not deep enough to accommodate fully loaded large vessels, it is the widest shipping channel in the Southeast U.S., wide enough for two ships to pass at the same time. Therefore, the port is heavily investing in channel deepening, as well as in port-related infrastructure, such as rail access. The new ICTF at Dames Point serves the port's Northside terminals and offers the direct transfer of containers between vessels and trains that speeds up the transshipment process and reduces the number of trucks on the roads. Ceres Rail Services will be responsible for managing the day-to-day operations and maintenance of the facility. Rail that connects to CSX's main line allows for two unit trains each day (one inbound and one outbound), carrying up to 200 containers each. Trucks transport containers to and from the adjacent shipping terminals (JAXPORT, 2017).

3.4. Port of Savannah

The port is owned and operated by the Georgia Ports Authority (GPA), which allows for operational flexibility and is, according to the port, the underlying reason for its success. The port has 2 cargo terminals: Garden City Terminal for containers and Ocean Terminal for heavy lift and RoRo. GPA handled a record 4 million TEUs with a rather balanced mix of export and import container traffic. In addition, intermodal rail lift surged to 435,000, which is a 16.1 % increase (GPA, 2018).

The Cordele Inland Port (CIP) start-up was a joint collaboration between government, port and the terminal/rail operator, as a part of a bigger development plan to develop inland terminals throughout the State. The port provides commercial, not financial support. CIP through Cordele Intermodal Services offers a direct 200-mile rail route to the Georgia Ports Authority's Garden City Terminal and expands international markets for regional business. Although no customs clearance or value added services are available at CIP, it offers an efficient option to an all road drayage to the port of Savannah for their markets in southwest Georgia, southern Alabama, and western Florida. The success of CIP encouraged another project. The Appalachian Regional Port is a joint effort of the State of Georgia, Murray County, CSX and the Georgia Ports Authority. This inland port should provide a powerful new gateway to the Port of Savannah; it is estimated to take 50,000 trucks off Georgia highways, improve container availability and reduce transportation costs for port customers in Georgia, Alabama, Tennessee and Kentucky (GPA, 2018).

3.5. Port of Charleston

Publicly owned and operated, the Port of Charleston, South Carolina, handled a record-setting 2.14 million TEUs in 2017 on its two container cargo terminals (SCP, 2018). The Wando Welch Terminal (WWT) has received worldwide recognition for its innovative design. At present, it is the Port's largest terminal in terms of volume and physical size and frequently accommodates Post-Panamax and Suez-class container vessels. The North Charleston Terminal (NCT) is a modern container handling facility, complete with post-Panamax container cranes, an on-terminal container freight station, and an on-terminal rail yard. In addition to Wando and North Charleston, the Port is constructing a third container terminal (the Hugh K. Leatherman, Senior Terminal) to open in 2021. Columbus Street Terminal (CST) is Charleston's premier combination breakbulk and container terminal. The Port operates a cruise terminal, the Union Pier Terminal, and has an additional bulk/breakbulk terminal, Veteran's Terminal. The Port offers near-dock rail access, coordinates the drayage of containers between its terminals and the two local class-one railroads through a program called RapidRail. Nearly 25 % of the total volumes are moved by rail and the port has daily express intermodal rail services through the CSX and Norfolk Southern systems.

Inland Port Greer (IPG) opened in October 2013, extending the Port of Charleston's inland access by 212 miles to Greer, S.C (WCN, 2013). IPG is owned by the South Carolina Ports Authority (SCPA) and double-stack rail service is provided exclusively by Norfolk Southern, providing shippers with access to more than 95 million consumers within a one-day drive. It acts like a free-trade zone and handles approx. 270,000 TEU. SCPA bought the land in Greer in the 1980s and started to lease the facility to BMW in early 1990s, which established a warehouse there. Since then, the port has the exclusive right to handle their containers. Other customers like Adidas and Michelin also use the facility, however, all customs clearance and inspections are done at the seaport. The inland port has an additional benefit since it gives regional shippers access to empty containers, allowing them to send trucks to Greer to pick up the containers they need to move their goods. The success of this inland port encouraged the port to build a second inland intermodal facility at Dillon, however, there was also demand for the enhanced efficiency of international container movements between the Port of Charleston and the growing markets in South and North Carolina (WCN, 2016b)." Inland Port Dillon will open in April 2018.

4. DIFFUSION OF INNOVATION FRAMEWORK AND OBSERVATIONS

The innovation to be studied is the dry port concept with its three critical components operating as one innovation, i.e., (1) on-dock rail, (2) reliable inland connection and (3) a functional intermodal inland facility, operating in coordination with one another, creating the dry port innovation.

With a growing demand for containerized freight transportation, efficient seaport inland access via dry ports is increasingly a necessity. If the attributes of successful innovations are understood, with respect to their influence specifically on dry ports, they can be managed to contribute to the successful implementation of dry ports. The novelty of the research lies in its approach of using the diffusion of innovation attributes, that have been historically proven to impact the adoption rates of innovations, to provide insight into the adoption of the dry port concept. To interpret the information gathered, this paper takes the diffusion of innovation approach to understanding the key influences on the adoption of dry port processes, particularly the processes involved in establishing trifecta of on-dock rail, reliable rail connection and a functional inland intermodal facility. The diffusion of innovation approach has already been successfully used in the supply chain context (Russell and Hoag, 2004) and provides a useful lens for assessing the innovation of the dry port concept. The elements of the diffusion of innovation model used to assess the dry port adoption issue are: (1) relative advantage, (2) trialability, (3) observability, (4) communication channels, (5) homophilious groups, (6) pace of innovation/ reinvention, (7) norm, roles and social networks, (8) opinion leaders, (9) compatibility, and (10) infrastructure. Below is a general description of each element, followed by an explanation of how the element informs our understanding of the adoption of dry ports.

The positive or negative impacts of the factors on the adoption of the inland port innovation are considered, based on literature and interviews, from the perspective of the stakeholders involved in the implementation of this innovation.

4.1. Relative Advantage

Relative advantage is the degree to which an innovation is perceived as better than the idea it supersedes. The degree of relative advantage may be measured in economic terms, but social-prestige factors, convenience, and satisfaction are also often important components. Whether an innovation has a great deal of "objective" advantage is less important. What does matter is whether an individual perceives the innovation as advantageous. The greater the perceived relative advantage of an innovation, the more rapid its rate of adoption is going to be (Rogers, 2003). Therefore it represents a comparison between the perceived transaction cost of innovation adoption and the perceived benefit of adoption. The higher this relative advantage is, the faster the adoption diffuses.

In the case of dry ports, there appears to be a high perceived relative advantage with respect to on-dock rail and a reliable rail connection. However, it is not clear whether all individuals at the studied seaports consider the functional inland facility as key to obtaining the relative advantage of dry ports might offer. The benefits for regional development are clear in the case of CIP which is located in a regional center for agriculture; including production and export of cotton, peanuts, and wood products; which makes those commodities more competitive on the global market, while reducing environmental impact. The inland port concept benefits truckers as well, allowing them to haul more loads over shorter distances, as in the case of CIP for the port of Savannah.

4.2. Trialability

Trialability is the degree to which an innovation may be experimented with on a limited basis. An innovation that is trialable is less uncertain for the individual who is considering it for adoption, since it allows learning through doing (Rogers, 2003).

Trialability in the dry port concept is limited because dry ports are a high cost, large infrastructure capital investment. While ports might run pilots on each of the individual initiatives, i.e., on-dock rail, reliable rail connection and functional inland facility, the financial and human resources required to pilot all three are prohibitive. Functional inland facilities are the most straightforward to pilot as many facilities exist. However, a functional inland facility, connected directly to a seaport by rail, is much more capital intensive to pilot. Even so, both the Ports of Savannah and Charleston encouraged by the success of their inland ports, IPG and CIP, have started or encouraged other stakeholders to undertake their second inland port developments in other regions of interest; i.e. they created trialability for expansion. On the other hand, the Ports of Jacksonville, Miami and Everglades view dry ports as too costly to fail and lacking any directly observable success, i.e., trialability, they hesitate to begin implementation.

4.3. Observability

Observability is the degree to which the results of an innovation are visible to others. The easier it is for individuals to see the results of an innovation, the more likely they are to adopt it. Such visibility stimulates peer discussion of a new idea, as friends and neighbours of an adopter seek innovation-evaluation information (Rogers, 2003).

There is growing opportunity for observability in inland access development due to the growing number of ports seeking the perceived relative advantage of improved inland access. This is closely related to the trialability and cases of Savannah and Charleston ports, which already have experience with their first inland ports, and owing to their success, are planning for second inland ports. The problem with observability is that on-dock rail and reliable rail connections are not easily observable because infrastructure is generally vast on a given continent. For example, on-dock rail at the Los Angeles Long Beach port is not easily observable by a Gulf Coast or East Coast port. The results of an on-dock rail can be observed by establishing the performance metrics after dry port improvements, but there is generally an extended time lapse before this type of information reaches the public. Consequently, while dry ports might be successful in one region, this innovative concept is slow to diffuse to other regions due to lack of observability. The functional inland facility is more observable because there are many functional inland facilities across the nation. Again, we see that although the individual components of the dry port concept are observable, all three components together are not.

4.4. Communication Channels

Diffusion is a particular type of communication in which message content exchanged is concerned with a new idea. The essence of the diffusion process is the information exchange through which one individual communicates a new idea to one or several others. At its most elementary, the process involves: (1) an innovation, (2) an individual or other unit of adoption that has knowledge of the innovation or experience with using it, (3) another individual or other unit that does not have knowledge of the innovation, and (4) a communication channel connecting the two units. The conditions under which a source will or will not transmit the innovation to the receiver, and the effect of the transfer depend on the nature of the information exchange relationship between that pair of individuals (Rogers, 2003). Mass media channels are often the most rapid and efficient means of informing an audience of potential adopters about the existence of an innovation, i.e. of creating awareness-knowledge – radio, television, newspapers, internet, social media. Interpersonal channels are more effective in persuading an individual to accept a new idea, especially if the interpersonal channel links two or more individuals who are similar in socioeconomic status, education, or other important ways – face-to-face exchange between two or more individuals (Rogers, 2003). Diffusion investigations show that most individuals do not evaluate an innovation on the basis of scientific studies of their consequences, although such objective evaluations are not entirely irrelevant, especially to the very first individuals who adopt. Instead, most people mainly depend on the subjective evaluation of an innovation conveyed to them by other individuals like themselves, who have previously adopted the innovation. This dependence on the experience of near peers suggests that the heart of the diffusion process consists of the modelling and imitation of network partners who have previously adopted (Rogers, 2003).

Communication channels are a missed opportunity for dry ports. In the current state of the port industry and particularly the dry port industry, there is limited communication about the three components among stakeholders. The lack of information transfer and collaborative decision-making contribute to the lack of diffusion of the dry port innovation. The port, the reliable rail connection and the functional inland facility all typically have separate information systems, separate means of sharing information with their suppliers and customers, and separate approaches to informing the media of their activities and performance. Without communication, it is difficult for others in the industry to understand the new innovation of the trifecta of the dry port concept.

4.5. Homophilious Groups

Homophilious Groups refers to homophily, i.e. the degree to which pairs of interacting individuals have certain attributes in common, such as beliefs, education, social status, and the like. In a free-choice situation, when an individual can interact with any one of a number of other individuals, there is a strong tendency for him to select someone who is most like him- or herself (Rogers, 2003).

Because the stakeholders involved in on-dock rail and reliable inland connections are a small network and geographically dispersed, the homophily or interaction with individuals with similar attributes is limited. There tends to be a larger network of stakeholders running functional inland facilities. However, as with several other influencers of innovation diffusion, the network of stakeholders who deal with all three components of the dry port concept is limited.

4.6. Pace of Innovation/Reinvention

The time dimension is relevant for diffusion: (1) in the innovation-decision process where an individual goes from first knowledge of an innovation to its adoption or rejection, (2) in the innovativeness of an individual or other unit of adoption compared with other system members, and (3) in an innovation's rate of adoption in a system, usually measured as the number of system members who adopt the innovation in a given time period (Rogers, 2003).

The pace of innovation in the trifecta of dry port components is hindered by the immense capital investment, required surface infrastructure improvements and the various agreements between stakeholders required for implementation. Probably the most difficult of these are the agreements between stakeholders, since different stakeholders have different business agendas. For example, the on-dock rail system stakeholders are looking to improve on-dock efficiency and throughput, but are not necessarily interested in the efficiency of the inland rail connection or the inland facility. Without incentive to ensure efficiency beyond the dock, stakeholders in the on-dock rail system can knowingly or unknowingly slow the pace of innovation due to the lack of coordination with the other dry port components.

4.7. Norms, Roles & Social Networks

A social system is defined as a set of interrelated units that are engaged in joint problem-solving to accomplish a common goal. Each unit in a social system is distinguishable from other units. All members cooperate at least to the extent of seeking to solve a common problem in order to reach a mutual goal. The sharing of a common objective binds the system together (Rogers, 2003).

Cooperation within the social system and the recognition of the common goal are imperative for the success of the dry port concept. Historically, each component operates in its own silo, passing off freight from one to another. However, the dry port concept requires that these components of on-dock rail, reliable inland connection and functional inland facility view themselves as one flow-through system, coordinating the many logistics activities, including scheduling, routing, security, loading, unloading and many other logistics activities.

4.8. Opinion Leaders

Opinion leadership is the degree to which an individual is able to influence other individuals' attitudes or overt behaviour informally in a desired way with relative frequency. It is a type of informal leadership, rather than a function of the individual's formal position or status in the system. Opinion leadership is earned and maintained by an individual's technical competence, social accessibility, and conformity to the system's norms (Rogers, 2003).

As the dry port concept gains momentum, opinion leaders, like those identified in the U.S. East Coast ports studies, will continue to emerge. As leaders gain traction and spread their influence in the industry, adoption is likely to be positively influenced. Of the three key components of dry ports, opinion leaders wield the most influence in the functional inland facility component, primarily because this is a mature industry. Since on-dock rail and reliable inland connection are much more recent concepts, it will take time for opinion leaders to emerge.

4.9. Compatibility

Compatibility is the degree to which an innovation is perceived as being consistent with the existing values, past experiences, and needs of potential adopters. An idea that is not compatible with the prevalent values and norms of a social system will not be adopted as rapidly as an innovation that is. The adoption of an incompatible innovation often requires the prior adoption of a new value system (Rogers 2003).

An innovation that is compatible with the existing values or needs of the systems should be rapidly adopted. Since two of the studied ports experience good compatibility of the dry port concept, future inland development plans are expected to be realized faster.

4.10. Infrastructure

Innovation adoption often depends on the presence or absence of some sort of infrastructure. Infrastructures can be hard, such as buildings, or soft like information systems. They enable spatial and temporal innovation diffusion (Rogers 2003).

Port of Jacksonville welcomed a 10100 TEU vessel, the largest containership to ever visit a Florida port, at the TraPac Container Terminal at Dames Point in the summer of 2017. The vessel transited the Suez Canal from Asia before reaching the U.S. East Coast, but not at full capacity due to the 40-foot depth of the channel at port entrance.

Three of the five studied ports have the status of "landlord ports", which was the main reason behind, e.g. Mitsui O.S.K Lines' investment in the Port of Jacksonville's TraPac Dames Point facility - the largest privately owned and operated terminal on the East Coast (TGC, 2017). Landlord ports are able to turn to local, state and/or federal government to deepen channels to make way for increasingly larger shipping vessels calling at ports, which is a huge advantage over operating ports. However, the successes of operating ports like Savannah and Charleston, are largely the result of embracing a vertically integrated structure - from maritime into inland distribution services, which might result in port regionalization as explained by Notteboom (2006). Furthermore, the model of directional development of intermodal inland ports/dry ports is closely related to the port-operation model, with the Outside–in model more often encountered in operating than landlord ports (Roso, 2013).

The main success factor, given the multiplicity of the agents involved, is to discuss operational agreements within a market-driven development framework in advance. The preconditions are the coordination among various government agencies and the willingness of actors of the transport system to cooperate. And, there must be a railway connecting the seaport with the hinterland to allow container transfer from road to rail.

5. ANALYSIS AND DISCUSSION

Functional inland access to seaports is an important decision-making factor of seaport development strategies. It is also a significant factor that affects shipping companies' port choice. A seaport's natural or immediate hinterland is no longer defined by geographical distance alone, but by competition with other seaports as well, i.e. by the quality of the service at seaport terminals, as well as at their inland facilities (Roso, 2013). In other words, for many seaports, the battle for the sea is won inland via dry ports. The main features of the studied seaports are summarized in Table 1which shows that operating ports handle two to four times more volume than landlord ports in any given year. We also observed that there are three components of the innovation trifecta present in the operating port business model. While the landlord ports show some elements of the key components of the dry port innovation, we came to the conclusion that landlord ports are not motivated by the same business goals as operating ports. This could be why landlord ports are slower at developing the infrastructure required for successful dry ports and why landlord ports experience the resultant low container volumes. Operating ports are driven by goals like growth and profit, which compel them to develop infrastructure that will provide ample capacity for increasing container volumes. Landlord ports, on the other hand, are driven by land usage; they appear to lack a common goal with all involved terminal operators, leaving the business goals of growth and profit to be achieved by the individual terminal operators.

In our assessment, dry port innovation is diffusing faster in the operating ports because both the seaport and the dry port are focused on the same goal. In the case of dry ports, there appears to be a high perceived relative advantage with respect to on-dock rail and a reliable rail connection.

The challenge of perceiving and ultimately adopting and utilizing the dry port concept is what makes the diffusion of innovation a useful assessment method. The diffusion of innovation helps us to theoretically understand what drives the adoption of new ideas, processes and products across many industries. Identifying areas that are working well and areas that need to be improved to achieve adoption and reap the benefits of innovations would be useful. The coordination trifecta requirement is what makes influencing the adoption of the dry port concept so difficult, while simultaneously making it a new and innovative approach to managing the growing volumes at seaports. The growth and changing needs of customers can not be successfully handled using old thinking and old processes. The problem must be seen in a new light, and solved accordingly.

In accordance with our first research question, the attributes of innovation diffusion having an impact on dry ports are illustrated in Figure 5.1 and fall into three categories:

Table 1.
Summary of the studied seaports' attributes.

Attributes	Miami	Everglades	Jacksonville	Savannah	Charleston
Landlord/operating	Landlord	Landlord	Landlord	Operating	Operating
On-dock rail	Yes	Near-dock	Yes*	Yes	Near-dock
Reliable rail connection	Yes	Yes	No	Yes	Yes
Functional inland facility	No	No	No	Yes	Yes
Volumes handled	≈1mil	≈1mil	≈1mil	4 mil	≈2mil

*available but not in use

stakeholder perceptions, information transfer and challenge to secure facilities. Figure 5.1 shows a theoretical model of the innovation diffusion assessment of the dry port concept. Given the coordination required across infrastructure and organizations to achieve the full dry port concept, individual stakeholders need a mechanism for understanding relative advantage, and experiencing trialability and observability. The information transfer attributes focus on the timing, organization, quality and actors involved in the non-linear communication that must occur to support dry ports. These information transfer attributes include communication channels; norms, roles and social networks; homophilius groups and opinion leaders. The third group provides facilities and includes infrastructure and the pace of innovation/reinvention as it relates to establishing sustainable inland access at seaports, including three crucial components of the dry port concept: (1) on-dock rail, (2) reliable inland connection and (3) a functional inland facility. Each of these components has an eclectic group of stakeholders, many of whom are unknown to one another. The challenge is to create understanding between and motivate all stakeholders, regardless of their position in the inland access system, to realize the relative advantage of the full system i.e. the dry port concept.

As for our second research question, one of the key findings is that communication channels present a challenge across all stakeholders required for the successful adoption and utilization of dry ports. Another key finding is that on-dock rail is a challenge in all information transfer areas: communication channels; norms, roles and social networks; homophilius groups and opinion leaders. According to Wiegmans et al (2007) the costs of innovations related to transshipments in the rail sector are perceived as high, which might be one of the barriers to the successful adoption of the dry port concept since the rail, and inevitable transshipments, are its key components and as such influence relative advantage which is usually measured in economic terms.

These are impactful findings because they allow us to identify areas of focus to facilitate adoption, based on the time tested diffusion of the innovation lens.

Information transfer is another category of adoption attributes that has an impact on the adoption of the dry port concept. In this category, communication channels are a dominant attribute influencing adoption because there are numerous and varied stakeholders across the on-dock rail, inland rail connection and inland facility.

The challenge of ensuring facilities is the third category in our theoretical model shown in Figure 1. This is currently not a significant barrier.

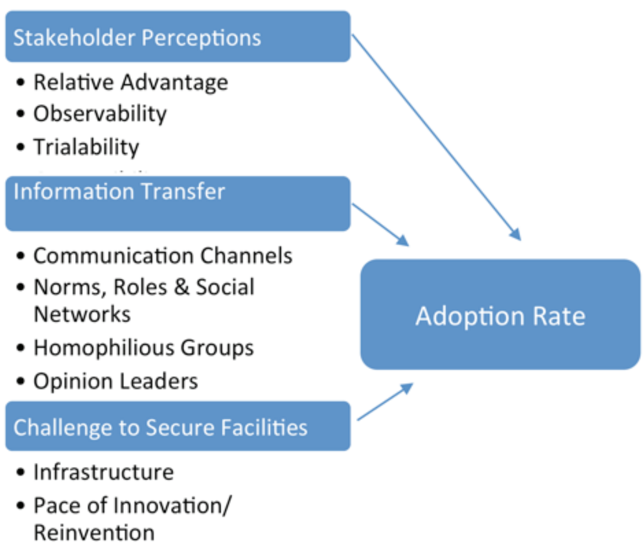

Figure 1.
Theoretical Model of Diffusion of Innovation for the Dry Ports Concept.

6. CONCLUSIONS

This research contributes to the knowledge about dry ports by demonstrating that the successful implementation of the dry port concept depends on the coordinated adoption of three key components: (1) on-dock rail, (2) reliable inland rail connection, and (2) functional inland facility. It provides a fresh perspective and compels researchers to look for a new lens through which to view this trifecta of components that make-up the dry port concept. Our assessment, using the time tested diffusion of innovation approach, reveals that one of the key challenge areas in the diffusion of the dry port concept is information transfer among stakeholders. This is understandable and can be managed once understood. For example, understanding that there are no well developed and utilized communication channels, and that this attribute is key to success, can motivate disparate stakeholder groups to develop and use effective communication channels. These communication channels can complement the formation of homophilious groups where similar beliefs and education can be a cohesive factor helping achieve coordinated operations and successful implementation of the dry port concept.

Further research insights were gained in the area of stakeholder perceptions, revealing that the relative advantage of the dry port concept is not clear to key stakeholders, thus possibly inhibiting adoption.

Infrastructure, on the other hand, is clearly an area where the dry port concept demonstrates the attributes for successful implementation with advanced infrastructure available in the key component areas. A look through the innovation diffusion lens also makes clear that, infrastructure or not, if stakeholders cannot see the value, or relative advantage, and do not choose to communicate effectively across organizations, infrastructure will not be used to reap the benefits of the dry port concept. Furthermore, it was observed that the dry port innovation diffuses faster in operating ports because both the seaport and the dry port are focused on the same goal.

From the managerial perspective, this paper offers managers initiatives on which to focus to improve their success in the adoption of the dry port concept. In particular, it reveals that although technological communication tools required for the diffusion of the dry port concept abound, it will take business processes that foster an environment of defined communication channels, communication as a culture, and a network of industry professionals choosing to share information across stakeholders and industry boundaries to insure that the concept takes root and grows.

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An earlier version of this paper based only on three cases has been presented at NOFOMA 2018 conference, and new shorter version of the paper based on five cases has been submitted and accepted for presentation at IMSC 2019 conference.

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Waiting for Breakthrough in Conventional Submarine's Prime Movers

Tomasz Lus

Submarines, as a very expensive and sophisticated type of weaponry, are being intensively exploited by the armed forces of many countries. This means that submarines are sent ever longer patrols, sometimes to distant regions. To meet such requirements, submarine sub-systems and components must have high reliability and operational readiness indicators. Among the many machines and devices found on submarines, the ones that generate, store, and consume energy (mainly electricity) deserve special attention. The largest energy consumers on the submarine are the components of its propulsion system. One of the most complicated and loaded devices on board submarine is a power generator with a diesel engine driving it, on whose continuous and reliable work the safe performance of tasks depends. According to statistical research, despite its importance for the process of performing tasks by submarines, diesel engines are still the least reliable devices on submarines. Despite the constant technological development of piston engines, their work in very difficult conditions under heavy load and at high counter-pressure at the exhaust outlet promotes their malfunction and damage. From this point of view, the development of charge air systems for submarine diesel engines based on the construction experience of MTU Company is described in the paper. The classification of submarines, their propulsion systems, and the working conditions of engines on submarines are presented in the paper. Air-Independent Propulsion (AIP) systems with their applications on chosen submarines are also described. The most significant change in submarine propulsion system observed in 2018, transition from lead-acid to lithium-ion batteries, is also presented.

KEY WORDS
~ Submarine
~ Prime mover
~ Diesel engine
~ Battery & air independent propulsion

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1. INTRODUCTION

Submarines are an important element of the naval forces of many countries. They can be classified, among other things, by their displacement, type of weapons carried, and type of propulsion system. Only the richest and largest countries (the USA, Russia, Great Britain, France, China, and India) operate submarines with nuclear propulsion and nuclear weapons. This is due to the very large construction / purchase and operation costs of such ships. Other countries such as Brazil and North Korea also aspire to this group. About 40 smaller and less wealthy countries operate smaller submarines with conventional weapons and propulsion systems.

SSBN submarines are carriers of ballistic missiles, SSGN submarines are equipped with missiles other than ballistic, and SSN submarines are carriers of conventional and nuclear torpedoes and mines. These types of submarines equipped with nuclear propulsion may theoretically, because of the source of energy which is the nuclear reactor, stay under water for a very long time, limited only by the time of nuclear fuel burning, even up to several years. Practically, the length of patrols carried out by SSBN, SSGN, and SSN craft is limited by the physical and psychological strength of the crews and other limitations not related to the propulsion system.

Things are quite different in the case of non-nuclear SSK submarines with conventional propulsion. The time of staying under water of these craft is determined mainly by limitations related to the propulsion system. In particular, the need to recharge batteries requires the craft to emerge or, if the snorkel system is used, the snorkel mast is raised above the water surface. Piston combustion engines driving the generators require large amounts of air to be delivered and exhaust gases removed. Battery charging time depending on the degree of their discharging can range from several dozen minutes to several hours. The period in which a submarine with the conventional drive charges batteries is very unfavorable from the point of view of secret operation - one of the most important features of the submarine. In order to minimize the probability of submarine's detection by the opponent, the aim is to increase the range of submarine's navigation in immersion by expanding the battery systems, increasing their capacity, eventually installing mechanical and electrical energy generating systems for submarines capable of operating without access to atmospheric air - AIP systems.

2. SUBMARINE DIESEL ENGINES

Due to the high concentration of power required and the resistance to intake air pressure depression, increased backpressure at the exhaust outlet, most modern submarines use high-speed, four-stroke, single-acting, exhaust gas turbocharged diesel engines to charge the battery when on surface or during snorkel. Historically, the four-stroke naturally aspirated medium-speed diesel engines, and then two-stroke diesel engines were used in submarines. The four-stroke naturally aspirated diesel engines which suck the air directly from the submarine engine room compartment through the filters had relatively low power. So, because of the power needed (to charge the submarine's battery and drive the screw propeller at the same time), more powerful two-stroke diesel engines, with Roots displacement blowers driven from the crankshaft of the engine, began to be used. In the meantime, on most of the conventional submarines direct mechanical drive of the propeller has been abandoned. The era of high-speed, four-stroke diesel engines with exhaust gas turbocharging has come.

The presented development of four-stroke submarine diesel engines focused on their charge air system based on MTU's operational experience [13].

2.1. Naturally Aspirated Diesel Engines

In naturally aspirated diesel engines, the pistons create a negative pressure in the air intake system in order to suck air into the combustion chamber (Figure1). Due to high vacuum on the air intake duct and high back pressure at the outlet, the valve opening times must be limited to a short time window (small angular range). The engine power is therefore relatively low, and the specific fuel consumption is high. MTU used this concept in the 12V 493 AZ type engines intended for submarines, which have a power of 455 kW at a rotational speed of 1,500 rpm.

2.2. Diesel Engines with Mechanically Driven Supercharger

In engines with mechanically driven supercharger, additional air mass is supplied to the combustion chambers of the engine (Figure 2). This results in a greater mass of available air for the combustion process, i.e. more fuel can be converted into thermal energy and then into mechanical and electrical energy. Compared to naturally aspirated engines, the efficiency of such

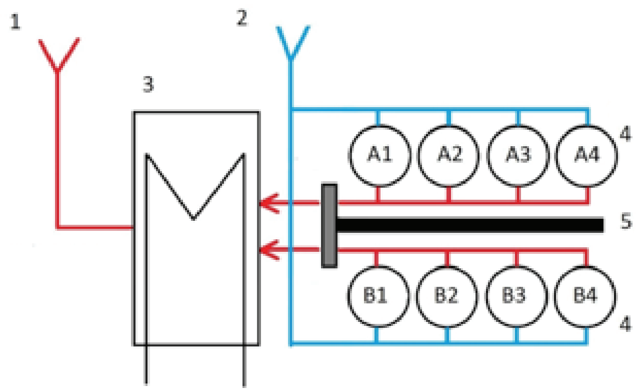

Figure 1.
Air flow diagram in naturally aspirated engine
A1-A4, B1-B4 – cylinders, 1 – exhaust gas outlet,
2 – intake air inlet, 3 – exhaust gas cooler/silencer,
4 – combustion chambers/cylinders,
5 – crankshaft and flywheel.

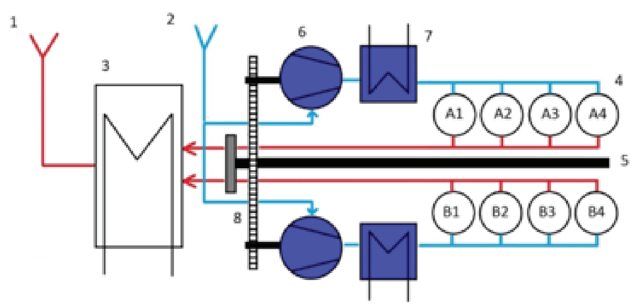

Figure 2.
Air flow diagram in engine with mechanically driven supercharger
A1-A4, B1-B4 – cylinders, 1 – exhaust gas outlet, 2 – intake air inlet, 3 – exhaust gas cooler/silencer, 4 – combustion chambers/cylinders, 5 – crankshaft and flywheel, 6 – intake air compressor, 7 – intake air cooler, 8 – engine gear train.

an engine on nominal loads is greater, but mechanical losses remain the same. Assuming that the compressor power demand is linearly proportional to the engine speed, engine work with a partial load at constant crankshaft speed (required on the submarine), results in a significant deterioration of the specific fuel consumption. Engines with a mechanically driven air compressor (Figure 2) are relatively insensitive to changes in backpressure at the outlet as the compressor is mechanically connected to the crankshaft. For submarines, MTU has implemented such a solution in 16V 652 MB type engines with the power of 1,200 kW at a rotational speed of 1,400 rpm.

2.3. Diesel Engines with Exhaust Gas Turbocharging

As in the case of the mechanically driven supercharger, a compressor supplies additional mass of air to the engine. However, the exhaust gas driven compressor (turbocharger) is mechanically separated from the engine (Figure 3). The power to drive the compressor is therefore not taken from the crankshaft, but is obtained by using the energy contained in the exhaust gases, through a turbine mounted on the same shaft as the compressor. The higher combustion air mass delivered in this way can be used to burn more fuel. By using the energy contained in the exhaust gas to drive the turbocharger, the efficiency of the engine can be increased at the rated power as well as at partial loads. Turbocharged engines were introduced on submarines in the 1980s. The reason for their relatively late implementation on submarines compared to other applications (surface ships since the 1950s) was that engines with standard turbochargers could not work with the required reliability index without special adaptation. This adaptation was required to meet the operating conditions of submarines. Appropriate technical solutions have been developed to ensure the safe operation of engines with the occurrence of intake air pressure depression on the inlet and high backpressure at the engine exhaust. In 1976, MTU started to develop, produce, and test turbochargers specially designed for work on submarines. In comparison to standard turbochargers, these turbochargers have larger compressor rotors and smaller turbine rotors, which increase their field of work. A large compressor rotor is required to ensure a sufficient volume of air flow under reduced pressure at the engine intake. On the outlet gas side, a small turbine rotor is needed due to the high pressure of the water column above the exhaust gas outlet from the engine. The difference in dimensions between the turbocharger for a submarine and the standard turbocharger results from the differences in pressure values at the inlet and outlet of the engine. A wider range of work area is required due to pressure fluctuations caused by sea waves during work on the snorkel and in the surface position. Due to large differences in pressure and continuous engine load changes due to changes in wave height, special attention must be paid to the seals as well as to the turbocharger impeller bearings. The turbocharged engine of MTU family 396, type 16V396 SE84 develops power of 1,200 kW at a rotational speed of 1,800 rpm.

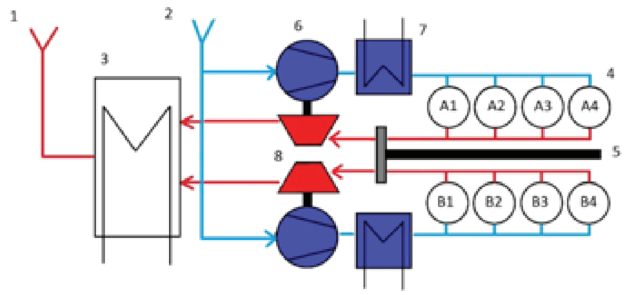

Figure 3.
Air flow diagram with exhaust gas turbocharger
A1-A4, B1-B4 – cylinders, 1 – exhaust gas outlet,
2 – intake air inlet, 3 – exhaust gas cooler/silencer,
4 – combustion chambers/cylinders, 5 – crankshaft and flywheel, 6 – intake air compressor, 7 – intake air cooler,
8 – exhaust gas turbine.

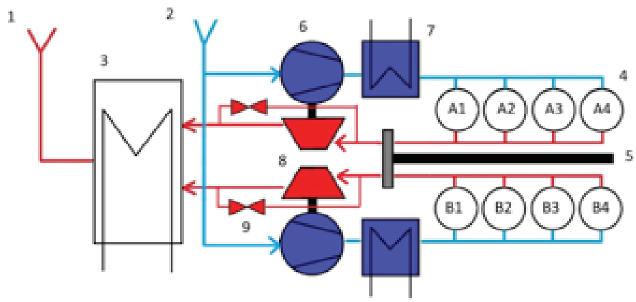

Figure 4.
Air flow diagram with exhaust gas turbocharger and waste gate
A1-A4, B1-B4 – cylinders, 1 – exhaust gas outlet,
2 – intake air inlet, 3 – exhaust gas cooler/silencer,
4 – combustion chambers/cylinders, 5 – crankshaft and flywheel, 6 – intake air compressor, 7 – intake air cooler,
8 – exhaust gas turbine, 9 – exhaust gas bypass/waste gate.

2.4. Diesel Engines with Exhaust Gas Turbocharging and Waste Gate

This charging system alternative (Figure 4) is a further development of the system with turbocharger. It contains valves that open and close the bypass of the turbine depending on the charge air mass, back pressure at the outlet, temperature of the intake air and exhaust gases as well as the rotational speed of the turbocharger. This allows the turbocharger to maintain constant speed regardless of the fluctuations in the intake air pressure depression and exhaust gas backpressure, ensuring constant volumetric flow to the combustion chambers. Thus, the geometry of the turbine can be even better suited to the working conditions with backpressure. The turbocharger performance map can be further optimized in this way depending on the fuel consumption at the rated load as well as at partial loads while maintaining the emission limits. Another advantage of the constant volumetric air flow is the constant value of the maximum combustion pressure, which reduces the stresses of the combustion chamber components that may occur at a variable mass of air flow. This results in longer periods between technical services and lower noise emissions. This solution also provides other benefits regarding operating engine safety, particularly in situations without back pressure at the exhaust (engine operation when submarines surface). This solution of the turbocharger with the waste valve is used in MTU engines Series 4,000 optimized for operation in submarines. Engines of this family, type 12V 4000 U83 develop the power of 1,300 kW at a rotational speed of 1,800 rpm.

3. SUBMARINE AIP SYSTEMS

Different than diesel engines, systems that can generate mechanical (and then/or electrical) energy on submarines without access to atmospheric air have been known since the very beginning of submarines, when stored compressed air was used to move the propeller of the craft. The application of the AIP system at the end of World War II on the German submarine is far better known, with a turbine driven by steam-gas obtained from the reaction of hydrogen peroxide with water, and developed by Walther. After the Second World War, several countries with greater or lesser success conducted research and built submarines with analogous and similar systems of turbines and diesel engines working in semi-closed cycle. The breakthrough in the construction of submarine underwater propulsion systems took place in the 1950s, when the US built the first submarine with nuclear propulsion - USS Nautilus. This drive has made submarine really a submarine, and not what it had been up to that point, i.e. a submersible ship with the need to resurface to charge battery for a definite time. Nuclear drive has caused the largest countries to limit or discontinue development and testing other than nuclear AIP systems for submarines. This idea was sustained in smaller countries such as Sweden, the Netherlands, or Germany. The last decades of the twentieth century were devoted to intensive research on AIP systems such as: a diesel engine working in a semi-closed cycle - Close Cycle Diesel (CCD) engine, external combustion piston engine operating in semi-closed cycle - Stirling engine, turbine working in a closed Rankine cycle driven by steam generated by heat from alcohol combustion in the semi-closed system - DCNS MESMA system, and low-temperature fuel cells - PEM Fuel Cells. Approximate indicators of AIP modules are presented in Table 1.

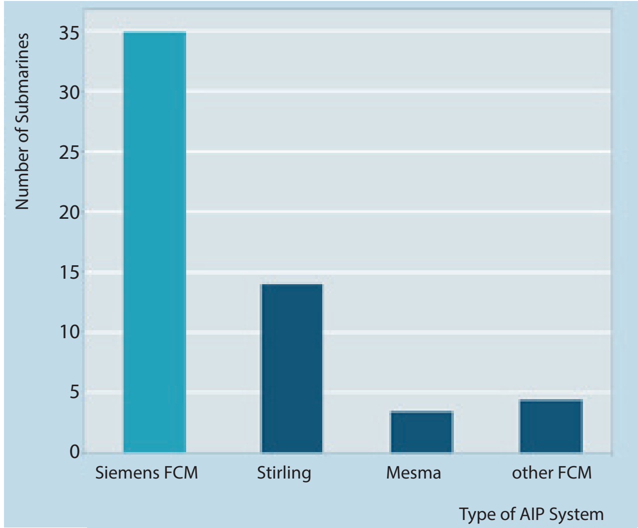

Figure 5.
Comparison of installed /contracted AIP systems (Siemens, 2013).

Table 1.
Approximate indicators of AIP modules.

AIP type/ Ship type	Approx. AIP module Mass [kg]	AIP module Power [kW]	Power to Mass Coefficient [kW/kg]	Approx. AIP Efficiency [%]
PMEFC/ 214	900	120	0.13	60
Stirling/ A19	600	75	0.12	35
MESMA/ Agosta 90B	3000	200	0.06	23

Recently, the most popular types of AIP systems (Fig. 5) installed in combat submarines are: Proton Exchange Membrane Fuel Cells (PEMFC), external combustion piston engines (Stirling engine), and Rankine cycle power turbine (MESMA). CCD AIP systems, although effectively tested (including real submarines) in some countries, so far have not found a practical application on submarines. This is due to their low efficiency and higher acoustic emission than the three other systems mentioned above.

3.1. PEM Fuel Cell AIP System

The first PEMFC AIP systems were installed in four German 212 class submarines in the period from 2005 to 2007. The propulsion plant of the 212 submarine combines a conventional system consisting of a diesel engine and a lead acid battery, with the PEMFC AIP system used for cruising at slow speed. The AIP system consists of seven PEMFCs, providing between 30 and 50 kW each (Fig. 6). The oxidant is liquid oxygen (LOX tank is installed inside the pressure hull), and the fuel is hydrogen, stored in metal hydride cylinders outside the pressure hull (Fig. 6). Another type of German submarines, the type 214, (sold to the South Korean Navy) has a similar AIP system with two modernized Siemens PEMFC modules that produce max. 120 kW each. Thanks to this system, the submarine could spend under water approximately 2 weeks without snorkeling.

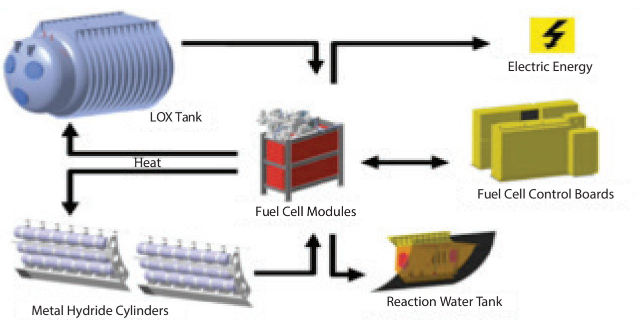

Figure 6.
Overview of Fuel Cell System components (Krummrich, 2010).

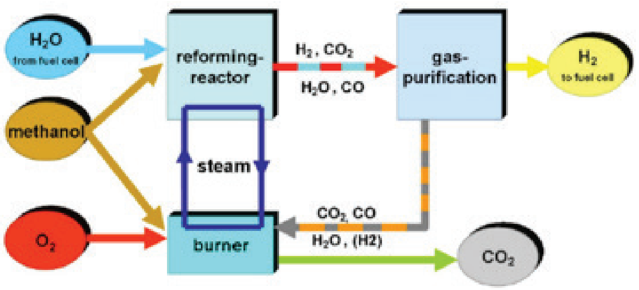

Figure 7.
Overview of Methanol Reformer System (Krummrich, 2010).

In a new submarine AIP system's technology development, the most important are higher amounts of stored fuel (hydrogen) and oxidant. The amount of hydrogen stored onboard is limited by the size of the submarine, especially as the system based on metal hydride storage is relatively heavy (Krummrich, 2010). This prompted the German submarine manufacturer HDW to develop reformer system (Fig. 7) for onboard hydrogen production from methanol. Two other feedstocks (Diesel fuel and ethanol) were also considered, but methanol was chosen because of the highest H/C ratio, highest efficiency of the reforming process, high hydrogen purity, very easy reformation at low temperature (app. 250 o C), and worldwide availability.

3.2. Stirling Engine AIP System

Stirling engine AIP systems (Fig. 8, 9), first installed in the Swedish Navy submarines Gotland and Nacken, are energy conversion devices that operate over a semi-closed, regenerative thermodynamic cycle. The power pistons operate in a closed helium (or hydrogen) working gas system, and heat is continuously transferred to the cycle via a heat exchanger. The oxidant of the AIP system is liquid oxygen, which is stored inside the pressure hull, and the fuel is Diesel oil. As the combustion chamber is external and separated from the working gas, it is possible to select the pressure of the combustion chamber. A relatively high combustion pressure allows the exhaust products to be discharged overboard at depth through a special mixing unit, where the carbon dioxide is dissolved in the seawater cooling system. Besides AIP system, Gotland submarine is equipped with two 970 kW Diesel engines. Two Kockums Stirling AIP units, which provide up to 75 kW each, provide over 14 days submerged endurance without snorkeling.

Figure 8.
Stirling Mark 3 to Mark 5 transition
(from 200 to 250 meters under water surface) (Saab, 2015).

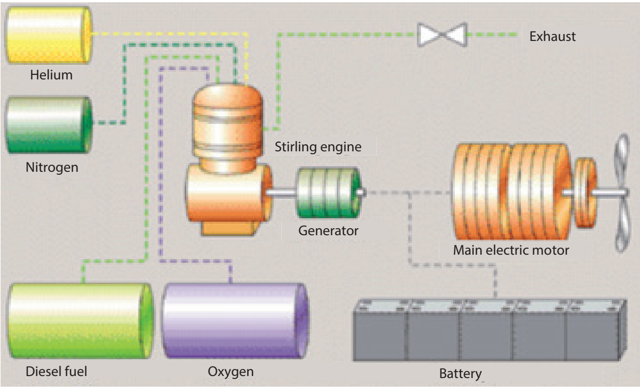

Figure 9.
Schematic of Stirling engine operation (Kukums Shipyard Website).

3.3. MESMA AIP System

The French DCNS Module Energie Sous-Marin Autonome (MESMA) system (Fig. 10) is an AIP system whose operation is based on a closed steam Rankine cycle. Liquid oxygen (stored in LOX tanks at -185 o C) is pumped into a vaporizer, where it becomes gaseous. It is then led into the combustion chamber, where it mixes with ethanol, and burned produces hot gasses of temperature of 700o C, at a pressure of 60 bar, to heat the secondary cycle. The high pressure of the exhaust gases allows for operation of the system at any diving depth without the need for additional equipment. The secondary circuit is a steam-driven turbine which drives a high-speed generator with output of about 200 kW. DCNS developed MESMA AIP system as a submarine hull module (Fig.11) which could be used for new ships and for retrofit.

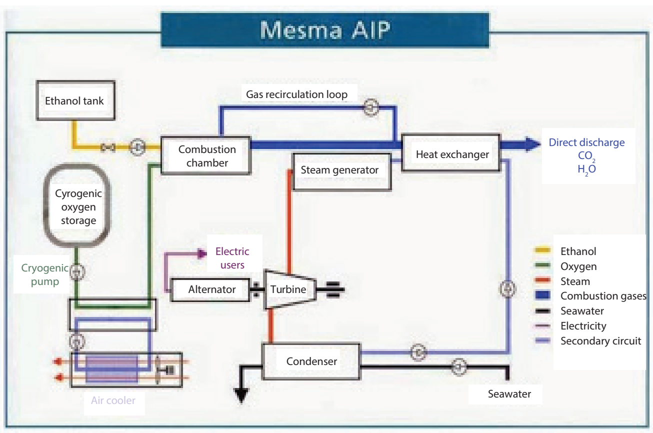

Figure 10.
MESMA AIP system diagram [DCNS].

Figure 11.
MESMA AIP system module [DCNS].

4. SUBMARINE BATTERIES

A Polish engineer, Stefan Drzewiecki, in the tsarist Russia (Kuźmicki, 2006) in 1883 was the first to install onboard a submarine an electric motor and electric batteries for its power supply. This system has become a canon on submarines as invented by John Holland Diesel-electric propulsion system. Batteries are standard features in all types of submarines (Koon, Kong & Wee, 2011) to provide standby and propulsion power. Prior to the advent of AIP and nuclear technology, a submarine's submerged endurance depended entirely on its battery life. Thus, the time required to charge its batteries remains as one of the submarine's key performance indicators – this determines how long a submarine has to snorkel and risk detection by adversaries.

4.1. Lead-Acid Batteries

Lead-acid batteries are commonly used (Kuźmicki, 2006) today and are one of the main elements of the submarine propulsion system despite a rather embarrassing exploitation (Fig. 12). Electric drive application involves the necessity of a periodic surface of the craft or positioning it on the periscope/snorkel depth and charging the batteries. The use of electric drive also significantly reduces the underwater speed of the ship, and the range decreases along with increasing speed. Even now at the speed "full ahead", the consumption of battery current is so high that it limits the craft's movement only to a time not much longer than 1 hour and in some ship types much below this value. However, modern submarine's lead-acid double-decker batteries are powerful, effective, reliable, and long-lasting. Lead acid batteries have high capacity during discharge, high current capability during discharge, low gassing, low H2 evolution during operation, and good shock resistance (EverExceed, 2019). Lead-acid batteries also have some drawbacks, so they are provided with built-in cooling systems, built-in acid circulation systems, and battery monitoring systems. All the time from Drzewiecki's invention the research works have been underway to prepare other types of batteries for submarines than the lead-acid type. Greater efficiency than from lead-acid batteries is provided by high-temperature sodium-sulfur batteries, sodium-nickel-sulfur batteries, and lithium-ion batteries.

4.2. Lithium-Ion Batteries

While lead-acid batteries have been the standard used in submarines, their dominance is increasingly challenged by a new generation of batteries that offer better power and energy density. Lithium-ion (Li-ion) batteries are currently one of the most popular types of battery for portable electronics (Koon, Kong & Wee, 2011). They have a superior energy-to-weight ratio and a slow loss of charge when not in use. Lithium is one of the lightest metals and has great electrochemical potential. In addition to the wide-ranging applications of Li-ion batteries in the consumer electronics domain, there is also a growing demand for it in the defense, automotive, and aerospace industries. This is due to the high energy density and technological maturity of Li-ion batteries. Figure 13 shows a simplified diagram of the charging and discharging sequence of a Li-ion battery. One of the key advantages of Li-ion batteries is their ability to be molded into different shapes and sizes to fill any space available in the devices they power efficiently. It has a low self-discharge rate of approximately five to ten percent, which is significantly lower in comparison with other battery types in the market. No memory and scheduled cycling is needed to prolong the battery life. Due to these desirable traits, Li-ion battery systems were tested for application in underwater vehicles and have demonstrated high potential in replacing lead-acid battery systems in Diesel-electric submarines.

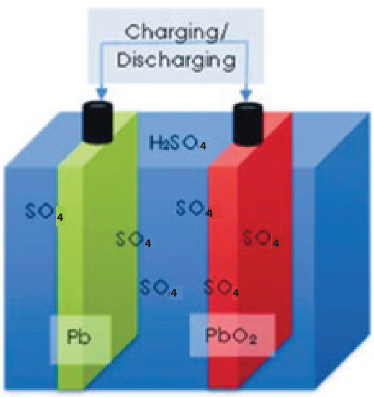

Figure 12.
Operation of lead-acid battery (Koon, Kong & Wee, 2011).

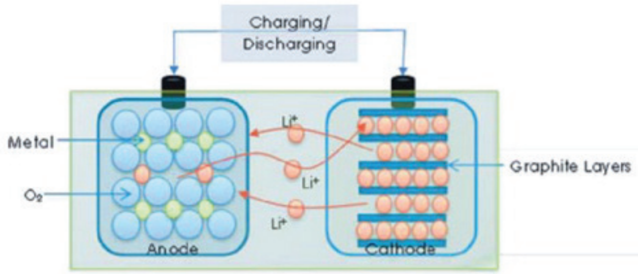

Figure 13.
Charging and discharging sequence of a Li-ion battery (Koon, Kong & Wee, 2011).

On 04 October, 2018, Japan's first submarine powered by lithium-ion batteries was launched (Fig. 14, 15). The 84-meter-long Oryu was lowered into the water (Rogoway, 2017) at the Kobe shipyard of Mitsubishi Heavy Industries. The submarine can reach speeds of approx. 20 knots and displaces 2,950 tons. It should be delivered to the Japan Maritime Self-Defense Force in March 2020. The Oryu is the eleventh submarine based on the Soryu's design. The Soryu-class vessels, which started being built in 2005, are among the largest Diesel-electric submarines in the world. The Oryu is a significantly updated version of the Soryu, the biggest change being the replacement of lead-acid batteries with lithium-ion ones. Mitsubishi tapped GS Yuasa to supply the high-performance batteries, which store about double the power of lead-acid batteries. Submarine batteries are recharged by the energy generated by Oryu's diesel engines. The craft switches to batteries during operations and actual combat in order to silence the engines and become harder to detect. The lithium-ion batteries radically extend the sub's range and time it can spend underwater.

Figure 14.
The Oryu, Japan's first submarine to run on lithium-ion batteries, launched in Kobe
(Photo by Kenji Asada)(Rogoway, 2017).

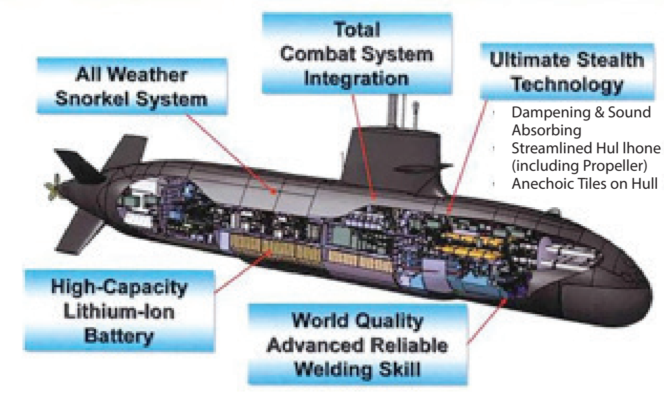

Figure 15.
The Oryu submarine visualization with lithium-ion battery (Rogoway, 2017).

The similar announcement released by South Korea says that it has developed lithium-ion batteries that can double the operational hours of submarines compared to those with lead-acid batteries. The lithium-ion batteries were created for the country's next-generation attack submarines, expected to be launched in the mid-2020s, according to the Defense Acquisition Program Administration (DAPA). Samsung SDI manufactured the battery module to be mounted on the second batch of three KSS-III submarines. Hanwha Land Systems is responsible for integrating the modules and other parts on the submarine, which is built by Daewoo Shipbuilding & Marine Engineering. According to the DAPA, the KSS-III class is 83.5 meters long and has a beam of 9.6 meters. It has a displacement of 3,358 tons when surfaced, and 3,705 tons when submerged.

In the same year 2018 (Thyssen Krupp MS, 2018), Thyssen Krupp Marine Systems also announced to have developed a new type of lithium-ion battery system for submarines together with Saft, a manufacturer of advanced battery systems for the industry. In an adapted form, the system could also be used for other maritime applications in future. Thyssen Krupp Marine Systems have presented the prototype at the EURONAVAL for the first time to the public. Saft specializes in advanced technology battery solutions for the industry, from the design and development to the production, customization, and service provision. Saft is a wholly-owned subsidiary of Total, the leading international oil-and-gas company.

Also in 2018, Naval Group announced (Naval Group, 2018) to have developed a high performance and highly secure Li-ion battery system (also together with Saft) to provide its conventional submarines with outstanding operational capabilities as well as an immersion period and reloading time largely optimized. The navies that will operate this new technology will boast a major technological superiority on the theatres of operations. This success is the result of a close cooperation between Naval Group, Saft, CEA Tech, and EDF R&D. The Li-ion battery system, LIBRT, improved security and performances on-board submarines developed by Naval Group. LIBRT increases significantly the submarines' submerged endurance and improves its stealth while guaranteeing better security conditions. This cutting-edge technology offers twice more available energy while reducing significantly the reloading time.

5. CONCLUSIONS

The next few years will show if the Li-ion batteries (really the cutting-edge technology) makes a breakthrough in the submarine propulsion systems similar to nuclear reactors. Many specialists think so although there are always those who are afraid. Especially after the fire of a Tesla car.

So far, high-speed, four-stroke diesel engines with exhaust gas turbocharging have been used for submarine generator drive. The power and the number of engines depend on the size of the craft and battery capacity. Possibly, with the implementation of lithium-ion batteries even higher power generators will be needed.

Regardless of the success or failure to implement lithium-ion batteries for submarines, AIP systems will still be a very desirable equipment, increasing the possibilities of their operation.

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Concept and First Results of Optical Navigational System

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The paper presents a concept of the optical coastal navigational system. The task of the system is to provide information about object position in coastal areas based on optical information. The system is intended for Autonomous Underwater Vehicles that operate in GPS denied environments. In addition to the concept itself, the paper also outlines the first results achieved during the research on the system.

KEY WORDS
~ Optical system
~ Coastal navigation
~ Autonomous navigation

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1. INTRODUCTION

The accuracy of underwater navigation depends on the quality of sensors and navigational devices. For small and medium size autonomous underwater vehicles equipped with sensors and devices of imperfect accuracy, the underwater navigation has to be often supported by other systems with the purpose to reduce position error produced by dead reckoning navigation. For this purpose, satellite systems are typically applied. However, the problem arises in GPS denied environments where access to navigational information from GPS is limited or completely impossible. In this case, visual information can be used. An underwater vehicle may surface and determine its own position based on the visual features of its location.

Vision systems are widely applied in navigation of air and land robots (indoor navigation). The former ones use databases with geo-information or with vision information derived from satellite recordings. The latter systems are based on SLAM technology, which assumes continuous access to the vision information about environment surrounding the robot. There are also maritime solutions including the underwater ones, which are based on SLAM technique like their land counterparts.

However, the problem arises if the vehicle does not have continuous access to the vision information; this information is rare and is accessible from time to time when the vehicle appears on the surface for correction of its position. In this case, SLAM algorithm is useless, and a different technique has to be applied. It should be able to improve indications of underwater dead reckoning system by determining approximate location of the vehicle based on rare visual scans of the external world. In order to design such a technique, Polish Naval Academy lunched a project called "Optical Coastal Marine Navigational System" (OCMNS), and the current paper is a short report on the first stage of the project.

Generally, the OCMNS is supposed to operate in different distances from the land, i.e. it should be able to work on the vision information of different characteristics. According to initial assumptions, the system is to work in three different modes: mode No. 1 – large distance to land, no land details are visible, only outline of the coast is visible; mode No. 2 – average distance to land, texture visible, e.g. beach, urban area, forest; mode No. 3 – small distance to land, details visible, e.g. trees, buildings, ships. The task of the first step of the project, which is reported in the paper, was to focus on the mode No. 1. The example results of this step are given below.

To determine the vehicle position, the OCMNS needs simplified navigational chart with contextual information, i.e. with the information that makes it possible to determine the nature of each coastal object visible in the chart. It is assumed that the chart is to be constructed based on freely available vision data derived e.g. from Google Map service. In order to build the chart, a database was implemented that is prepared to store Google Map images combined with the contextual information mentioned above. Moreover, a computer application was implemented which makes it possible to categorize selected fragments of the images. Both software components are shortly outlined below.

The other critical element of the OCMNS and the entire project is a set of example vision data (images) along with the contextual information (geographical coordinates, Euler angles at the point of image recording) that are necessary to prepare the system to work. Many image processing solutions that are intended for use in the OCMNS require training data, i.e. example images that can be recorded by underwater vehicle during its operation on the surface. In order to acquire the above mentioned data for different weather conditions, at daytime, at night, in winter, in summer, etc., a small remotely operated surface vehicle was constructed and equipped with two digital cameras, an inertial unit, and GPS receiver. The construction of the vehicle is also outlined in the paper.

The rest of the paper is organized as follows: Section II introduces the small surface vehicle mentioned above, Section III outlines design and implementation of both the database and the computer application for constructing and storing the chart with the contextual information, Section IV reports the first results of the OCMNS, and the final section summarizes the paper.

2. SURFACE VEHICLE

The primary ability of the OCMNS is image processing oriented to the estimation of vehicle position based on visual clues. The components of the system responsible for image processing can implement different algorithms. All of them require tuning and testing, and some of them also require training. To this end, example images are necessary, combined with exact position and orientation of the camera at the point of

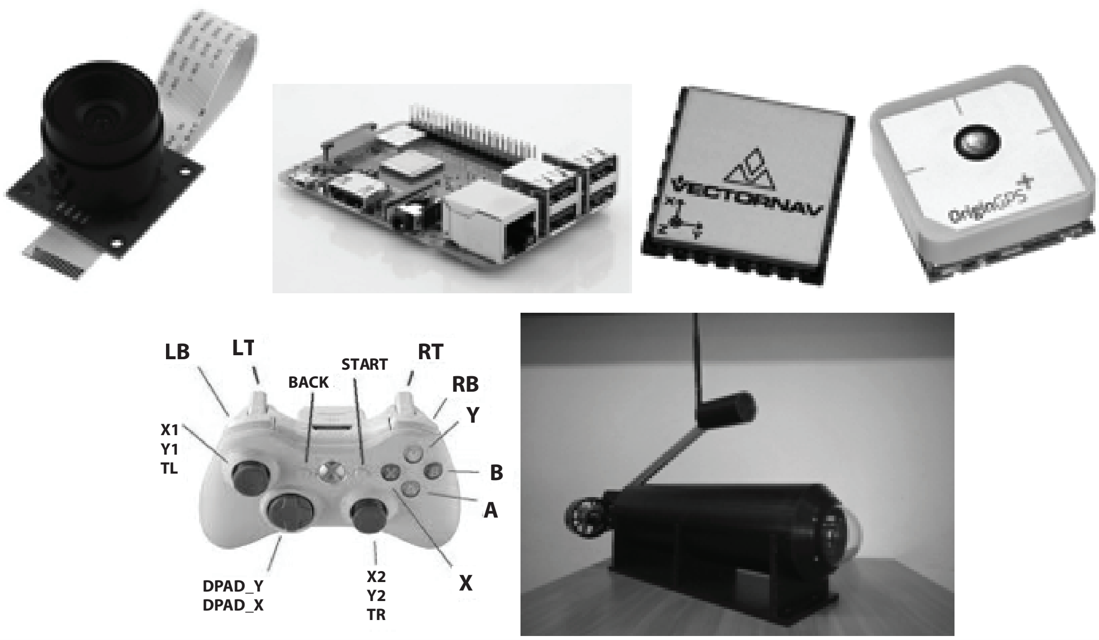


Figure 1.
Key components of the surface vehicle, and the vehicle itself.

image recording. To record the images, a small remotely operated surface vehicle was designed and equipped with two cameras (one is mounted on the mast and the other is integrated within the vehicle hull), an inertial unit, and GPS receiver. Moreover, it was equipped with Wi-Fi communication system, batteries as an independent energy source, memory card for storing images, and Raspberry Pi 3 computer as a control system. Software of the vehicle enables an external operator to control motion of the vehicle and to record images along with the contextual information on memory card. The camera mounted on the mast can be raised up to a certain height. All key components of the vehicle are illustrated in Figure 1.

3. SOFTWARE TOOLS FOR CONSTRUCTION VEHICLE CHART

The primary assumption of the OCMNS is the ability to employ two types of information. The first one is visual information which, depending on the distance to land, takes different forms. The second type of information needed by the system is map/terrain information which, according to a next assumption, is acquired from freely accessible map sources like Google Maps service.

In order to determine the vehicle position based on visual information, extra information is necessary which is used to confront and to adjust the recorded image or sequence of images to the appearance of the coast from an assumed point of observation. In the best case, the extra information should take the form of example pattern images of the coast that should be recorded in advance (before the mission). Since the case when the system is in possession of example coast images is very rare, the decision was made to rely on publicly available data derived e.g. from above mentioned Google Maps service. The service provides images of almost any area in the form of a simple topographic map or a terrain map (satellite images). The images enable the system to determine the distance to land and the type of an observed object for a given vehicle position and a line of sight.

The above information can be used away from the land when no details are identifiable in the images – distances to land estimated for a number of lines of sight, based on visual information, are confronted with the distances determined with the help of Google Maps images. In this case a position is sought which fits the estimations best. If some details are noticeable in images, e.g. beaches or forests, then their location in the images can also be matched with the map to find best position estimation. If "point" objects like trees or buildings are detected, they are first placed on the map (if the system knows its own position, the line of sight for which the object is detected and distance to land from the position and for the line of sight, then it can estimate the position of the object), and after that, they can be further applied as landmarks to fix the vehicle position in successive points in time. In the latter case, Google Maps images are unnecessary.

To sum up, in further distances to land, the system should rely on the map and terrain information derived from Google Maps, and simultaneously it should try to extract isolated objects like trees and buildings from the recorded images. In turn, in closer distances to land, the vehicle position should be estimated based on the objects extracted earlier.

In order for the OCMNS to be able to take advantage of the information derived from Google Map, two software components were implemented. The first one is on-board system, and its task is to provide information about the distance to land for a given observation point and line of sight. Moreover, its responsibility is to supply the OCMNS with the information about the type of object that is observed from the specified point and line of sight.

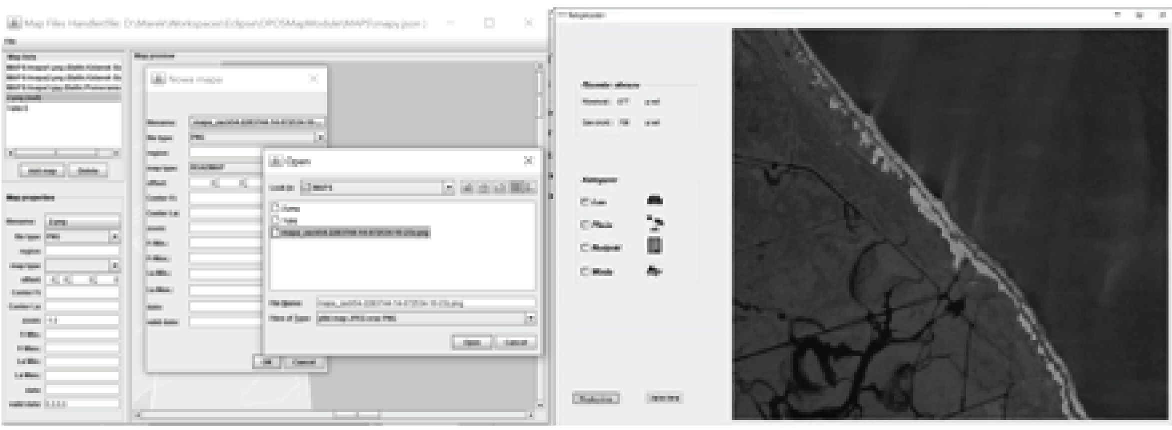


Figure 2.
Example user interfaces of the software for building the database of Google Maps images.

A next software component is applied to prepare the database of Google Maps images and to link pixels of the images to a number of categories, e.g. forest, beach, urban area, cliff. Since it is difficult to determine with one hundred percent certainty what the vehicle can see looking from a given point in a certain direction and using exclusively satellite images, each fragment of the coast in the images can have a number of categories assigned. Each assignment is also described by probability of a given category at a given place. Figure 2 illustrates example GUIs of the software outlined above.

4. EXTRACTION OF LAND FROM MARITIME IMAGES

In the first stage of the project, the objective was to design an algorithm for estimating the position of the vehicle far away from the land. To this end, a solution can be applied which, for a number of lines of sight, determines where the land is closer and where it is farther. The system equipped with such information can search the map for a point which best fits the observed situation. Of course, the point should be sought in proximity of position fixed by a dead reckoning navigational system. In order to determine the relative distance to land for different lines of sight, a method can be applied which extracts land from the images and compares the size of land in each image. If land occupies only a fragment of the image, left or right, the tip of the land can be used by the system as an extra useful landmark.

In order to extract the land from the images, three approaches can be applied, i.e. traditional segmentation, separating the land from the rest of the image by means of sky-land and land-sea lines, and Deep Learning semantic segmentation. In the first stage of the project, the first two approaches were considered. The example results of the research in this field are given below.

4.1. Traditional Segmentation

For the purpose of land extraction, three traditional image segmentation methods were used: Floodfill (Bradski & Kaehler, 2008), Watershed (Hlavac, 2011), and Graph Cut (Szeliski, 2011). All the tests were performed on 150 example images of Gdynia harbour that were recorded at a different distance to land. In order to facilitate the task of Floodfill and Watershed, the land extraction was performed as a two-stage process of sky extraction (upper part of the image), and sea extraction (bottom part of image). In the case of Graph Cut, segmentation was preceded by a rough marking of land segment. The example results are presented in the Figure 3-5.

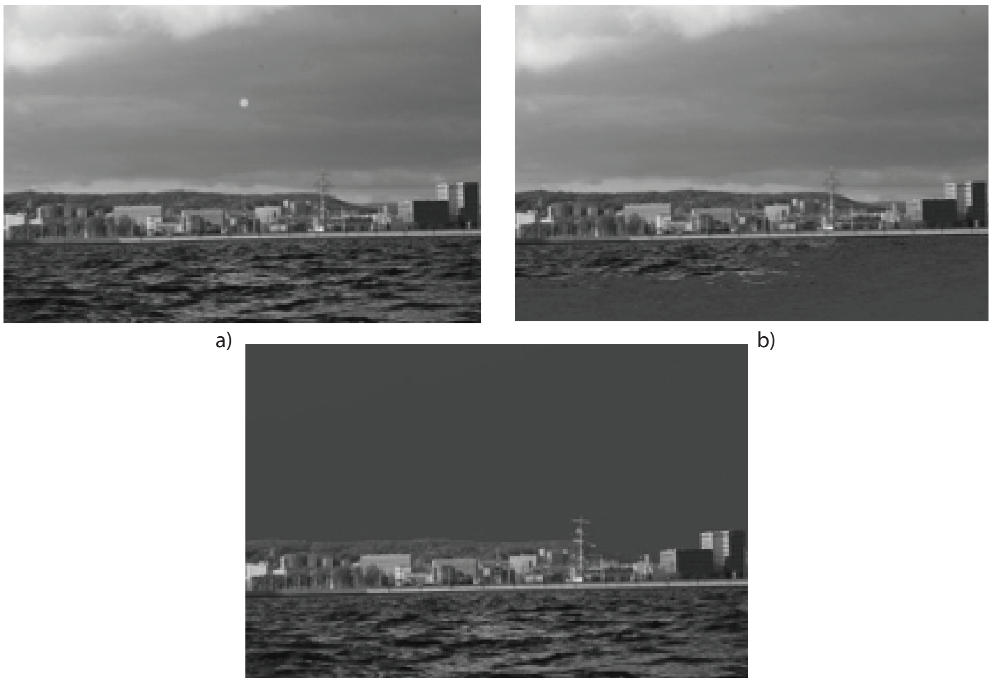
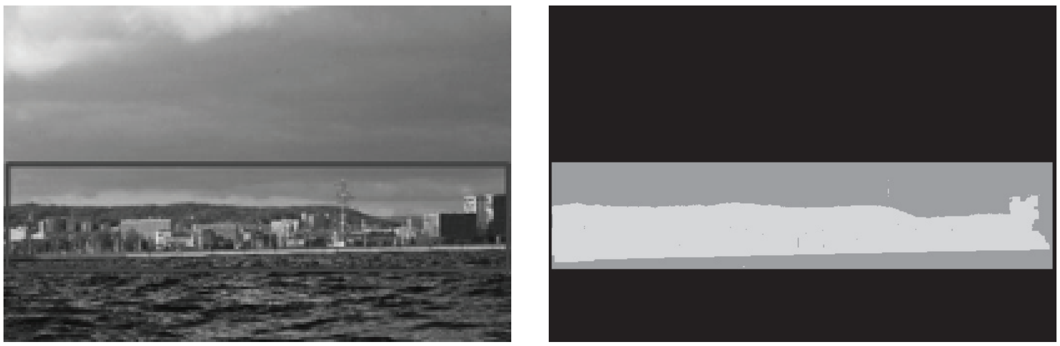


Figure 3.
Example application of Floodfill: (a) original image, (b) image after extraction of the sea (black pixels), and (c) image after extraction of the sky.

a) b)

Figure 4.
Example application of Watershed: (a) original image, and (b) image after extraction of the sky.



a) b)

Figure 5.
Example application of Graph Cut: (a) original image, and (b) image after land extraction.

Generally, the experiments with traditional segmentation revealed that, regardless of the applied method, the traditional approach is insufficient to effectively extract land from marine images. The least problem was sky extraction, and Floodfill method often coped with this task quite effectively. In the case of sea extraction, the results were definitely worse in general. Additionally, the applicability of Graph Cut to the OCMNS appeared to be reduced due to the necessity of manually indicating rough land segment before segmentation.

4.2. Land-sea Line Extraction

Other method for land extraction is to separate it from the sky and the sea. To determine the line separating the sea from the land (land-sea line), Hough transform can be applied (Duda & Hart, 1972; Gershikov, Libe & Kosolapov, 2013). The transform is able to detect all the straight lines visible in the image. The set of lines determined by the transform can include both segments belonging to the land-sea line and other lines. The problem is, however, how to select the land-sea line from all the set. The simplest method is to select the longest line. The tests revealed, however, that this method is not effective. Another method is to describe each detected line with a feature vector and then to use identification techniques to find the right line. In the experiments made on marine images recorded at the open sea (without land visible), AutoEncoder neural networks were applied as tools for identification of the lines separating the sea and the remaining parts of the image. Each line detected by Hough transform was represented by a feature vector describing the average brightness of the image fragment below and above the line. Then, an AutoEncoder was trained on the representations of only true lines, while the remaining lines were neglected in the training process. The task of the training was to obtain the network that would be able to reconstruct an input signal on an output layer of the network. The objective of this approach is to sensitize the network to only true lines, which, after a training, should be properly reconstructed. Other lines which differ from those applied in the training process should be reconstructed with a noticeably greater error than the true lines. The results of the experiments with the Hough transform combined with AutoEncoders revealed a high effectiveness of this method. Example lines are presented in Figure 6. Unfortunately, the same experiments also showed that this method is computationally very demanding and, therefore, it is not suitable for on-the-fly calculations on board the underwater vehicle. A useful alternative for the Hough-transform-based method is the QHLD algorithm (Quick Horizon Line Detection) proposed in (Praczyk, 2017). In this case, most calculations are performed on a small resized counterpart of an original image with the effect that the algorithm is very fast and, therefore, suitable for the task of land extraction and position estimation. The example results achieved by the QHLD algorithm are illustrated in Figure 8.

Figure 6.
Example lines determined by Hough transform and AutoEncoders.

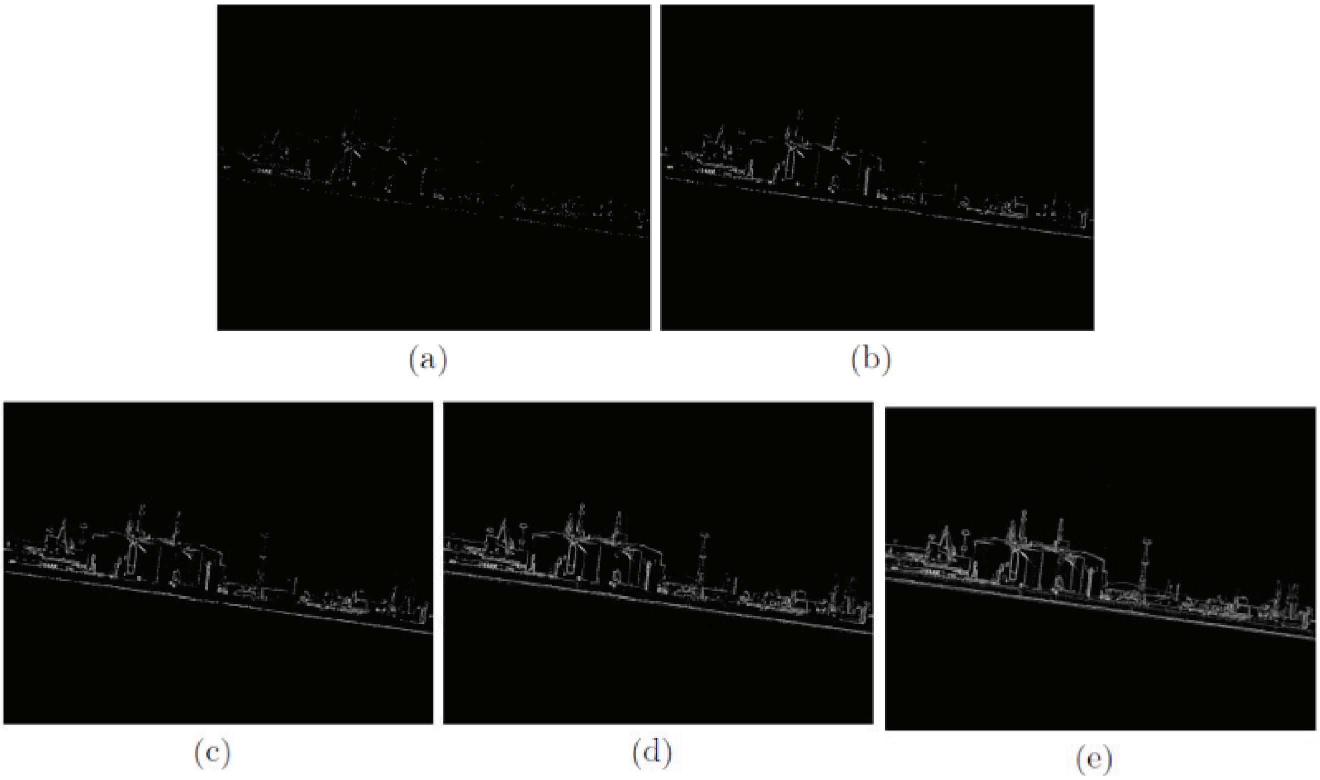


Figure 7.
Successive contours generated by the GELD (Figure taken from (Praczyk, 2018)).

4.3. Sky-land Line Extraction

In order to separate land from the other elements of the image, in addition to the land-sea line, the sky-land line which separates the land from upper part of the image is necessary. To this end, an algorithm called GELD (Gradual Edge Level Decrease) was proposed (Praczyk, 2018). It generates contours in the image and tries to find the path from the left to the right edge of the image, or in the opposite direction. The path consists of contour pixels separated by a small predefined distance from each other. First, the path is sought for very strong contours (Figure 7a). In case of a failure, weaker contours are generated (Figure 7b-e) and the process of searching the path is repeated. Weakening of the contours and searching the path is continued until it is found.

Figure 8.
Example application of the GELD and the QHLD (Figure taken from (Praczyk, 2018)).

To verify the effectiveness of the combined application of the GELD and the QHLD, they were tested on 150 images of Gdynia harbour and its neighbourhood. The tests revealed a high effectiveness of both algorithms in land extraction. What is more, the algorithms also showed that they are very quick, which makes them a perfect tool for land extraction in the OCMNS. The example application of the GELD and the QHLD is illustrated in Figure 8.

In addition to the GELD and the QHLD, an algorithm was proposed which is their more complex and more computationally demanding variant. At the moment of preparing the paper, the algorithm is still under construction and tuning process. However, the first tests performed on a few selected images showed its almost perfect effectiveness in land extraction – see Figure 9.

Figure 9.
Example performance of newly designed algorithm.

5. SUMMARY

The paper presents the concept of the Optical Coastal Marine Navigational System which is intended for autonomous underwater vehicles that operate in GPS denied environments. The task of the system is to reduce the position error of dead reckoning navigational system when the vehicle is on the surface. To this end, the system extracts visual clues from images recorded by means of a single camera and uses the clues along with the map information to determine vehicle position.

Apart from the concept of the OCMNS, the paper shortly presents the first results of the project focused on the system. The following three artefacts are described: (i) remotely operated small surface vehicle for recording visual data that are necessary for further research, (ii) software for building the database of map images along with contextual information, (iii) algorithms for land extraction from marine images along with results of the verification tests.

ACKNOWLEDGMENT:

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Preliminary Calculations for Minehunter's Genset Foundations

Andrzej Grządziela, Marcin Kluczyk

The requirements for the foundations of naval vessel engines are based on classification rules devised by classification societies or/and military standardization rules. A class guideline was published, defining the requirements, acceptance criteria and machinery seating methods. There is also a schedule of basic calculation procedures for cast resin or rubber chocks which facilitates the process of machinery foundation design, preloading force calculation, the establishment of boundary conditions etc. In case of naval vessels, typical procedures do not meet tactical requirements due to potential explosion loads. Since minehunters are mainly deployed at sea, handling active, naval mines, the shock resistance calculation for the entire machinery, including the Genset, is required. The paper presents preliminary MatLab calculation methods which can be used to analyse the type, number and location of rubber or elastomer chocks. The procedure consists of input data such as UNDEX pressure and technical data of the Genset used in the Polish Navy. Calculation results include the analysis of the dynamic interaction between the Genset and the foundation, as well as the damping effect generated by the UNDEX (**UND**erwater **EX**plosion) shock pulse.

KEY WORDS
~ Minehunter
~ Foundation
~ Shock
~ Undex

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1. INTRODUCTION

The foundations of machines and engines on naval ships have been designed in accordance with the regulations of marine classification societies and military standardization. Since each navy has its own test results and naval battle experience, the details of requirements and calculation algorithms are classified or, more frequently than not, confidential documents. The main differences between the machine foundations on commercial vessels and navy ships are the ability to absorb energy from UNDEX (underwater explosion) and hydroacoustic signature reduction by noise and vibration damping. The main recommendations for engine seatings have been defined in the classification rules set by classification societies. The basic requirements for main engine foundations include the following parameters: seating structure thickness, minimum mating surface of cast resin chocks, preloading force exerted on a foundation bolt, tightening torque of foundation bolt, tensile stress depending on the thread root diameter of the foundation bolt on the basis of preloading force, etc. The paper presents a preliminary simulation of a GenSet foundation with introduced new load element i.e. the impact of UNDEX shock pulse.

2. OBJECT OF RESEARCH, EXTERNAL AND INTERNAL FORCES

The object analysed in this paper is a Poweras Generating Set MPAP 108, described in Figure 1.

The technical parameters and basic dimensions of this Genset are indicated in Table 1.

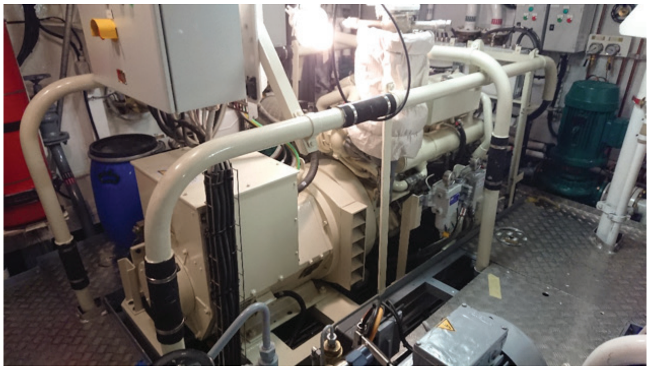

Figure 1.
Object of research – GenSet MPAP - 108 type.

Table 1.
Parameters and dimensions of MAN B&W 6L16/24 GenSet.

Parameter	**Value**	**Unit**
Type	MPAP 108	
Power	135 (cos 0.8)	kVa
Voltage	3 x 400	V
Rotational speed	1500	rpm
Engine Power	122	kW

2.1. External forces

External forces have been defined as forces originating in the marine environment, unelated to the working processes within the engine. The first external force is slamming, i.e. the impact of a hull bottom in motion on a wavy sea surface. The effect of slamming exposes the high loads exerted on the hull structure and the machinery inside the vessel. The second external force is the impulse of underwater explosion (UNDEX) which affects a sea mine's pulse excitation. The UNDEX in-fluid phenomena consist of the preliminary calculation of the following parameters: resultant pressures, shockwave peak pressure, decay constant, as well as gas bubble parameters for different explosives (Cole, 1948). The shockwave has spherical shape, which, after detonation, expands at a celerity dependant on explosion pressure, from (Keil, 1961):

$$C = c\,(\,1 + 8{,}7 \cdot 10^{-4} \cdot p_0\,) \tag{1}$$

Where: C - is shockwave celerity, c - speed of sound in water, p_0 – pressure decline on the shock wave [MPa].

The direct propagation of the pressure wave along the vessel's hull was used in the calculations. In the simulation model the distance from the detonation epicentre is four times greater than the diameter of the first gas bubble, which is a realistic scenario for minehunter operations. The model disregarded the effect of pulsation from cavitation and the waves reflected from the sea bed, recognizing their energy value as significantly lower than that of the direct detonation wave. However, it should be noted that further analysis of the impact of both pulsations could be of relevance for calculating the resonance effects of solid structures mounted inside the ship's hull. In empirical formulas, there is maximum pressure p_{max}. Robert Cole (Cole, 1948) described it with the following formula for TNT:

$$p_{max} = 523\left(\frac{\sqrt[3]{W}}{R}\right)^{1,13} \cdot 10^{5} \tag{2}$$

where: W– explosive mass TNT, [kg], R – distance from epicentre, [m].

Apart from maximum pressure value, the function describing the performance of pressure in the function of time is also important. Its course is approximated by the following exponential function:

$$p(t) = \left[K_1 \cdot \left(\frac{\sqrt[3]{W}}{R}\right)\right] e^{-\frac{t-t_0}{\theta}} \tag{3}$$

where: t_0 - time calculated from the moment the first pressure wave came into contact with the hull, [ms],K1 – shock wave coefficient, for TNT K1 =52,12, A1 – pressure coefficient, for TNT A1=1,18, θ - time constant [ms], calculated as follows:

$$\theta = 9{,}3 \cdot \sqrt[3]{W}\left[\frac{\sqrt[3]{W}}{R}\right]^{(-0,22)} \cdot 10^{-5} \tag{4}$$

The value of the maximum pressure on the shockwave front is not the only parameter that has the destructive power. The time of its impact should also be taken into account. Both parameters have one relationship called a shock pulse pressure, its value for TNT is calculated as follows (Cole, 1948):

$$I = 5768\,\frac{W^{0,63}}{R^{0,89}} \tag{5}$$

The equation facilitates the calculation of shock pulse pressure during the first pulsation, provided that the explosion occurs far from both the seabed and the sea surface (the diameter of the first gas bubble is much smaller than depth) (Park et al., 2003). The Boussinesq-Basset force model (added water) was used for simulation calculations of the effect of the shock on the hull (Basset, 1961). The comparison of the result of the hull acceleration simulation model with the result of the UNDEX sea trials is presented in the figure below:

Due to the inevitable use of the Laplace transform to obtain the frequency transform, the Dirac delta impulse response served as the UNDEX impulse model in initial simulations.

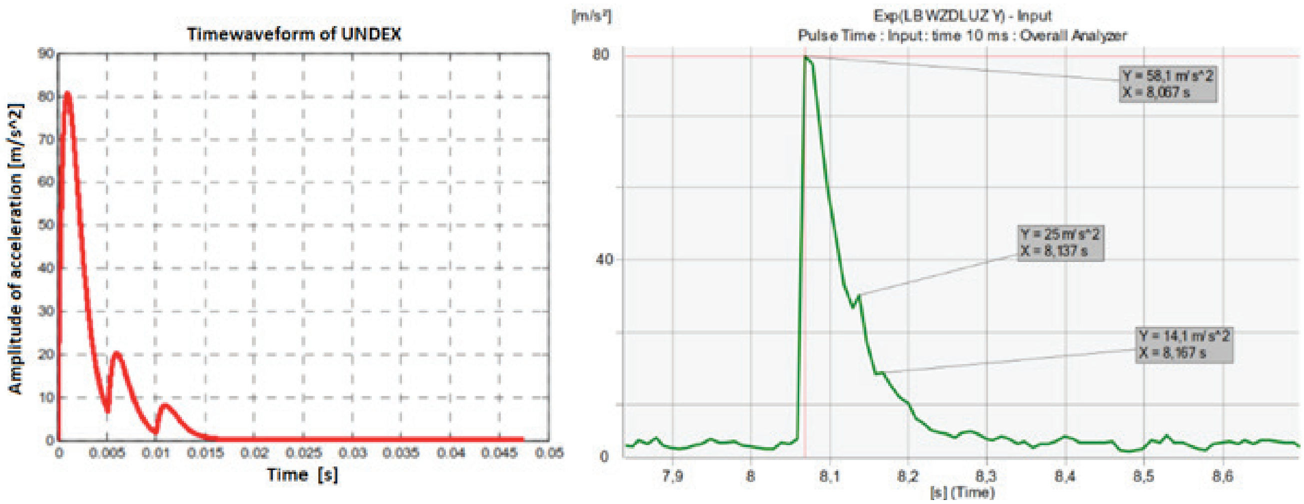

Figure 2.
Simulation model of impact interaction with 3 successive pulsations of the gas bubble and the magnitude of the detonation effect.

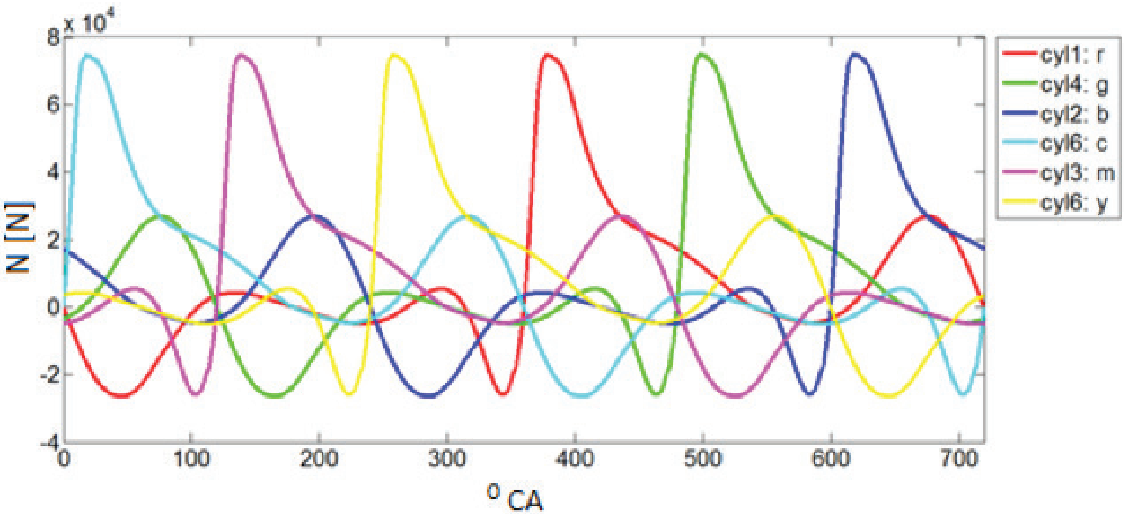

Figure 3.
Fluctuations of tangential forces of individual cylinders of a GenSet, six-cylinder engine.

3. INTERNAL FORCES

Genset's internal forces include inertia forces and gas forces, which is the principle of diesel engine operation. Inertia forces were calculated based on the analysis of the system's crankshaft kinematics and the residual unbalancing of the rotor system in the generator. Other inertia forces were disregarded. After implementing the equations describing the kinematics and dynamics of the crank and piston system in MatLab, defining the geometry and determining the cylinder pressures and the masses performing individual types of movement, the tangent force courses for individual cylinder systems of the 4 stroke, six-cylinder engine were obtained. Figure 3 illustrates the waveforms of individual tangential forces when all cylinders have identical combustion pressures for 90 % of effective engine power (Kluczyk & Grządziela, 2015). The residual forces generated by generator rotor unbalancing have a very small energy effect but were not disregarded in the calculations due to their potential resonance effect.

The simulation of gas forces was performed as a spline interpolation of four engine work strokes (Kluczyk, Grządziela & Batur, 2016). During the intake stroke, the cylinder pressure F_g remains constant and can be defined as:

$$F_g = \frac{\Pi D^2}{4}(p_d - p_0) \tag{6}$$

In the next compression, pressure increase can be described by the following equation:

$$F_g = \frac{\Pi D^2}{4}\left\{p_d\left[\frac{2\varepsilon}{(\varepsilon-1)(1-\cos\varphi+0{,}5\lambda\sin^2\varphi)+2}\right]^{n_1}\right\} \tag{7}$$

In the combustion stroke, the intra-cylinder pressure can approximately be described as:

$$F_g = \frac{\Pi D^2}{4}\left\{p_d\varphi_c\varepsilon^{n_1}\left[\frac{2\rho}{(\varepsilon-1)(1-\cos\varphi+0{,}5\lambda\sin^2\varphi)+2}\right]^{n_2}\right\} \tag{8}$$

And finally, the exhaust stroke was described with the following formula:

$$F_g = \frac{\Pi D^2}{4}(p_w - p_0) \tag{9}$$

where: p_0 – is atmospheric pressure, p_w – outlet gas pressure, p_d - air boost (turbo) pressure, D – piston diameter, ε - compression ratio, ρ - volume increase ratio, φ_c - pressure increase ratio, n_1 - polytropic compression exponent, n_2 - polytropic expansion exponent.

The simulation of Time Waveform and its FFT spectrum of acceleration on the Genset engine foundation are shown in Figure 4.

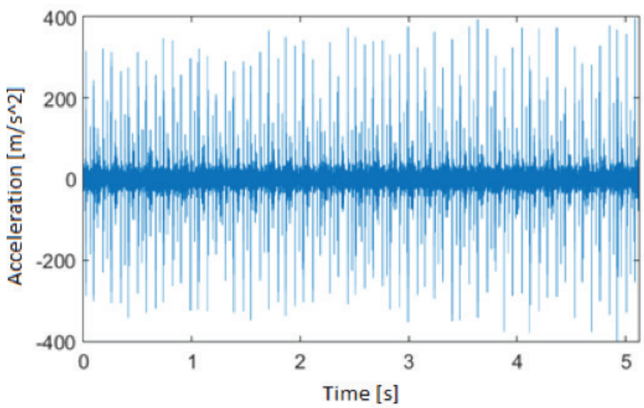

Figure 4.
Simulation of the time course of engine's vibration acceleration, vertical axis.

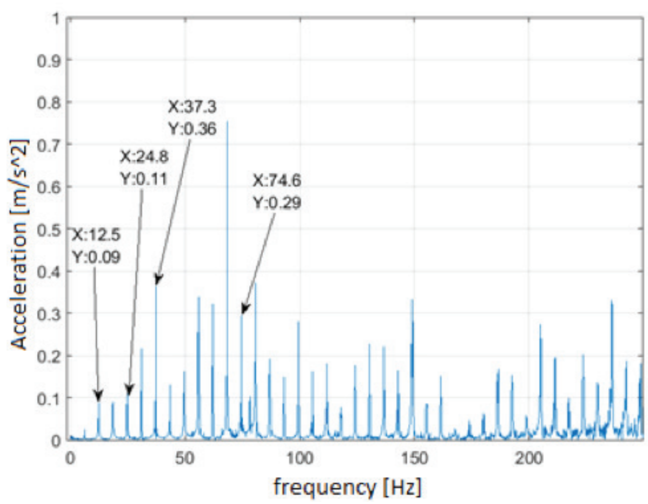

Figure 5.
Simulation of the FFT spectrum of engine's vibration acceleration, vertical axis.

Finally, the redundant generator unbalancing model was applied. Taking into account standardization rules and electric power, it is assumed the harmonic excitation of the rotor can be described as follows:

$$F_{RM} = m_{UB}\, sin\omega \tag{10}$$

However, although preliminary UNDEX resistance tests do not require engine and generator operation, dynamic models of internal and external loads would be useful for further research. A real operational scenario needs to be set up, with the engine and the generator working during an UNDEX detonation.

4. MATHEMATICAL AND PHYSICAL MODEL

Since the supporting floor – hull structure is sufficiently flexible, a two-level model is a sufficiently accurate representation. Figure 6 illustrates the basic forces acting on Genset's mass with respect to time and displacements. Due to the fact that the ship's hull is submerged in sea water and taking into account the acceleration effect of the UNDEX pulse, the sum of the hull's mass and the added water mass was analysed for simulation purposes.

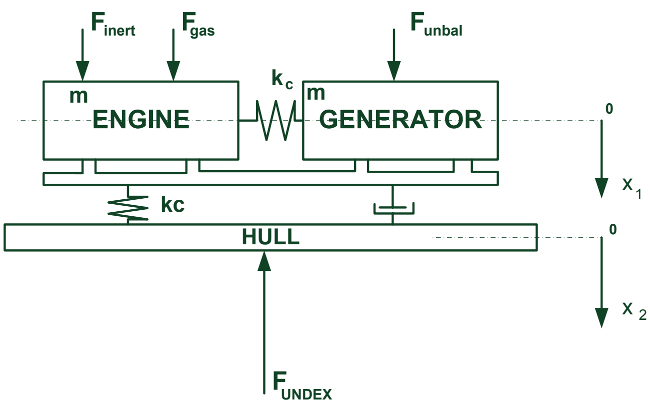

Figure 6.
Scheme of forces acting on Genset.

The proposed design of washers assumes a two-stage sandwich-type system, called system 2, opposite to homogeneous system washers – system 1. In system 2, the first, upper washer layer has to withstand static deflection from Genset's mass and the dissipated energy from the dynamic interactions of the inertia forces of the generator and the engine, as well as the engine's gaseous forces and sea wave forces (Tappu, Sen and Lele, 2013). The lower layer has a different physical performance and acts as UNDEX pulse suppressor. The detonation wave affecting the ship's hull was anticipated to transfer its energy to Genset before hull displacement, due to the considerable inertia of the hull and the mass of accompanying water. Task formulated in this manner allows for the application of Newton's second law, as follows:

$$F_n = F_g - (cx - kx) = \left(m\frac{d^2x}{dt^2}\right) - \left(c\frac{dx}{dt} + kx\right) \tag{11}$$

Rewritten (11) to obtain a second order linear differential equation

$$\frac{d^2x}{dt^2} + \frac{c}{m}\cdot\frac{dx}{dt} + \frac{k}{m} = \frac{F_n}{m} \tag{12}$$

where x is displacement, c is damping resistance and k is the spring constant.

The homogeneous form of (12) can be described as:

$$\frac{d^2x}{dt^2} + \frac{c}{m}\cdot\frac{dx}{dt} + \frac{k}{m} = 0 \tag{13}$$

and the general solution to (12) is:

$$x(t) = x_{HS}(t) + x_{PS}(t) \tag{14}$$

where $x_{HS}(t)$ is the general solution to (13), i.e. homogeneous solution, and $x_{PS}(t)$ is the particular solution which depends on F_n forms, [Haynes]. Although homogeneous solutions can have three forms of response, only two are of interest in this case, i.e.:

$$x_{HS}(t) = C_1 \cdot e^{at} + C_2 \cdot e^{bt} \tag{15}$$

$$x_{HS}(t) = C_1 \cdot e^{at} + C_2 \cdot t \cdot e^{bt} \tag{16}$$

Furthermore, the system is overdamped in the first form and critically damped in the next form. This is to be expected in a proper foundation. The homogeneous solution in this form has constants which are complex conjugates in real solutions. In case of a homogeneous solution (13), they depend on the roots of the characteristic equation:

$$s^2 + \frac{c}{m}s + \frac{k}{m} = 0 \tag{17}$$

Eq. (15) illustrates an overdamped system; it has real and distinct roots, i.e. roots α and b. Eq.(16) has the reiterated root α and the system is critically damped.

The system has response with (t) as input and the impulse response denoted as *h(t)* (Tappu, Sen & Lele, 2013). The Laplace transform of the system output response - eq. (12) is presented as follows:

$$X(s) = \frac{F_n(s)}{s^2 + \frac{c}{m}s + \frac{k}{m}} \tag{18}$$

Where $F_n(s)$ is system input. Impulse response *h(t)* can than be defined as:

$$h(t) = L^{-1}\left(\frac{1}{s^2 + \frac{c}{m}s + \frac{k}{m}}\right) \tag{19}$$

The system transfer function is defined as

$$\frac{X(s)}{F_n(s)} = \frac{1}{s^2 + \frac{c}{m}s + \frac{k}{m}} \tag{20}$$

If the input forcing function *F(t)* is presumed to consist of several pulses, as shown in Figure 2, function *F(t)* will take the following form:

$$F(t) = B_1 \cos\omega t + B_2 \sin\omega t = C \cdot \cos(\omega t + \varphi) \tag{21}$$

If time *t* is presumed to tend to infinity, the general solution of the equation takes the form of a steady state solution and tends to the particular solution *(t)*. If *(iω)* is substituted with *s* in (20), it obtains the following frequency response:

$$F(\omega) = \left(\frac{1}{i \cdot \frac{c}{m}\omega + (\frac{k}{m} - \omega^2)}\right) \tag{22}$$

For further analysis, the following simplifications are assumed:

- the system has equivalent stiffness and damping constants,
- stiffness and damping were introduced as a flexible coupling connecting the engine and the generator,
- the arrangement of shock absorbers is symmetrical,
- there is only one shock impulse which acts vertically on the center of gravity of the Genset system.

5. SIMULATION RESULTS

Due to Genset's constant rotational speed, resonant frequencies were defined as the natural frequency of the overall system and its elements, calculated numerically, as the frequency equal to the rotational speed of the diesel engine – generator, the rotating system. The operational scenario facilitates the calculation of single pulse force of 5000 kN in the duration of 0.005 sec, assuming the Dirac impulse shape. The ensuing pulses are disregarded due to the effect of a huge explosive charge and the shallow water along the Baltic coastline.

The result of the numerical calculation of the natural frequencies of the bending vibration in the vertical axis of Gensets' foundation system gave 4.45 Hz and 3,87 Hz (respectively for engine and generator), with the first harmonic of the rotational speed of the Genset rotor being 15 Hz. Simulations were made for two different shock absorption systems – system 1 and system 2, with the first consisting of 10 homogenous shock absorbers and the second having the same number of shock absorbers, but a sandwich-type construction. Shock absorbers used in system 2 were constructed as a sandwich elastomeric element, with two layers of different hardness.

Figure 7 shows simulation results for shock absorption system No. 1 and Figure 8 results for system 2. Both simulations were carried out for non-operational Genset, as is the case during sea acceptance tests with UNDEX.

The results indicate a much smaller displacement of both spectral components in system 2. Figure 9 shows the time waveform amplitude of displacement for both systems. It should be noted that both systems are underdamped, although the damping effects are completely different. The solution in system 1 has higher amplitude value and greater number of cycles. System 2 is far from critical damping, however, the use of two layers of the damper sandwich construction, with different hardness, reduced amplitude two times, simultaneously reducing the number of oscillation cycles. The result was obtained for the non-linear characteristics of stiffness and damping of the damper in system 2. Nonlinearity is the effect of bottom layer geometry, which takes prismatic form. In the near future, dampers will be tested further using similar construction and different physical properties of these layers.

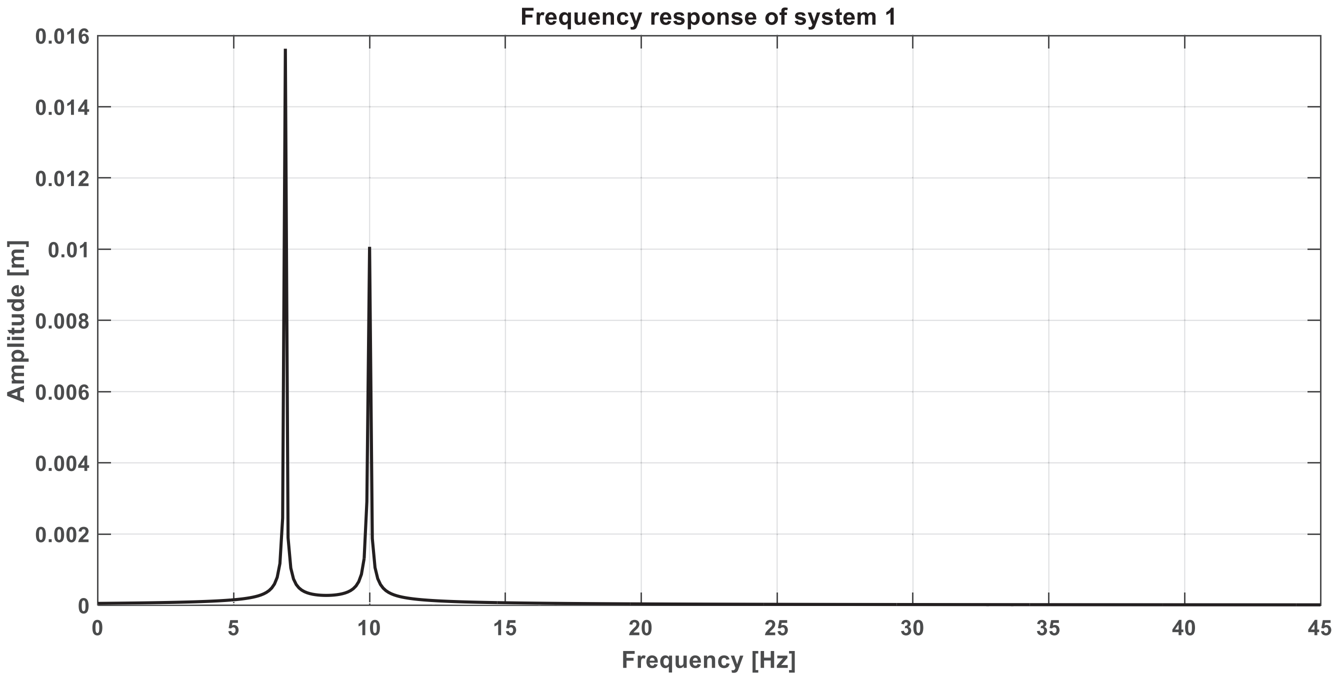

Figure 7.
Simulation spectra of frequency response for system No. 1.

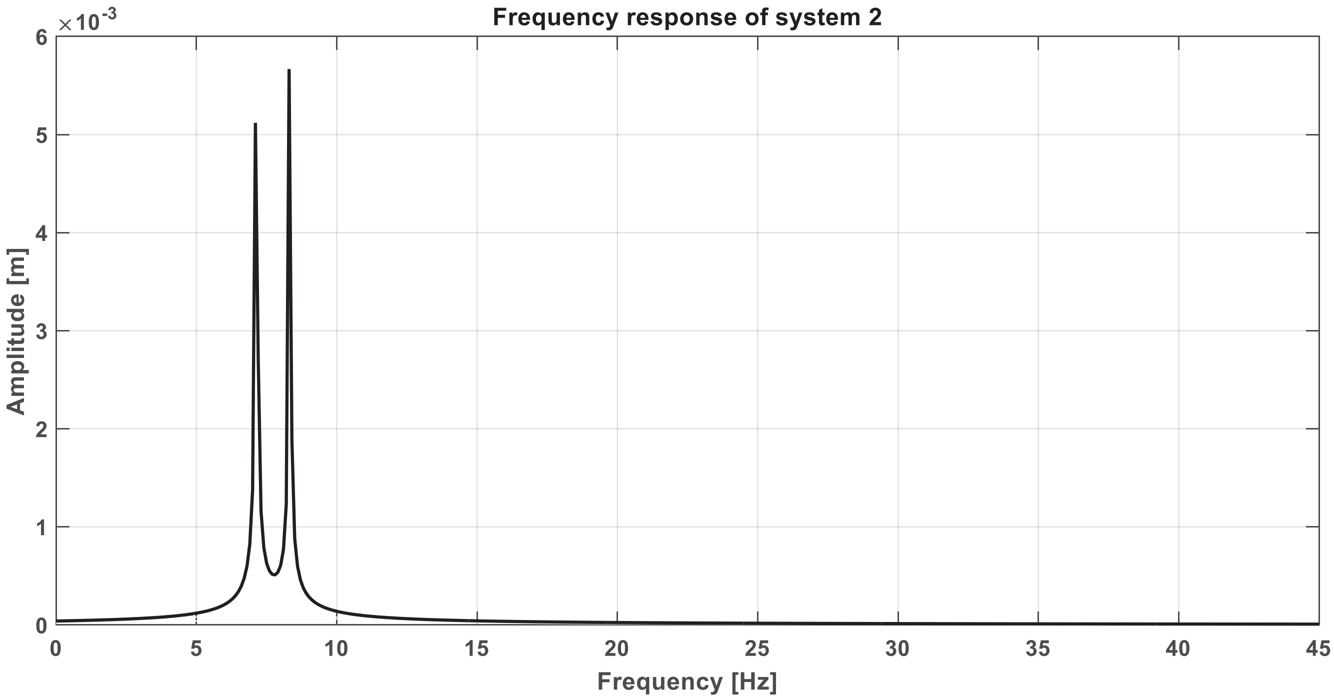

Figure 8.
Simulation spectra of frequency response for system No. 2.

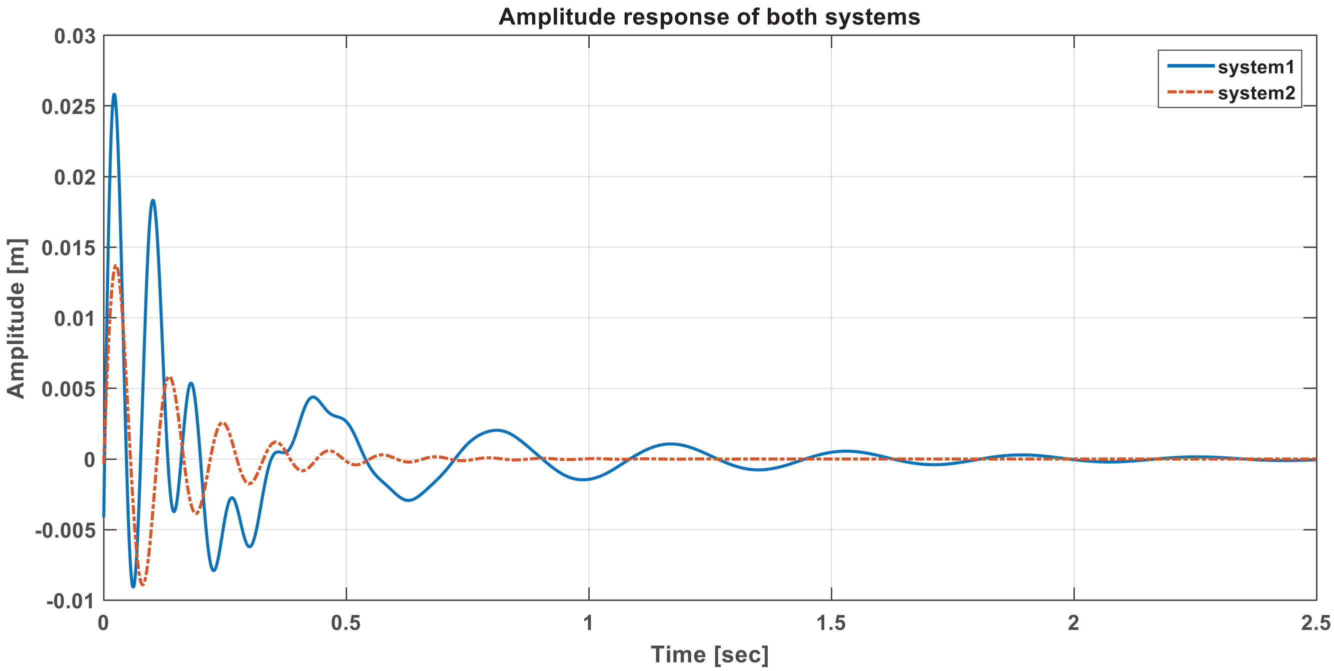

Figure 9.
Simulation of time waveform of displacement for both systems.

The purpose of these tests will be the performance of passive experiments on a small shock machine to determine the damping and stiffness values at high-speed changing load. Genset operating conditions on minehunters require further simulations with both harmonic and pulse loads.

6. CONCLUSIONS

The presented research outcomes are the result of the first work package, as part of the project researching the issue of shock resistant foundation of naval machinery. The preliminary tests with a simulated load in the form of Dirac's pulse were carried out on the current package. The next step is the calculation of the unambiguous Laplace transform for the model presented in Figure 2 and the simulation of the response of both systems under simultaneous harmonic and pulse loads.

The simplifications adopted in the paper, including the empirical determination of damper damping and stiffness values, will be developed in the next work package as construction-material models.

The obtained results are satisfactory and, as expected, correspond to the value of a real system's response.

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Seafarer Market – Challenges for the Future

Zvonimir Lušić, Mario Bakota, Mirko Čorić, Ivica Skoko

In today's seafarer market, one of the key problems is the lack of seafarers, especially experienced officers. Although the global supply of officers is increasing steadily, the demand is still higher than the supply. An additional problem is that an increased demand may lead to a decreased quality of education. Ships and shipping technology in general have become more advanced and require well educated and trained personnel. In addition, over the next several decades it is expected that partially or fully autonomous vessels will be in commercial use, and this will require significant changes in the education and training of crew members. So, regarding the education of seafarers, the main future challenges include the ways of ensuring sufficient supply of seafarers, especially well-trained officers, and adapting the education systems for the upcoming introduction of autonomous ships. This paper analyzes the present situation of the seafarers and shipping market, and provides forecast for the near future. Also, the main challenges in the education and training of seafarers will refer to observing the recommendations for improvement and adaptation to future demands.

KEY WORDS

~ Seafarers
~ Vessels
~ Ship officers
~ Education and training
~ Autonomous ships

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1. INTRODUCTION

Minimum knowledge, familiarization and skills required for obtaining specific certificates of competence on board merchant sea-going ships have been laid down by the International convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW). The last significant amendments to this Convention were introduced in 2010 and entered into effect on 1 January, 2012 (STCW 2010 Manila Amendments). These have been the first major changes since 1995. However, although substantial new competence requirements related to leadership, teamwork, and managerial skills for deck and engine officers were added, the amendments have not yielded spectacular effects. As a whole, STCW remains a set of minimum knowledge and skill requirements which individual states, i.e. their administrations, use as a reference framework for granting relevant certificates, and their education institutions as a groundwork for creating curricula and syllabi. Generally speaking, STCW is a useful and necessary prerequisite for the standardization of knowledge and skill acquisition, but its content remains too general and allows education institutions for arbitrary interpretations of the guidelines. In addition to the general sections and the ones dealing with more specific aspects, the STCW Convention provides tabular specification of minimum standards of competence, e.g. Competence, Knowledge, Understanding and Proficiency, Methods for demonstrating competence, and Criteria for evaluating competence (STCW, 2017). Given the fact that the STCW does not define executive curricula, many education institutions and training centers rely on additional recommendations and model courses provided by the International Maritime Organization (IMO): IMO Model Course 7.01 (unlimited) for future Masters and Chief Mates, IMO Model Course 7.03 (unlimited) for future Chief Engineer Officers and Second Engineer Officers, etc. However, both the STCW guidelines and IMO Model Courses change very slowly and it is clear that their specifications of standards have not been efficiently following modern trends and demands in the maritime transport. This is proved, for instance, by the numerous non-STCW training courses that the seafarers at various shipping companies have to attend. When all these issues are considered within the context of maritime staff shortage, where many employers tend to fill position gaps as soon as possible, it seems that the degradation of quality is inevitable. This forecast is additionally supported by the trend of shortening formal periods of education and training in certain countries, and outsourcing of the education processes from the higher education institutions. On the other hand, methods and technologies related to maritime shipping have been developing very fast, thus presenting new challenges and requirements to the seafarers, particularly seafaring officers. These requirements are much higher than the minimum requirements as described by the current international regulations. Moreover, it is expected that the following decades will experience a gradual introduction of autonomous vessels and other technologies that would significantly change the ways the ships are managed and handled at sea. It is therefore necessary to start adjusting the education and training systems to be able to cope with the impending challenges in a timely and efficient manner.

2. WORLD MERCHANT FLEET AND WORLD TRADE

The world merchant fleet has been growing steadily over the past few decades. In 2017, the world fleet reached 93,161[1] vessels (of which around 50,155 above 1,000 GT), with 1.9 billion dwt, twice the size it had 12 years ago (Figure 1). Today, bulk carriers account for 43 % of the fleet, followed by oil tankers (29 %) and container ships (13 %). LNG and other gas carriers recorded continued high growth (9.7 %). Growth was also experienced in other trades: oil tankers (5.8 %), chemical tankers (4.7 %), and container ships (0.5 %). By contrast, a long-term decline has continued in the general cargo segment, which experienced a fall by 0.2 %; its share in the world's tonnage is currently 4 %, down from 17 % in 1980 (UNCTAD- Review of Maritime Transport, 2017).

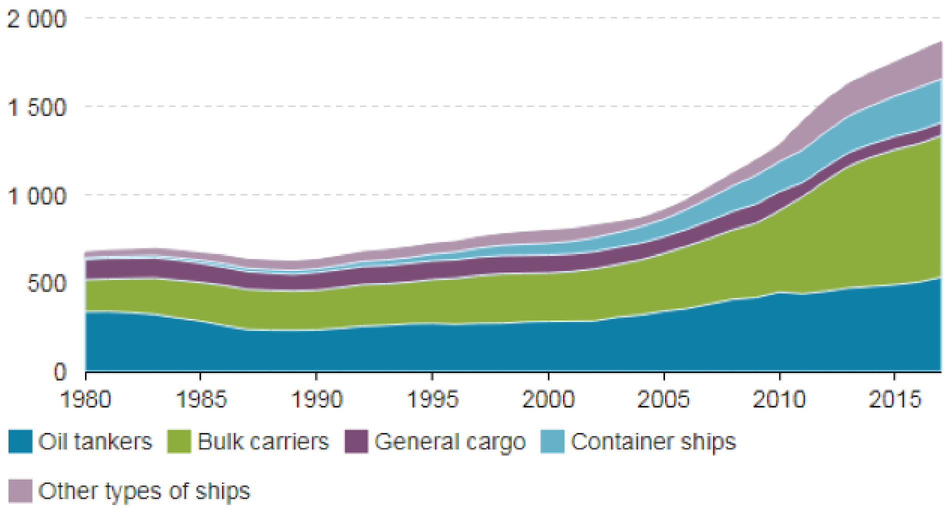

Figure 1.
World fleet by principal vessel type (mill. of dwt) (e-handbook of statistics-Merchant fleet, 2017).

When taking into consideration the overall number of merchant vessels, general cargo ships are ranked as the most common type of vessel in the global merchant fleet (18 %), followed by tankers (15 %), and bulk carriers (13 %) (Table 1) (Equasis Statistics, 2016). If we take into account the vessels above 1,000 GT, general cargo ships are ranked first, accounting for about a third of the fleet, followed by bulk carriers, crude oil tankers, and container ships (Statista-The Statistics Portal, 2018).

At the end of 2016, the top five ship owners included Greece, Japan, China, Germany, and Singapore. Together these ship owners had a market share of 50 % in dwt. The top five flag registries were Panama, Liberia, the Marshall Islands, Hong Kong SAR, and Singapore. It is worth noting that in 2016, 92 % of world tonnage was built by only three economies, namely the Republic of Korea, China, and Japan (UNCTAD- Review of Maritime Transport, 2017).

1. *Propelled seagoing merchant vessels of 100 gross tons and above.*

Table 1.
World fleet – total number of ships, by type and size (Equasis Statistics, 2016).

Ship Type	Small[(1)]		Medium[(2)]		Large[(3)]		Very Large[(4)]		Total	
General Cargo Ship	4,374	13.1 %	11,830	30.3 %	229	2.0 %			16,433	18.3 %
Specialized Cargo Ships	8		225	0.6 %	64	0.6 %	4	0.1 %	301	0.3 %
Container Ships	18	0.1 %	2,253	5.8 %	1,507	13.0 %	1,329	22.9 %	5,107	5.7 %
Ro-Ro Cargo Ships	31	0.1 %	641	1.6 %	592	5.1 %	223	3.8 %	1,487	1.7 %
Bulk Carriers	309	0.9 %	3,792	9.7 %	5,830	50.2 %	1,683	28.9 %	11,614	12.9 %
Oil and Chem. Tankers	1,902	5.7 %	6,912	17.7 %	2,629	22.6 %	1,779	30.6 %	13,222	14.7 %
Gas Tankers	38	0.1 %	1,126	2.9 %	337	2.9 %	420	7.2 %	1,921	2.1 %
Other Tankers	364	1.1 %	605	1.6 %	9	0.1 %			978	1.1 %
Passenger Ships	3,894	11.7 %	2,674	6.9 %	272	2.3 %	171	2.9 %	7,011	7.8 %
Offshore Vessels	2,685	8.0 %	5,402	13.8 %	120	1.0 %	201	3.5 %	8,408	9.4 %
Service Ships	2,537	7.6 %	2,554	6.5 %	26	0.2 %	6	0.1 %	5,123	5.7 %
Tugs	17,196	51.6 %	1,003	2.6 %					18,199	20.3 %
Total	**33,356**	100 %	**39,017**	100 %	**11,615**	100 %	**5,816**	100 %	**89,804**	100 %

[(1)]GT<500; [(2)]500≤GT<25,000; [(3)]25,000≤GT<60,000; [(4)]GT≥60,000

Figure 2 shows the change in the number of vessels for the three main types: tanker, bulk carrier, and container/multipurpose ship over the period 2000-2016. It is likely that the tendency of growth will continue.

It is expected that the number of vessels will increase even further in the years to come, given the forecasts of the world economy growth and, consequently, the increasing amount of goods handled by maritime shipping.

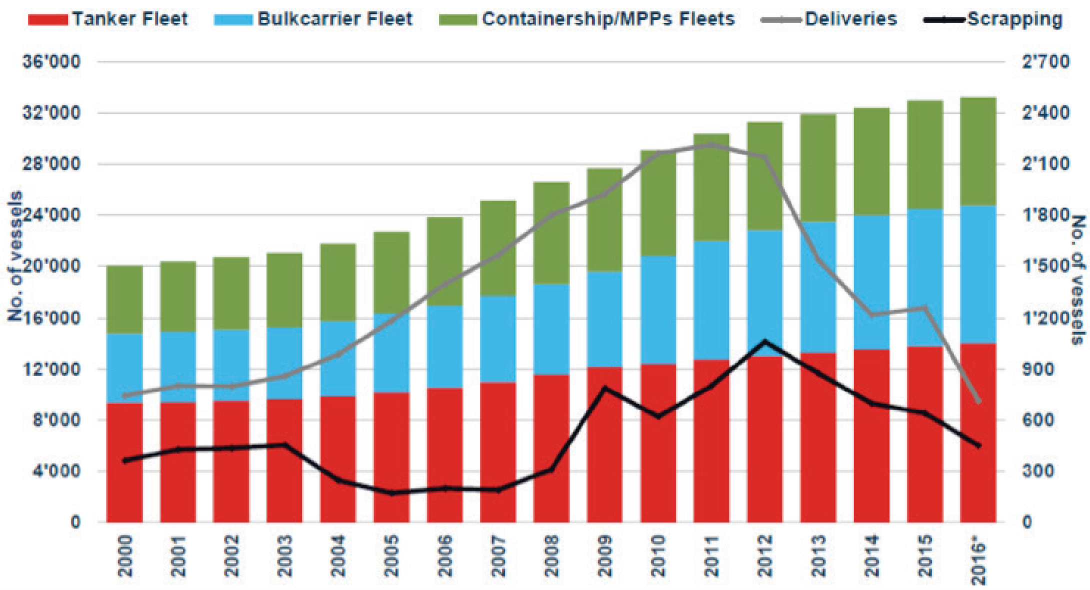

Figure 2.
Tanker, bulk carrier, container ship and multipurpose fleet (Kern Ferretti, 2016) (all vessels above 100 GT).

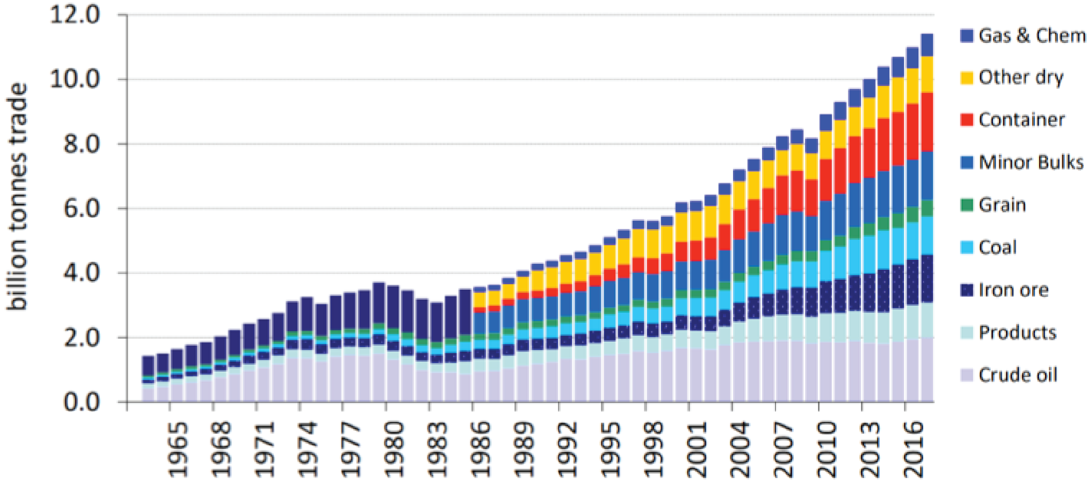

Figure 3.
Seaborne trade by commodity [Stopford, 2018].

The total volume of the seaborne trade reached 10.3 billion tons in 2016. Forecasts for the following mid-term periods indicate a continued expansion, with volumes growing at an estimated compound annual rate of 3.2 % between 2017 and 2022 (UNCTAD-Review of Maritime Transport, 2017) or 1.8 % until 2035 (Sea Europe, 2017). In the year 2017, the world industry was growing at the rate of 4.3 %, the trade increased up to 3.9 %, and the merchant fleet increased by 3.5 % (Stopford, 2018). While experiencing a slightly slower growth rate compared to the longer-term historical average, the global sea-borne trade is forecast to rise to an excess of 15,000 million tons in 2035 (Sea Europe, 2017). Figure 3 shows the sea-borne trade from 1965 to 2017, while Figure 4 presents a forecast of the sea-borne trade until 2066 (between 16 and 46 billion tons) (Stopford, 2017).

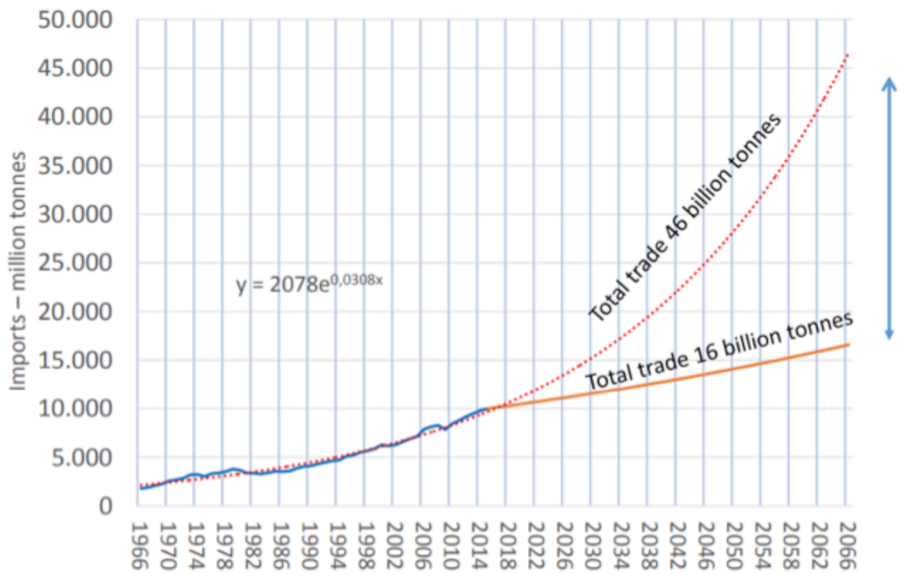

Figure 4.
World seaborne trade [Stopford, 2017].

The DNV-GL analysis forecasts that trade measured as tonne miles will experience 2.2 % annual growth over the period 2015-2030 and 0.6 % per year thereafter. The merchant fleet will grow somewhat more slowly than trade, but the crude oil fleet will start to decline after 2030, also the bulk fleet but after 2035. An assumption is that a better utilisiation of ships and larger ships will reduce the deadweight tonnage needed. The average size of deep sea vessels will rise 40 % for LNG tankers, 30 % for containers and other cargo, and 10 % for bulkers (Maritime Forecast to 2050, 2017). Most authors predict positive trends in the maritime transport, but there are threats that can disrupt these projections. At present, the greatest threats arise from potential trade wars and national protectionism (UNCTAD/press/pr/2018/030, 2018); however, there is always a risk of the emergence of large scale war conflicts, large natural disaster, changes in the global political scene, etc.

3. GLOBAL SUPPLY OF SEAFARERS

The global supply of seafarers in 2015 was estimated at 1,647,500 of which 774,000 were officers and 873,500 were ratings. This represents an increase of about 66 % in officers and about 21 % in ratings over the last ten years (see Table 2) (BIMCO, 2015). At sea, 1 per cent of seafarers are women (UNCTAD-Review of Maritime Transport, 2017).

Table 2.
Estimated supply of seafarers (BIMCO, 2015).

Rank	2005	2010	2015
Officers	466,000	624,000	774,000
Ratings	721,000	747,000	873,500
Total	1,187,000	1,371,000	1,647,500

Five countries with the largest number of seafarers are listed in Table 3. Ten years ago the major seafarer supply countries for officers where the Philippines (12 %), China (9 %), and Russia (5 %), while most of ratings came from the Philippines (22 %), Indonesia (8 %), and China (6 %) (Galić et al, 2012). Today, China is thought to have overtaken the Philippines as the largest single source of seafarers.

Table 3.
Estimated five largest seafarer supply countries (BIMCO, 2015).

	For all seafarers	officers	Ratings
1	China	China	Philippines
2	Philippines	Philippines	China
3	Indonesia	India	Indonesia
4	Russian Federation	Indonesia	Russian Federation
5	Ukraine	Russian Federation	Ukraine

The global demand for seafarers in 2015 was estimated at 1,545,000 seafarers, including approximately 790,500 officers and 754,500 ratings (Table 4).

In 2015, the global shortage of officers was estimated at 16,500 (2.1 %), while the total number of ratings was in surplus of 119,000 (15.8 %), resulting in the total number of extra seafarers of 102,500 (BIMCO, 2015). An especially pronounced shortage referred to engineer officers at management level and officers needed for specialized ships such as chemical, LNG and LPG carriers (World Maritime News, 2016).

The 2015 report completed by the Baltic and International Maritime Council (BIMCO) indicates that the world merchant fleet will grow over the next ten years and the anticipated demand for seafarers will likely continue, as will the trend of an overall shortage in the supply of seafaring officers. It has been forecast that additional 147,500 officers will be required by 2025 to serve the world merchant fleet (Table 5). Unless seafarer training capacities are increased significantly, the growing demand for seafarers could generate a serious shortage in the total supply of officers. This can be prevented only through continuing efforts in promoting careers at sea and by improving levels of recruitment and retention (Safety4Sea, 2018).

Table 4.
Estimated global demand for seafarers (BIMCO, 2015).

Rank	2005	2010	2015
Officers	476,000	637,000	790,500
Ratings	586,000	747,000	754,500
Total	1,062,000	1,384,000	1,545,000

Table 5.
Estimated supply-demand balance for officers (BIMCO, 2015).

	2015	2020	2025
Supply	774,000	789,500	805,000
Demand	790,500	881,500	952,500
Shortage/Surplus	-16,500	-92,000	-147,500
%	2.1 %	11.7 %	18.3 %

4. SHIPPING TECHNOLOGY DEVELOPMENT AND AVERAGE CREW SIZE

When observing the development of the shipping industry over the last several decades, it can be noticed that the world merchant fleet has been growing steadily, with the average size and number of ships getting bigger and bigger. Recently, the growth has been particularly generated by the increasing capacities of container ships whose average size (in dwt) increased by 90 % through the period 1999-2015. For the sake of comparison, the average size of bulk carriers increased by 55 % over the same period, while the tanker size increased by 21 %. Ro-ro and passenger ships did not experience significant changes in size, whereas the size of general cargo ships decreased (Figure 5) (International Transport Forum, 2015).

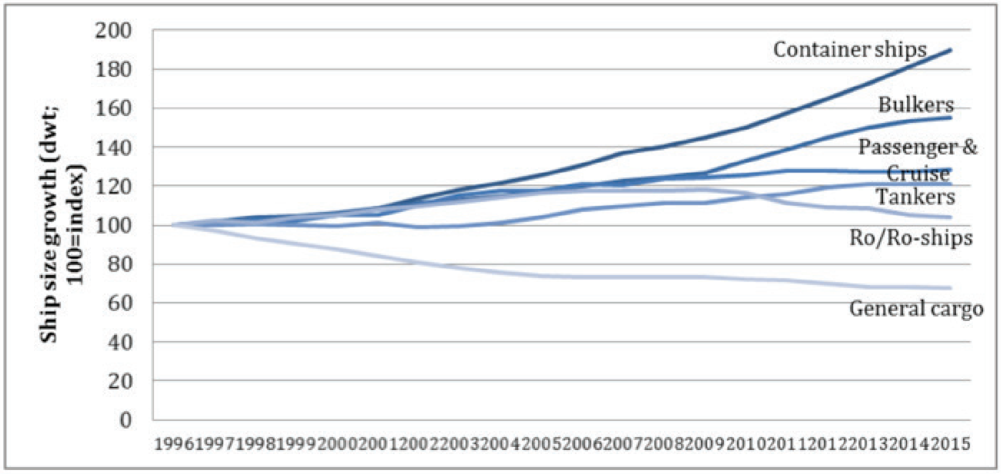

Figure 5.
Ship size development of various ship types 1996-2015 (International Transport Forum, 2015).

When discussing the containerization phenomenon, it should be noted that it took 30 years for the average size to grow to 1,500 TEU, and then only 10 years to reach 3,000 TEU. In 2015, the average new-build size was around 8,000 TEU, while today's largest container ships have a capacity of over 21,000 TEU (around 200,000 dwt and 400 m in length) (International Transport Forum, 2015). The trend of increased ship capacities can be justified by a simple fact that the increase in ship size reduces the average freight rates per cargo unit. However, the size of ships has not been accompanied by the crew size; on the contrary, the manpower has been decreasing so that fewer crew members operate vessels that get ever larger. A long time ago, an average crew size amounted to 40-50 members, while today even the largest ships carry about 20-25 crew members on the average (Berg et al., 2013). For instance, the minimum manning requirements for operating the largest container ships (200,000 dwt) amount to only 13 crew members, i.e. 19 crew members for operations under normal conditions (Martin, 2011). Although the crew size is greatly affected by the ship size, the essential factor remains the type of the vessel. Figure 6 presents average crew sizes for various tanker sizes.

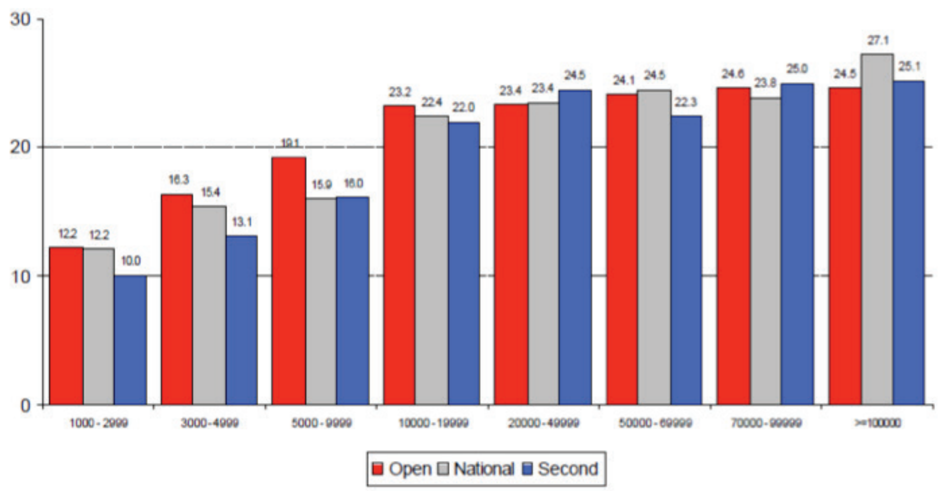

Figure 6.
Mean number of crew (tankers) (Winchester et al., 2006) (Open Registers Flag, National Registers Flag, Second Registers Flag).

As the operation costs are directly affected by the size of the onboard personnel, a further reduction in crew size can be expected. A rapid development of technologies is likely to facilitate the process. Here is a short list of several innovations that considerably affected ship management and crew reduction in the second half of the 20th century (King, 2000):

- introduction of the autopilot enabled the potential crew reduction of one and a half able seamen,
- introduction of radar was not accompanied by any decrease in manpower, but undoubtedly contributed to a more efficient surveillance and collision avoidance,
- remote monitoring and control of the main engine resulted in the development of the unmanned machinery space operation,
- reorganization and redefinition of work at sea,
- introduction of the Global Maritime Distress and Safety System (GMDSS) made the service of the Radio Officer redundant on board ships,
- satellite and communications systems, Electronic Chart Display and Information System (ECDIS), Integrated Bridge Systems, surveillance and monitoring systems, etc., indirectly affected the number of deck officers,
- communications technology brought the ship into direct contact with people on shore, so that it could no longer be regarded as a completely independent unit as it used to be,
- highly automated systems, etc.

The size of the ocean-going cargo ship crews has been decreasing steadily over the past 250 years (~1860: 250 men; ~1880: 140 men; ~1900: 100 men; ~1950: 40 men (diesel propulsion); ~2000: 16 men (container ship); ~???: 0 men [Bertram, 2013].

In addition to the reduced manning over the past 30 years, there have also been essential changes in the role of the ship crews. For instance, cargo handling has been reduced to monitoring loading/unloading operations; hold washing has become impossible without shore crew assistance; shore-based personnel is occasionally also required for major repairs; maintenance work has been reduced to basic tasks; complex navigation tasks are completed by pressing a button; the master's role is changing due to the fact that ships are no longer independent units that are isolated from the rest of the world, etc.

Nowadays we can see various investments around the world which may totally transform shipping business. Technologies that could shake the maritime industry and have already been here for some time include artificial intelligence, Internet of Things (IoT), Augmented reality (AR), Virtual reality (VR), Drones, Robotics, Cyborg crew, Autonomous vessels, etc. [Wingrove, 2018]. One of the special technological novelties is the autonomous ship, i.e. autonomous surface vessel. Building of such vessels will present a revolution in shipping, although their use will be initially limited to short sea shipping. In 2018, Lloyd's Register (LR), along with QinetiQ and the University of Southampton, released The Global Marine Technology Trends 2030 report (GMTT 2030) (Global Marine Technology Trends 2030, 2015). The GMTT 2030 identifies two main areas of change: one will transform ship design and building, the other will impact safety, commercial, and operational performance. The GMTT 2030 also focuses on 18 specific technologies that will potentially transform the shipping industry: robotics, sensors, big data analytics, propulsion and powering, advanced materials, smart ship, autonomous systems, advanced manufacturing, sustainable energy generation, shipbuilding, carbon capture and storage, energy management, cyber and electronic warfare, marine biotechnology, human–computer interaction, deep ocean mining, human augmentation, and communication.

Given all these efforts and possibilities to reduce the number of crews on ships. it is difficult to believe that the shortage of seafarers will increase in the years to come. As mentioned before, BIMCO predicts shortage in the total supply of officers of 18 % for the year 2025. These numbers can be justified by the positive trends of maritime transport, the forecast growth in the world merchant fleet as well as the slow introduction of highly sophisticated vessels, i.e. autonomous vessels. Prediction is that the merchant fleet will reduce its growth, or even begin to decline (in some sectors) somewhere between 2030 and 2035 (Maritime Forecast to 2050, 2017). Regarding autonomous vessels, about the year 2025 the first commercial remote-controlled unmanned coastal vessels are expected, about 2030 remote controlled unmanned ocean-going ships, and about 2035 autonomous unamanned ocean-going ships (Rolls-Royce-Autonomous ships, 2016). Also, autonomous ships will eventually reduce the jobs on board but will increase the number of 'crew' on shore in the supporting functions. By 2025, in a very optimistic scenario, some 1,000 ships will be fully autonomous and some further 2,000 vessels semi-autonomous; this may possibly reduce the demand for seafarers only by 30,000 – 50,000. However, at the same time the need for highly skilled remote-operators, pilots of a new kind, and "special crews" will be needed to keep these ships operational [Seafarers and digital disruption, 2018]. According to all of the above, a lack of seafarers, especially experienced officers, at least in the next decade is imminent.

5. EDUCATION OF SEAFARERS

In the past, a seafarer's career usually started at sea, where people were sent to work on board ships at a very early age. Over time, the development of different ships, specialization of ships, technological advances, etc. resulted in the demand for a higher level of education and training. Nautical education started to be provided at schools on shore, combined with the onboard training. One of the most important steps in the development of the seafarer's education system was the adoption of the International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers. The shipping market is inherently international by nature and cannot reach its full potential without effective onboard personnel. The STCW Convention has set minimum qualification standards for masters, officers, and watch personnel on seagoing merchant ships. The Convention was adopted at the International Maritime Organization (IMO) conference in London in 1978 and entered into force in 1984. It was significantly amended in 1995 and 2010. This was the first convention to establish the minimum basic requirements on training, certification, and watchkeeping for seafarers at a global level. Before that, the minimum standards of training, certification, and watchkeeping of officers and ratings had been established by individual governments, usually without reference to practices in other countries, which caused large differences in the minimum standards and procedures as well as discrepancies in the process of certification in general.

5.1. The Existing Problems and Challenges

Although the STCW Convention defines the minimum levels of knowledge and skills required for specific qualifications, national and international education systems have not been harmonized in terms of learning contents, ways the curricula have been designed and performed, and the time required for acquiring specific qualifications. Generally speaking, education systems can be divided into two categories: the traditional education system combines theory and learning through practice, while the other form of education is performed through formal national education systems (gradient system and university system) (Ćorović et al, 2012). The traditional system consists of several stages which individually last 2 or 3 months, while the whole system takes between 5 and 7 years to complete.

This system is typical for Asian and African countries, but it is also under way in some West European countries (e.g. the UK). A gradient system usually includes formal education over 3 to 4 years and navigational practice lasting from 6 to 12 months, after which the candidate acquires a BSc degree (Bachelor of Science) and the STCW Certificate Officer of the Watch (Deck/Engine). For obtaining the Chief Officer / Master license, additional education is required. It usually takes 2 to 4 years at the university (master degree study). However, some countries also recognize special courses in duration of approximately 3 to 6 months, without formal education degree. If the above discrepancies are transferred into man-hours, it results that the total time of a ship master formal education, not including primary education, may vary from 1,500 hours [Model Course 7.03 & 7.01, 2014] to 7,000 hours (4 years of secondary school + 4 years of university). These values are incomparable. It is rightfully expected that a more formal (gradient) type of education will produce a far better quality of personnel. This quality is particularly reflected in increased abilities to acquire new knowledge and to adapt to new technologies over the entire working life. Potential problems may occur if the education is performed under inadequate conditions, i.e. with poor material, technical, and teaching support or if an attendant leaves the system at an older age and without onboard practice. More man-hours spent in education, i.e. more extensive curricula, imply that the future seafarers may attend a variety of courses that extend beyond minimum requirements as described by the international regulations. As every national administration is free to design education programs, the acquired competences inevitably vary among countries and institutions.

Table 6.
Years of education for a maritime officer degree in some countries.
Source: (Berg et al, 2013); for Croatia – the authors

	Level of education		
Country	**Compulsory**	**Maritime**	**Total**
China	12	1.5-2	13-14
The Philippines	10	4-5	14-15
Finland	9	7 (3+4) Vocational lower maritime + officer programs	16
The Netherlands	12-14	1-4 years of vocational training for lower ranks 3-5 years of university / polytechnic	13-19
Croatia	8	4 (for lower ranks) + 0.5 vocational course or 3 years of university	12.5-15
	12	3-5 years university	15-17

Another major issue that the seafarer market has been coping with is the corruption and issuance of counterfeit certificates. Some shipping companies require additional compulsory training for the seafarers arriving from the countries that are not efficient in dealing with the above problems (Berg et al., 2013).

Finally, it should be emphasized that the two main global challenges the seafarers' profession faces today and will continue to face in the future even more profoundly are the shortage of skilled seafarers and prediction of future skill needs due to digitization and automation. These days it is evident that the workforce shortage directly affects the ways of maritime officer education as there is a trend to produce as many officers as possible within the shortest possible education time-frame. In some countries, there is a tendency to switch from the gradient system to the training system, to reduce the minimum time-frame within the gradient system, or to abandon the university level altogether. This approach may result in a lower quality of maritime personnel, particularly in terms of their ability to adjust to cutting-edge technologies. Some analyses indicate that the seafarer market does not lack seafaring personnel, but it does lack high-quality seafaring personnel. It is expected that 1 out of 12 seafarers completes STCW tests with just 40 % achievement (IHS Markit-The maritime world, 2017). The problem is even more serious when those who fail the tests eventually find employment at other companies, i.e. shipping companies that have no other choice.

The application of new technologies in maritime shipping industry should be observed in two ways. On the one hand, the new solutions make work easier or even eliminate the need of performing routine chores, thus making some of the traditional skills redundant. On the other, new technologies require new knowledge and additional competences in operating complex systems and devices, processing of large amounts of data, developing new communication skills, and responding fast to new solutions and regulations. Moreover, one cannot overlook the sociological aspects, familiarization with new environments and acting within complex relationships between man and man, and man and machine. Some of the expected specific education features in digital maritime industries include (Nguyen, 2018):

- simulator-based and computer-based training,
- use of 3D simulation and gamification, which also allow seafarers to train and practice on board,
- training that is absolutely tailored to the individual needs,
- training provided for the seafarers should be, to a certain extent, similar to the training provided for nearly all other technical industries, in particular STEM competences (science, technology, engineering and math),
- advance knowledge in leadership and managing people, associated with management in the sector,
- preparing the young for the life at sea,
- education of personnel who will control future autonomous ships and their driving systems, whether from on board or remotely, whether as deck officers, marine engineers, or electro-technicians.

Education systems will have to respond to these challenges by producing the workforce with adequate competences and capacities to meet further training needs. Taking into consideration the existing education systems that are implemented globally as well as the very nature of onboard work that implies life-long learning, it is clear that some of the seafarers will turn out to be under-qualified while others will become over-qualified, and that the higher-quality workforce will gravitate towards "better" companies, i.e. the companies offering better salaries and working conditions. Once a good seafarer enters the payroll, however, the question will be how to keep him or her and how to maintain his or her loyalty and commitment.

5.2. Education System for Partly or Fully Autonomous Ships

The introduction of Maritime Autonomous Surface Ships (MASS) and, in particular, those which are fully autonomous, presents a huge challenge to all the parties engaged in the future education of officers. MASS is defined "as a ship which, to a varying degree, can operate independently of human interaction." The degrees of autonomy of MASS are organized (non-hierarchically) as follows (IMO MSC 99, 2018):

- Ship with automated processes and decision support: Seafarers are on board to operate and control shipboard systems and functions. Some operations may be automated.
- Remotely controlled ship with seafarers on board: The ship is controlled and operated from another location, but seafarers are on board.
- Remotely controlled ship without seafarers on board: The ship is controlled and operated from another location. There are no seafarers on board.
- Fully autonomous ship: The operating system of the ship is able to make decisions and take actions by itself.

Automated ships will be commanded from a shore operating center, where shore masters (or MASS operators) will be monitoring and controlling their navigation and performance through detectors, sensors, cameras and advanced communication systems. The first question concerns the source of the future operators of fully autonomous vessels. Will they be requalified deck or engine officers holding the highest seafaring ranks, graduate technical or information engineers who will run through supplementary requalification in line with STCW requirements, or people holding adequate professional degrees who will complete specialized formal training for autonomous ship management (Figure 7). Similarly to unmanned aerial vehicles, the best way of educating the required personnel is perhaps within specialized university studies designed for this purpose. However, such studies are in their early beginnings and will require an appropriate time for realization. Accordingly, it may be expected that the operators of the first autonomous vessels will be the existing onboard officers, i.e. experienced masters, who will have to complete adequate training programs. However, recruitment can also be feasible from the staff primarily specialized in remote control processes and who have completed adequate STCW programs.

The MASS vessels will be controlled by ship masters, shore masters, and MASS operators, depending on the degree of vessel autonomy (Figure 8). Given the possible variants of future autonomous, semi-autonomous, and remotely controlled vessels, it will be a great challenge to design education programs covering the needs and requirements of the future MASS operators. In addition to minimal STCW competences, future MASS operators will have to acquire specific competences, i.e. knowledge and skills in a variety of fields, including computer science, robotics, communication theory and skills, legislation, math, and science in general.

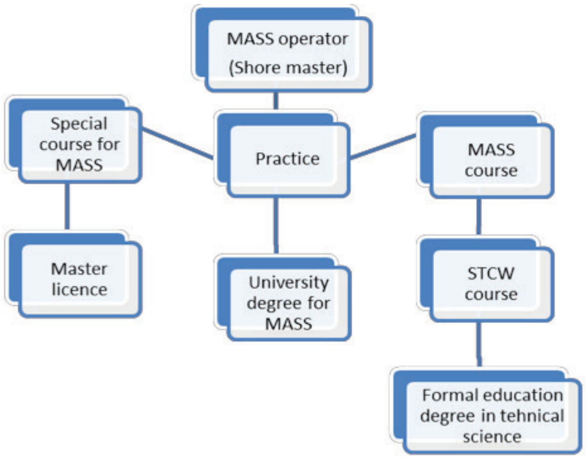

Figure 7.
Training process of the operator for the fully autonomous ship.

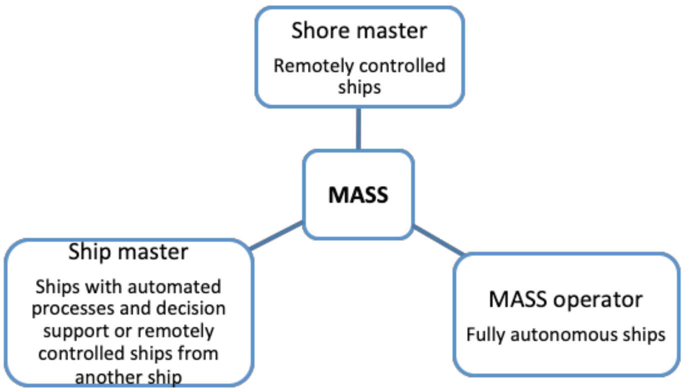

Figure 8.
MASS operators in a Shore/Ship Control Centre.

6. CONCLUSION

It is expected that the demand for maritime shipping and seafaring personnel will continue to grow in the near future. For some years now, the global market has been experiencing a lack of seafaring officers, and it is forecast that the shortage will be even more pronounced in the years to come. The increased demand for onboard officers is likely to result in a lower quality of work performance as the future officers will not be able to deal with constant technical and technological developments. Although the STCW Convention provides a standardized framework for the education and training of seafarers, the relevant schools and centers have diverse approaches to designing and performing the teaching and learning processes. The minimum knowledge and skills required for specific qualifications have been clearly defined, but the differences and problems arise from the non-standardized periods of schooling, education within or out of higher education institutions, various ways of performing the required practice, different human and material resources that are available at educational institutions, corruption, etc. By all means, a formal education system at a higher education institution is preferable and has more advantages over other systems, provided that adequate human, material, and technical resources are available.

The development of science and technology has significantly changed the features of seafaring: directly, through making certain tasks easier and through replacing human workforce by automated systems and indirectly, through the development of communication systems that have changed the relationships between the master and the crew, and between the onboard personnel and their principals ashore. As a consequence, the size of the crew has been continuously reduced, and the trends may eventually result in unmanned automated vessels. However, this is surely not going to happen in the next decade; most analyses forecast shortage of seafarers in this period, especially of experienced officers.

Education institutions have been recently facing difficult challenges. As the demand for onboard officers is growing, it is expected that efforts will be made to produce the maximum seafaring personnel while maintaining the level of quality or even enhancing it, given the development of new technologies and the modern market demands. A particular focus should be on the education and training for the future work on (or with) the highly sophisticated vessels, including autonomous vessels.

Although the use of the autonomous vessels in the first phase will be limited in many ways, education system should respond in time. In order to timely respond to the new challenges, maritime education and training centers have to develop adequate curricula and syllabi, and start implementing them as soon as possible, according to the market requirements.

The tasks and duties onboard ships related to ship operations are very complex and prone to constant changes. Accordingly, they require constant and life-long learning and requalification. Educational and training institutions, together with the companies employing seafarers, must constantly invest into supplementary training of the crew members, and create long-term plans and strategies in order to ensure sufficient high-quality workforce on the seafarer market, particularly at the management level.

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Friction Stir Welding for Marine Applications: Mechanical Behaviour and Microstructural Characteristics of Al-Mg-Si-Cu Plates

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Friction stir welding is a multipurpose solid-state joining process mainly used for aluminium and steel plates and frames. Friction stir welded non-ferrous metallic alloys, similar or dissimilar, in particular aluminium alloys, provide opportunities for the improvement and developement of new product designs. This paper investigates the correlation between the mechanical behaviour and morphological structures of friction stir welded Al-Mg-Si(Cu) alloy plates in two temper conditions. Micro Vickers hardness and tensile tests were carried out. Additionally, morphology was investigated using optical microscopy and scanning electron microscopy. Samples subjected to the post weld heat treatment were shown to have the best properties owing to the formation of a significant number of hardening particles which, added to the nugget grain refinement, resulted in the increase of the material strength.

KEY WORDS
~ Friction stir welding
~ Al-Mg-Si-Cu alloy
~ Shipbuilding
~ Solid-state welding

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1. INTRODUCTION

After two decades of research and collection of data on friction stir welding (FSW), the technological progress achieved in the area can be logically and fairly said to prove the reliability of the FSW, especially when it comes to aluminium alloys.

As a solid-state welding process, FSW causes less distortion and changes in metallurgical and mechanical properties compared to conventional fusion processes (Mishra and Ma, 2005; Mishra, Partha and Kumar, 2014). The transversal tool movement produces an intricate material flow pattern, which varies depending on the following parameters: tool geometry and workpiece penetration, heat flow, tilt angle, rotational and transverse speed (Chao et al., 2003; Galvão et al., 2010; Leal et al., 2008; Sun et al., 2013; Velichko et al., 2016).

Post-welding aging treatments tend to increase microhardness in the weld zone. However, in some circumstances they may also increase or decrease elongation, yield and tensile strength, as well as the fatigue crack propagation rate (Cerri and Leo, 2013; Malopheyev, S. et al., 2016; Mishra, Partha and Kumar, 2014).

The research on the FSW process and its weldable alloys focuses on a wide range of structures. Typical uses are from window frames to heavily loaded structures, like airframes, aerospace parts, oil and gas tanks, wagons and for automotive purposes, as well as different types of ships and ship parts (Chen et al., 2009; Engler and Hirsch, 2002; Johnson and Threadgill, 2003; Mendes et al., 2016). The FSW process results in high quality welds, with virtually no solidification cracking, porosity, oxidation and other defects commonly found in fusion welding processes (Chao et al., 2003; Chen et al., 2009). Due to its energy efficiency, environment friendliness and versatility, the FSW process is considered a "green" and efficient technology. The FSW process therefore uses a non-consumable tool; no cover gas or flux is used, thus making the process environmentally friendly (Mishra and Ma, 2005; Thomas, 1998).

Friction stir welds of polymers, mild steel, non-ferrous metallic alloys, similar or dissimilar, in particular aluminium alloys, provide opportunities for the improvement and development of new product designs. In this type of welding, residual stresses, field distribution and crack propagation require a carefully thought-out tool design (Fratini and Pasta, 2012; Kallee et al., 2001), particularly in case of complex joints such as lap, overlap welds, T-sections and corner welds and welding positions like overhead and orbital, which are included in the project (ISO 25239-2:2011, 2011; Kallee et al., 2001; Thomas, 1998).

Aluminium alloys are suitable for friction stir welding process due to their relatively low solid-state welding temperature – approximately 80 % of Al melting point (660°C) (Callister, 2013; Hatch, 1984; Mishra, Partha and Kumar, 2014). Al alloys are likewise suitable for FSW processes due to their corrosion resistance (due to the formation of an adherent thin film of Al2O3) and low mass density (Al-Jarrah et al., 2014, Callister, 2013; Mishra, Partha and Kumar, 2014; Vargel, 2004).

The purpose of this paper is to analyse the mechanical behaviour and the microstructure of Al-Mg-Si-Cu alloy plates which are friction stir welded and heat treated in two different temper conditions.

2. TECHNICAL APPROACH

2.1. Aluminium Alloys in Shipbuilding

Recommendations for aluminium alloys used in shipbuilding, specific for hull construction and marine structures, are divided into two general groups – rolled and extruded products. Rolled plates, sheets and strips are manufactured using Al 5xxx series - AA 5083, 5086, 5383, 5059, 5754, 5454, 5456, 5474 aluminium alloys - usually alloyed with Mg under O, H112, H116 and H321 temper conditions. Extruded products – bars, profiles and shapes – are made from aluminium alloys AA 5083, 5383, 5059 and 5086 under O, H111, H112 temper conditions. Likewise, in the Al 6xxx series - AA 6005A, 6060, 6106, 6061, 6063, 6082 – Mg and Si are the dominant alloying elements used in T5 and T6 temper conditions (ASM Handbook vol 2 and 4, 2001; IACS, 2009; Hatch, 1984; Sielski 2007; SSC-452, 2007; Vargel, 2004).

Broad aluminium panels manufactured with the FSW process, used in cruise ships, catamarans and other high-speed ferrys are the examples of typical applications (Kallee, 2000; Kallee, Nicholas and Thomas, 2001), as are the FSW of extruded Al panels used for freezing fish onboard fishing ships, and extruded Al honeycomb and seawater resistant panels for hulls and decks, welded using the same process (Johnson and Threadgill, 2003; Kallee, 2000; Kallee, Nicholas and Thomas, 2001).

AA5xxx and AA6xxx plates and extrusions, and the FSW process are among the most common marine applications (Johnson and Threadgill, 2003). AA 6061, 6082 T6, AA 5083 and H112 and H116 were among the first aluminium alloy FSW joints to be commercially introduced into shipbuilding (Colligan, 2004; Johnson and Threadgill, 2003; Kallee, 2000; Kallee, Nicholas and Thomas, 2001).

The mechanical properties of 5xxx series aluminium alloys are usually improved by cold working. On the other hand, mechanical properties of 6xxx series alloys are improved considerably by the precipitation of coherent second phase particles after thermal treatment (Hatch, 1984).

Aluminium alloys with Cu additions, more specifically the AA6xxx and 7xxx-series Al, are used as medium-strength structural alloys, due to their good corrosion resistance and mechanical properties owing to the formation of fine intermetallic particles (Esmaily et al., 2016; Mishra, Partha and Kumar, 2014; Olea et al, 2007). AA5xxx-series aluminium alloys H116 under tempered condition have shown good corrosion resistance, especially to exfoliation corrosion (Mishra, Partha and Kumar, 2014; Vargel, 2004).

2.2. Friction Stir Welding Process

Developed by The Welding Institute (TWI), UK, in the early 1990's, the FSW process works by plunging a rotating tool into the joint until the tool's shoulder touches the joint line; then traversing the rotating tool along the joint, as shown schematically in Figure 1 (Mendes et al., 2016; Mishra and Ma, 2005; Thomas, 1991). The rotating tool is usually slightly tilted during the FSW process, within a tilt angle of maximum 3°, to ensure the necessary amount of torque and forces needed to obtain defect-free welds in the initial stages of welding (Banik et al., 2018).

The large plastic deformation around the rotating tool during the welding process and the friction between the tool and the workpieces are the two main heat generators in FSW. Both aspects increase temperature in and around the stirred zone, although friction is considered the major source of heat (Mishra and Ma, 2005; Olea, 2008; Mishra, Partha and Kumar, 2014).

The microstructural changes and the consequential altered mechanical operation of friction stir welded joints are important issues to be studied. The influence of the heat flow, rotation and welding speed on workpiece structure, mainly in the nugget and thermomechanical affected zone, are evident (Moreira et. al., 2009; Mishra, Partha and Kumar, 2014). Dynamic recrystallization is likely to occur due to the temperature and pressure applied

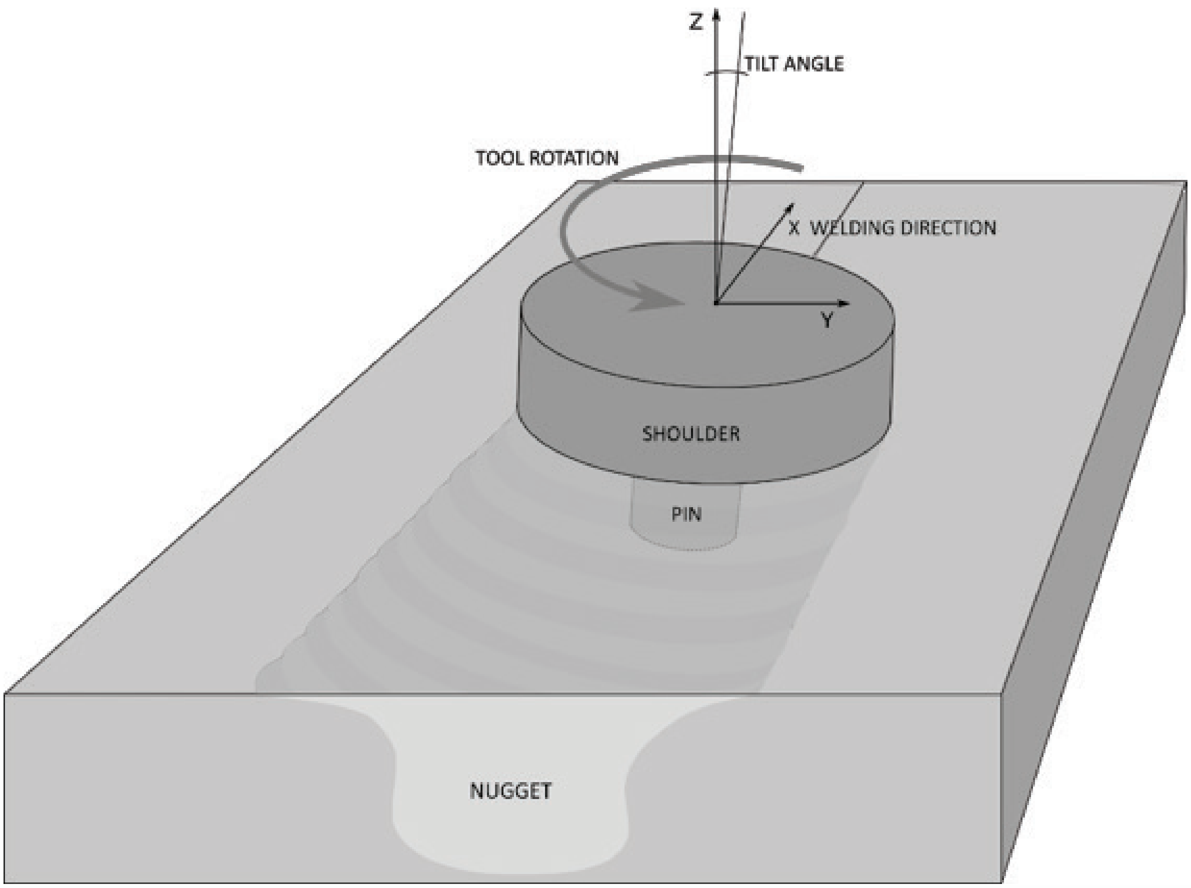


Figure 1.
Illustration of the FSW process.

during the FSW of aluminium alloys (Heinz and Skrotzki, 2002). The FSW process also causes a decrease in dislocation density and in the dissolution of the strengthening precipitates (Mishra and Ma, 2005; Sidhar et al., 2016). However, the mechanical properties of a post-weld heat treatment of heat-treatable aluminium alloys change significantly due to the formation of alloying element second phase particles, such as CuAl2 – θ phase, Mg2Si – β phase and Q phase, a quaternary compound of Al-Cu-Mg and Si with varying stoichiometry and different morphologies (Chakrabarti, D. J. and Laughlin, 2004; Heinz and Skrotzki, 2002; Murayama et al., 2001; Olea et al., 2007, Sidhar et al., 2016; Vivas et al., 1997). According to Hill (2015) and Liu et al. (2018), when alloying elements such as Fe and Mn are kept at high temperatures, they might generate second phase particles which increase their volume fracture and particle size.

The FSW technology was developed using sophisticated robotic systems and software, facilitating the use of the FSW process in a wide range of industrial applications and working conditions (Mendes et al., 2016). Both experimental and numerical analysis are important for understanding the heat flow and the transfer between the steel tool and the workpiece during the FSW process, and the weld morphology (Chao et al., 2003; Fratini et al., 2006; Sadeghian, Taherizadeh and Atapour, 2018; Zhao et al., 2018). Authors Ku, Ha and Roh (2014) developed a mobile welding robot and software controls to be used for welding double hull structures in shipyards. On the other hand, Cavaliere (2013), using a database obtained from experimental data, developed a friction stir weld mechanical behaviour prediction model. The model takes mechanical properties into consideration.

3. EXPERIMENT

Al-Mg-Si with Cu alloy 4 mm thick rolled plates were friction stir butt welded using a Tricept 805 robot with a CNC controller. The FSW was performed at rotational speed of 1600 rpm and tool transverse speed of 800 mm/min, with a 3° tilt. The investigated heat treatment conditions are listed in Table 1.

Table 1.
Description of the plate heat treatement.

Temper condition	Description
PWHT	FSW in T4 and heat treatment in an air furnace to T6 at 190°C for 4h (ASM Handbook vol. 4, 2001)
FSW T6	Artificially aged at 190°C for 4h and friction stir welded

Vickers microhardness profiles were obtained from the perpendicular cross section welding direction, using a HMV200 Shimadzu from Struers, with a Vickers indenter having the load of 100 gf (HV0.1). A 0.5 mm step between indentations was used along the centerline of the plates.

The tensile tests were performed using a servo-hydraulic INSTRON model 1195. In the conventional tensile test, full-scale load was 50 kN, with a test speed of 1 mm/min.

Optical microscopy (OM) samples were etched with Flick reagent (i.e. 10 ml HF, 15ml HCl and 90 ml deionized water) and analysed with an Olympus PMG3.

The morphologies of the grains and second phase particles were obtained by SEM, using a Zeiss DSM 962 device in SE and BSE modes. The chemical composition of the particles was obtained by energy dispersive X-Ray spectroscopy (EDS) with a Si-Li detector coupled with SEM.

Specimens were not etched in SEM analysis. The macro- and microstructures of the weld were revealed with Flick reagent (i.e. 10 ml HF, 15ml HCl and 90 ml deionized water) and analysed with an Olympus PMG3 optical microscope (OP).

The chemical composition of the base material in weight % is given in Table 2.

Table 2.
Composition of the Al-Mg-Si-Cu alloy (wt. %).

Elements	Mg	Si	Cu	Mn	Fe	Zn	Ti	Zr	Pb	Al
Wt. %	0.76	0.92	0.77	0.56	0.24	0.19	0.012	0.11	0.003	bal.

4. RESULTS AND DISCUSSION

The Al-6xxx series alloyed mainly with Mg, Si and Cu, also contains a fair amount of Mn and Fe. The alloying elements mostly contribute by increasing material hardness and strength by forming complex, intermetallic second phase particles and the substitutional solid solution (Hatch, 1984).

4.1. Mechanical testing

The relationship between macrostructure and microhardness, taken as a function of position along the weld cross section, is shown in Figure 1. The macrostructure presented in Figure 1(a) outlines the base material (BM) and the weld zones – heat-affected zone (HAZ), thermo-mechanically affected zone (TMAZ) and nugget zone (NZ). Figure 1(b) illustrates the Vickers microhardness profile of Al-Mg-Si-Cu plates in FSW T4, FSW T4 + PWHT and FSW T6 conditions, measured along the centerline of the cross section.

The macrostructure of the weld is a source of information on the retreating and advancing sides, and facilitates clear identification of the NZ (coloured with a darker tone after etching). Also, the U-shape of the weld zone broadens at the top due to the firm contact between the shoulder of the tool and the upper surface – Figure 1(a).

The hardness profile of the plates showed that the hardness of the PWHT increased compared to the FSW T6, especially the TMAZ and NZ zones. Taking into consideration the lowest TMAZ and the highest NZ hardness values, the hardness of PWHT plates increased by approx. 20 HV in TMAZ and 40 HV in NZ when compared to FSW T6 hardness results – Figure 1(b). HAZ is not significantly affected by the FSW process.

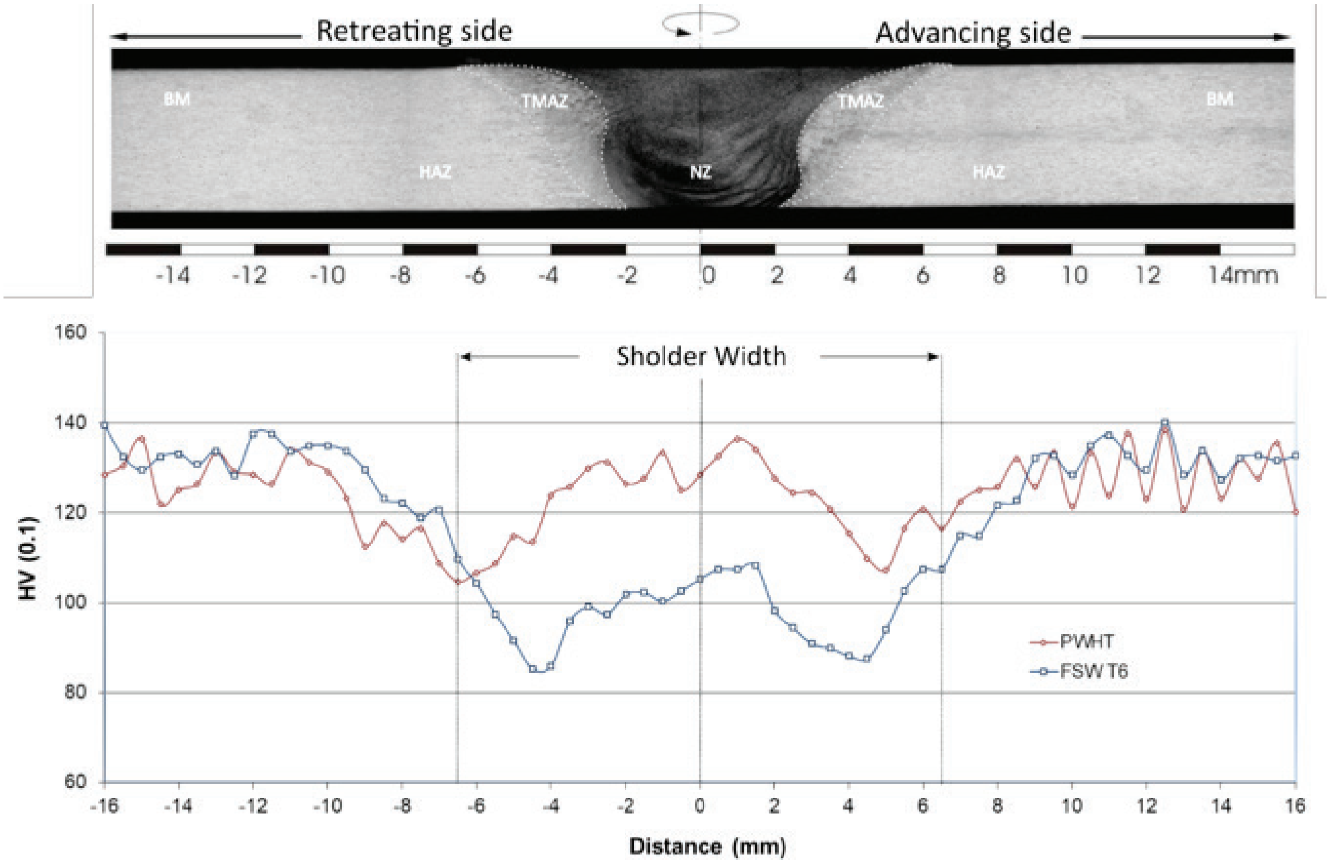


Figure 2.
(a) Macrostructure of the weld cross section and (b) Microhardness profiles of FSW PWHT and FSW T6.

Uniaxial tensile tests were performed at room temperature. The results for both base materials (BM) with welded components are given for an average of three specimens. Table 3 illustrates the mechanical properties of the base material and welded specimens under T6 temper conditions.

Table 3.
Results of uniaxial tensile tests for the base material and welded specimens under given temper conditions.

Material: Al-Mg-Si-Cu	$R_{p0,2}$ [MPa]	R_m [MPa]	A[%]	WF $R_{p0,2}$ [%]	WF R_m [%]	WF A[%]
BM T6	339	353	7	--	--	--
PWHT	318	329	1	94	93	14,3
FSW T6	218	299	4	64	85	57

$R_{p\,0.2}$ – yield strength; R_m – tensile strength; *A* – elongation.
WF – weld/joint efficiency (i.e. *WF* ratio between the static properties of the weld and of the BM).

A failure pattern was observed in TMAZ in the retreating side of the welds - Figure 2(a). Except in the welded tested specimens in T6 temper conditions, the value of WF exceeded 85 % for $R_{p\,0.2}$ and R_m, confirming the high strength of joints made by friction stir welds.

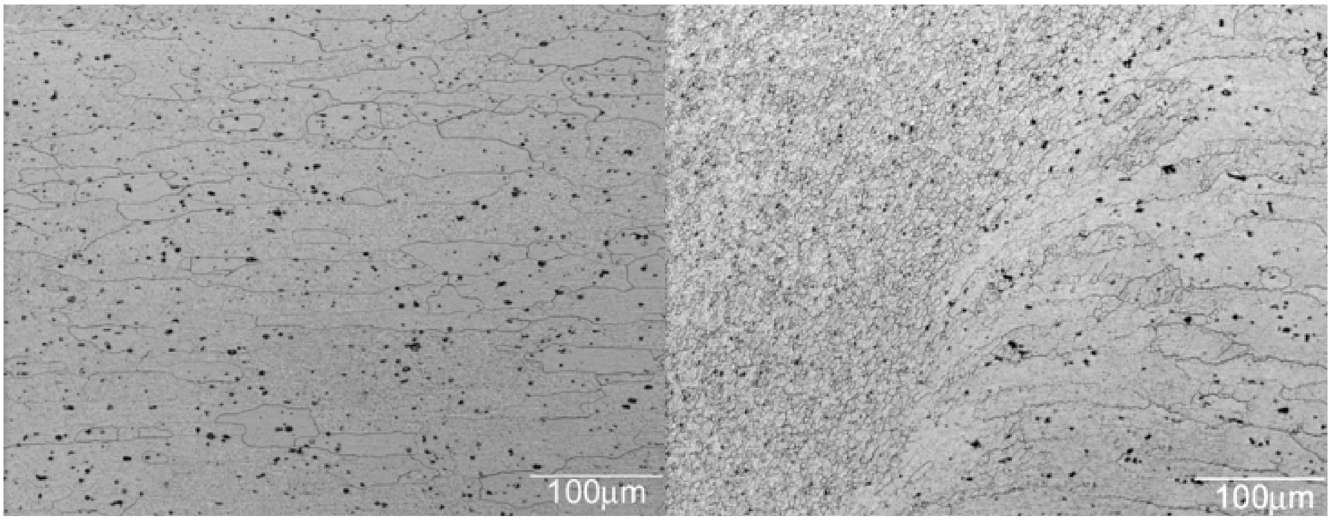
The yield strength ($R_{p\,0.2}$) and tensile strength (R_m) of PWHT tested specimens are in the range of the mechanical properties required for hull construction and marine structures. The results of the SSC-452 (2007) guide have shown that an AA 6082 T6 base material yielded 286 MPa and 301 MPa of $R_{p\,0.2}$ and R_m, respectively. The same AA 6082 Al alloy, friction stir welded in T6, delivered the yield strength of 160 MPa and tensile strength of 254 MPa. The PWHT results for the same alloy delivered 285 MPa and 310 MPa of $R_{p\,0.2}$ and R_m, respectively. The elongation % of the AA 6082 T6 base material and the T4 FSW, aged to T6, were approx. 10 % and 9 %, respectively (SSC-452, 2007).

5-50 mm thick sheets and plates for marine applications, made from 5xxx series aluminium alloys yielded $R_{p\,0.2}$ between 195 and 270 MPa and R_m between 250 and 438 MPa (Sielski, 2007).

The extruded products of Al 6xxx series alloys having the thickness of 3 and 50 mm require 170-200 MPa and 260 MPa of yield strength and 260 and 310 MPa of tensile strength in T6 temper conditions (IACS, 2009; Sielski 2007; SSC-452, 2007).

4.2. Morfology

Figure 4 shows the microstructure of the Al-6xxx alloy PWHT and FSW of the friction stir welded specimens from the SEM perspective. SEM image - Figure 4(a) shows the details of the interface between TMAZ and NZ, while Figure 4(b) shows NZ with small equiaxed recrystallized grains.



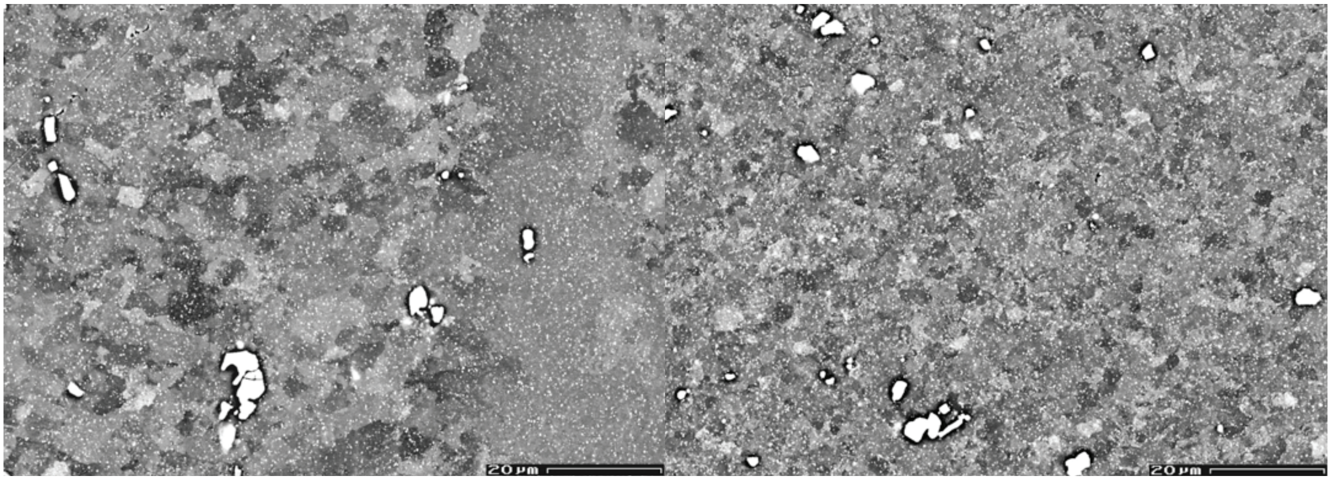
a) b)

Figure 3.
OP images of the (a) base material grain morphology, and (b) interface between the nugget zone and the thermomechanically affected zone. Flick reagent.

Grain size and the morphology of friction stir welded plates in NZ, TMAZ and HAZ of PWHT and FSW T6 did not show significant changes.

The grain morphology along the weld zones of the Al-Mg-Si-Cu alloy PWHT changes under FSW T6 conditions – Figure 2(a). The BM represents elongated, pancake-shaped, 100-300 µm long grains on the BM - Figure 3(a) equiaxed 5.6 - 2.8 µm grains at NZ - Figures 3(b) and 4(b). Between the TMAZ and the NZ, there is a distinct interface of elongated grains twisted at 90° and small equiaxed grains – Figures 2(a), 3(b) and 4(a).

Figure 5 shows evenly distributed second phase particles – white spherical, oval and rod-shaped, having the average size between 100 and 500 nm - and coarse irregular micrometric particles. The SEM/EDS particle analysis from Figure 5 indicates the presence of Al-Cu-Mg-Si-Mn and Fe, suggesting the formation of Mg-Si, Al-Cu, Al-Cu-Mg-Si, and Al(Mn,Fe)Si second phase particles (Chakrabarti, D. J. and Laughlin, 2004; Hill, 2015). Previous work on Al-Mg-Si-Cu alloys using transmission electron microscopy (TEM) and the selected area diffraction pattern (SADP) indicate that the greatest contribution to alloy hardening



a) b)

Figure 4.
SEM images of the weld (a) interface between NZ (small recrystallized grains) and TMAZ (elongated grain), and (b) nugget zone.

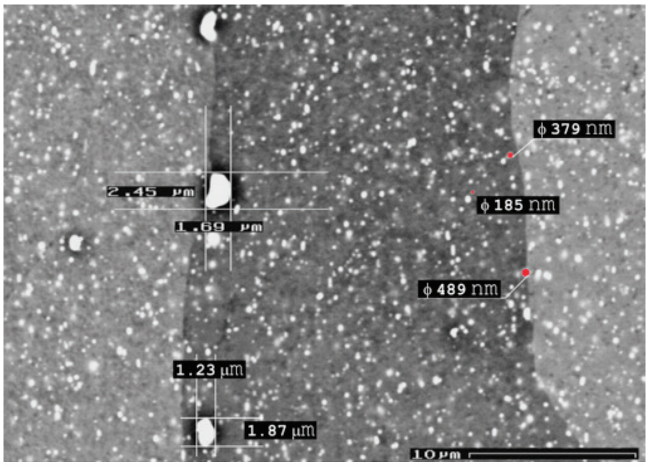


Figure 5.
SEM image - TMAZ zone under PWHT temper condition, with the sizes of several second phase particles.

and strengthening occurs in the Q phase (Al-Cu-Mg-Si particles) (Chakrabarti, D. J. and Laughlin, 2004; Olea et al., 2007; Gallais, 2008).

The grain refinement in NZ under the FSW T6 condition does not have the main role in material strengthening. For example, the BM T6 condition yields the strength of 339 MPa, which is considerable higher than the FSW T6 yield strength of 218 MPa. Under this condition, the extra heat generated by the high temperature of the FSW process (approximately 80 % of melting point) dissolved the strengthening precipitates in the Al matrix. In addition, the contribution of coarse particles to alloy strengthening is low (Hill, 2015; Mishra and Ma, 2005; Sidhar et al., 2016). On the other hand, the PWHT - FSW in T4 and the 4-hour heat treatment of T6 at 190°C, resulted in only a minor decrease in hardness in comparison with BM yield strength. In this case, the heat treatment after friction stir welding greatly contributes to the precipitation of the strengthening Q phase precipitates (Chakrabarti, D. J. and Laughlin, 2004; Heinz and Skrotzki, 2002; Murayama et al., 2001; Sidhar et al., 2016).

The results of the microhardness profile correlate very well with the tensile test results. Hardness in NZ and TMAZ increased with the PWHT. FSW T6 small grain size in NZ compared with BM did not effectively contribute to the increase in hardness.

5. CONCLUSIONS

The results indicate there is a correlation between the mechanical properties and the microstructural evolution associated with the FSW solid-state welding process using the Al-Mg-Si-Cu alloy under PWHT and FSW T6 temper conditions.

The FSW joint had four distinct zones - BM, HAZ, TMAZ and NZ. BM and HAZ did not show significant alterations either in grain morphology and size, nor in mechanical properties in either of these temper conditions. The BM elongated pancake-shaped 100-300 µm long grains and the NZ equiaxed and 5.6-2.8 µm recrystallized grains were found. SEM also identified and measured second phase particles sized 100 nm - several µm.

The evaluation of the microhardness profile and tensile tests indicated that the TMAZ and the NZ of a joint welded under the PWHT condition increased the strength along the joint, giving better results than FSW T6. These results indicate that the PWHT propitiated the formation of a significant amount of strengthening precipitates in the NZ, which increased the strength of the material. However, the decrease in grain size did not translate into a significant increase in material strength.

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Maritime and Other Key Transport Issues for the Future – Education and Training in the Context of Lifelong Learning

Jeannette Edler[a], Virginia Infante[b]

The entire transport system will transform into an integrated transport system in response to future trends and demands. The EU Skilful project defines the impact on job profiles across all transport modes and at all levels of work and duties. Changing and emerging job profiles require training which on the one hand makes use of the latest training and education methods, while on the other meeting the need for the acquisition of special competencies, skills and abilities. The demand for individualization of training contents will soar in the interlinked global world and integrated transport systems.

An additional questionnaire was conducted in the spring of 2018, in the assessment of the maritime and transport sectors. The answers of course lecturers and organisers concerning present and future needs and lifelong learning issues were instructive, with most of the people having concrete ideas about lifelong learning.

Courses will therefore include future oriented contents, a practicable registration procedure with information for qualified trainers capable of tailoring course contents to the specific focus of the course and participants' requirements, giving excellent lectures with relevant learning material and real usable factors, clear structure, practical parts, remarks of concrete relevance, communication parts for improving soft skills, experience exchange and learning from other participants, intercultural aspects for globalization, reconciling mixed group needs and requirements and learning to learn methods, using different adult suitable methods and finally focusing on emotions to capitalize on the motivation to learn.

Lifelong learning is a key issue for successful employers and employees.

KEY WORDS
~ Lifelong learning
~ Future transport
~ Training and education
~ Emerging and new job profiles
~ Employees' needs

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1. INTRODUCTION

More than 11 million people in Europe are directly employed in the transport industry (EU Transport Policy, 2014; European Commission, 2014; EUROSTAT, 2011; Transport in Europe, 2016; Deliverable D1,1), accounting for 4.5 % of total employment in the European Union. If transport equipment manufacturing is included, the figure can be increased by an additional 1.5 % of EU employment in the direct and indirect transport sector (EU Transport Policy, 2014; European Commission, 2014; EUROSTAT, 2011; Transport in Europe, 2016; Deliverable D1,1).

Transport is changing due to the new impacts such as globalisation, electrification, smart technologies, 3-D-printing, alternative fuels, more renewable energies, alternative propulsion systems, big data, automatization, new transport concepts like mobility as a service, transport on demand and autonomous vehicles (Deliverable D1.1). Other aspects, like demographic change, global warming or climate change, will likewise influence the transport sector.

Employability has a central role in the Europe 2020 strategy and the Education and Training 2020. Vocational education and training, academic qualifications and lifelong training have a direct impact on employability and chances of employability.

Due to the future changes in professional positions owing to the mentioned paradigm shifters and game changers like, for example green and smart transport, automatization, digitalisation and innovative transport concepts, there is a perceived lack of education and training, including in the field of lifelong learning. There are:

- Jobs/ positions which will be eliminated or vanish in the short-term, medium-term and long-term horizon (Deliverable D1.1),
- Jobs/ positions which will emerge in the short-term, medium-term and long-term horizon (Deliverable D1.1),
- Jobs/ positions which will change in the short-term, medium-term and long-term horizon (Deliverable D1.1).

The EU Skilful project, funded by the European Union's Horizon 2020 research and innovation programme, is mainly focussed on the development of skills and competences of future transportation professionals at all levels and for all modes. The "Skilful" aimed to identify future transport trends across all transport modes, establish the main impacts on present job profiles and finally to give recommendations for the future for low-, middle- and high skilled employees. This paper refers mainly to the maritime sector.

2. FUTURE TRANSPORT ISSUES

2.1. Maritime Transport Trends

Transport will change in the next decades due to growing population, urbanisation and changes in consumer needs. (Tipping, Schmal & Duiven, 2016).

Non-industrial, underdeveloped regions and countries suffering from overpopulation and/or food shortage caused by climate change will be forced to import more food and consumer goods. Price policy and availability will be decisive for the origin of these goods. Transport will change in Europe as well, due to infrastructural limitations. There must be a movement towards more seaborne and rail-borne short-distance transport, instead of transport by trucks or other road vehicles.

India and China will be number 1 in total population. People tend to live longer, couples will grow less children and the society will become richer. China, the USA and India will be the biggest economies in 2030. Consumer purchasing power will increase until 2030, with the developing Asia growing by a factor of eight and the OECD region by a factor of three. (Argyros & Smith, 2013) Maritime transport mode currently accounts for nearly 90 % of global trade transport. (Castonguay, 2015; UNCTAD, 2017)

Climate change costs will increase, causing water shortages in southern regions like Africa or Australia, with global warming reshaping the coastal zones. (Argyros & Smith, 2013; Saxon & Stone, 2017)

The transport of raw materials and resources will increase due to the global population growth, climate change and the anticipated impacts of easy 3-D-printing which will influence consumer demands and shipping tonnage. Easy 3-D printing is estimated to have real global impact approx. 20-50 years from now. (AEB, 2016; Müller & Karevska, 2016; DHL Trend Research, 2016)

2.2. Autonomous Shipping and New Shipping Routes

The usage of the Arctic and Atlantic trade routes will increase due to global warming and the minimization of ice, while the Suez Canal will probably lose importance. Unsafe passages will be avoided. (Argyros & Smith, 2013; Saxon & Stone, 2017)

Autonomous shipping will partly increase at different stages of long distance passages or short tracks. Another important factor will be the autonomous shipping of the future. Several levels of remote-controlled, partly and fully autonomous ships will be developed in the next decades and used in short and long distances shipping, all traversing the same oceanic waterways. (AAWA, 2016; MSC 98/20/2; Parasuraman, Sheridan & Wickens, 2000; Twomey & Berry, 2016; Blanke, Henriques & Bang, 2017; DNV GL, 2019)

Another new application are automated mooring systems. (Cavotec, 2017)

2.3. Alternative fuels: Decarbonisation, Electrification / Energy / Environmental Protection

Transport by ships is currently the most energy efficient mode of transport, anticipated to become increasingly decarbonised like other transport sectors due to the finite nature and instability of fossil fuel supply and the necessary reduction of greenhouse gases. However, the efforts will depend both on the availability of marketable alternative fuels which will replace today´s heavy fuel oil and on the already starting era of LNG or LPG, methane or electrification by fuel cells, already approved by the IMO. There will be a need for the establishment of supply infrastructure for the comprehensive, nationwide use of alternative fuels.

China will become the largest oil consumer in 2030, and the US the biggest natural gas consumer. Natural gas consumption in the Middle East and Europe will overtake oil consumption in 2030. China and India will have the biggest steel consumption in the world, causing iron ore to remain an important seaborne cargo in 2030. (Argyros & Smith, 2013)

New technologies will support green, smart and clean power supply in the port shore connections, as well as the reduction of energy consumption, and effective control and management of available energy. (Grolinger et al. 2016; Acciaro & Wilmsemeier, 2015)

Another important factor is the increasing awareness of the protection of the maritime inventory and the sensitive marine ecosystems. The number of initiatives to develop technologies which reduce the negative impacts of humans on the ocean, e.g. reduce underwater noise and optimize shipping efficiently, will grow. (Hagen, 2017)

Moreover, the ocean, as the home of blue biotechnology and resources, will come into greater focus as means to meet the increasing demand for food and medicines, as well as a potential source of renewable energy, like optimized offshore wind turbines, ocean tidal power stations or ocean current power plants. The ocean will consequently come under even bigger pressure as a space for different existing and new uses and demands.

2.4. Digitalisation "Maritime 4.0"

The maritime industry is one of the most important economic sectors of the future and has to come to terms with more than one megatrend like the fourth industrial revolution, the digitalisation.

Ports will become increasingly interconnected and digitized. Appropriate infrastructure is of great importance, with the use of the data obtained emerging as a new field of interest in reaping valuable efficiency, security and energy saving benefits. (Hagen, 2017; Jahn, 2017)

On the other hand, data management, evaluation, safety and flow are new problem areas. The opportunities of digitalization are the development of new processes, production, ship operations, port and cross-modal aspects, as well as the overall port logistics. Innovative port technologies will become key competitive advantages. Process modifications are anticipated to increase efficiency. The collection and consolidation of data, combined with intelligent forecasting models for weather, navigation, ship operation and specific (cargo) vessel data, interconnected with hinterland traffic systems and logistics centres, will develop into an optimized logistics chain with efficient ship and port operations. If production is also connected, digital lifecycle management could no longer be merely a concept of an entire logistics chain. The safety of all networked systems is one of the most important factors for the future. (Shaikh, 2017; Hiranandani, 2014)

2.5. Shipbuilding

Sustainable, smart, green shipbuilding will become the main task and a new business field in the yard industry of the future, with integrated complex systems to meet the expectations of the next decades. Climate friendly and environmental friendly products will have big potential. Shipbuilding industry has to adjust to the future trends in shipping, e.g. by building more passenger ships to meet the needs of growing population and due to the negative balances of freight transport, taking advantage of opportunities like 3-D-printing or the naval industry, due to the increasing risks of terrorism or private interests. There will be big differences between Europe, Asia and America. There will be more competition between Asia and Europe. IT-based development in ship design and shipbuilding will result in increased innovation dynamics, faster implementation and customization, small series at competitive costs. 3 D printing will also come to be used in production. Material, component and system providers are very important actors due to the fact that 70-80 % of added value in ship construction is created by the supplier business makes shipyards future system integrators.

2.6. Marine Technology / Deep Sea Mining / Offshore and Floating Platforms

The development of offshore oil and gas exploration and exploitation technology will go hand in hand with the opening up of new mining technically challenging fields like deep-sea mining for gas hydrates and renewable energies like ocean currents. Blue biotechnology and deep sea mining require the use of deep-sea robots, unmanned remote-operated vehicles, state-of-the-art digital observation technology, production of powerful offshore oil and gas conveyors. Floating platforms will also be an option for innovative systems- likewise meeting the needs of new zones for population.

2.7. Retrofitting /Maintenance

Services will become one of the most sought-after working fields of the future. The need of qualified retrofitting and repair workforce for ship and port operations, shipyards, supply business, machinery and equipment manufacturers, will grow owing to the increasing number of ships, plants and uses in the ocean.

The use of constantly evolving digital technologies is important. The effective realization of potential for innovations, further development of new technologies, strengthening cross-innovations for cross-sectoral development of technologies and activities, interdisciplinarity and the growing innovative power are required. Worldwide harmonization of international standards will be the main success factor in the maritime industry. For Europe to be competitive, it must harmonize interfaces and data formats. Strategic partnerships seem to be one of the most promising components.

2.8. Education and Training

Over 1.2 million people are directly employed in the shipping industry as both seafarers and port workers. If logistics, supply chain management and other shipping related businesses are included, the figure increases to tens of millions worldwide. (Castonguay, 2015)

The increasing trend of utilization of complex systems in maritime-related businesses and the use of new, smart information and communication technologies and digitalisation in shipping, port logistics, offshore and maritime technologies will transform the skills required of maritime professionals to include more extensive or specialised contents and abilities. (Hagen, 2017; DNV GL Shipping, 2019)

Ongoing digitalization requires the development of a trustful dialogue between educational and training institutions, in addition to the promotion of education and training. The development of qualified personnel will be the main task of the future. Investment in not only hardware and software, but also in human resources will secure and create many maritime jobs, although their profile will dramatically change.

2.9. Endangered Jobs, Changing Job Profiles and New Job Profiles

The trends and the set of consequently required skills and competencies suggest that the following job profiles will be eliminated in short (2020-2030), middle (2030-2045) or long term horizon (from 2045/2050) (Bekiaris & Loukea, 2017; Ahern et al., 2019). Over the next couple of decades, mainly manual jobs are anticipated to become obsolete and replaced by technical and automated jobs using electrification and new technologies like automation and robotics. Recurring workflows and repetitive

Table 1.
Endangered Job Profiles.
[own summary in accordance with Bekiaris & Loukea, 2017; Ahern et al., 2019].

Endangered maritime transport job profiles in the short term	Endangered maritime transport job profiles in the medium term	Endangered maritime transport job profiles in the long term
Manual port operators (e.g. stevedores, machine operators, conductors, loaders/ unloaders, mooring personnel)	Drivers (truck driver, logistics drivers, drivers in ports)	Dispatchers
Manual warehouse operatives	Traditional fuel station operators and fuel station maintenance personnel	Port managers
Ticket issuers and ticket controllers	Port operatives	Decentralised maritime traffic managers
Freight forwarders	Package handlers	Office-based dispatchers
Logistic centre staff	Toll collectors and toll handling clerks	Preventive maintenance technicians and engineers
Clerks handling transport documents	Booking clerks, Travel agents	Technicians for port vehicles
Onsite/Outdoor maintenance staff	Maritime traffic violation officers	Signallers
Inspectors/ Quality inspectors	Security guards	Insurance agents
Schedulers	Fossil fuel transport deliverers	
Manufacturing personnel (blue collar worker)	Ship crew	
	Steel production manufacturers	
	Controllers and low level data interpretation clerks	
	HR Administration personnel	

Table 2.
Changing and New Job Profiles.
[own summary in accordance with Bekiaris & Loukea, 2017; Ahern et al., 2019].

Changing Maritime Transport Jobs	New maritime Transport Job Profiles
Drivers Manual Operators Ticket issuers & controllers Freight forwarders, Logistic centre staff Booking clerks & travel agents Transportation schedulers/planners Mobility planners Customer service personnel Customer suppliers & suppliers planning, Custom officials Manufacturing staff Fuel station operators, fuel distributors and retailers, fuel quality control personnel Maritime traffic police Security controllers IT engineers Security managers Driving license instructors	Logistics managers Global freight forwarders/managers Logistic operators at terminals & delivery dispatchers/ City logistics service providers Experts on AI, Digital transformation, Big data IoT developers, IoE Engineers, 3D Printing Engineers Automation & Robotics experts Innovators development & maintenance of automated systems Predicting engineers Alternative fuels distributors & Alternative fuel station operators Charging station operators & managers E-charge maintenance technicians Remote flying object operators Automated vehicle operators Drones operators Designers of autonomous vehicles, ships Security & cyber security experts Legal services personnel and privacy protection specialists Info-mobility experts Ethics and law specialists in transportation Mobility integrators & MaaS aggregators/ Integrated transport system planners Smart delivery: Transport planners & tool developers

operating cycles in a static environment will be replaced by robots and automated machinery. Digitalization will accelerate workflows, rendering low-skilled, straightforward, simple bureaucratic jobs, paperwork and simple tasks redundant. Jobs involving the application of simple rules and simple decision making will also be replaced by computerized automatism and technologies. The blue collar worker executing manual tasks will become increasingly unnecessary, owing to the new maintenance philosophy and servicing modes preferring the replacement of entire units, like in the airplane industry, and well-organised maintenance in specialized workshops instead on-site. Experts will program machinery and computers to learn about maintenance and failures, after which the machines will learn by themselves (artificial intelligence). Autonomous driving will replace real drivers and intelligent networks, steered by intelligent predicting computer programmes using multiple sensors enabling them to take all traffic participants into account will take over the operation of autonomous vehicles and ships. Security duties will be replaced by watch-keeping drones, sensors and decision-making intelligent data programmes. (Bekiaris & Loukea, 2017; Ahern et al., 2019)

There will be a transition period in which jobs will completely or partly vanish or change. This interim period will be very important for innovators, employees and employers since accumulated existing and available knowledge needs to be saved and carefully transferred into new technologies. This circumstance will be decisive for the speed of implementation of new technologies, the pace of process adoption and sustainability. Employees have to be motivated, openminded, convinced and even fearless. Employers have to take the employees along and give them the opportunity to influence the processes, change their minds in their own time and decide to lend valuable support to the altered processes. Nevertheless, all groups participate in system alteration, have to find their new roles and fulfil their tasks.

Alteration implementation should be a bit easier in the case of changing job profiles, since there should be a basis to work on and a starting point for the adoption of new topics, instruments, processes and technologies. The traditional manual work processes will be replaced by workflows using robots and machinery. Employees are familiar with the traditional workflow, the starting point, the materials used, the support systems and the procedure until the product is manufactured or achievement realized. Parts of this traditional flow could be easily replaced owing to knowledge and established procedures. Furthermore, innovation has always been a part of work and there has always been awareness that job profiles are living, not frozen, fixed and unchanging.

However, the introduction and the establishment of new job profiles will be a more challenging process. Completely new systematic, technological, economic, legal and ethical issues will emerge, as well as crosscutting tasks. New curricula have to be compiled, appropriate conditions defined, prerequisites met, lecturers and trainers educated and national bodies involved in the approval process.

There is a need for further sustainable employment of people who already work in this area and are losing parts of their job profiles. According to these findings, there is a need for the training and education of people whose jobs are changing, as well as for the implementation of new education and training courses for emerging jobs.

Elderly people should be motivated and encouraged to pursue lifelong learning, have an intrinsic motivation to learn about new topics and technologies in order to be up to date with their jobs and flexible enough for the employment market. This is not the sole responsibility of the employees, but of the employers as well, in the sense of good governance, responsible and sustainable human resources policies.

There are different levels of knowledge, different working conditions, levels of knowledge, skill and technologies used across Europe. For different reasons, employees need individualized training schemes for successful learning, motivation and sustainable training, as well as to maximize the effectiveness of the training and education for the employer. Additionally, there is also a lack of training and education courses for future job profiles.

Lifelong learning is a key factor if one does not want to miss the boat.

3. LIFELONG LEARNING

The international framework for lifelong learning and training refers to the work of the OECD, UNESCO, ILO and the EU. The European Commission Communication "Making a European area of lifelong learning a reality", published in November 2001, is the main EU document on lifelong learning. This document emphasizes the importance of lifelong learning for four objectives: personal fulfilment, active citizenship, social inclusion and employability/adaptability.

Lifelong learning includes all purposeful learning activity, whether formal, non-formal or informal, undertaken on an ongoing basis with the aim of improving knowledge, skills and competence.

The European organisation for education, including lifelong learning, is the "Education, Audio-visual and Culture Executive Agency" (EACEA) supported by the Eurydice Network (EURYDICE) (Council EU, 2015), which facilitates European cooperation in the field of lifelong learning by providing information on education systems and policies in 38 countries and by producing studies on issues common to European education systems.

3.1. Legal Framework

There are many legal and political provisions in the European framework, like the relaunched Lisbon Strategy 2005, the Recommendation of the European Parliament and of the Council from December 2006 on Key Competences for Lifelong learning (2006/962/EC), the Conclusions of the Council on education and training from May 2009, the Education and Training 2010 Work Programme, the European Employment Strategy, the European Commission's 2007 Communication on the Integrated Guidelines for Growth and Jobs (2008-2010) and the Europe 2020 strategy, aiming to create "an agenda for new skills and jobs", the Strategic framework 2020 and the Framework for education and training (ET 2020). The "Europe 2020 strategy for smart, sustainable and inclusive growth" contains integrated economic and employment guideline number 8 on the development of skilled workforce in response to the needs of the labour market and promotion of job quality and lifelong learning. Moreover, the Commission adopted the proposal for a new Recommendation on Key Competences for Lifelong learning on 17 January 2018. All EU documents acknowledge that lifelong learning is a strategic issue for the EU and some set benchmarks for the participation in education and training for 2020.

3.2. Benchmarks for Participation in Lifelong Learning

In May 2002 the Council adopted the "Reference Level of European Average Performance" (Benchmark) in the framework of the "Education and Training 2010" lifelong learning process: "In a knowledge society individuals must update and complement their knowledge, competencies and skills throughout life to maximise their personal development and to maintain and improve their position in the labour market. – Therefore, by 2010, the European Union average level of participation in lifelong learning, should be at least 12.5 % of the adult working age population (25-64 age group)."

The "Strategic Framework for European Cooperation in Education and Training" adopted in May 2009 also contained a benchmark for adult participation in learning to be achieved by 2020. According to this main goal, the average of at least 15 % of adults aged 25 - 64 should participate in lifelong learning. Both benchmarks were ambitious. This figure was reached neither in 2011, nor in 2016. (Adult Participation…, 2016) Adult learning statistics in the European Union (EU) are based on data collected through the labour force survey (LFS) and the adult education survey (AES). The Adult Education Survey (AES) is one of the main data sources for EU lifelong learning statistics. In this context adult learning means the participation of adults aged 25-64 in lifelong learning. Four forms of further educational activities were formulated:

- courses or courses at work or leisure,
- short-term educational or training events, like lectures, trainings, seminars or workshops,
- on-the-job training (e.g. scheduled instructions or training by supervisors, colleagues, through trainers or teletutors),
- private lessons during leisure time (e.g. driving lessons for driving license, coaching lessons in sports, music lessons, tutoring lessons).

In the AES, lifelong learning, limited to the 18-64 year old group, is the starting point for capturing various learning. On the conceptual basis, the CLA (Eurostat 2016) includes three types of learning: Formal Education (FED, means regular or formal learning), Non-Formal Education (NFE, contains continuing education) and Informal Learning (INF). These three different types of learning vary depending on the degree of their organisation. (Bilger, Behringer & Kuper, 2013)

3.3. Labour Force Survey (LFS)

The reference period for participation in (formal and non-formal) education and training are the four weeks immediately preceding the interview, as is usual in the LFS. In 2016 in the EU-28, the share of persons aged 25 - 64 who participated in education or training was 10.8 %; which is 1.7 % more than in 2011. Denmark, Sweden and Finland had much higher shares of adults´ participation in lifelong learning in the four weeks preceding the interview. The Netherlands, Estonia, Luxembourg and France were the only other member states of the European Union to reach the 15 % benchmark. In Austria and the United Kingdom the participation rate in 2016 came close to the 15 % benchmark with 14,9 and 14,4 % respectively. Romania, Bulgaria, Slovakia, Croatia, Poland and Greece have the lowest rates of adult participation in lifelong learning with 4.0 % or less. In the EU-28, women´s participation rate of 11.7 % in 2016 was higher than the men's 9,8 %. However, it should be pointed out that the shares for both were higher in 2016 than in 2011. (Vemuri, 1993)

3.4. Adult Education Survey (AES)

Information about education and training is also available from the AES. The data shall be interpreted in addition to the LFS which contains information about participation in education and training in the four weeks before the survey interview. The difference between the methods used by the AES and the LFS is the reference period, i.e. the LFS is concerned with participation in education and training during the 12 months preceding the survey interview. Furthermore, the AES is carried out only every 5 years. According to the AES 2011, 40.3 % of persons in the EU-27 aged 25-64 took part in education and training (during the 12 months preceding the interview), the majority of which was non-formal. Participation rates in education and training in the EU-27 were almost the same for men and women. While in Finland, Latvia and Lithuania women participated in education and training more frequently, men had higher representation shares in the Netherlands and Germany. In 2011 the participation rates of younger persons (aged 25–34) in the EU-28 were nearly twice as high as those of older employees (aged 55–64). (AES, 2011)

The three most cited among the eleven obstacles to participation in education and training are:

- no need for training (50.0 % in the EU-27)
- lack of time due to family responsibilities (20.9 %)
- and conflict with work schedules (18.0 %). (AES, 2011)

Judging from the legal framework and the ambitious benchmarks, access of European employees to lifelong learning varies significantly and there is a considerable difference between northern and southern countries, as well as in their economies. Employees who live in the north have a better chance of taking up future trends, improving their employability and taking next career steps, and employers in the north invest not only in modern technologies, but in human resources as well.

3.5. Lifelong Learning Strategies

"You can´t teach an old dog new tricks- can you?"

Lifelong learning and training means all learning activities undertaken throughout life to develop competencies and qualifications, with the aim of improving knowledge, skills and/ or qualifications for personal, social and/or professional reasons.

3.5.1. Advantages and Obstacles for the Society, Employers and Employees

Lifelong learning and training are advantageous for societies, employers and employees. The advantages of lifelong learning are manifold: societies benefit from employees who share new technologies, from new impulses and other branches. Lifelong learning increases mobility, internationality and employability. Less time is lost due to sicknesses, insurance and social system costs decrease. Incentives for employers, like grants or tax benefits, could be provided by the state. Certificates, keeping the human resources and preserving accumulated knowledge. Motivation increases and fluctuation decreases, improving the independence of companies. Other advantages for the employer are increased critical thinking, problem solving, preparedness and willingness to work. As for the employees, the advantages of active participation in lifelong learning are high qualification, ability, eligibility. Added values for the employees could be incentives like paid leave for education, more vacation or even higher wages.

On the other hand, lifelong learning and training have to overcome the same obstacles as societies, employers and employees.

It is not an overstatement to say that the availability, quality and quantity of a society's technical infrastructure could be obstacles, as could the acceptance of appreciation of lifelong learning, social motivation and financial support by the administration and existing conditions like employment and qualification. With respect to employers, the four greatest obstacles are the loss of working hours, personal gaps, costs and organizing efforts. Furthermore, there is fear of overqualification of personnel, interlinked with the fear for turnover and fluctuation, and last but not least, fear of leadership problems in case of smart employees. Obstacles encountered by employees are money, effort, time, fear of asking the boss, bureaucracy, demotivation, lethargy. Some employees also have fear of the new or fear of failure, and problems with the acceptance of personal and professional setting and environment.

3.5.2. Half Life of Knowledge

An individual's available knowledge changes throughout his/her life. That's another reason why everyone needs lifelong training. Current expertise and knowledge become irrelevant, incorrect or lost over time. While half of the knowledge obtained in school is lost after 20 years, 50 percent of knowledge gained at the university is forgotten in 10 years. The value of professional expertise plummets by 50 percent after 5, technical knowledge after 3 and IT expertise after 1 – 2 years. As for content relevance, knowledge from the field of mechanical engineering can be said to become incorrect or obsolete after 20, medical knowledge after 10, traditional marketing after 7 years and social media marketing after 1 year or less. (Vemuri, 1993)

3.5.3. Social Lifelong Learning Framework

The framework of lifelong training includes aspects like legal requirements, the mandatory nature of the course or lack thereof, the time aspect, costs and duration, as well as the existence of standards for courses, their content and objectives, or lack thereof.

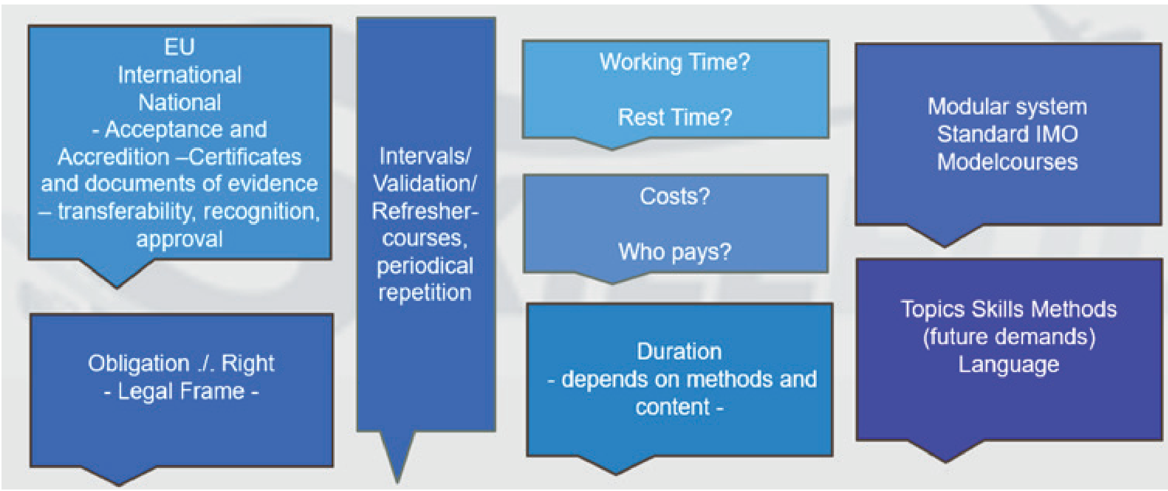

Figure 1.
Social lifelong learning framework.

External reasons for lifelong learning in the maritime sector could be mandatory, like obligations under international law, such as the STCW-Convention, the related SOLAS codes or national regulations. Another external, but compulsory reason could be - depending on the requirements of industrial standards like BIMCO and INTERTANKO - company policies, taking into account accidents, extraordinary political developments like refugees in the Mediterranean, 9/11, pirates or environmental concerns.

3.5.4. General Lifelong Learning and Training Content

In the following scheme all content-related aspects of lifelong learning are visualised. There are competences and skills falling under the heading health (3 types of grey) in which individuals should be trained and educated, although the team (dark grey) is also an important aspect which should be involved in lifelong training. The lifelong training process is characterised

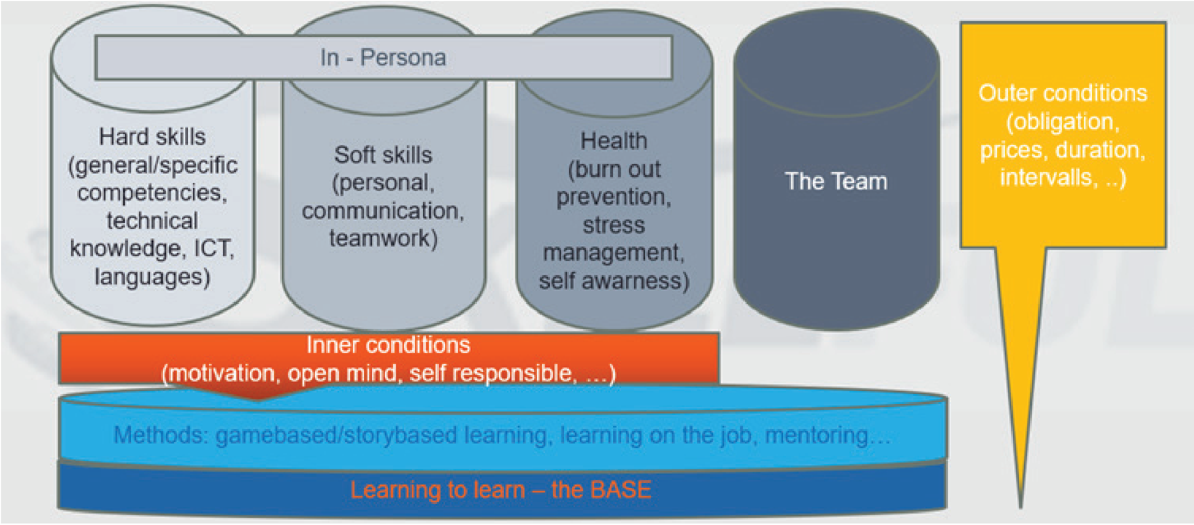

Figure 2.
Lifelong learning and training content columns scheme.

Table 3.
Time-related training schemes..

Category	Minimum	Intermediate	Maximum
According to legal Requirements			
Interval	STCW refresher all 5 years + new courses or training by the job (familarization)	All 2-3 years	Monthly, every half year
Content	Education and Training only according to the law (mostly knowledge-oriented), general	Minimun Variant + knowledge, skills, team, general and object related individual	Intermediate Variant + individual needs oriented
Duration	According to the law		½ day-a few days, depending on object
Orientation	According to the law, general	Needs of company	Needs of trainee and company, individual
Sustainability / Preservation of knowledge, skills	According to the law suficient, but less effective, not suitable e. g. for ICT	ICT conform	Best variant, enough time for refreshment of various contents
Growth of knowledge, skills	Only according to the law, topics identified by authorities, administration, less growth because of less time / periods	Corresponding to interval and objects, better than minimum	Excellent possibilities
Actuality	Sufficient, but sometimes delayed because of slow law enforcement	More actual	Up to date, also including newest technologies
Costs	According to the law, at first sight minimum effort but...	More expensive than minimum variant on first sight, but...	More expensive variant, but only on first sight...
(+ (in principle) "unvalidated" informal learning by the way in all variants, only depending on the person him - or herself)			

by inner (orange) and outer conditions (yellow). Various methods used in lifelong training are suitable for the education and

There are three time-related lifelong learning schemes. The minimum version, barely meeting the legal requirements with a long term horizon and the intermediate alternative with midterm brushing up of knowledge and soft skills, as well as further qualification, depending on the work and the position, are not preferable. The maximum short-term version includes continuous, e.g. half a day per month, 1 day every 3 or 6 months, mixed and need-oriented content, involving the repetition of basics and the acquisition of new know-how, improvement of soft skills, health awareness and team aspects. It provides sufficient time to take a look at the shortcomings and needs of the team and the company, further qualification and development of individual employees, the team and the company. The performance, work force, quality of the work, employee satisfaction and know-how of the employees and the company improve when the periods between lifelong training courses decrease. Table 3 shows the differences between several time-related schemes in terms of several aspects, like legal requirements, content, duration, orientation, sustainability, growth of knowledge and skills, actuality and costs.

The maximum, short-term variant is the most preferable.

4. ASSESSMENT OF LIFELONG TRAINING SCHEMES IN THE TRANSPORT SECTOR

In the light of future trends and bearing obstacles in mind, the partners of the Skilful project devised novel training schemes for low to medium skilled transport professionals, with the aim of meeting the requirements of future transport systems and the needs of adult transport professionals by providing lifelong training schemes enhancing quality and transparency, and promoting the recognition of competencies and qualifications to increase the mobility of learners and employees. (Ahern et al., 2019) The use of ICT/C-ICT on-board technologies, cyber security, technical inspection and maintenance of clean ships and infrastructures by the relevant technical staff, environmental issues like alternative fuels and alternative propulsion, new shipping routes and new approaches for infrastructure managers and intermodal terminal and logistics experts, are some of the content-related aspects of lifelong training schemes. (Ahern et al., 2019)

A questionnaire with 27 different question types (open or closed, yes, no, no answer, alternative 1, 2, etc.) was designed to be answered by institutions which organize lifelong learning courses in the framework of the Skilful project, inquiring about used or planned methods, communication tools and motivating parts and aiming to get further detailed information on the characteristics of lifelong learning courses and the awareness of the institutions proposing and offering courses. The answers were given using the mysurvio.com internet platform.

training of adults. The necessary basis for every lifelong training is the ability and competence of "learning to learn".

The courses are dispersed across Europe, since proposing and offering institutions are located, for example in Germany, Slovakia, Lithuania, Finland and Spain. The institutions planned, structured and prepared various courses in anticipation of future trends in the transport industry, striving to meet the requirements of changing and emerging job profiles. Due to the preparation of various courses, the selected and preferred tools, instruments and studied methods were mentioned in the answers. Sometimes the answers were influenced by the organisers who opted for the use of strict frames and tools, or by the surroundings and prerequisites. The lecturers often offered answers from their lectures, selected their preferred methods and even conclusions from other former courses or participants' wishes in feedback forms were included in the solutions and methodological and structural frames or course boundary conditions. Finally, the answers were collected, structured and are presented below as assessment results.

4.1. Methods Used in the Lifelong Learning and Training for Adults

Methods used in lifelong learning courses offered by institutions, limited to the Skilful Project, vary from knowledge-based methods and learning to learn, to evaluation, feedback and knowledge consolidation. Course descriptions contain concrete methods, provide information on the general way in which adult participants are taught in the specific training course and main approaches used in the lectures. The individualisation and adaptation of training content to participants' needs and requirements, issues raised during training, as well as to the level of their understanding, depending on the background of the participants, is important. The different solutions used in the training courses were analysed using the objects of lifelong training methods, ideas for motivation, practical parts and communication. The results of this analysis are summarized and presented in the section below.

Adults, being experienced workers and employees from every branch, do not need academic theories –rendered unnecessary by their experience and real understanding of the job requirements, Instead, they need lectures which combine new theories, help them refresh the knowledge they need, using practical and real experienced-based learning elements.

For this reason, different type of learning approaches would be the best solution in daily life and lifelong training. Smart education enables smart learners to meet the needs and successfully cope with the technologies used at the workplace and necessary for life in the 21st century.

Asked which types of "traditional" lecture parts were included in the courses, the offering institutions replied: knowledge transfer by frontal teaching in seminar form, introduction (including technical introduction of the training systems and reasoning behind the course, explanation of current learning methods and the experiences of other trainees with the training), individual lecturing and traditional individual preparation of open questions. "Traditional" supporting learning methods were indicated as lectures supported by a presentation programme tool with slides, but including lots of pictures or lectures supported by short video clips. The use of visual aids, handling simulations and games are also frequently mentioned as good tools. Case studies, where applicable, are another good method, as is scenario/story-based learning. In all the offered courses, the institutions thought it very important to use different methods during the day and even in the course of a single lesson or unit.

Communication-supported learning is one of the top learning tools for adults or experienced professionals. The lecturer can initiate topic discussions or ask questions. Discussions in the form of a roundtable, spontaneously proceeding discussions or personal experience reports are welcome instruments. The lecturer can introduce these developments in the classroom by encouraging the participants to speak up if there is something they do not understand, ask additional questions or by asking for feedback.

Both participants and lecturers often prefer team-supported learning, such as collaborative/team-based learning or work in small groups.

Concrete varied, promising and adult suitable methods for application in traditional lectures, combining several elements and for different stages of the teaching and learning process are for example:

- Science Fiction
- TABU
- Spectator
- Active Text Reading
- Learning slogan
- Minutes paper
- Active structure
- Generating questions for examination/assessment
- Brainwriting.

The more technical a topic is, the more experienced, older, mixed or low-skilled the participants; since practice-supported learning is a very good alternative to traditional lecturer-led presentations, lectures should be enriched with practical experience like on-the-job training, experiential learning, learning by doing or simulation tools like virtual training for practical operations and new technologies, as well as practical exercises suitable for individual, pair and group work. The repetition of practical elements is a factor which guarantees the successful understanding and integration of the related content into the participants' practices and memory.

4.2. Motivation for and in Lifelong Training Courses

Motivation can be improved by several methods. The ideas used in lifelong training courses include motivation by establishing suitable organisational framework, using communication, self-motivating and general motivating methods.

The organisational framework is in itself an opportunity to create new and strengthen pre-existent motivation. Some common rules apply: the lecturers have to be respectful to participants. The timetable or working plan should provide for the changes of lecturers and trainers during the day, and set aside sufficient time for discussion, reflection and exchange of experience. Organisers and lecturers should take into account the autonomy and personal responsibility of adult students. Knowing participants' backgrounds and utilising that knowledge in discussions can be a very strong instrument for opening up their minds and creating a positive learning atmosphere. As expected, boring topics should be taught taking into account their tediousness. An opportunity not to lose the participants' attention is the maxim "Legal aspects, yes - but free from time limits". In spite of participants being adults, a reward for well completed tasks or precise work, e.g. sweets, is always a successful tool.

The essential development of new skills, promotion at the workplace and the advantages of staying abreast of the current trends in decision-making are also promising. All participants should know why they learn, for whom and which advantages they may expect for themselves.

Emphasis on the opportunity to learn new technologies and features without reality or time limits, without stress and expectations, automatically results in the creation of positive, open-minded atmosphere. Lectures for older or unexperienced participants should take the form of a safe room, where mistakes are allowed and accepted, even desirable. In case of e-learning, computer- or web-based tools, the advantage of being able to study anytime and anywhere in the world, travel cost savings and no travel time should be proactively communicated.

The use of a clock, allowing the participants to see when the breaks are, and giving them an opportunity to interrupt the lecture whenever necessary, taking into account and meeting their need for short, flexible breaks which increase concentration, are other structural characteristics of adult learning. Organisers and lecturers should schedule short active breaks when using passive teaching methods and vice versa. The practical part should be scheduled after the lunch break, due to the decreased attention and concentration. One of the best advices is: laughter is very welcome!

Self-motivating ideas for adult courses are the introduction of course objects directly relevant for the participants' workplaces and discussion. Participants find it motivating to know that the opinion of every last one of them is valuable; this inner feeling contributes to the courses´ success. Additionally, courses may allow participants to leave early if required by their activities. Success stories of people who upgraded their qualifications are a welcome motivational factor to be used in different stages of the course. Another motivating factor is the understanding that the improvement of skills makes participants more independent and responsible for specific levels of operative decision-making.

Understanding how new ideas and business changes were developed, the knowledge of the decision-making processes, opening the participants to new ideas, improvements based on the use of artificial intelligence and the manner of their introduction by responsible company managers can contribute to sustainable implementation.

General motivating methods are, e.g. learning mainly based on practical methods, case studies, making course objects relevant for participants, including as many practical examples as possible, no theory without practical implementation/example. Other motivating aspects are: guessing when objects will be introduced using an estimation task, the anticipated results at the end of the lesson, the timing of the teaching and explanation of individual objects, using different types of teaching and training and at least three different methods in the course of the lecture. Games or guesses can be perceived as welcome breaks in trainer-led lectures. The combination of theory and emotions, e.g. storytelling or the use of different sorts of materials, references, infographics, short videos, lectures, podcasts and other resources, can make lessons more interesting. Institutions also offer new online methods of learning and gaining competencies, as well as virtual learning platforms, to engage more people. The use of current IT-oriented decision support tools is a good practical opportunity for updating one's technical skills. High level of interaction during e-learning, achieved by making available different discussion forum threads or a chat tool for interaction among trainees and trainer and discussion about course contents, can be motivating. The use of new technologies (tablets and apps) is a guarantee of greater involvement.

4.3. Practical Parts of Lifelong Training Courses

Alternating methods containing interchanging active and passive parts, shifting between interaction in groups, in pairs or individual work, complete each lecture with the practical postulates of lifelong training and future-oriented courses. Support by trainers includes introduction at the beginning of the course and individual prepping where required. Communication tools such as table top exercises and mini-workshop, are some of the popular practical course parts. Excursions can be used to this end, e.g. visits to transport companies, logistics terminals and manufacturers. The organisation of course activities in special educational centres and teaching in other locations, as well as the use of laptops or mobile devices represent a valuable diversifications of classroom-centred schedules.

Several practical exercises should be incorporated, including observation and discovery, not only observing, but handling actual equipment or using the practical parts of the course for medical care and first aid training by incorporating real exercises involving the treatment of typical injuries into occupational health training, practical training for several circumstance in the fire hall, on-the-job training, e.g. in the port; training should consists of introduction, sample, training and test from all its part. The use of laboratories as practical parts is also valid, and may include the conduct of actual experiments at real labs (chemical, ...) or the use of labs equipped specifically for the training of transport experts and workers. Simulation or virtual training are likewise often used as practical lesson parts, involving simulation tools or training by (driving) simulators, virtual learning of technical details in the framework of the learning-by-doing methodology may include 3D models of transport modes and tools.

4.4. Communication

With respect to communication, organisers and lecturers are invited to begin with various "Openers" – starting the day with a short self-introduction of participants, with topic-pertinent information or completely random, unexpected facts, because they will be spending the entire day together. One popular opener is completing the sentence "I´m here today although / because … " or the expectations of the course worded as a weather forecast. Bringing up own issues and ideas related to the lecture increases motivation and subjective involvement.

Adults are valuable participants; asking them for feedback and having them introduce themselves at the beginning of the course can be used as a tool for demonstrating respect. Another communication method at the end of the lecture is a joint short evaluation involving all participants, feedback with hints for improvement, as well as praise for a work well done.

Communication is a very important constituent of the lifelong training because the employees already have experience in their working fields, and their knowledge and experience are very useful. Courses must include parts in which participants can exchange experiences. The teachers must provide motivation and create opportunities for communication, e.g. by using provocative questions, guesses, asking for opinion or experiences. Communication, as group conversation, must be included in every lesson, minimum 10-15 minutes.

The general communication framework implies necessary interaction with the participants. The lecturers and trainers have to be motivated to integrate communication into their lessons. Examples of communication events are, for example, introducing the participants and talking about their professions and job experience ("welcome opener"), frontal teaching in seminar form, analysis and the presentation of case studies by participants, opportunity to ask questions and express concerns during lectures or even prepared questions/discussion topics for each topic area. Lunch breaks should also be used as an opportunity for topical discussion, background variability may later be included into discussions, trainees should be given an opportunity to converse with the trainer individually, mini workshops may be organised after each subtopic to encourage comprehensive discussion on the topics just learned, to exchange understanding and experiences. There should be a question & answer session, as well as the final workshop organised at the end, where experts can share their experience.

Evaluation and feedback are also common communication events. At the end of the day or course, the participants get the "last" word, where they say what they have learned during the course or give feedback to the trainer and closing remarks at the end of the day or several times. A prepared questionnaire as feedback for the course can be a useful support for the communication part.

New learning methods and communication include, for example, personal contact when using e-learning platform, to share materials, download examples and interesting links to alternative educational sources, supplemented by the possibility of scheduling individual meetings with the lecturer to discuss his/her progress in the course. A discussion forum, as the main communication tool, or a chat, as complementary tool, facilitating more informal conversation, are also communication.

5. CONCLUSIONS

The lifelong training aspects of future-oriented courses in the framework of the Skilful project cover various transport modes and future trends. (Bekiaris & Loukea, 2017; Ahern et al., 2019; Infante et al., 2019) In the light of future trends and bearing obstacles in mind, the partners of the Skilful project devised novel training schemes for low to medium skilled transport professionals, with the aim of meeting the requirements of future transport systems and the needs of adult transport professionals by providing lifelong training schemes enhancing quality and transparency, and promoting the recognition of competencies and qualifications to increase the mobility of learners and employees.

Lifelong training courses, not limited to the maritime or transport topic, will therefore include future-oriented contents, a good and practicable registration procedure providing all the necessary information for participants, organisers and lecturers. Qualified lecturers and trainers capable of tailoring course contents to the specific focus of the course and participants' requirements, giving excellent lectures with motivating parts, summarizing relevant learning material and offering real usable factors, delivering clearly structured lectures including introduction, main content, feedback or even assessment. Practical parts support the learning process for individuals and groups, and strengthen motivation which should be further improved by including remarks of concrete relevance for individual participants, their profession, area of work or even concrete workplace in every lecture. Both lecturers and participants recommend reserved communication parts for different reasons: lecturers for informal learning and as part of the lectures used to evaluate knowledge or strengthen motivation. Another important fact is reserved communication, planned and stimulated by lecturers, the chance for important social contacts which improve soft skills and can likewise be used to exchange experiences and learn from other participants. Participants mostly appreciate the possibility to exchange experiences and compare their own professional frameworks with those of other participants. There should be awareness and recognition of intercultural aspects due to globalisation and at best incorporation of suitable subjects. Lecturers should be able to meet the needs and requirements of mixed groups, e.g. participants from different age groups, with varying level of work experience, understanding and responsibility. A repetition or a new learning to learn method should always be included in the course. Lecturers should furthermore be able to use different, adult-suitable methods and alternate methods in the course of a unit. Focus on emotions to increase the motivation to learn and using various motivating methods will guarantee an interested auditorium for the lecturer.

Every single course should include the lifelong training aspects of the European Union like: communication in mother tongue, communication in foreign languages, mathematical competence and basic competence in science and technology, digital competence, learning to learn, social and civic competences, sense of initiative and entrepreneurship; and cultural awareness and expression.

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Satellite Derived Bathymetry Survey Method – Example of Hramina Bay

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Satellite Derived Bathymetry (SDB) method uses satellite or other remote multispectral imagery for depth determination in very shallow coastal areas with clear waters. Commonly, SDB survey method can be used when planning hydrographic surveying of marine areas not surveyed or areas with old bathymetric data. This method has become widely used in the past few years. SDB is a survey method founded on analytical modelling of light penetration through the water column in visible and infrared bands. In this article, SDB method was applied by using free-of-charge Landsat 8 and Sentinel 2 satellite images to get the bathymetric data in the area of Hramina Bay in the Central Adriatic. SDB processing procedures and algorithms were described. Processed satellite data was uploaded on geodetic software and ENC S-57 format. The bathymetric map of Hramina Bay obtained by the SDB method was compared with the approach usage band Electronic Nautical Chart (ENC) HR400512 with satisfying positional and vertical accuracy.

KEY WORDS
~ Satellite Derived Bathymetry
~ Hydrography
~ Middle Adriatic Sea

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1. INTRODUCTION

Satellite Derived Bathymetry (SDB) is a relatively new survey method which uses satellite or other remote multispectral imagery for depth determination (Marks, 2018). The results of SDB method are applicable in many hydrographic branches and generally in marine sciences (bathymetry, cartography, coastal management, water quality monitoring, etc.).

This method was developed in the late 1970s, but the frequency of its use has increased considerably in the last few years (UKHO, 2015). It should be mentioned that accuracy of SDB does not meet current International Hydrographic Organization (IHO) S-44 standards (IHO, 2008). However, according to Pe'eri et al. (2013), it can be used when planning hydrographic surveying of marine areas not surveyed or areas with old data. Since the data of some satellite missions is free or available for a relatively small price, it can be said that this is almost the cheapest source of spatial data in general.

Hydrographic surveying by conventional shipborne sounding techniques is time consuming, demanding, and expensive.

About 50 % of the USA territories were surveyed by using old hydrographic methods that do not meet today's requirements (Marks, 2018), while in the Republic of Croatia there is about 45 % of the marine territory with depths below 200 m, surveyed with inadequate hydrographic accuracy standards (Leder, 2016).

Analytical modelling of light penetration through the water column in visible, and infrared bands are the physical basis of the SDB method. SDB used optical remote sensing data for depth determination whose shortwave electromagnetic part of the spectrum has a strong penetration capacity (Stumpf et al., 2003). Solar radiation is absorbed and it scatters while spreading through water, and residue energy has been backscattered and recorded in remote sensing imagery. There are different methods of SDB determination over near-shore area which are mainly classified into analytical, empirical and combined models (Vinayaraj, 2017).

Model development requires a knowledge of the water optical properties in the coastal area, such as absorption coefficients of suspended and dissolved substances, attenuation, scattering and backscatter, bottom reflections, coefficient, etc. (Lee et al., 1998; Mobley et al., 2001). Such models are generally referred to as radiation transfer models and include the inherent assumption of bottom reflection, corresponding level of water quality and shallow depth (Baban, 1993; Muslim and Foody, 2008), and their use is not recommended in coastal waters with weak bottom reflection and high turbidity.

In empirical modelling, the relationship between remotely sensed radiance and the depth is established empirically regardless of whether the light propagates in the water or not. The correlation between water depth and spectral band radiation is used to calculate SDB. Empirical modelling is based on the assumption that the total reflectance is primarily related to water depth and the secondary to water turbidity (Vinayaraj, 2017). Empirical parametric regression based models, such as Stumpf et al. (2003), are very popular and easily applied. There is also nonparametric regression as explained by Ribeiro et al. (2008). These models enable fast data processing, but require depth point calibration.

A combination of analytical and empirical models is proposed by many authors in order to overcome the disadvantages of both models. The most popular and widest applicable model is suggested by Lyzenga et al., 2006 (Kanno and Tanaka, 2012; Su et al., 2013; Vinayaraj et al., 2016), as physically based algorithm, and the predictor can be analytically derived from a radiative transfer model. Calibration depth is used to calculate the attenuation of spectral band parameters as they are obligatory for low quality water areas. The empirically derived parameters are related to the inherent optical water properties. These models are faster and need less prior knowledge of water spectral properties. The method presented in this article is based on a combined model.

In this paper, SDB method will be applied in order to get bathymetric data in the area of Murter island Hramina Bay situated in the eastern part of the Central Adriatic (Figures 1 and 2) and compared with Electronic Nautical Chart (ENC) composed on the basis of echo-sounder bathymetric data.

Figure 1.
Murter island, Hramina Bay: Google (top) and photo from N (Source: https://www.apartmanija.hr/apartmani/murter; bottom).

2. STUDY AREA

Murter is an island in the middle of the Adriatic Sea at 43°49'37"N 15°35'50"E, inhabited in prehistoric times. In the 18th century, it was named after a stone grove of oil presses. The island's area is 17.58 km^2, the coastline length is 42,605 km (Duplančić Leder et al., 2004). There are 4 settlements on the island: Murter, Betina, Jezera, and Tisno, with 5,138 inhabitants. In Hramina Bay, there are remains of the ancient Roman settlement Colentum.

The island's largest settlement is Murter in Hramina Bay, situated in the north-western part of the island (Figures 1 and 2). It is a shallow bay with a maximum depth of 7 m (HIRC, 2004), making it suitable for SDB survey method. The Adriatic is a very clear and transparent sea; therefore, this method can be applied to the entire area. In the NE part of the bay, there is Marina Hramina.

The area of the central Adriatic is commonly a nautical area, especially in the summer period when the traffic increases, especially by tourist and excursion boats. The last survey on this area is over 70 years old - methods that were used were not contemporary; a very shallow area with a sandy bottom is suitable for using the SDB method.

Satellite derived bathymetry method is convenient for bathymetric survey of shallow areas with clear water. In practice, it is being used approximately to the depth of 2 secchi disc depth - measure of sea water transparency or turbidity. The eastern Adriatic Sea coastal area has mostly very shallow water, very clear in a greater part of the year. Thus, SDB method met two basic components which are the prerequisites for its usage.

The transparency of the area as well as the transparency of the entire Adriatic is high, especially in the spring, except in periods when sudden warming causes the phenomenon of sea bloom, which is a relatively rare occurrence. The Mediterranean Sea water clarity is 23-30 m (Hartman et al., 2017), and the average transparency value in the Adriatic is 10-20 m (Žuljević et al, 2016; Morović et al., 2008). Turbidity and the sea currents of this area are also not expressed because it is a relatively closed area. The bottom type is sand (Figure 1), where sand has high and kelp has low albedo or reflection (Hartman et al., 2017).

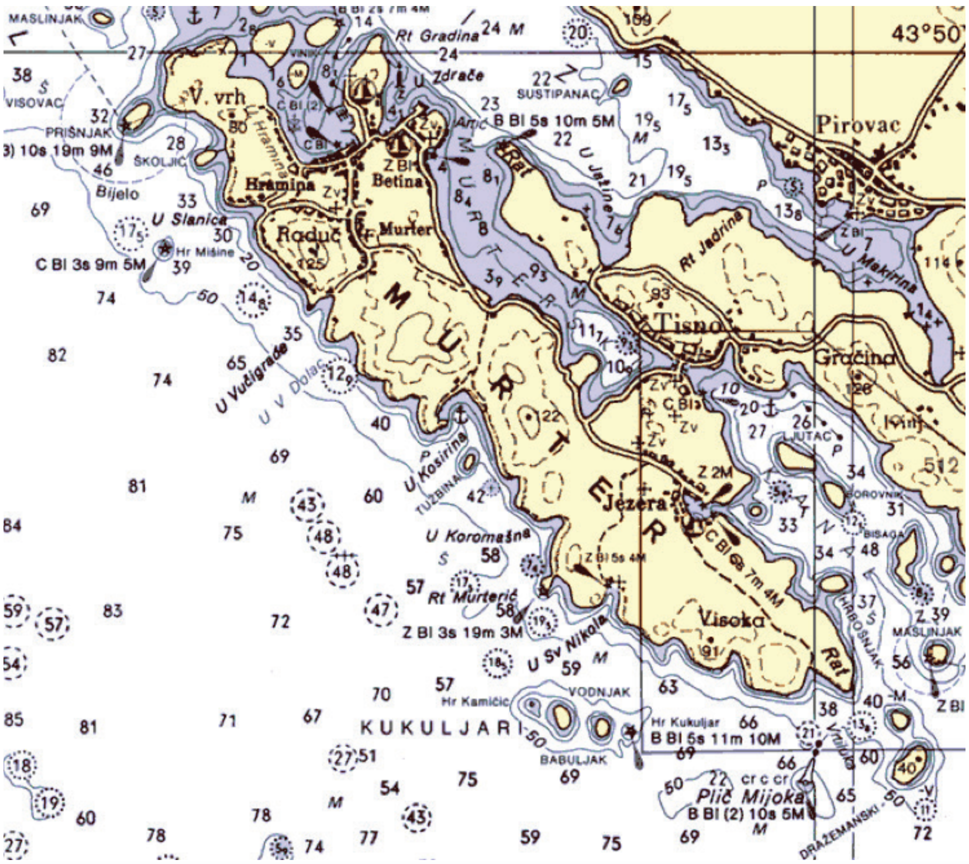

Figure 2.
Part of the nautical chart 100-21 with the island of Murter (Hydrographic Institute of the Republic of Croatia).

3. MATERIALS USED FOR SDB METHOD

In this research the Landsat 8 and Sentinel 2, both open data satellite missions, were used. The closest time scenes from the winter-spring period were selected. In this period, there is no heavy boat traffic in this area, and the seawater is very transparent.

3.1. Landsat 8

Landsat program is the most timely satellite imagery mission of series of Earth-observing satellites. Landsat 8 satellite was launched on 11 February, 2013. It is a collaboration between the National Aeronautics and Space Administration (NASA) and the United States Geological Survey (USGS). Landsat scene is 185 km long and 185 km wide (Figure 3). The data can be downloaded through the USGS EarthExplorer, GloVis or the LandsatLook Viewer websites. Landsat's most important tasks are observation and exploration of the Earth's surface, which has a wide range of applications.

Landsat 8 carries two push-broom instruments: The Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS). The OLI sensor acquires a total of 9 bands: eight multispectral bands with 30 m, and one panchromatic band with 15 m spatial resolution (Figure 5). The TIRS instrument collects two spectral bands for the thermal infrared wavelength.

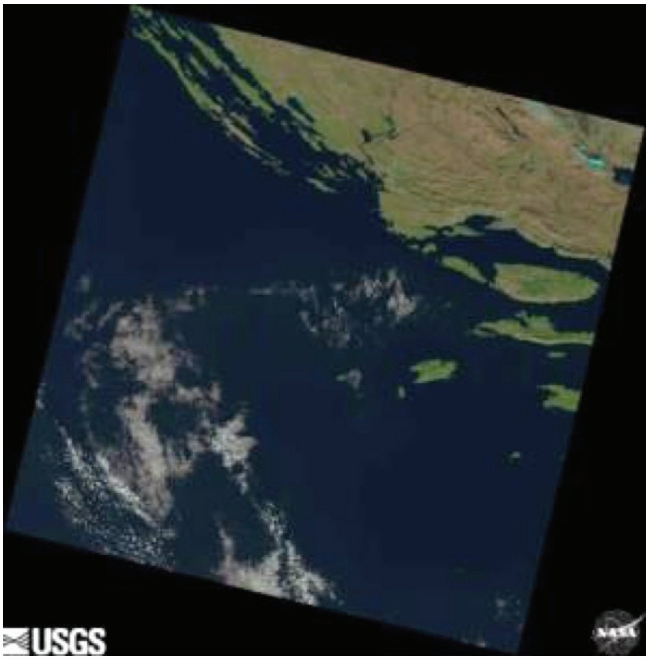

Figure 3.
Landsat 8 image of the Central Adriatic area on February 14th, 2017.

The temporal resolution of this mission is 16 days. Landsat orbit is un-synchronous at an altitude of 705 km, with 233 orbit cycles per day. The orbit inclination is 98.2°, and the equatorial crossing time is 10:00 a.m. +/-15 minutes. The sensors both provide improved 12-bit radiometric resolution data (4096 level of grey).

3.2. Sentinel 2

Sentinel-2 is the European Space Agency (ESA) Earth observation mission as part of the Copernicus Program. Sentinel-2A was launched on 23 June, 2015 and Sentinel-2B was launched on 7 March, 2017 from French Guiana. The mission performs terrestrial observations to support services such as forest monitoring, land cover changes detection, and natural disaster management. All Sentinel mission data can be downloaded through Copernicus Open Access Hub and USGS Earth Explorer.

The mission consists of two identical satellites, Sentinel-2A and Sentinel-2B. The satellites' orbit is Sun synchronous at 786 km (488 mi) altitude and 14.3 revolutions per day. The orbit inclination is 98.62°, and the Mean Local Solar Time (MLST) at the descending node is 10:30 (am). The Sentinel-2 swath width is 290 km (Figure 4).

The temporal resolution of this mission is 10 days with one satellite, and 5 days with 2 satellites. Sentinel-2 is a multi-spectral mission with 13 bands in the visible, near infrared, and short wave infrared part of the spectrum and spatial resolution of 10 m, 20 m and 60 m (Figure 5), and 12-bit radiometric resolution.

Figure 4.
Sentinel 2 image of the Central Adriatic area on 9 May, 2017.

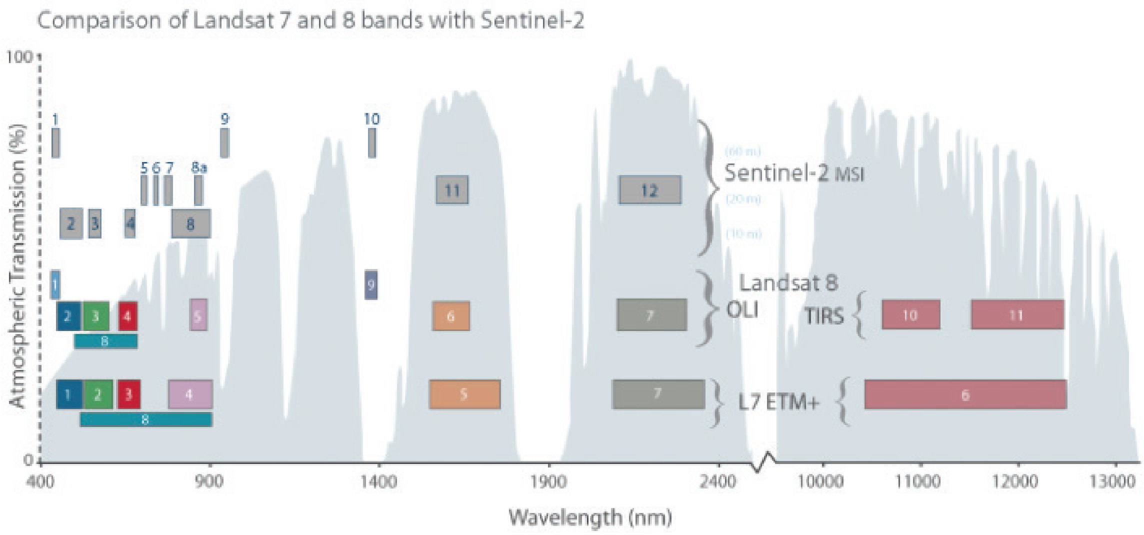

Figure 5.
Comparison of Landsat 7 and 8 bands with Sentinel 2 (Source: https://landsat.gsfc.nasa.gov).

3.3. Electronic Navigational Charts

In today's modern digital era technology advances also affect the design and publishing of maritime navigational charts, i.e. paper navigational charts are rapidly replaced by electronic navigational charts. Electronic Navigational Chart (ENC) is a digital version of the paper navigational chart. It is a vector database (chart) whose content, structure and format are standardized according to S-57 - Transfer Standard for Digital Hydrographic Data (IHO, 1994; IHO, 2017) suggested by both

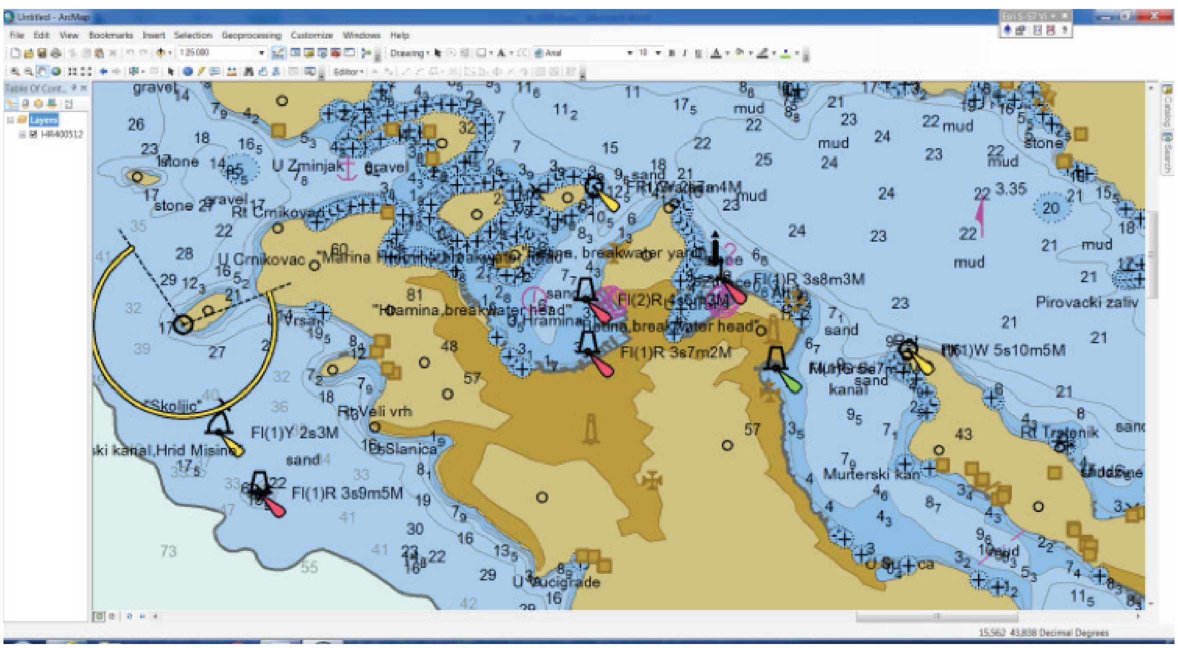

Figure 6.
Part of the Croatian ENC HR400512 with Hramina Bay area.

the International Hydrographic Organization (IHO) and the International Maritime Organization (IMO). ENC contains all the chart information necessary for safe navigation, but it may also include additional information (e.g. information contained in the Pilot, List of Lights and Fog Signals) (IHO, 1997; IMO, 1995). Together with the positioning system and the information on positions obtained from navigational sensors (e.g. radar, echo sounder, ship's speedometer), ENCs make up an Electronic Chart Display and Information System - ECDIS (IMO, 1995; IHO, 1997; Hecht et al., 2002). ENCs are published by national hydrographic offices and authorized data providers which are obliged to keep ENCs up to date in the same manner as paper navigational charts (Hecht et al., 2002).

ENC data is forwarded to users on board, grouped into usage bands according to navigational purposes: overview, general, coastal, approach, harbour and berthing (most details), which mariners use depending on the situation.

The Hydrographic Institute of the Republic of Croatia (HIRC) released more than 120 overview, general, coastal approach, harbour and berthing ENCs through PRIMAR Norway as the Regional Coordination Centre for ENC distributions. ENC HR400512 Kornat - Murter is an approach usage band ENC, scale 1:40,000 (Figure 6), HR500512 Murterski kanal - SE part is a harbour usage band, issued by HIRC. ENC HR400512 chart was used in this research as a basis, and for control depths data obtained by the SDB method.

4. METHODS USED FOR PROCESSING SATELLITE IMAGES

Depth estimation from satellite images is based on the theory that light is attenuated exponentially in the water. The procedure (workflow) to obtain bathymetric data from satellite imagery includes the following basic steps (Figure 7), according to Gao (2009):

1. Pre-processing
2. SDB Depth Calculation
    a. Water separation
    b. Spatial image filtering
    c. Glint/cloud correction
    d. Bathymetry algorithm application
    e. Vertical referencing or Tidal Correction
3. Post processing (QA/QC).

4.1. Pre-Processing

Similarly, as pre-planning phase for the acoustic survey, it is necessary to download satellite imagery based on the geographic location and optimal environmental conditions (e.g. cloud coverage and sun glint). After this phase, it is necessary to do radiometric and geometric correction (if necessary). Radiometric correction converts digital number values to Top of Atmosphere (ToA) radiance and reflectance. Corrected digital numbers to ground reflectance significantly reduced the accuracy of SDB estimates (Marks, 2018). The next phase is sun glint correction or noise reduction created by the sun's reflectance (USGS, 2015).

4.2. SDB Depth Calculation

The first phase of SDB calculation is water separation or removed dry land and most of the clouds by the obtained threshold value from Blue and Green band images and converting each pixel of the satellite image into a floating point representation. Thereafter comes the second phase with spatial image filtering with low-pass filter to remove "speckle noise" from the satellite imagery. The next phase is glint/cloud correction by using Hedley et al. (2005) algorithm to correct radiometric contributions from the sun glint and low clouds which is calculated according to the formula:

$$R'_i = R_i - b_i\,(R_{NIR} - Min_{NIR}) \tag{1}$$

where:

R'_i = Sun glint-corrected pixel

R_i = pixel value in the B and G bands;

b_i = regression slope;

R_{NIR} - Min_{NIR} = difference between pixel NIR (near infrared) value of R_{NIR} and ambient NIR level Min_{NIR} which gives the R'_i Sun glint-corrected pixel brightness of NIR with no Sun glint and can be assessed by the minimum NIR value.

There are several algorithm models developed for deriving bathymetry data from satellite images. This study uses the two most accepted empirical algorithm band Ratio Model. Band Ratio Model (Stumpf et al., 2003) compares band ratios with in situ data to obtain a mathematical relation between the ratio and the depth. Different bands of light will be absorbed to different degrees based on the water's inherent optical properties. For example, in clear waters with low quantities of sediment, phytoplankton and dissolved organic matter, blue light will be less absorbed than green light, while in coastal waters green light will penetrate to greater depths than blue light. This relationship is used to derive the depth of a pixel and the exact mathematical representation is identified empirically through SDB natural logarithm ratio of the blue and green band illustrated by Equation 2:

$$z = m_1\left(\frac{\ln(L_{obs}(Band_i))}{\ln(L_{obs}(Band_j))}\right) - m_0 \tag{2}$$

where:

L_{obs} = observed radiance of bands;

m_1, m_0 = offset and gain determined empirically;

($Band_i$) = B band; ($Band_j$) = G band;

z = depth.

Identifying the extinction depth or the optic depth limit for inferring bathymetry (also known as the extinction depth) is specified by calculated m_1, m_0 parameters. This is understandable as these bands can penetrate deeper than other colours, and they are available with most sensors.

The final stage of calculating the depth is data vertical referencing, i.e. reference depth to the chart datum.

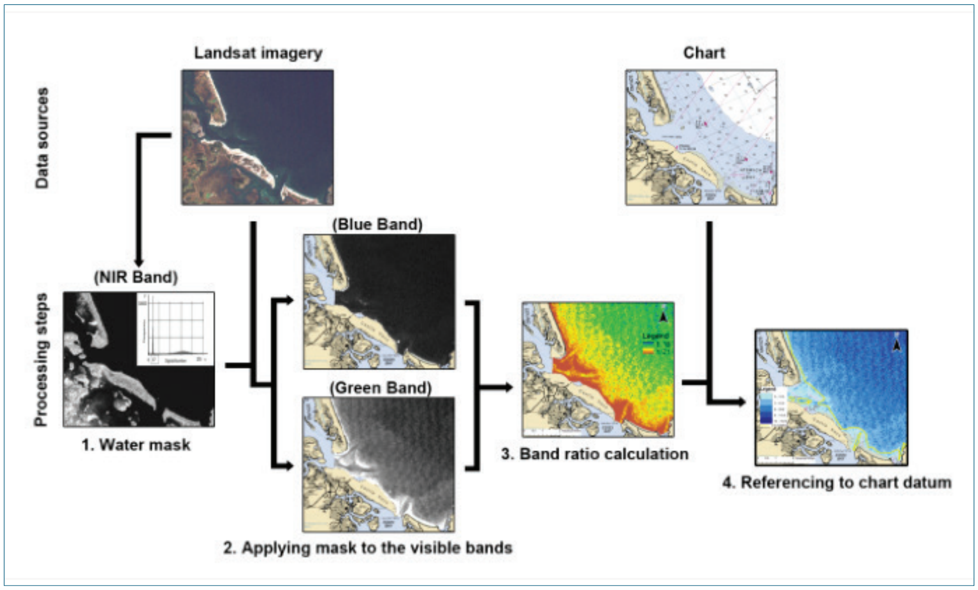

Figure 7.
Key step of SDB procedure (according to Pe'eri et al., 2013).

4.3. Post Processing (QA/QC)

The final phase of SDB process is the quality assurance process used to measure and assure the quality of a product and quality control, which ensures that products and services meet consumer expectations.

4.4. Processing Software

After the processing of satellite data, the product obtained was uploaded on ESRI ArcMap software Version 10.6 with the support of 3D Analyst Tool and ENC S-57 format capabilities for estimating the bathymetry using the log transformation algorithm. ArcMap Raster Calculator and Model Builder features were used for the majority of the works which involved geoprocessing. Landast 8 image data has been geometric and radiometric Top-of-Atmosphere (ToA) Radiance, ToA Reflectance, Sun Glint and Atmosphere Correction corrected. Sentinel 2 image data has been geometrically and radiometrically corrected in SNAP program. The median filter, a nonlinear digital filtering technique used for removing the noise from images, was applied to this study. A median filter was used to manage the reduction of high frequency noise.

5. RESULTS

The result of satellite derived bathymetry (SDB) method for the acquisition of bathymetric data by the non-survey vessels, which used free of charge Landsat 8 image on 14 February, 2017 (Figure 3) and Sentinel 2 image taken on 09 May, 2017 (Figure 4), for depth assessment in the area of Hramina Bay is shown in Figures 1 and 2. The only Landsat 8 and Sentinel 2 image was processed because of a small number of images that have recently been at disposal (free of charge) and without atmospheric/oceanographic "noise".

The maximum tidal range in Hramina Bay was about 40 cm (calculated from the Tide tables for the secondary port) on the date and time of the satellite scene recording. The depth values determined were referenced to the chart datum level.

Consequently, the bathymetric map of the wider area of Hramina Bay (Figures 8 and 9) could be treated as a "preliminary" bathymetric map. Figures 8 and 9 illustrate the estimated water depths computed by the satellite bathymetry model developed by Stumpf et al. (2003) from Landsat 8 and Sentinel 2 satellite images. In Figures 8 and 9, the depths are shown in the colour range from 0 m (red) to 50 m (dark blue).

By comparing the “preliminary” bathymetric map (depths and depth contours in the background) shown in Figure 2 with ENC HR400512 (Figure 6), it can be concluded that the depth gradients and coastline are actually very well surveyed by using SDB method, while individual shoals are not revealed because of the low spatial resolution of SDB method.

Figure 9 shows a more detailed view of the calculated depths, on Landsat 8 image (left) and on Sentinel 2 image (right). The figure shows that the depths shown on the right hand side image are much better because Sentinel 2 resolution is three times better than Landsat 8 resolution.

For better results, SDB method should be used on commercial satellite data in which the current image resolution reaches up from 0.5 to 0.3 m (WorldView 3 and 4).

According to SHOM (2015) and ARGANS (2016), almost all the available SDB data were within positional accuracy ±500 m and depth accuracy of ±2 m + 5 % of depth. In Hramina Bay, SDB data positional accuracies were 10 and 30 m (pixel size of the used satellite images), while the vertical accuracy was ±2-3 m.

In very shallow waters (shallower than 10 m), SHOM researchers compared the results of different methods to obtain the bathymetry data (Table 1). The table has been updated with the data used from free satellite missions from this research.

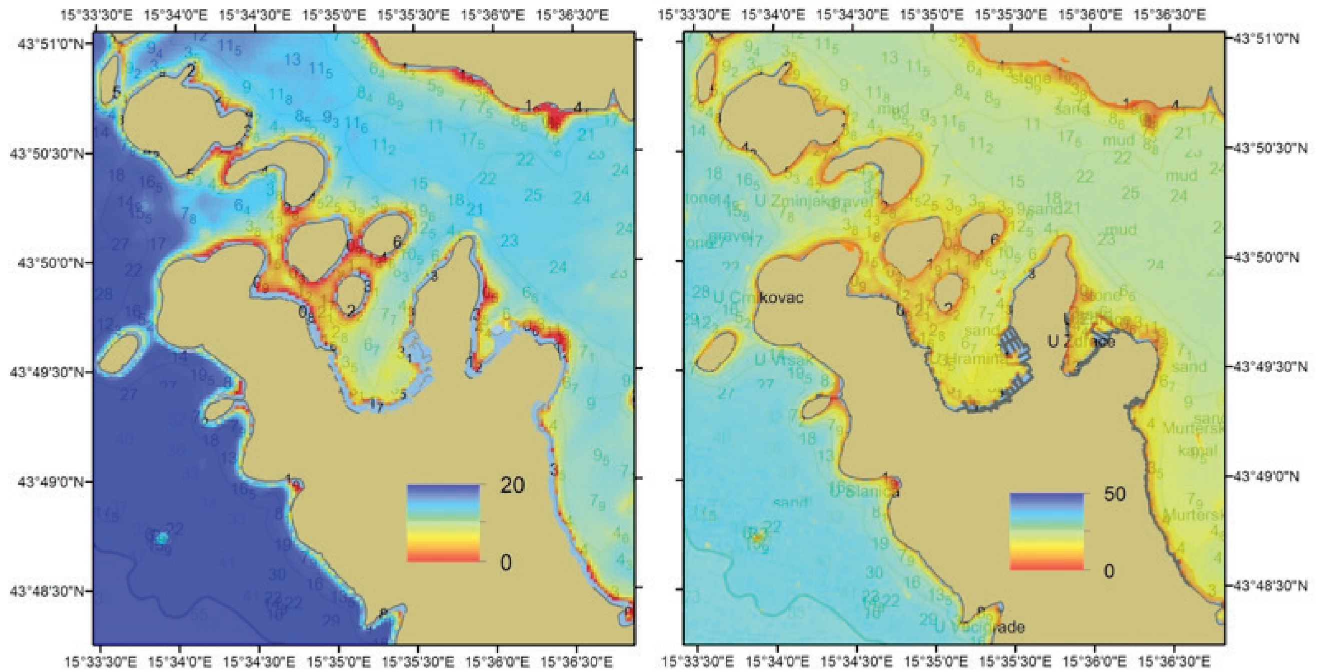

Figure 8.
Satellite-derived water depth of Hramina Bay obtained from Landsat 8 (left) and Sentinel 2 (right).

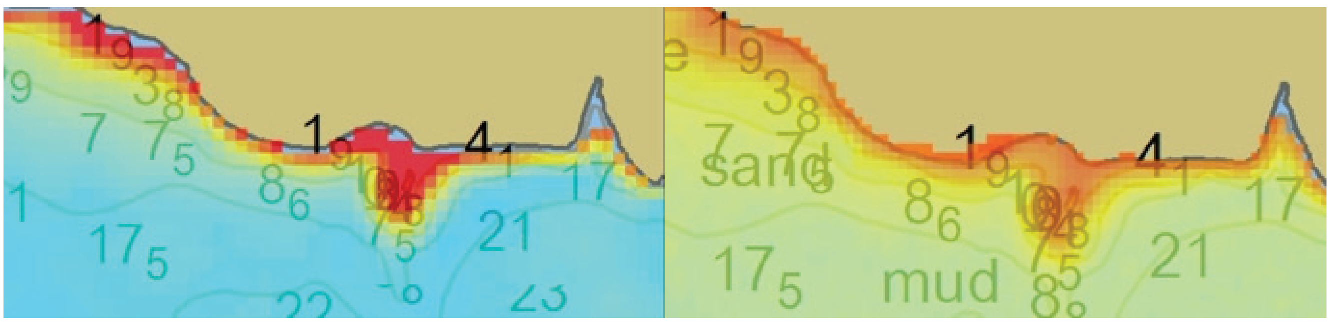

Figure 9.
A more detailed view of satellite-derived bathymetry obtained from Landsat 8 (left) and from Sentinel 2 (right).

Table 1.
Comparison of the characteristics of acoustic and Lidar method (ARGANS, 2016; SHOM, 2015) and SDB methods (this study).

	Acoustic	Lidar	Satellite		
Device	EM204	CZMI	Landsat 8	Sentinel 2	Palaides
Survey (€/km^2)	2.5	1.5	0	0	0.01
Survey (hour/km^2)	7	0.08	0	0	0
Prosessing (hour/ km^2)	21	4	2	2	3
Total cost (€/km^2)	3.3	1.7	0	0	0.1
Total duration (hour/km^2)	28	4	3	3	3
Hor. resolution (m)	0.2	0.5	30	10	2
Ver. resolution (m)	0.1	0.2	1	1	1
Density (depth/m^2)	25	4	0.01	0.01	0.25
Hor. acc. (m)	0.5	1	30	10	10
Ver. acc. (m)	0.2	0.3	30 % of depht	30 % of depht	10-30 % of depht

6. CONCLUSION

Satellite-derived-bathymetry survey method can be used when planning hydrographic surveying of marine areas not surveyed or areas with old bathymetric data. Unlike hydrographic surveying performed by conventional shipborne sounding techniques, SDB method for depth determination is not time consuming, demanding or expensive. SDB cost generally depends on the costs of satellite images, which ranges from 0 (free of charge) to 60 €/km2, depending on the image quality.

By applying SDB method in Hramina Bay area in the eastern part of the Central Adriatic, it could be concluded that the method is suitable for a bathymetric survey of shallow areas with clear water (approximately to the depth of 2 secchi disc depth), which the researched area fills during most of the year.

In Hramina Bay SDB data, the positional accuracies were 10 and 30 m (pixel size of used satellite images), while vertical accuracy cannot be exactly estimated because the depths measured by the echo sounder and the depth estimated from the satellite images do not have the same spatial resolution.

From the satellite-derived depths, it is obvious that the depth gradients and coastline are actually very well surveyed by using SDB method, while individual shoals are not revealed because of the low spatial resolution of SDB method. SDB depth data has better result by using Sentinel 2 scenes, because Sentinel 2 space resolution is three times better than Landsat 8 resolution. The results obtained are satisfying for only one satellite scene and without knowledge of the atmospheric/oceanographic conditions in Hramina Bay area.

When choosing the satellite scene, we chose the free Landsat and Sentinel missions, but on the same principle the depth can be calculated with commercial satellite mission, which has a higher spatial resolution (e.g. Worldview 3 or 4 with spatial resolution of 0.3 m).

Finally, it can be concluded that SDB method presented in this paper can be scientifically improved by satellite scenes obtained from commercial satellite data, all in order to achieve current International Hydrographic Organization (IHO) S-44 standards for hydrographic survey (IHO, 2008).

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Marina Operator Liability Insurance in Croatian and Slovenian Law and Practice

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The paper deals with marina operator liability insurance (hereinafter: MOLI) in the context of Croatian and Slovenian insurance law and business practice. The authors analyse, discuss and compare the salient features of MOLI contracts, their standard terms and conditions, scope of coverage and exclusions in Croatian and Slovenian law. The paper describes the relevant business practice in the two Adriatic countries. The analysis is based on the comparative study of the relevant national legislation and private regulation, as well as on the data and documentation gathered by field research, consisting of written questionnaires and live interviews with the representatives of insurance companies and marina operators. Our thesis is that the legal framework in the two observed jurisdictions, as well as the insurers' private regulation in Croatia and Slovenia are very similar. The aim is to establish the common features of MOLI contracts and of the related practices of marina operators and their insurers in the respective countries and explain the background that has led to the formation of a MOLI product specific for the eastern Adriatic marina industry. Suggestions are given for the improvement of the relevant business practices and administrative requirements regarding the minimum insurance standards imposed on marina operators by the concessioning process

KEY WORDS

~ Marina operator
~ Liability insurance
~ Berthing contract
~ Nautical tourism port

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1. INTRODUCTION

Marina operator liability insurance (hereinafter: MOLI) is a special type of liability insurance protecting marina operators from civil liability incurred in relation to and as a consequence of performance of their core business activities. In the manner and to the extent agreed by the insurance contract, the insurer undertakes to indemnify the insured marina operator for any sums the insured becomes liable to pay to an injured party as a consequence of damage or loss caused in the course of performance of marina operator's business activities. In particular, marina operators may be liable to their clients for damage caused by a breach of a contractual obligation (contractual liability). The most frequent example of marina operators' contractual liability is liability for damage to vessels whilst berthed or during lifting and launching operations or in the course of repair, servicing or maintenance work performed by the marina operator. Marina operators may likewise be liable in tort for personal injury to third parties or for causing damage to or loss of a third party's property (third party liability, tortious liability). For example, a third party visitor could suffer an injury at the marina premises; a vessel berthed in a marina could get loose, float out of the marina and collide with another vessel outside the marina or hit a fixed or floating object; a fire or an explosion in the marina could spread out injuring persons and causing damage to property outside the marina etc. Finally, a marina operator may become liable for damage caused by pollution originating from the marina operator's business activities. Due to the high business liability risks, a valid insurance policy with an adequate scope of coverage is a conditio sine qua non for a prudent marina operator to run business and function on the market uninterruptedly.

For the purpose of this paper, a marina can be defined as a harbour designated for vessels used for leisure, serving for the provision of berths and other accompanying services to yachts and other pleasure craft, their owners, users and crew. It is the most complex type of nautical tourism port. Other nautical tourism ports are usually smaller, simpler, providing only the basic berthing service (e.g. mooring or berthing facility, anchorage) or accommodation or storage of vessels on land.

In Croatia and Slovenia, marinas, as special purpose seaports, are subject to the legal regimen of public maritime domain and operated by commercial companies (concessionaires) based on concessions awarded by the competent public authorities. As port operators, they are responsible for the safety of navigation and order in the port, operation and maintenance of port infrastructure, facilities and equipment, for which purpose they hold certain delegated public powers.[1]

The capacities of marinas on the eastern Adriatic coast range from 70 to 1,500 berths. The difference in capacity obviously influences their exposure to liability risks. Apart from marinas, there are a number of small ports operated by sport yachting clubs as non-profit associations in Croatia and Slovenia. Although their management, purpose and set-up are different than in commercial marinas, the basic service provided to club members with respect to berthed pleasure craft is essentially the same as the marina operator's core business of providing berths. Insurers normally provide the same type of coverage (MOLI) to marinas and other nautical tourism ports, as well as to non-commercial ports designated for sport purposes, albeit the respective insurance policies are always tailor made to suit the specific needs of each client. The latter is reflected in the respective limits of liability, scope of coverage, exclusion clauses and optional insurance packages.

In the following chapters we will analyse, discuss and compare the main characteristics of MOLI contracts in Croatian and Slovenian law. We will also look into the relevant business practices of local marina operators and insurers in the two Adriatic countries. The analysis should prove the similarity of the legal framework in the two observed jurisdictions, as well as in the relevant private regulation of the market stakeholders. The aim is to establish the common features of MOLI contracts and the related practices of marina operators and their insurers in these countries and to explain the background that has led to the creation of a MOLI product specific to the eastern Adriatic marina industry.

2. RESEARCH METHODS

The analysis is based on the data and documentation collected by means of a written questionnaire circulated amongst Croatian and Slovenian insurance companies. Furthermore, the relevant information was gathered through interviews with professionals from insurance companies and insurance brokers. The research encompassed the leading insurance companies involved in the MOLI business in both countries, insuring over 80 % of all marina operators in Slovenia and Croatia. The analysis also included information collected by means of a written questionnaire for marina operators, combined with field research consisting of interviews with marina operators' management staff in Croatia and Slovenia[2], which covered 37 marinas (over 60 %) in Croatia[3] and 1 major marina (out of 3) in Sloveni[4] . Finally, interviews were held with the responsible staff of the Croatian Ministry of Maritime Affairs responsible for the administrative management of Croatian maritime domain and seaports.

So far the topic of research has not been discussed in Slovenian legal literature, whilst in Croatia, it was previously touched upon by only two papers dealing with MOLI in the context of the Croatian legal framework.[5] Similarly, very few

1. *For a more detailed analysis of the legal status of marinas under Croatian law see Iva Tuhtan Grgić, The Legal Regime of Nautical Tourism Ports in Croatia, Stefano Zunarelli, Massimiliano Musi (eds.), Current Issues in Maritime and Transport Law, Il Diritto Marittimo - Quaderni 2, Bonomo Editore, Bologna, 2016, pp. 273-297. For Slovenian law perspective see Patrick Vlačić et al., Pomorsko pravo (Maritime Law), Book 2, Uradni list Republike Slovenije, 2008, Ljubljana, pp. 147-166. The main source of legislation regulating ports in Croatia is Maritime Domain and Seaports Act, Official Gazette of the Republic of Croatia no. 158/2003, 100/2004, 141/2006, 38/2009, 123/2011, 56/2016 (hereinafter: MDSPA); in Slovenia the ports are regulated under Slovenian Maritime Code, Uradni list Official Gazette of the Republic of Slovenia), no. 26/20011, 21/2002, 2/2004, 98/2005, 49/2006, 88/2010, 59/2011, 33/2016, 41/2017, 21/2018, 31/2018 (hereinafter: SMC).*

2. *Six leading insurance companies based in Croatia and one based in Slovenia providing MOLI coverage for the majority of Croatian and Slovenian marinas participated in the questionnaire and interviews.*
3. *According to Croatian Bureau of Statistics, Nautical Tourism - Capacity and Turnover of Ports, 2017, First Release no. 4.3.4, 27 March 2018, there are 140 nautical tourism ports in Croatia, i.e. 57 marinas, 13 land marinas and 70 other nautical tourism ports (anchorages, mooring or berthing facilities, boat storages, uncategorised nautical tourism ports). The numbers do not include sport ports and the areas of ports open to public traffic designated for nautical tourism berths. In this context, it is important to distinguish communal berth areas of the public ports designated for smaller vessels and pleasure craft. This paper focuses on liability insurance of proper marinas, although, the same insurance product is frequently adjusted and used for the sport ports and less complex types of nautical tourism ports.*
4. *Slovenia has 43 km of coast and three marinas with a total of 1,800 berths for pleasure craft and more than 1,700 berths in communal ports.*
5. *Adriana Vincenca Padovan, Marina Operator's Liability from the Contract of Berth and Insurance Matters, Poredbeno pomorsko pravo = Comparative Maritime Law, Vol. 52(2013), no. 167, pp. 1-35; Adriana Vincenca Padovan, Osiguranje odgovornosti luke nautičkog turizma (Marina Operator Liability Insurance), Svijet osiguranja, no. 7/2013, pp. 40-42.*

sources dealing specifically with this subject are available in comparative legal literature.[6]

3. RESULTS AND DISCUSSION

3.1. The Legal Framework

The research has shown that the legal framework for MOLI is very similar in Croatia and Slovenia. The similarity stems from their common legal history and tradition. Following the breakup of the Socialist Federal Republic of Yugoslavia in 1991, Slovenia and Croatia incorporated the former Yugoslav Civil Obligations Act of 1978 and the Marine and Inland Navigation Act of 1977 into their legal systems, and have afterwards developed their modern national civil and maritime law legislation based on those legal sources. Nowadays, both in Croatia and Slovenia, MOLI as a special type of liability insurance contract is subject to the general insurance contract law, i.e. governed by the civil obligations codes of these countries.[7] Both civil obligations codes contain special provisions regulating insurance contracts,[8] whereas the provisions setting out the general rules of contract law apply in accordance with the principle of subsidiarity of *lex generalis*.[9]

The Croatian and Slovenian civil obligations codes contain an article expressly excluding the application of the special provisions regulating insurance contracts to the contracts of marine and transport insurance (CCOA, Art. 923; SCOC, Art. 923). Marine insurance contracts are regulated by the maritime codes of these countries.[10] Both maritime codes similarly prescribe the types of insurance contracts that are subject to the legislative provisions governing marine insurance contracts. The list typically encompasses insurance of vessels, including vessels under construction, and related interests, shipowners' liability insurance and insurance of cargo in transport. The legislative provisions regulating marine insurance contracts also apply to ship repairers' liability insurance and to other insurance contracts concluded under the terms and conditions typical for marine insurance (CMC, Art. 684; SMC, Art. 680). Whilst the special provisions on insurance contracts prescribed by Croatian and Slovenian civil obligation codes are expressly excluded in respect of marine insurance contracts, the general rules of contract law contained in Croatian and Slovenian civil obligations codes are relevant for the interpretation of marine insurance contracts under the principle of subsidiary application of the law governing general matters (*lex generalis*).[11]

MOLI, as well as the insurance of port operators' liability in general, do not fall under the scope of application of the maritime law rules on marine insurance contracts, but are rather subject to the rules of general insurance law. However, MOLI standard terms and conditions of Croatian and Slovenian insurers commonly allow for an extension of coverage of marina operators' liability arising from their business activity of ship repair and ship maintenance work. Namely, many marina operators provide ship repair and maintenance services for vessels berthed in their marinas, and when they do perform such business activity they need to have their liability arising in connection therewith insured. This is sometimes done within the framework of the same MOLI contract. Since under Croatian and Slovenian law ship repairer's liability insurance is regulated by the maritime law rules on marine insurance contracts (CMC, Art. 684.1.3; SMC, Art. 680.2), the part of MOLI coverage relating to liability arising from the performance of ship repair and maintenance services will exceptionally be subject to the legislative provisions governing marine insurance contracts. In particular, the provisions of maritime law regulating marine liability insurance will be relevant (CMC, Art. 743; SMC, Art. 739).

Unlike the mandatory nature of the majority of legal provisions governing general insurance contracts, the provisions of maritime law regulating marine insurance contracts are predominantly dispositive.[12] Therefore, particular contractual provisions prevail over the dispositive legislative provisions on marine insurance. An important difference between a general liability insurance contract and a marine liability insurance contract under Croatian and Slovenian laws relates to the concept of direct action of an injured third party against the liability insurer. In both countries direct action is envisaged as an independent right of an injured third party by the mandatory rules of general insurance law applying to liability insurance contracts

6. *See e.g. James N. Hurley, Maritime Law and Practice, 5th edition, The Florida Bar, 2017, Chapter 17. Marina Liability, § 17.22 - § 17.27 Insurance for Marinas.*
7. *See Croatian Civil Obligations Act, Official Gazette no. 35/2005, 41/2008, 125/2011, 78/2015, 29/2018 (hereinafter: CCOA) and Slovenian Civil Obligations Code, Uradni list , no. 83/2001, 28/2006, 40/2007, 97/2007, 64/2016 (hereinafter: SCOC).*
8. *See CCOA, Arts. 921 – 989; SCOC, Arts. 921 – 989.*
9. *For Croatian law see Drago Pavić, Ugovorno pravo osiguranja (The Law of Insurance Contracts), Tectus, 2009, Zagreb, pp. 86 – 88; for Slovenian law see Marko Pavliha, Zavarovalno pravo (Insurance Law), Gospodarski vestnik, 2000, Ljubljana, pp. 154 – 161.*
10. *See Croatian Maritime Code Official Gazette no. 181/2004, 76/2007, 146/2008, 61/2011, 56/2013, 26/2015 (hereinafter: CMC), Arts. 684 – 747.d; SMC, Arts. 680 – 743.*
11. *For Croatian law position regarding the relationship of the CMC provisions on marine insurance contracts and the CCOA see Pavić, Ugovorno pravo osiguranja, op. cit., pp. 89 – 91; for Slovenian position regarding the same matter see Patrick Vlačić et al., Pomorsko pravo (Maritime Law), Book 1, Uradni list Republike Slovenije, 2008, Ljubljana, pp. 401 – 405 and Pomorski zakonik (PZ) z uvodnimi pojasnili prof. dr. Marka Ilešiča in prof. dr. Marka Pavlihe in stvarnim kazalom (Maritime Code with the Introductory Explanations by Prof. Marko Pavliha and Prof. Marko Ilešič, Uradni list Republike Slovenije, 2001, Ljubljana, pp. 48 – 51.*
12. *Pavić, Ugovorno pravo osiguranja, op. cit., pp. 88 – 89, 92; similarly Ilešič, Pavliha, Pomorski zakonik (PZ) z uvodnimi pojasnili…, op. cit., pp. 48 – 49.*

(CCOA, Art. 965; SCOC, Art. 965),[13] whilst under maritime law rules direct action is allowed only in the context of compulsory marine insurance (CMC, Art. 743; SMC, Art. 739.2).[14]

In both countries MOLI is voluntary, i.e. it is not prescribed by law as compulsory insurance and is, therefore, as a rule, subject to the freedom of contract. By its nature, it is always a commercial contract, since marina operators effect this insurance in the course of and in connection with their business. The aim is to protect the marina operators from potential liabilities arising from the performance of their business activities. The parties are in principle free to define the scope of coverage, insurance limits, deductibles, exclusions and other terms and conditions of insurance depending on their commercial needs and expectations. In practice, coverage is tailored to account for marina operators' exposure to liability risks and financial capacity. The freedom of contract is partly limited by the mandatory rules of general insurance law, and individual marina concession agreements. Namely, when awarding concessions for the development and operation of marinas, the competent public authorities usually include provisions in the concession contract obliging the marina operator to effect business liability insurance which should meet certain requirements as defined therein. These concession contract stipulations define the subject matter of insurance as contractual and tortious liability arising from the marina operator's business activities and sometimes set the minimum limit of insurance per event.[15]

From the aspect of business organisation, although MOLI is regulated by general insurance law, in the practice of Croatian and Slovenian insurance companies it is handled as a part of marine, aviation and transport insurance business, i.e. it is usually written by the underwriters specialised in marine, transport and aviation insurance.[16]

Croatian and Slovenian marina operators have so far always insured their liability with local insurers who drew up their own general terms and conditions. A comparative analysis of the standard insurance clauses for MOLI in Croatia and Slovenia shows that they are very similar. The similarity is a result of the specific common historical circumstances related to the development of the marina industry and MOLI business on the eastern Adriatic coast. The intensive development of marina business and the accompanying MOLI practice in this region is closely related to the development of the Adriatic Club Yugoslavia (ACY) established in 1983, operating the largest chain of marinas in the Adriatic. By 1986 ACY built sixteen brand new marinas along the Croatian Adriatic coast and another two by 1990. In 1994 the company was restructured into a joint-stock company and registered as Adriatic Croatia International Club d.d. (ACI). Nowadays, it operates twenty-two marinas along the eastern Adriatic coast.[17] On the other hand, the dominant player of the Croatian insurance market of the time was Croatia Insurance Company, a social enterprise that practically held most of the marine insurance portfolio in the former Yugoslavia, including the MOLI business emerging in the 1960s and intensively developing in the 1980s along with the formation of ACI. During this period, a mutual adjustment and standardisation of the general terms and conditions of marina operators and insurers took place, owing to the joint efforts of professionals representing the stakeholders[18] of the contemporary common Yugoslav market. In effect, smaller market players adopted ACI standard terms of berthing contracts and Croatia Insurance MOLI standard terms and conditions. In the late 1990s, with the liberalisation of the Croatian and Slovenian markets, a number of insurance companies emerged and new marinas were constructed.[19] Simultaneously, Croatia saw a sudden development of the yacht chartering market. There

13. *For a more detailed discussion on direct action under Croatian law, see e.g. Pavić, Ugovorno pravo osiguranja, op. cit., 326-334; Drago Pavić, Pomorsko osiguranje: pravo i praksa (Marine Insurance: Law and Practice), Književni krug Split, 2012, Split, pp. 429 – 440; and under Slovenian law see e.g. Jernej Veberič, Pogodba o zavarovanju odgovornosti (Liability Insurance Contract), Pravni ljetopis, 2008, no. 1, pp 169-179.*

14. *See Pavić, Ugovorno pravo osiguranja, op. cit., pp. 621-625; Pavić, Pomorsko osiguranje, op. cit., pp. 425 – 429; Vlačič et al., Book 1, op.cit., pp. 402. Both states prescribe compulsory marine liability insurance for damage caused by motor yachts and boats. Furthermore, both states are parties to the following conventions prescribing compulsory shipowner's liability insurance and direct action: Convention on Civil Liability for Oil Pollution Damage, London, 1992, International Convention on Civil Liability for Bunker Oil Pollution Damage, London, 2001 and Athens Convention Relating to the Carriage of Passengers and their Luggage by Sea, 2002. Croatia is also a party to Nairobi International Convention on the Removal of Wrecks, 2007 prescribing compulsory insurance for the costs of wreck removal. See http://www.imo.org/en/About/Conventions/StatusOfConventions/Pages/Default.aspx (accessed on 2 January 2019). In addition, direct action in Croatia is prescribed for the seafarers' claims (CMC, Art. 743.2).*

15. *See e.g. Decision on the concession for the operation of Marina Portorož, Uradni list no. 28/2016, 15 April 2016, Art. 31 stipulates that marina operators must insure their business liability for damage caused to marina users, third parties or to the concession awarding authority up to a minimum insurance limit of 500.000 EUR per event.*

16. *The group includes liability insurance for shipowners, ship repairers, marine agents, freight forwarders, air carriers, airport operators, road carriers. It is interesting to note that liability insurance policies for airport operators, freight forwarders, road carriers and marine agents are also subject to the rules of the civil obligation codes of Croatia and Slovenia governing insurance contracts. See Pavić, Pomorsko osiguranje, op. cit., pp. 52 – 53, 474 – 475; Katarina Sunara, Osiguranje djelatnosti sudionika zračnog prometa (Business Liability Insurance in Air Transport), workshop materials, Croatian Transport Law Association, Zagreb, 16 March 2017, , http://hdtp.eu/wp-content/uploads/2018/01/Sunara-OSIGURANJE-ODGOVORNOSTI-ZRA%C4%8CNIH-LUKA.pptx (accessed on 30 November 2018).*

17. *For more information see Mladen Gerovac, Postanak (Formation), Adriatic Croatia International Club d.d., Opatija, 2016.*

18. *Maja Bosnić Tabain, Marina Operator Liability Insurance in Croatian Judicial Practice (invited lecture), Conference Book of Abstracts: The New Legal Regime for Marinas, 22 – 23 November 2018, Croatian Academy of Sciences and Arts, Zagreb, p. 43.*

19. *Ibid.*

was also a substantial increase in the number of pleasure craft used for private purposes. The value of pleasure craft increased and the related technologies and materials became more sophisticated.[20] Marina operators' general terms and conditions of berthing contracts were adjusted to the new market circumstances with the trend of reduction of the scope of marina operators' liability. Consequently, MOLI practice diversified. Some insurers followed the trend of reduction of the scope of marina operators' liability by reducing the scope of coverage and introducing more exclusion clauses in their standard MOLI terms and conditions. However, the original core structure and the main content of those insurance terms and conditions applied by Slovenian and Croatian insurers still remains recognizable. It can therefore be concluded that the MOLI standard terms and conditions originally created and predominantly applied in Croatia and Slovenia influenced the marina operators' general terms and conditions of berthing contracts used at the time. Furthermore, although there were no official common MOLI standard terms and conditions for Croatian and Slovenian markets, local insurers on those markets can be concluded to have followed the common practice and developed their own mutually very similar MOLI terms and conditions. Finally, the MOLI terms and conditions available on the Croatian and Slovenian markets today still resemble their early versions in terms of structure and main content, especially with respect to the definition of the scope of coverage and standard exclusions. They were not strongly influenced by MOLI clauses used on the international insurance markets because local marina operators have traditionally always insured their liability with the local insurers on their own MOLI terms and conditions.

3.2. Scope of Coverage

MOLI is a special type of insurance of liability arising from a specific type of business. In Croatia and Slovenia, this insurance is commonly provided as a separate insurance product and combined with other insurance policies covering marina operator's general liability, employer's liability, shipowner's liability (for vessels owned or used by the marina in the course of its business activities), property insurance of docks, peers, pontoons, port infrastructures, installations, equipment and buildings. This paper deals only with the MOLI contracts typical for the Croatian and Slovenian markets.

As stated in the introduction, MOLI covers liability stemming from the marina operator's business of providing berths, related and additional services to vessels, owners, crews and nautical tourists. The insurance covers marina operator's contractual liability, i.e. liability towards the customers and users of marina services. Furthermore, it covers marina operator's tortious liability, i.e. liability to third parties for damage to their property and bodily injury caused by the performance of marina operator's activities. The marina operator's liability may result from a negligent act or omission of marina staff (employees), management or marina operator's subcontractors.

The insurance further covers the costs of legal proceedings and other reasonable costs incurred in the ascertainment of liability of the insured marina operator. The costs of measures taken at the request of or in agreement with the insurer, for the purpose of legal defence against unfounded or excessive third party claims are also recoverable under the insurance contract (CCOA, Art. 964; SCOC, Art. 964). Some insurers undertake to cover these costs together with the main claim up to the limit of insurance, whilst others cover them in addition to the insurance limit up to a certain maximum amount defined under the policy. If not expressly stipulated in the policy, the legislative rule providing that the insurer covers these costs up to the limit of insurance (CCOA, Art. 964.2; SCOC, Art. 964.2) applies. Furthermore, the insured marina operator is obligated to take all prescribed, agreed and reasonable measures to prevent or minimize loss, damage or cost giving rise to its liability covered by insurance. The insurer covers the costs of such measures, as well as any loss or damage suffered by the insured marina operator due to such measures. These costs and losses are recoverable under insurance even if the attempts were unsuccessful, provided that the measures were reasonable or compulsory by law or undertaken at the request or with the approval of the insurer. The law prescribes that these costs and losses are recoverable under insurance even if they exceed the limit of insurance together with indemnity. If, however, the insured marina operator fails to meet this obligation for no justified reason, the insurer's liability is reduced in proportion to the increase in the marina operator's liability covered by insurance resulting from this breach (CCOA, Art. 950; SCOC, Art. 950).

A major part of marina operators' liability risks is related to the potential damage to, or loss of a vessel at berth. Marina operators' liability for this type of damage or loss is defined by the relevant berthing contracts. One of the most discussed matters in theory and practice is the legal nature of this type of contract and the extent of a marina operator's liability thereunder. So far in Croatia and Slovenia the berthing contract has not been regulated as a special type of contract, in other words, it is an innominate contract. Furthermore, research has shown that in Croatia and Slovenia marina operator's general terms and conditions of berthing contracts have not reached the level of standardisation required for them to be considered a typical

20. *Ibid.*

contract. Frequently imprecise and incomplete berthing contractual terms and conditions have led to legal disputes resulting in rather inconsistent court practice and a discrepancy between the concept of a marina operator's liability as perceived by the industry on one hand, and by the courts on the other hand. The main point of contention is whether the contract should be interpreted as a contract of deposit of the vessel or a berth rental contract. The predominant position in judicial practice is that by its nature a berthing contract is a contract of deposit, whereby the vessel is in the care, custody and control of the marina operator who is presumed to be liable for damage to or loss of the vessel during the period of deposit, unless he proves that as a bailee he exercised due care (professional care) in protecting the vessel from possible accidents, incidents or malicious acts of third parties.

The Croatian legal doctrine differentiates between two main groups of berthing contracts: a) contracts for use of a safe berth (berth rental contracts) and b) contracts for use of a safe berth with additional marina services. The additional services can, inter alia, include care, custody and control services. Research has shown that the so called transit or daily berths are commonly regulated by contracts for use of a safe berth. It is submitted that not all marina operators' permanent berth contracts include the marina's obligation to safeguard the vessel, i.e. the obligation of custody in the sense of the legislative provisions of the contract of deposit.[22] The fact that a vessel is berthed in a marina and that the marina accepted the vessel's documentation and keys, is not enough to establish that the contract is a contract of deposit. In other words, the issue whether the vessel was delivered into the possession of the marina, as a bailee, needs to be established in each individual case by a true interpretation of the contract in question. Research has shown that the majority of marina operators in Croatia apply a model of annual rental of a safe berth, including a certain level of control of the berthed vessel, without taking the vessel into possession.[23]

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21. *Berthing contracts under Croatian law have so far been discussed in the following literature: Padovan, Marina Operator's Liability…, op.cit.; Vesna Skorupan Wolff, Ranka Petrinović, Nikola Mandić, Marina Operator's Obligations from the Contract of Berth According to the Business Practices of Croatian Marinas, Pero Vidan et al. (ed.), IMSC 2017 Book of Proceedings, Faculty of Maritime Studies, Split, 2017, pp. 104-111; Vesna Skorupan Wolff, Adriana Vincenca Padovan, Are there any Elements of the Contract of Custody in the Marina Operators' Contracts of Berth?, Dora Ćorić, Nikoleta Radionov, Aleksandra Čar (ed.), Conference Book of Proceedings of the 2nd International Conference on Transport and Insurance Law, INTRANSLAW Zagreb 2017, Faculty of Law, University of Zagreb, Zagreb, 2017, pp. 313-353; Marija Pijaca, Legal Relationship between Marina Operator and Charter Company Arising from the Contract of Berth – Analysis of Croatian and Comparative Commercial Practice, Poredbeno pomorsko pravo = Comparative Maritime Law, Vol. 57 (2018), no. 172, pp. 253-284; Adriana Vincenca Padovan, Vesna Skorupan Wolff, The Effect of the Craft's Sinking on the Contractual Relationship of the Parties to the Contract of Berth and Custody of a Pleasurecraft, Poredbeno pomorsko pravo = Comparative Maritime Law, Vol. 57 (2018), no. 172, pp. 149-175; Vesna Skorupan Wolff, Adriana Vincenca Padovan, Berth Contract De Lege Ferenda, Jakša Barbić (ed.), The Legal Framework for the Nautical Tourism Ports, Book Series Modernisation of Law, Book 42, Croatian Academy of Sciences and Arts, Zagreb, 2018, pp. 41-93; Vesna Skorupan Wolff, Adriana Vincenca Padovan, Obligations of the User of Berth Arising from the Berth Contract According to the Business Practices of Croatian Marinas, Petra Amižić Jelovčić et al. (ed.), Book of Proceedings, 2nd International Scientific Conference on Maritime Law - Modern Challenges of Marine Navigation, ISCML Split 2018, pp. 333-379; Miho Baće, Priroda ugovora o godišnjem vezu u marinama (The Nature of the Annual Berthing Contracts in Marinas), Pravo u gospodarstvu: časopis za gospodarsko-pravnu teoriju i praksu - A Journal for Business Law Theory and Practice, Vol. 57 (2018) no. 3; pp. 497-519.*

22. *See similar discussion in Italian and Spanish legal literature: Daniel Rodríguez Ruiz de Villa, El contrato de cmarre en puerto ceportivo, UNED. Boletín de la Facultad de Derecho, no. 25, 2004, 115-152; Maria Victoria Petit Lavall, Régimen jurídico del contrato de amarre, José Luis García-Pita et al. (ed.) El Derecho marítimo de los nuevos tiempos, Civitas, 2018, pp. 689-712; Umberto La Torre, Ormeggio di Nave, Studi in onore di Gustavo Romanelli, Giuffrè, Milan, 1997, pp. 726 et seq.; Alessio Claroni, Il contratto di ormeggio nella portualità turistica, Bonomo editrice, Bologna, 2003; Alfredo Antonini, Il contratto di ormeggio, Diritto Marittimo, 1999, p. 1067 et seq.; Alfredo Antonini, Dal contratto di ormeggio al contratto di locazione di posto barca, Diritto dei Trasporti, 2009, p. 109 et seq.; Marco Badagliacca, Il contratto di ormeggio, Michele M. Comenale Pinto, Elisabetta G. Rosafio (ed.), Il diporto come fenomeno diffuso. Problemi e prospettive del diritto della navigazione, Aracne, Rome, 2015, pp. 199-215.*

23. *Josip Pavliček, Adriana Vincenca Padovan, Marija Pijaca, Criminological and Legal Aspects of Croatian Ports and Marinas Security, Gorazd Meško et al. (ed.), Book of Proceedings, Twelfth Biennial International Conference Criminal Justice and Security in Central and Eastern Europe: From Common Sense to Evidence-based Policy-making, Ljubljana, 25-27 September 2018, University of Maribor Press, Maribor, 2018, p.479. In the following decisions of Croatian courts marina operator berthing contracts were interpreted as deposit contracts: Commercial Court in Rijeka, decision no. P-2590/1994 of 28 Feb. 2007; Commercial Court in Rijeka, decision no. 9-P-4327/11-72 of 13 Sept. 2012; High Commercial Court, decision no. 3667/02-3 of 18 Jan. 2006; Supreme Court, decision no. 756/11-2 of 30 Oct. 2013; Supreme Court Rev. 2333/2010 of 14 May 2013; Commercial Court in Zagreb, decision no. 42. P-915/2014 of 10 Jan. 2019.*

24. *Skorupan Wolff, Padovan, Berth Contract de Lege Ferenda, op. cit., pp. 46-49; Padovan, Skorupan Wolff, The effect of the Craft's Sinking…, op.cit., pp.*

25. *See CCOA, Arts. 725 – 743 and SCOC, Arts. 729 – 746 on the contract of deposit.*

in question.[26] Research has shown that the majority of marina operators in Croatia apply a model of annual rental of a safe berth, including a certain level of control of the berthed vessel, without taking the vessel into possession.[27]

Slovenian marinas also use two types of berthing contracts. One type is the contract of accommodation and deposit of a vessel in a marina and the other is the contract of accommodation of a vessel in a marina. The difference is primarily in that the contracts of accommodation of vessels expressly state that they are not to be considered deposit contracts and that the SCOC provisions governing deposit contracts do not apply to them. Still, the majority of provisions in both types of berthing contract are almost identical.

According to the standard clauses of Slovenian marina operator berthing contracts, a marina undertakes to allocate a place for a safe berth and accommodation of a vessel and its crew and allow the use of port infrastructure, facilities and equipment. Berthing contracts with the elements of deposit stipulate that a marina operator's liability for deposit commences when the owner or user of the vessel hands over the vessel keys and certificates at the marina reception. The obligation ends when the owner or user of the vessel takes over the vessel keys and certificates at the reception desk. During the period of deposit a marina is liable for the care, custody and control of the vessel and this obligation must be fulfilled with professional care.

It is peculiar that berthing contracts expressly excluding the application of the rules of deposit state that upon handing over the vessel keys and certificates the marina enters into possession of the vessel. This provision is in contradiction with the express exclusion of the rules of deposit, since it clearly defines the moment of vessel bailment commencement. Effectively it follows that a marina operator's liability under this type of contract is the same as under the contracts of accommodation and deposit of a vessel in a marina.

The above described legal uncertainty regarding the nature of a berthing contract is reflected in the results of the written questionnaire for insurers. For example, one of the questions posed to the insurers was whether in their opinion under annual berthing contracts marina operators assume liability for deposit, or just berth rental, or for berth rental combined with supervision of the vessels at berth. Two out of seven insurers replied that this depended on the standard berthing contract of a particular marina operator and that their coverage corresponds to the marina operator's liability assumed under that contract. Any liability assumed beyond the standard berthing contract submitted to the insurer upon the negotiation of the insurance policy will not be covered unless prior approval is obtained from the insurer. The other five insurers stated that in their opinion marina operator annual berthing contracts are contracts of care, custody and control of the vessel. Concerning the standard transit berth contracts, four insurers consider them contracts for use of a safe berth (berth rental). One insurer stated that they consider them berth rental contracts combined with the marina operator's obligation to supervise the vessel at berth. One insurer stated that transit berth general terms and conditions varied between marina operators and that they relied on the standard contract declared to them by the insured marina operator. One insurer stated that in their opinion transit berth contracts are also contracts of care, custody and control of a vessel, just like the annual ones. Some insurers stated that they do not differentiate between the obligations of safeguarding and supervising the vessel, in other words, if a marina operator assumes the obligation to supervise the vessel at berth, in their opinion, it qualifies as a contract of care, custody and control of a vessel (deposit). They hold that a marina operator is obliged to organize: technical and personal protection of the marina premises, piers and berths; regular rounds of all berths by the marina mariners and guards; operational and functional CCTV system 24/7; maintenance of the marina premises, piers, moorings, infrastructure, buildings, facilities and equipment in a safe and sound condition; berthing assistance; prevention of accidents, incidents or malicious third party acts in the marina etc.

Considerable differences in the insurers' answers to the questionnaire are indicative of the level of legal uncertainty surrounding the concept of marina operators' liability and the scope of the accompanying insurance coverage. The ideal way of resolving this issue in our opinion is to devise standard general terms and conditions of berthing contracts and the corresponding standard insurance clauses to be adopted by marina operators and their insurers. Research has shown that, although there are discrepancies in the perception of legal concepts, the actual business practice, the concrete contents of marina services and the way they are performed are ultimately very similar. Therefore the standardisation of contractual terms and conditions is absolutely possible and desirable in the interest of legal certainty and all stakeholders in question.

The scope of marina operators' liability insurance coverage depends, inter alia, on the scope of services provided by a particular marina operator. This information is normally declared to the insurer when insurance is contracted and taken into account in the risk assessment process. The scope of coverage is then tailored to suit the needs of the particular client.

When underwriting MOLI, the insurer relies on the standard terms of berthing contracts and other types of contract commonly concluded by marina operators with their customers and partners in the course of business. The insurer examines marina rules and regulations, as well as other internal acts of

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26. *Adriana Vincenca Padovan, Maria-Victoria Petit Lavall, Angelo Merialdi, Fabio Cerasuolo: Security and Enforcement of Marina Operator's Claims: Croatian, Italian and Spanish Law Perspectives, Journal of Maritime Law and Commerce, Vol. 49 (2018), no. 4, pp. 522-523.*
27. *Ibid, p. 522.*

the insured marina operator. Some marina operators provide a whole range of high quality services, whilst others limit their business to the basic service of providing a safe berth. The corresponding liability insurance thereby follows the underlying marina operator's business model. The standard contracts used by the insured marina operator must therefore be approved by the insurer and any liability assumed by the marina operator that goes beyond the standard contract terms is commonly excluded from insurance coverage, unless previously presented to the insurer and expressly approved.

Croatian and Slovenian insurers normally cover the following marina operators' activities: berth rental, custody of the vessel at berth, lifting and launching operations, open air dry berth, vessel storage in closed premises such as halls, hangars etc. Furthermore, most local insurers may include coverage for liability arising in the course of and in connection with vessel maintenance, laying-up, recommissioning or repair works and transport by land, provided that the marina operator undertakes to perform these services, either directly or through subcontractors. Additional coverage can be provided for food and beverage catering services, provision of recreational facilities and chandlery.

Any third party liability that is not in direct connection with a marina operator's business is not covered by MOLI, but can be insured under a different type of policy available on Croatian and Slovenian markets, covering general third party liability. This type of policy usually contains optional employer's liability coverage, i.e. liability of the marina operator as an employer for personal injury or property damage suffered by the employees in the course of or in connection with their work.

3.3. Standard exclusions

The usual exclusions from MOLI terms and conditions of Croatian and Slovenian insurers are as follows:

- claims arising from wilful misconduct and gross negligence of the insured marina operator, its employees, subcontractors and their employees
- claims that are not directly related to the marina operator's business activity
- contractual extension of the marina operator's liability beyond the standard terms and conditions approved by the insurer
- claims for non-performance of the insured's contractual obligations, consequential damage
- damage to property owned or leased by the insured or his subcontractors
- costs of repairing the insured's bad workmanship, material or design
- damage arising from bad maintenance, wear and tear, bad overall condition of the vessel, corrosion, breaking of mooring lines belonging to the vessel
- damage arising from latent defects in the vessel's hull or machinery
- damage arising from defective electrical installation or piping system in the vessel
- damage caused by rodents or pests
- damage caused by water freezing in the engine or other parts of the vessel
- costs of painting the hull of an undamaged vessel
- damage arising from erroneous or unprofessional act or omission of the owner or crew of the vessel
- damage arising in connection with the breach of customs regulations, port regulations or other administrative regulations; breach of marina rules and regulations
- loss of or damage to artefacts, money or other valuables
- loss of or damage to cameras, TVs, mobile phones, PCs, binoculars, and similar objects, unless occurring because of sinking, explosion or fire on the vessel, provided that the insured is liable for the cause of damage
- loss of fenders, anchors, mooring lines belonging to the vessel or other equipment that can be removed from the vessel without using force
- loss of reputation, loss of goodwill, loss of business
- loss of earnings, loss of profits or similar economic loss
- fines and penalties
- contractual penalties, pre-liquidated damages or similar
- claims arising in connection with the insured's insolvency or business interruption
- war, insurrection, strike, labour disruption, sabotage, terrorist acts and similar events
- nuclear and radioactive contamination exclusions
- damage resulting from temperature, gas, steam, humidity, smoke and similar phenomena (emissions) if such influence has a slow damaging effect
- damage caused by asbestos

The following exclusions that can be found in MOLI terms and conditions of Croatian and Slovenian insurers' can usually be insured by expanding standard coverage:

- damage caused by shifting of the vessel within the marina
- product liability
- liability related to grocery and chandlery supply
- liability related to (food and drinks) catering
- liability related to vessel chartering or sales
- liability for the costs of wreck removal and recovery
- pollution liability

We noticed that many of these exceptions can also be found in the general terms and conditions of berthing contracts of Croatian and Slovenian marina operators. However, especially in Croatia, there is a variety of marina operators' general terms and conditions of berthing contracts, and when compared with the usual MOLI scope of coverage and exclusions, they are mostly not "back-to-back". This is cause of uncertainty for marina operators, since there are instances in which their potential liability will remain uninsured. This issue should be resolved by devising model berthing contracts and standard marina operator general terms and conditions combined with standard MOLI insurance clauses designed on a back-to-back basis.

3.4. Insurance Limits

In case of MOLI, the insurance limits currently available on the respective markets range from EUR 5,500 to EUR 7,900,000 per event in Croatia and from EUR 1,000,000 to EUR 4,000,000 in Slovenia. Most of the local insurers reinsure these risks on the international markets, depending on the insurance limit in question and in line with their internal reinsurance programmes. The extremely wide range of liability limits on the Croatian market proves there exist vast differences between the various kinds and sizes of nautical tourism ports and liability risks they are exposed to in the course of their business. This is because in Croatia, there are 83 other nautical tourism ports apart from 57 marinas, including anchorages, mooring areas, land marinas and uncategorised nautical tourism ports.[28] The research results are further affected by the data on the insurance of sport ports.

3.5. Risk Assessment

When assessing the risk upon contracting insurance for the first time with a marina operator, the insurers rely on the written questionnaires specifically created for this type of insurance. Most insurers also hire surveyors to inspect the marina facilities, including the marina premises, peers, pontoons and docks, marina cranes, travel-lifts and other equipment and devices, marina security system etc. Some of them also look into the marina operators' documentation (licences, concession, public authorities' inspection records, certification, internal protocols etc.). Inspections may be repeated every several years if required by insurance results. Some insurers further rely on information available on the internet or in the media. Good practice of risk assessment normally takes into account the following factors:

- marina's location and micro-location (hydro-meteorology, security, traffic)
- limited, partly limited or open access[29]
- organisation and number of marina masters and mariners and other marina staff
- scope of marina services and standard contracts used
- subcontractors (are they licenced service providers, do they hold business or product liability insurance policies, do they have good references?)
- firefighting system
- overall condition and maintenance of marina premises, infrastructure, equipment, devices and berthing facilities
- planned investments
- security service
- design, functionality and quality of CCTV system
- environmental standards and measures
- entry and exit control and recording system

When underwriting MOLI, the insurers first look into the scope of services performed by a particular marina operator directly or through subcontractors. In the latter case, the subcontractors should also be taken into consideration during the risk assessment process. Furthermore, the insurers should assess whether a marina meets the minimum standards for safe operation under the relevant laws and regulations with respect to construction and maintenance, sanitary standards, firefighting, first aid, safety at work, environmental protection, waste management and similar. They should also check the marina operator's compliance with any specific standards prescribed by the concession contract, but this is not always the case. Namely, three out of seven interviewed insurance companies replied that they do not take concession documentation, licences and other documentation or certification required by law into consideration during risk assessment, and that it is presumed that the marina operator is in possession of the necessary documentation. However, in case of a claim, any missing certificates or licences should give rise to exclusion of insurance coverage. Furthermore, the insurers should take into consideration the security, safety and environmental protection systems and protocols implemented by marina operators in addition to the prescribed minimum standards, but in practice these considerations do not seem to substantially affect the insurance price on the markets in question. Namely, all seven interviewed insurance companies stated that they did not take into consideration classification or certification of marinas according to internationally recognized quality standards during risk assessment.

As for marina security standards, it is interesting to note that four out of seven interviewed insurance companies state that hiring professional private security guards is a condition for a valid insurance coverage. On the other hand, this requirement is not prescribed by law and the marina operator decides at his discretion whether to outsource this service or to set up and implement an in-house security system depending on its specific security risk assessment and plan of measures.[30]

28. *Croatian Bureau of Statistics, 2017, op. cit.*
29. *It should be noted that none of Croatian and Slovenian marinas are fully closed to the public due to the specific legal regimen of public maritime domain.*
30. *For more information on marina security standards in the context of Croatian legal framework see Pavliček, Padovan, Pijaca, op. cit., pp. 469-484.*

If a marina operator provides ship repair, maintenance or similar services, risk assessment should take into account whether this sort of work is carried out only on site or at other locations as well, in which case insurers should also inspect such locations, equipment and devices used.

Information of particular relevance are the fire protection organisation in the marina, whether the marina has its own firefighting unit and what is the response time by the nearest firefighting brigade? Are the employees well trained in firefighting operations? Does the marina have adequate firefighting equipment and protocols in place, including regular control and maintenance of firefighting equipment? All this can be checked in the firefighting plan and protocols.

Finally, a thorough risk assessment should take into account the minimum requirements that marina operators apply towards the clients. These can be established by reviewing the marina operator's general terms and conditions of berthing contracts, marina regulations and the actual practice applied. In particular, it would be important to establish whether a marina operator is consistent in requiring that each vessel be fully covered by a standard hull and third-party liability insurance policy. The required scope of hull and liability insurance coverage should be at least similar to the one provided under Institute Yacht Clauses 1/1/85, with adequate insured values and liability limits. Research has shown that the risk assessment requirement is observed more thoroughly in Slovenia. It is recommended that this approach be more stringently applied in Croatia as it would contribute to optimum risk distribution between marina operators, their clients and respective insurers.

3.6. Claims

Research has shown that MOLI business on the eastern Adriatic coast gives positive results. The claims ratio for the observed period amounts to less than 40 % (Table 1). As stated above, the data was collected from six Croatian and one Slovenian leading insurance companies, holding more than 80 % of the MOLI portfolio in those two countries. As for the distribution of claims by direct cause of damage, research has shown that most claims arise from damage to the vessel at berth or its equipment (Table 2). The most frequent direct cause of damage is inclement weather, as 40 % of the declared total number of claims in the observed period was caused by bad weather conditions. Furthermore, nearly 10 % of all claims pertain to collisions or contacts of berthed vessels with fixed or floating objects. Nearly 6 % of claims relate to damage caused by vessel break-ins (Table 2).

In practice, disputes arise when damage occurs during inclement weather, because marina operators or their insurers attempt to rely on the vis maior defence. The MOLI terms and conditions typical for Croatian and Slovenian markets do not define an exact borderline, e.g. by reference to the Beaufort wind force scale, as to which weather conditions are to be considered vis maior. Therefore, in case of a dispute, the competent court will have to consider the relevant facts and circumstances of each particular case to determine if bad weather can qualify as vis maior, in which case the marina operator would be released from liability.

Table 1.
Marina operator liability insurance statistics 2013 – 2016.

Year	Gross written premium in EUR	Number of insurance contracts	Number of claims	Value of claims in EUR	Claims ratio
2013	1,045,301.09	147	138	240,094.88	0,2297
2014	892,283.41	153	121	807,316.95	0,9048
2015	975,044.00	144	105	116,583.76	0,1196
2016	1,104,814.54	158	165	414,826.30	0,3755
TOTAL	**4,017,443.04**	**602**	**529**	**1,578,821.89**	**0,3930**

When analysing and comparing MOLI business practice, looking into the specific claims handling procedures of Croatian and Slovenian insurers is interesting. When a claim pertains to the damage to or loss of a berthed vessel, the usual documentation required by the insurer includes:

- the relevant berthing contract / ship repair contract / vessel owner's work order
- the marina operator's general terms and conditions
- documentation proving the ownership of the damaged vessel

Table 2.
Distribution of claims by cause of damage 2013 – 2016.

	2013	2014	2015	2016	TOTAL	Proportion in the total number of claims
Collision, contact with fixed or floating objects	17	23	6	6	**52**	**9,8 %**
Sinking, capsizing	2	2	2	5	**11**	**2,1 %**
Flooding	0	0	0	0	**0**	**-**
Lifting / launching accidents	0	4	0	3	**7**	**1,3 %**
Stranding	0	0	0	0	**0**	**-**
Fire	0	1	0	5	**6**	**1,1 %**
Pollution	0	0	0	0	**0**	**-**
Personal injury	0	1	0	2	**3**	**0,6 %**
Theft of a vessel	0	0	0	0	**0**	**-**
Break-in	10	16	1	3	**30**	**5,7 %**
Inclement weather	34	36	54	88	**212**	**40,1 %**
Other (e.g. damage caused by contact with marina crane, damage to hull due to flooding of the tarpaulin, inadequate mooring, marina ship repairer's error, transport by land, ice, third party liability, etc.)	75	38	42	53	**208**	**39,3 %**

- the original claim of the vessel owner
- the insured's statement describing the incident/accident and his position regarding his liability
- the statement of the insured's staff directly familiar with the incident/accident giving the relevant details of the event
- a pro forma invoice or a survey report indicating the cost of repair
- a market price valuation (in case of total loss of the vessel)
- in case that damage or loss was caused by a criminal offence or a trespass, the insured is required to submit the official documentation of the competent public authorities (police, harbour master's office)
- official weather forecast for the critical period (damage caused by inclement weather)
- vessel inventory list (in case of damage to or loss of vessel's equipment) etc.

Pursuant to the usual MOLI clauses, it is the obligation of the insured to produce evidence proving the extent of the damage covered and ascertaining the insured's liability covered by insurance. Therefore, the insurer may require the insured to provide the necessary documentation or other evidence to establish the existence and extent of the insurer's obligation. The insured is obliged to cooperate with the insurer in the claims handling process, as well as in the legal defence against unfounded, unreasonable or excessive third-party claims. He must also preserve all his rights of recourse against other persons responsible for the damage and assist the insurer in realizing the subrogated rights against such persons. Finally, the insured is not allowed to admit liability or negotiate a settlement without the insurer's approval. A breach of any of these duties by the insured may result in the insurer being partly or entirely released from liability under the insurance contract, i.e. to the extent that the insurer's legal position was prejudiced by the breach (CCOA, Art. 963; SCOC, Art. 963).

As explained above, there is a possibility of direct action of a third-party claimant against the insurer (CCOA, Art. 965; SCOC, Art. 965), unless the claim arose from damage to the vessel caused in the course of repair or servicing. In the latter case, the relevant rules on marine insurance contracts apply, according to which no direct action is allowed for this type of claim (CMC, Art. 743; SMC, Art. 739). In case of direct action, the insurer has at his disposal all defences that would have been available to the insured marina operator had the claim been filed against him. For example, in case of a claim for damage to a vessel at berth, the insurer may use the same defence the marina operator would have been entitled to, had it been sued. Furthermore, since this is a voluntary liability insurance, the insurer may also use the defences stemming from the insurance contract (CCOA, Art. 945).

For example, the insurer could defend itself by establishing that the damage resulted from gross negligence on the part of the marina operator, which is excluded from insurance coverage. However, when contesting a direct action, the insurer only has at his disposal the defences that were available to him before the insured event occured (CCOA, Art. 945.3; SCOC, Art. 965.2).

In case of right to direct action, the injured third party's right to file a claim against the insurer is subject to a prescription period which expires simultaneously with the prescription period applying to the injured party's claim against the insured marina operator liable for damage (CCOA, Art. 234.5; SCOC, Art. 357.5). The applicable prescription period depends on the underlying indemnity claim against the insured marina operator. The general prescription period stipulated by law is five years. However, prescription period for tort-based claims is three years from the injured party becoming aware of the damage and the identity of the tortfeasor, but maximum five years from the occurrence of damage. The prescription period for a contractual claim for damages is the period stipulated by law for prescription of the breached obligation (CCOA, Art. 230; SCOC, Art. 352). Claims of the insured marina operator against the insurer arising from a MOLI contract are subject to a prescription period of three years from the moment the injured person files a court claim for indemnity against the insured marina operator, or from the moment the marina operator indemnifies the injured person. In effect, this means that the insurer's exposure to potential claims under a MOLI policy continues for a number of years after policy expiry. An incident occurring during the insurance period may result in a court claim five years later. If the insurer or the insured marina operator contest the claim, the court proceedings may last for a number of years until the final court decision is reached. Five out of seven interviewed insurers declared that they had unsettled MOLI policy claims pending in court. Most of them are direct action claims. There are some rare examples of unsettled MOLI claims that have been kept in the claims reserve funds for more than twenty years due to pending court proceedings. This is possible because standard MOLI policies of Croatian and Slovenian insurance companies are "loss occurring" and not "claims made" policies.[31] In fact, according to Croatian and Slovenian mandatory rules of general insurance law, insurance clauses excluding the insurer's obligation to pay indemnity for the claims made after the expiry of the insured period have no legal effect.[32] The determining factor for the insurer's obligation to pay indemnity is that the loss or damage giving rise to a claim occur during the insurance period. The moment the claim is made is irrelevant as long as it is made within the prescription period. Under Croatian and Slovenian law the legislative rules on prescription are mandatory and cannot be altered contractually (CCOA, Art. 218; SCOC Art. 339).

4. CONCLUSION

A valid MOLI policy with an adequate scope of coverage is a conditio sine qua non for a prudent marina operator. Croatian and Slovenian marina operators have so far always insured their liability with local insurers who have developed their own general terms and conditions. Standard MOLI insurance clauses in Croatia and Slovenia are very similar due to the common historical circumstances in which the marina industry and MOLI business developed on the eastern Adriatic coast. Croatian and Slovenian insurers' MOLI terms and conditions have influenced the marina operators' general terms and conditions of berthing contracts which is reflected especially in the liability exclusion clauses.

MOLI contracts in Croatia and Slovenia are subject to general insurance law, with the exception of shiprepairer's liability coverage extension which is governed by the maritime law rules on marine insurance contracts. However, from the aspect of business organisation, MOLI is handled as a part of the marine, aviation and transport insurance business.

MOLI is voluntary insurance in the sense that it is not prescribed as compulsory by law, but in practice, it is usually imposed on marina operators as a condition of the concession-awarding contract. Public authorities competent for the granting of nautical tourism port concessions are recommended to always include such stipulation in the concession contracts defining the minimum scope of coverage and insurance limits.

MOLI in Croatia and Slovenia covers marina operator contractual and tortious liability arising from the operator's core business activity. General third party liability and employer's liability are usually covered under a different insurance policy.

31. *According to Dunham, claims-made policies are common in the professional liability context, and gained popularity in the 1970s when medical malpractice claims and larger damage awards became more common. Claims-made policies differ from traditional occurrence or accident policies in that coverage under a claims-made policy is triggered when the claim is made, and not when the bodily injury or property damage occurs. Furthermore, depending on the wording of the claims-made policy, there may not be coverage for events occurring prior to a certain date if the claim is made after the policy came into effect. However, depending on policy wording, there may still be coverage for claims made after the expiry of the policy period if the insured had obtained a so-called "discovery" or extended coverage. See Wolcott B. Dunham, Jr., New Appleman New York Insurance Law, Second Edition, Vol. 1, § 16.04, Matthew Bender & Company, Inc., a member of the LexisNexis Group, New York, 2017.*

32. *CCOA, Art. 922 in connection with Art. 964.1 and Art. 218; SCOC, Art. 922 in connection with Art. 964.1 and Art. 339. See Marijan Ćurković, Claims made clause in liability insurance contracts, Hrvatska pravna revija 11 (2011), no. 11, pp. 44-47; Drago Klobučar, Claims made or Losses occurring, Osiguranje, 34 (2003), no. 7-8, pp. 40-43. Vesna Markić, Rizik i osigurani slučaj u osiguranju od odgovornosti, Zbornik Pravnog fakulteta Sveučilišta u Rijeci 16 (1995), no. 2, pp. 353-364; Adriana Vincenca Padovan, Claims made clause in a shipbuilder's liability insurance contract under Croatian law, Sanja Ćorić et al. (ur.), Zbornik radova s međunarodne znanstveno-stručne konferencije Dani hrvatskog osiguranja 2014., Croatian Chamber of Commerce, Croatian Insurance Office, Zagreb, 2014, pp. 57-67.*

The scope of contractual liability covered by MOLI is disputable. The issue is whether the marina operator undertakes to safeguard the vessel at berth, i.e. whether berthing contracts are contracts of deposit, or primarily contracts for use of a safe berth similar to berth rental. The problem could be overcome by developing and implementing standard general terms and conditions of berthing contracts and standard MOLI clauses.

In both countries in question direct action is allowed in case of voluntary liability insurance governed by general insurance law, which includes MOLI policies. Exceptionally a direct action is not allowed with respect to claims pertaining to damage to the vessel arising from ship repair or maintenance work.

As for risk assessment, local insurers are recommended to periodically inspect the marinas they insure. The inspections should include the checking of the necessary documentation (concession, technical safety, fire-protection etc.). Marina operators should require that all vessels berthed in their marinas are insured under the common hull and liability insurance policies and that all of their subcontractors hold adequate business, professional or product liability insurance policies.

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Can Marinas Qualify as Places of Refuge?

Ranka Petrinović, Nikola Mandić

This paper deals with marinas as potential places of refuge. A place of refuge is a port, a part of a port, a sheltered wharf or anchorage, or another sheltered area where temporary accommodation of vessels and marine facilities is possible in order to render assistance or avoid potential threats to humans, ships and the environment. Marinas, as the most important type of nautical port, are suitable for smaller vessels. In countries like the Republic of Croatia, where the development of nautical tourism is of great importance, the obligation of marinas to provide assistance or grant access to ships in distress needs to be established. Thereby, it is essential to take into account all marina characteristics and compare them with those of other types of ports. In Croatian legislation, places of refuge are regulated by the Ordinance on Places of Refuge compliant with IMO Guidelines A.949 (23) and A.950 (23) and European Directives (2002/59 / EC). The paper analyses the suitability of the marinas as places of refuge for vessels, primarily vessels for nautical tourism.

KEY WORDS

~ Place of refuge
~ Marina
~ IMO resolution A.949 (23) and A.950 (23)
~ EU Directive 2002/59/EC
~ Ordinance on Places of Refuge

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1. INTRODUCTION

A place of refuge is a port, a part of a port, a sheltered wharf, anchorage or another sheltered area in the inner sea waters or the territorial sea where a ship or a watercraft in distress can find refuge, and where it is less exposed to wind and sea, regardless of whether it sails, floats, or is anchored.

In the broadest sense, a sea port is defined as an area by the sea or directly connected to the sea with developed or undeveloped coast, breakwaters, appliances, plants and other facilities intended for landing, anchoring and protecting ships, yachts and boats, passenger embarkation and disembarkation, cargo loading, unloading, storage and other cargo handling, such as cargo production, refining and completion, as well as other commercial activities related to economy, traffic or technology. (Maritime Law and Seaports Act of the Republic of Croatia, 2003)

Depending on their intended purpose, ports can be divided into ports open to public transport and special purpose ports. Depending on activities performed in special purpose ports, they can be divided into: military ports, nautical ports, industrial ports, shipyard ports, as well as sports, fishing and other comparable ports. (Grabovac and Petrinović, 2006) Nautical tourism activities take place in special purpose ports, primarily in nautical tourism ports. These ports, depending on the type of service provided, can be classified as: anchorages, watercraft storage sites, dry marinas and marinas. Marinas are a part of the water area and coastline specifically constructed and designed to render services like berthing, tourist accommodation in watercraft and similar. (The Ordinance on Classification and Categorization of Ports of Nautical Tourism of the Republic of Croatia, 2008)

Firstly, places of refuge are primarily required for the salvage of ships, especially those whose cargo or large amounts of propulsion fuel might endanger the marine environment of coastal states. However, places of refuge are required by all vessels, crews or salvors in need of assistance, who are injured or threatened by total destruction.

Pursuant to the International Maritime Organization (IMO) and EU Directives directly or indirectly related to the places of refuge, Croatia has brought its national legislation into conformity with international and EU regulations governing the issue of the places of refuge; in this respect, the Maritime Code 2004, stipulated that the Ministry in charge of maritime affairs (hereinafter referred to as the "Ministry of Maritime Affairs") would issue a special regulation on the places of refuge, which was done in early 2008. The Croatian Ordinance on Places of Refuge prescribes: the procedure for selecting and giving approval for the places of refuge for ships and other vessels and naval facilities in need of assistance, competent bodies and persons responsible for the selection and the approval of places of refuge, conditions to be met by such places, as well as the conditions and manner in which the places of refuge will be used.

The Ordinance defines the place of refuge as a place where temporary berthing accommodation can be provided in order to render assistance or provide safety from potential threats to people, ships and the environment. (The Croatian Ordinance on Places of Refuge, 2008) The provisions of the Ordinance apply to all maritime facilities except warships, which are required to ask the competent authorities of the Republic of Croatia to allow them refuge. (The Croatian Ordinance on Places of Refuge, 2008) The Ordinance uses the term vessel in need of assistance or vessel in distress. This includes any maritime facility (other than a warship) that is in a situation which does not require the search and rescue of people, indicating the possibility of loss of ship or the endangerment of the marine environment or navigation. (The Croatian Ordinance on Places of Refuge, 2008) Since the Ordinance applies to all maritime facilities, it undoubtedly also applies to nautical tourism facilities. A variety of vessels of different characteristics and uses are involved in nautical tourism but what they all have in common is that they are used for sports and recreation.

The question is whether marinas are suitable places of refuge for ships and other watercraft found in distress near the coast. At this point, nautical tourism vessels, normally accommodated in marinas, need to be distinguished from traditional passenger and, in particular, cargo vessels (tankers, etc.) that pose a much bigger threat of pollution of the marine environment. It is especially important to determine if marinas are obliged to grant admission to vessels in distress, a detailed analysis of the Ordinance will reflect on this matter in the text that follows.

No relevant research dealing with the issue of the establishment of the place of refuge for ships in distress, delves either into the status of marina as a special type of port, nor examines the possibility of designating marinas as a place of refuge for ships. (Qi et al., 2018; Sanchez Ramos, 2017)

2. CONCEPT OF PLACE OF REFUGE

As stated in the introduction, place of refuge must provide temporary accommodation to vessels with the purpose of providing assistance or avoiding potential harm to humans, ships or the environment. These sites are conceived as particular geographic areas along the coast where damage can be effectively repaired, urgent vessel repairs performed, and cargo or propulsion fuel removed, especially if the safety of the ship or the marine environment is in danger. Suitable geographic areas are facilities with equipment that is either available or easily obtainable, offering services and other conditions suitable for identifying and effectively repairing damage, carrying out emergency repairs and salvaging vessels.

The Croatian concept of area designation, based on the Ordinance on Places of Refuge, is a combination of procedural and partial pre-selection models that presupposes the existence of clear procedures for different cases of ships in distress. It is partially selective because there is a wide list of places of refuge that narrows in iterative procedure on a case-to-case basis. The Ordinance on Places of Refuge does not explicitly mention any port or place of refuge, but rather emphasizes that such a place is determined depending on the situation. Information on possible places of refuge is listed in the Geographical Information System (GIS) application as software support to the decision-making system that contains possible refuge locations and other relevant information.

3. INTERNATIONAL LEGAL FRAMEWORK ON PLACES OF REFUGE

The obligation to provide assistance to ships and people in distress at sea has long been based on the principle of international maritime law, as well as on the Maritime Code. This principle is contained in the UN Convention on the Law of the Sea, the International Convention On Salvage, The International Convention on Safety of Life at Sea (SOLAS) and the International Convention on Maritime Search and Rescue (SAR-Convention).

The issue of place of refuge is in direct correlation with the modern right to salvage, since the salvors are the first to confront the issue of coastal states' rejection to provide a place of refuge to the ship being rescued. The provisions of Article 8, which oblige all salvage operation participants to give due consideration to the prevention or reduction of environmental damage, largely comply with the most important reason for the passing of International Convention On Salvage, IMO 1989, which is the protection of the marine environment. (Petrinović, 2005)

The very idea of providing shelter for ships in distress came into consideration by IMO in the late 1980s, when the IMO Legal Committee considered the draft of the Convention on Salvage. At the time, it was suggested that coastal states should be required to accept ships in distress in their ports. Although the proposal was supported by the representatives of some states, others expressed doubt as to the desirability of incorporating public law regulations into private law conventions such as the Convention on Salvage. They also stressed that the interests of coastal states should be taken into account when making any such provision. Concerns were also expressed as to the impact of such a provision on final decisions by coastal authorities in specific cases where a ship is in distress and poses a threat to the marine environment. (Petrinović and Plančić, 2007)

As a result of these proposals, Article 11 of the Convention on Salvage, which reads as follows: "A State Party shall, whenever regulating or deciding upon matters relating to salvage operations such as admittance to ports of vessels in distress or the provision of facilities to salvors, take into account the need for co-operation between salvors, other interested parties and public authorities in order to ensure the efficient and successful performance of salvage operations for the purpose of saving life or property in danger as well as preventing damage to the environment in general." However, the 2002 International Maritime Committee (CMI) survey showed that no country ratifying the Convention on Salvage has explicitly accepted, in its national law, the legal effects of Article 11 of the Convention. (Petrinović and Škiljo, 2010)

Following several maritime accidents with disastrous consequences for the marine environment, particularly the disasters of tankers Erika and Prestige, the IMO Assembly adopted two resolutions in November 2003 regarding the designation of places of refuge for ships in need of assistance. On December 12, 1999, tanker Erika suffered an accident about 60 nautical miles from the French coast. The tanker broke into two parts and sank. She was carrying 31,000 tons of crude oil. As a result of the accident, approximately 20,000 tons of oil escaped into the sea, and the rest remained in the fore and aft tanks of the sunken ship. The disaster caused a great deal of damage to the marine environment. In November 2002, tanker Prestige suffered structural damage due to inclement weather. After several days of floating in extremely adverse weather, the ship broke into two parts and sank about 60 nautical miles from Galicia's coast (Spain). The ship carried 77,000 tons of crude oil and the majority of cargo (about 63,000 tons) escaped into the sea.

Resolution A. 949 (23), under heading Guidelines on Places of Refuge for Ships in Need of Assistance, applies in cases where a ship needs assistance and there is no threat to human life. (Comite Maritime International, 2003) When the safety of human life is involved, the provisions of the SAR Convention apply. The guidelines of IMO's Resolution A 949 (23) stipulate that, in case of a maritime accident in which the vessel experiences progressive demise, the best way to prevent damage or pollution is to remove its cargo and bunkers (fuel supplies) to facilitate vessel repair. A place of refuge is the most appropriate venue for the implementation of this process. However, since hauling such a ship to a place of refuge in the vicinity of the coast may endanger the coastal state economically and environmentally, the local authorities and residents of coastal states are opposed to this process. Thus, granting a ship in distress access to a place of refuge could involve a political decision, which can only be taken on a case-to-case basis. In that event, the decision makers should take into consideration both the interests of the ship and the protection of the marine environment. (Petrinović and Škiljo, 2010)

The second Resolution of A.950 (23) Maritime Assistance Services - MAS, recommends all Coastal States to set up a Data Collection Service for granting ships access to the location of a place of refuge. (Ozcayir, 2004) The Republic of Croatia has chosen the existing National Search and Rescue Center (hereinafter referred to as the "National Center") as the service to assist ships at sea. The main tasks of the service are to receive various reports, advice and information required by numerous IMO instruments; to monitor the state of the ship if such a report indicates that an accident may lead to the situation in which the ship needs assistance; to serve as a data collection center if the state of the ship is not alarming and dangerous, but still requires information exchange between the ship and the coastal state (due to the possible deterioration of the ship's state); and to serve as a communication center with private salvage agents involved in salvage operations of a threatened ship if the coastal state decides that all stages of salvage operations should be monitored. It should be noted that the IMO Guidelines on Places of Refuge attempted to strike a balance between the interests of the damaged ship and the interests of the coastal states the environment of which is in danger. (Petrinović and Škiljo, 2010)

Even after the IMO adopted the resolution of 2003 containing guidelines on the designation of places of refuge, the international community continued to address this issue in an attempt to make the idea of the places of refuge more acceptable to coastal states. The CMI Conference, held in Vancouver 2004, devoted a considerable amount of time to places of refuge and opened up many issues that needed to be resolved in the future (from the question of whether there was a requirement under the existing legal regulation for the coastal state to determine such a place, to granting financial guarantees for civil liability in case of environmental pollution).

The EU has been involved in the resolution of the places of refuge issue since the accidents of tankers Erika and Prestige took place in its waters. The disasters of the tankers Erika (1999) and Prestige (2002) urged the EU to drastically reform the existing maritime safety regime aiming at better prevention, especially when it comes to tankers, as they have caused the largest ecological disasters at sea.

On the basis of the Resolution on a Common Maritime Safety Policy of the European Council, the EU Commission proposed and adopted at least ten directives in the 1993-2002 period. The most important directive for the designation of ports of refuge is Directive 2002/59 / EC of 27 June 2002, which entered into force in February 2005. The aim of this Directive was to establish a computerized maritime surveillance system in maritime areas under EU jurisdiction with a view of increasing the degree of safety of navigation and reducing marine pollution damage caused by maritime accidents. (Petrinović and Plančić, 2007)

This Directive requires EU member states to draw up a detailed plan for cases where ships need assistance, as well as to determine and deliver a list of places of refuge at which ships in distress could be more easily salvaged. The member states had a deadline by the end of 2007 to meet the requirements of the Directive. In this way, the guidelines of IMO Resolution A. 949 (23) on the places of refuge were to become mandatory for EU member states. A great many European countries have acted in accordance with the IMO Guidelines and Directive 2002/59 / EC by declaring the existence of places of refuge, but the data on such sites are usually not publicly available.

In addition to special Directive 2002/59 / EC, the EU has adopted other measures aimed at enhancing the safety of navigation and the protection of the marine environment against pollution from ships in EU waters. Thus, after the Erika tanker incident, the EU prepared two packages of measures called Erika packages I and II. Erika package I aims to narrow the existing legislation in favour of port state control and classification societies, proposing new measures to accelerate the withdrawal of single-hull tankers from the market and improve maritime control in European seas (Ozcayir, 2004), while Erika package II established the European Maritime Safety Agency (EMSA), introduced an information system for improved monitoring of traffic in European waters, and set up an additional compensatory fund for oil pollution damage. (Ozcayir, 2004) In addition, criminal sanctions have been introduced for the infringement of regulations on sea-water pollution from ships (EU Directive 2005/35 / EC on the introduction of sanctions for sea-to-sea pollution). (Grabovac, 2008) In late 2005, the Third Maritime Safety Package (Erika III package) was adopted, which consists of seven proposals that include amendments to the existing directives and relate to: the harmonization of rules and standards of different flag states, classification societies, port state controls, navigation surveillance services, maritime incident investigations, liability and compensation for passenger casualties and shipowners' offshore liability. (Ćorić, 2009)

4. CROATIAN LEGAL FRAMEWORK – ORDINANCE ON PLACES OF REFUGE

In accordance with IMO guidelines and the provisions of the 2004 Maritime Code, the Croatian Minister of Maritime Affairs was obliged to establish the places of refuge within three years (by the end of 2007), prescribe the requirements to be met by places of refuge, as well as conditions and procedures for their use. (Grabovac, 2008) In January 2008, the Ministry of Maritime Affairs issued the Ordinance on Places of Refuge, together with the basic execution document – The Plan for Accommodation of Ships in Need of Assistance.

The Ordinance on Places of Refuge prescribes the procedure for deciding on and approving the place of refuge for ships in need of assistance, authorized bodies and persons responsible for the selection and approval of places of refuge, conditions to be met and the manner of use of the places of refuge. The Ordinance also prescribes the content, the manner of adoption and amendment of the Plan for Accommodation of Ships in Need of Assistance. The Plan contains various data required to successfully admit endangered ships into the places of rescue. The pertinent Ordinance provisions prescribe obligations with respect to the compensation for damages and expenses, compulsory insurance or other financial guarantee for ships seeking shelter. The Ordinance also provides for a special and detailed procedure to be followed after the approval of the place of refuge. (The Croatian Ordinance on Places of Refuge)

The procedure for determining the place of refuge has several stages. The request for approval and allocation of a place of refuge must first be submitted by the master of the vessel in distress. The request should contain all the information required to assess the situation of the ship in distress. (The Croatian Ordinance on Places of Refuge) For an abandoned vessel in distress, the request for approval and allocation of a place of refuge is submitted by the authorized harbour master, and in case a salvage contract was concluded, the request may also be filed by the master of the salvage vessel. A request for the allocation of a place of refuge is received by the National Center which will, upon receipt of the request, confirm the receipt of the same.

In the second phase, the justification behind the approval of the place of refuge is assessed. The National Center assesses the justification behind the request for approval and assigns a place of refuge based on the request submitted, all available data, risk assessment, availability of financial guarantees which must be supplied by the owner or the operator of the ship in distress. If the National Center finds that additional information on the state of the ship and other circumstances is required before the decision is made, and the circumstances permit, a special expert group will be sent to the ship (harbour master, authorized pilot and other experts). The expert group is obliged to submit to the National Center its findings and opinions as soon as possible and propose ways of providing assistance, if necessary. When the National Center estimates that the request is justified, it will designate a place of refuge, in accordance with the Plan for Accommodation of Ships in Need of Assistance. The National Center will propose the rejection of the request (The

Croatian Ordinance on Places of Refuge) if it estimates that the request is unfounded or that a ship's accommodation in the port of refuge would pose a greater risk to human life and health and the environment than another mean of assistance.

If the place of refuge is approved, the National Center is obliged to continue to monitor the condition of the ship and other relevant circumstances as long as the ship is in the area under the jurisdiction of the Republic of Croatia, i.e. until the threat has been removed. After assessing the justification of the approval of the place of refuge, the third stage begins, which is the allocation of the place of refuge. On the basis of the proposal of the National Center, the Assistant Minister responsible for the affairs of the navigation and protection of the sea against pollution, with the consent of the Ministry responsible for environmental protection, brings a decision on the allocation of a place of refuge and vessel's admission to a place of refuge, or he/she decides to reject the request for the designation of the place of refuge. If a port is determined as a place of refuge, the port authority or other body managing the port shall admit the ship in the port and provide the assistance required. (The Croatian Ordinance on Places of Refuge) The provisions of the Ordinance suggest that if a marina is determined as a place of refuge, the concessionaire of the marina is obliged to admit the vessel in distress and provide the necessary assistance. A similar provision is contained in the Ordinance on the Conditions and Manner of Maintaining the Order in Ports and in Other Parts of the Inland Waters and the Territorial Sea of the Republic of Croatia according to which the concessionaire is obliged to give berthing priority to a ship, yacht or boat in distress when human life or safety of navigation are endangered. (The Ordinance on the Conditions and Manner of Maintaining the Order in Ports and in Other Parts of the Inland Waters and the Territorial Sea of the Republic of Croatia, 2005)

The next, fourth and most important stage is the process following the approval of a place of refuge. Once a place of refuge is approved, the harbour master or another authority decides on other assistance measures if necessary. The National Center coordinates all activities related to the provision of assistance to the ship, while the direct execution of these activities at the location of the place of refuge is in the domain of the authorized harbour master. If circumstances require the activation of the Emergency plan in case of unexpected sea pollution (Emergency plan in case of unexpected sea pollution, 2008), further activities shall be conducted accordingly. When the circumstances leading to the designation of the place of refuge cease to apply, the ship is obliged to leave the place of refuge. The National Center is obliged to keep records of all the circumstances and facts related to the designation of the place of refuge from the moment of the receipt of the request until the ship leaves the jurisdiction of the Republic of Croatia, i.e., until the threat is eliminated. (The Croatian Ordinance on Places of Refuge)

Upon completion of each event leading to the designation of a place of refuge and provision of assistance to a ship in accordance with the provisions of the Ordinance, an expert team appointed by the Minister of Maritime Affairs shall analyse all the circumstances of the case, measures and activities carried out, and if necessary, propose appropriate improvements. At least once a year, the Administration of the Ministry of Maritime Affairs responsible for the safety of navigation and the protection of the sea against pollution from the ships shall organize a training programme to ensure readiness for Ordinance implementation. (The Croatian Ordinance on Places of Refuge)

The Ordinance on Places of Refuge establishes the obligation to enact and regularly update the Plan for Accommodation of Ships in Need of Assistance as a basic execution document. The Plan for Accommodation of Ships in Need of Assistance must contain information on the competent body responsible for receiving and processing the call from the vessel in distress, and on the competent authority or person responsible for the assessment of the circumstances, as well as the selection of a suitable place of refuge and a decision to admit a ship in distress to the chosen place of refuge.

It also contains a summary of factors that enable prompt assessment and decision making, including descriptions of social and environmental factors, and natural conditions of potential places of refuge. The procedure for assessing and deciding on the place of refuge shall be determined on the basis of potential places of refuge. The accurate list of the places of refuge is kept in the Ministry of Maritime Affairs. The Plan must include a list of available resources and devices suitable for provision of assistance, salvage or pollution restriction and removal, as well as procedures for international harmonization and decision-making where applicable, procedures relating to financial guarantees and accountability systems accepted at the place of refuge. (The Croatian Ordinance on Places of Refuge)

4.1. The Plan for Accommodation of Ships in Need of Assistance

The Plan for Accommodation of Ships in Need of Assistance defines the terms used in the Plan. It details the stages of place of refuge designation prescribed by the Ordinance on Places of Refuge (request for the approval and allocation of a place of refuge, assessment of the justification for the approval of the place of refuge, allocation of appropriate place of refuge and rendering assistance at the place of refuge). According to this Plan, the location of the place of refuge is a port, a part of a port, a sheltered wharf, anchorage or other sheltered area, and the sheltered area is any area in the inland waters or territorial sea where the ship is exposed to minor effects of the wind and sea, regardless of whether it is proceeding, afloat or anchored. (The Croatian Ordinance on Places of Refuge - The Plan for Accommodation of Ships in Need of Assistance, 2008)

4.1.1. Decision on the Choice of a Suitable Place of Refuge

The choice of possible places of refuge, based on the assessment of the circumstances and characteristics of the coast where the ship may be accommodated, is made by the acting Authorized Officer of the National Center. The choice is limited to two, or sometimes three potential places of refuge. (The Croatian Ordinance on Places of Refuge - The Plan for Accommodation of Ships in Need of Assistance, 2008) If the marine environment is threatened, the decision to choose a place of refuge along the coast is made only if damage to the environment would be lesser in the event of an unfavourable development near the coast than at open sea, provided that it does not endanger the safety and health of people on the coast. This would enable the crew of the ship to repair defects that could, at some later point in time, pose a significant threat to human safety or contribute to environmental pollution, and facilitate the provision of effective assistance onshore. (The Croatian Ordinance on Places of Refuge - The Plan for Accommodation of Ships in Need of Assistance, 2008) A place of refuge along the coast should not be proposed in any other case. A place of refuge along the coast will likewise not be proposed if the request is not grounded or if the master of the vessel refuses to provide the necessary information and explanations.

After identifying possible places of refuge or determining that there are no such places along the coast, the National Center's officer is required to notify the Assistant Minister thereof, also providing him with a brief account of the proposal in the agreed form, upon which the Assistant Minister will make further decisions and be responsible for the execution of the safety and pollution-protection activities.

4.1.2. Possible Places of Refuge

The ADRIA-GIS computing application is a computer decision making support system that contains potential places of refuge and other related information. The application (as shown in Figure 1.) is used by the authorized persons in the process of making a final decision on the request for a place of refuge. The application provides rapid access and analyses the relevant safety, economic, legislative, environmental, logistical and technical-technological parameters, facilitating the decision making process. The content of the application complies with IMO Resolution A. 949 (23) and EU Directive 2002/59 / EC. The ADRIA-GIS application has been in use since April 1, 2007.

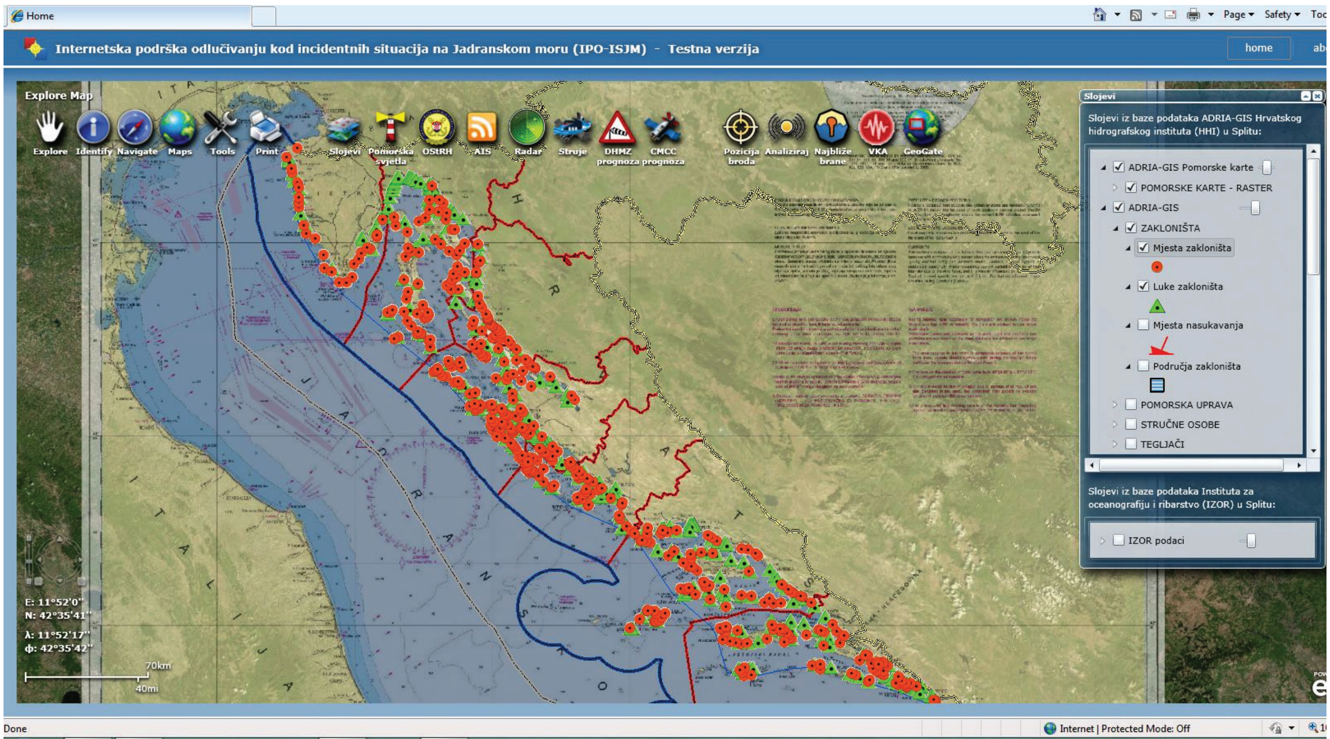

Figure 1.
ADRIA-GIS decision support system.

Information on potential places of refuge is provided in the GIS application. In addition, all suitable places in the immediate vicinity that could, under special circumstances, provide higher level of ship safety or environmental protection could also serve as places of refuge. ADRIA-GIS decision support is based on multi-criteria analysis (MCA) (Mladineo el al., 2017; Bradarić et al., 2008; Gržetić et al., 2008) which, among other criteria, includes potential places of refuges. However, judging from the available data, no marina in the Republic of Croatia was identified as a potential place of refuge in the GIS application. Still, given that other suitable places in the vicinity of the previously determined venues could also be designated as places of refuge, marinas could indisputable serve that purpose as well. This is especially the case when the safety of nautical tourism is at risk.

A ship can be accommodated at a place of refuge by having her anchored in a protected coastal area, or along the developed coastline, or stranded on the beach. When it comes to larger vessels (cargo and passenger ships), the ship is berthed alongside the built-up shore usually by means of a tug. After the ship has been accommodated in the place of refuge, the ship's crew members are not permitted to move about freely on land, except to carry out activities necessary to ensure the ship's safety, i.e. pollution prevention or cleaning up activities. A list of places of refuge, i.e. developed ports and beaches where a ship can be intentionally stranded is updated by the National Centre manager. The GIS application is usually updated once a month by the person in charge at the Croatian Hydrographic Institute.

The places of refuge are chosen as follows - the starting point in the selection of a place of refuge is the identification of a venue indicated in the list of potential places of refuge which is the closest to the location of the ship in distress. If the starting point of a place of refuge is unsuitable or inadequate in any respect, then the next place from the list is chosen as the potential place of refuge. Exceptionally, a place inadequate on the basis of general environmental protection principles can be taken into account if it significantly reduces the threat or possible environmental pollution and can effectively limit environmental damage. (The Croatian Ordinance on Places of Refuge - The Plan for Accommodation of Ships in Need of Assistance, 2008) The decision making process is repeated until the location which allows greater support to the ship is identified. After the implementation of the basic procedure, a multi-criteria analysis of available refuge locations can be performed. If it is certain that a threat to safety of humans and the ship cannot be avoided by implementing the procedure of rendering assistance provided for in Chapter 7 of the Plan, then the rescue of people begins, and a place of refuge is chosen solely from the standpoint of environmental protection.

Whether a location of a place of refuge is deemed suitable or not is determined by the Plan. The place of refuge is considered suitable with regard to the ship's safety if it (The Croatian Ordinance on Places of Refuge - The Plan for Accommodation of Ships in Need of Assistance, 2008):

– provides satisfactory protection against external forces, especially wind and waves, to preserve the vessel's buoyancy, stability and / or strength;
– enables disembarkation of people from the ship;
– enables the performance of operations required for the removal of threats or the reduction of the risk of maritime or other incidents;
– allows getting people and equipment on board to eliminate threats or reduce danger;
– a ship can be intentionally stranded to prevent uncontrolled sinking.

A place of refuge should be considered suitable if it: allows the reduction of unauthorized discharge of the substance from the ship into the sea, primarily through reduced exposure to wind, waves and currents; provides adequate protection against the spread of pollution (single or multiple fence of protective barriers); and allows the ship to be deliberately stranded to prevent pollution from spreading (somewhere else in case of sinking).

A designated land or sea area is deemed unsuitable for the accommodation of a ship if (The Croatian Ordinance on Places of Refuge - The Plan for Accommodation of Ships in Need of Assistance, 2008):

– it is not sheltered against the prevailing winds and waves;
– it does not ensure satisfactory ship safety (e.g. force of 8 Beaufort in the event of deterioration of weather conditions);
– there is dense traffic of other vessels and watercraft in the immediate vicinity;
– it would be much more difficult to abandon the ship in case of emergency;
– the access of people and land resources to the ship becomes inadequate or lengthy due to a slight increase in wind and waves.

The place of refuge should be deemed unsuitable if: it is located close to national parks, nature parks and other natural resources; there are a number of settlements in the vicinity; there are farms and similar facilities nearby the successful operation of which, in the long term, heavily depends on the quality of the sea; it is not possible to effectively enclose the ship or to close off a smaller area by protective barriers; the sinking of the ship would hinder regular maritime traffic. Unsuitable places of refuge are all areas in the vicinity of tourist and similar facilities where merchant ship visits are uncommon. In view of the size and potential danger represented by vessels in nautical tourism, some of the above-mentioned limitations do not apply in their case.

Namely, marinas that are the starting point of sailing vessels of nautical tourism are tourist destinations and are often located near populated areas. On the other hand, vessels in nautical tourism pose a lower risk to the marine environment than traditional cargo and passenger ships, but more often lead to greater risks to human lives. Therefore, when considering marinas as places of refuge for nautical tourism vessels, these facts should also be taken into account.

Industrial ports, especially those away from settlements, should be considered suitable places of refuge if assistance can be rendered without increased risk to people on the coast. Economic activity in such ports is not considered a hindrance to rendering assistance to a ship, especially if it reduces threat to the environment. If several places of refuge have largely similar characteristics and/or are almost equidistant from the position of the vessel in need of assistance, the advantage should be given to: a place that provides greater protection from external influences (if they pose a primary threat); a place that can be reached faster and with fewer navigational restrictions, and a place where people and equipment have easier access from land. If the ship is in imminent danger from sinking, capsizing or breaking, the priority in the selection of a place of refuge should be given to: a place that allows better confinement or clean-up of sea pollution, a place more suitable for intentional stranding, and a place in the vicinity of which there are no protected areas, farms, tourist destinations or larger settlements. (The Croatian Ordinance on Places of Refuge - The Plan for Accommodation of Ships in Need of Assistance, 2008) If neither place stands out even after the aforementioned principles are applied, all the places that were considered should be suggested as a place of refuge. The total number of places of refuge should be limited to a maximum of three.

4.1.3. Approval for Entering a Sheltered Area

Entering the port of refuge is proposed as an aid measure in case of: repair of machinery, hull or other equipment which cannot be adequately performed during navigation on account of weather conditions; cargo shifting; a ship's taking shelter in an area that would not be endangered by the direct action of wind and waves or navigation through such area. Entering the sheltered area includes navigation, floating and/or anchoring in the territorial sea and inland waters.

The repair of machinery, hull or other equipment is normally carried out within the boundaries of the territorial sea on board a floating or anchored vessel, as required by the ship's master. When a vessel is required to float for longer than 4 hours or during the night, if possible, the vessel should be anchored.

In case approval for anchoring or floating in the territorial sea or in inland waters is obtained, the anchorage or floating location are determined by the harbour master, who informs the National Center's official accordingly. Shelter in a port of refuge may be allowed to vessels of up to 80 m in length, vessels not carrying dangerous or toxic cargo and vessels with less than 150 tonnes of fuel. Vessels in nautical tourism without doubt, fit into this category. Shelter is only exceptionally allowed to vessels longer than 80 m, vessels not carrying dangerous or toxic cargo and vessels with less than 150 tonnes of fuel. Providing shelter to vessels longer than 200 m is not allowed. (The Croatian Ordinance on Places of Refuge - the Plan for Accommodation of Ships in Need of Assistance, 2008)

5. CONCLUSIONS

The accidents of the Erika and Prestige tankers urged the IMO and the EU to drastically reform the existing maritime safety procedures to improve prevention, especially with respect to tankers as potential causes of major marine ecological disasters. The accidents of these two tankers have opened up numerous issues, and the EU reacted by adopting special measures which member states were required to implement into their national legislation. The Republic of Croatia complied with the IMO Guidelines and Directives of the EU in 2007 by adopting the Ordinance on Places of Refuge and defining the procedure for the selection and approval of places of rescue for ships in need of assistance, competent bodies and responsible persons for the selection and approval of places of refuge, conditions to be met, as well as the terms and conditions of their use.

Information on possible places of refuge is listed in the GIS application. In addition to these places of refuge, all other suitable places in their immediate vicinity are also considered if they could provide a higher level of safety to the ship or facilitate environmental protection as places of refuge. A ship can be accommodated at a place of refuge by anchoring in the protected coastal area, along the coastline or by getting intentionally stranded on a beach.

Marinas, in the function of nautical tourism ports, can be seen as ports of refuge for nautical tourism vessels. If a nautical tourism vessel finds itself in distress, the nearest, or according to the Plan for Accommodation of Ships in Need of Assistance, the most suitable marina is obliged to provide a place of refuge to such a vessel. A problem may arise if the marina's capacities are filled, which happens often during the tourist season. The problem is particularly acute during frequent summer storms when a large number of nautical vessels are looking for a safe berth. If, in such a situation, human life on the vessel, or the safety of navigation in general are endangered, the marina is obligated to give the vessel mooring priority.

The second question is whether marinas are suitable places of refuge for vessels which have suffered excessive damage, or pose a threat to the marine environment due to their cargo or propulsion fuel. Theoretically, marinas could become places of refuge if they are chosen by the competent services as the closest and most convenient places to accommodate a vessel in distress. In such a case, the body managing the port, i.e. the marina concessionaire is obliged to accept the ship into the marina and provide necessary assistance. In practice, such outcomes are highly unlikely.

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Maritime Cyber Security Analysis – How to Reduce Threats?

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Maritime cyber security management requires a holistic approach as there is an increase in complexity, digitalization, and automation of systems in maritime industry. Numerous interconnected systems between ship and shore, which are in need of a special focus in the internet environment, are increasing on daily basis. Nowadays one of the major concerns in maritime computing is vulnerability to cyber-attacks. In maritime industry, cyber incidents can lead to loss of life, loss of control over ships or sensitive data, as well as ship and/or cargo hijacking. This paper therefore covers key problems of maritime industry from cyber security perspective and proposes solutions on how to eliminate or minimize them.

KEY WORDS

~ Maritime cyber security
~ Cyber threat
~ Cyber risk
~ Cyber-attack
~ Maritime industry

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1. INTRODUCTION

Maritime business is rapidly changing. The number of integrated and interconnected systems, as well as those where a company can access and operate from shore, is rapidly increasing. The term "maritime" refers to ships, yachts, offshore structures, other floating objects, infrastructure, and anything else that connects and unifies all of the afore mentioned elements in business.

Cloud computing is flourishing as well. It brings an increase in productivity, scalability, and a significant degree of independence of user location, able to access database from any location via internet connection. "Many organizations are now migrating towards cloud due to its favorable features" (Balobaid and Debnath, 2018).

As an example, the shipping company "UASC" have migrated to a system for bunker ordering via cloud computing. The "classic" way of bunker ordering was inexpensive, so the representatives of "UASC" moved a step forward, signing the contract with "Shiptech" in order to create a cloud based bunker ordering platform. Migrating to the new system enables "UASC" to track market prices, to have a better communication with suppliers, to improve the ship's performance monitoring and to plan bunkering of their whole fleet (Shiptech, 2015).

There is no company or ship operating totally or partly online which is immune to cyber threats. Research (Einsig, 2016) shows that business digitalization is obstructed by many factors. The biggest threat is security vulnerability, especially cyber security. In the end, cyber incidents are ranked as the second most important risk of running a company. In maritime shipping, 31% of respondents have stated that they are frightened of cyber-criminal, data theft, and other similar risks (Allianz Global Corporate & Specialty SE, 2018).

„Maritime cyber risk refers to 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" (International Maritime Organization, Guidelines on maritime cyber risk management, MSC-FAL.1/Circ.3, 2017).

The increase of cyber risks is a consequence of an increase in connectivity and dependency of global navigational systems. Therefore "cyber security refers to the protection of information systems (hardware, software, and associated infrastructure), the data on them, and the services they provide, from unauthorized access, harm or misuse. This includes harm caused intentionally by the operator of the system, or accidentally, as a result of failing to follow security procedures" (Shaikh, 2017).

Vulnerable systems onboard include the navigation bridge, cargo handling equipment, the engine room, the power management system, and administrative as well as communicational systems. Numerous systems onboard which could be attacked are represented on Figure 1.

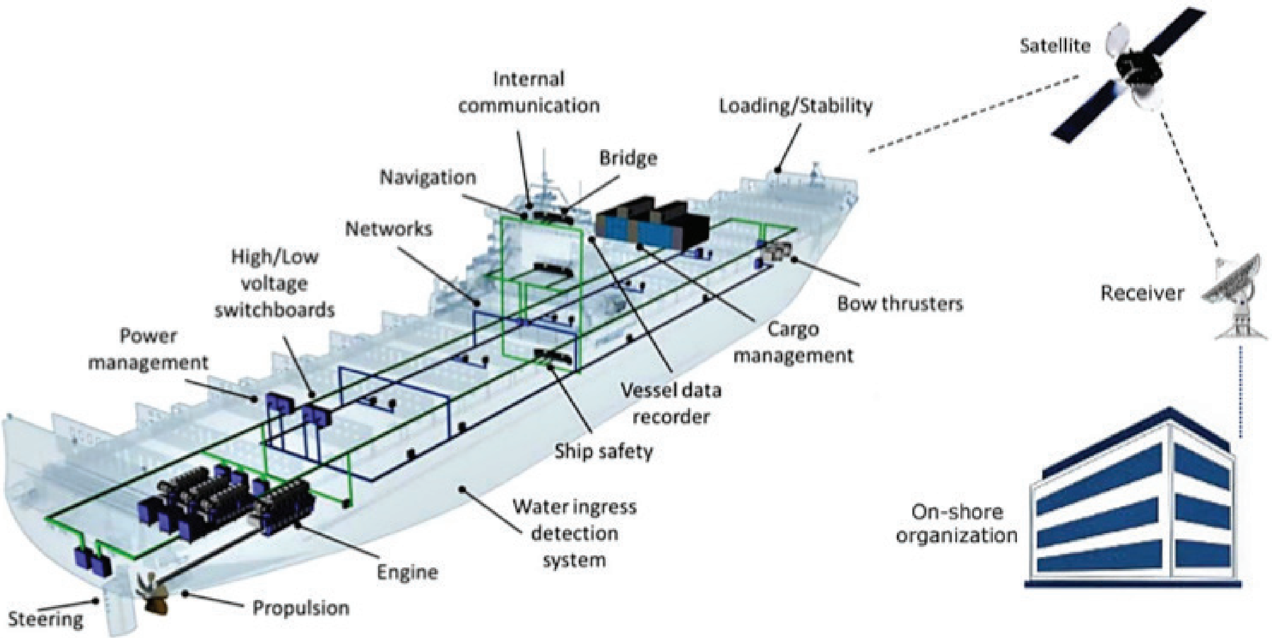

Figure 1.
Connectivity between ship's systems – all of them represent potential targets (Ording, 2019).

Risk management is fundamental for safe and secure maritime operations and it should adapt to the world of digitalization, automation, and interconnected businesses (International Maritime Organization, Guidelines on maritime cyber risk management, MSC-FAL.1/Circ.3, 2017).

In the following sections we review the most common forms of cyber-attacks in maritime industry, the most important threats and ways of defending upon them with a focus on ship's infrastructure and operations.

2. INTERNATIONAL REGULATION AND GUIDELINES

Upon analyzing literature sources we have arrived at the conclusion that many maritime transport participants, in the first-place regulatory bodies and international organizations, are taking part and offering different solutions for dealing with cyber threats in maritime industry.

The common feature of all analyzed sources is setting risk assessment as a first step towards protection from unwanted consequences.

The National Institute of Standards and Technology (NIST) brings „NIST Framework" which is widely used as approach to cyber security assessment, as well as a step towards the fulfillment of cyber risk management. The advantage of "NIST framework" lies in its universality and flexibility, which is why it can be employed in many industries, including the maritime one (National Institute of Standards and Technology NIST, 2018).

The International Maritime Organization (IMO) has taken decisive steps in order to solve and control maritime cyber risks.

Actually, Maritime Safety Committee (MSC) and The Facilitation Committee (FAL) have issued "Guidelines on maritime cyber risk management" (MSC-FAL.1/Circ.3) as an answer to the increased number of cyber-attacks. The Guidelines completely accept NIST framework with five key elements: identification, protection, detection, response, and recovery (International Maritime Organization, Guidelines on maritime cyber risk management, MSC-FAL.1/Circ.3, 2017).

There is also a Resolution numbered as MSC.428(98) – "Maritime Cyber Risk Management in Safety Management Systems". This Resolution encourages flag states to force the companies to treat cyber security management at company level through "Safety Management System" (SMS) as the requirement of "International Safety Management Code" (ISM). Such a requirement should be fulfilled no later than first annual ISM verification after 1.1.2021. (International Maritime Organization, Maritime cyber risk management in safety management systems, MSC.428(98), 2017). If the companies fail to implement the required measures, their ships could be detained by Port State Control (PSC), thereby causing additional costs and business losses.

The IMO have developed a Strategic plan (International Maritime Organization, Strategic plan for the organization for the six-year period (2018 to 2023), A 30/Res.1110, 2017) for the period between 2018 and 2023 where the need for an integration between the existing and new technologies in the regulatory process is recognized, aiming at balancing benefits between security, safety, and environmental protection as well as the influence on personnel both onboard and ashore.

For the same purpose the Baltic and International Maritime Councils (BIMCO) in (BIMCO, 2017) rely on publications of NIST and IMO. The BIMCO's attitude is published as „Guidelines on Cyber Security Onboard Ships". BIMCO approaches to cyber risk problems through the following items: 1-identification of threats and vulnerabilities, 2-assesment of risk exposure, 3-development of protection and detection measures, 4-establishment of contingency plans to respond and recover upon a cyber security incident.

In "Code of Practice – Cyber Security for Ships" (Boyes, H. and Isbell, 2017) cyber risk problems are solved without reliance on the afore mentioned NIST framework. Actually the development of cyber risk management plan should rely upon cyber risk security assessment, which remind us of the fundaments of "International Ship and Port Facility Security Code" (ISPS) dealing with general security onboard ships and at port facilities.

All that has been stated above is complemented by numerous classification societies which are publishing guidelines in order to direct their clients towards the right path. In (DNV-GL, 2016), the most important classification society „DNVGL", taking into consideration the IMO's and BIMCO's guidelines, as well as NIST framework, defines three factors as key elements in order to improve cyber security: 1-assessment, 2-improvement, 3-verification, followed by validation.

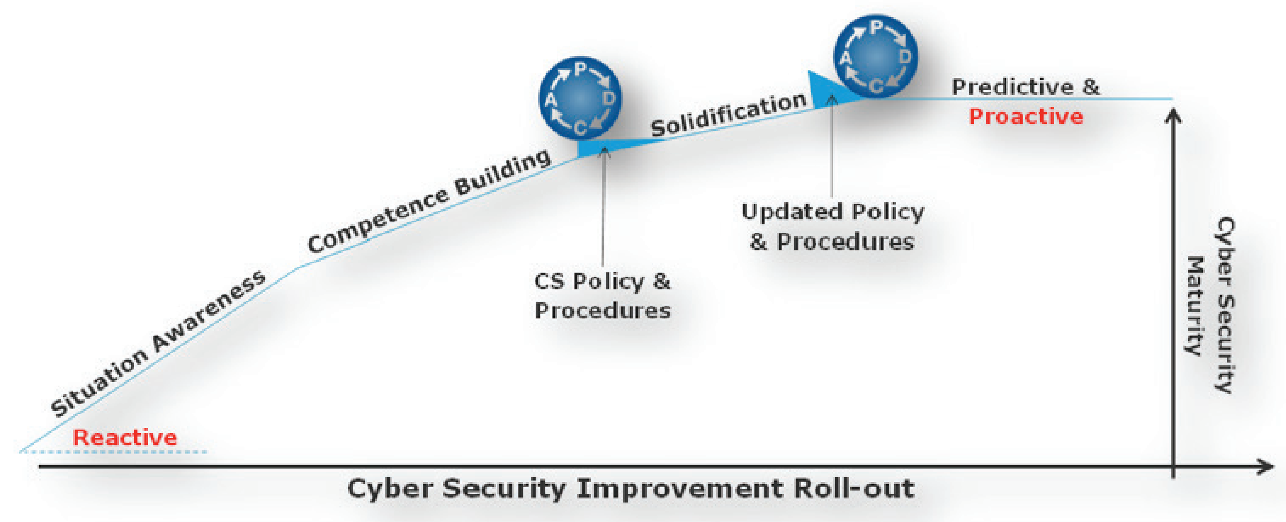

Figure 2.
Flow of adequate approach to cyber security problem onboard (DNV-GL, 2016).

"DNVGL" relies on Deming circle, namely „PDCA" cycle, as it is trying to induce maritime transport participants to continually asses their current risk using the risk matrix and other methods, with a view to creating a productive and proactive system (Figure 2). Due to a rapid technology development, cyber security assessment should not rely only upon the well-known risks. On the contrary, it requires a predictive and proactive approach which takes into account all systems onboard and ashore, their design, interconnection, and management manner.

In repetitive „PDCA" cycle, the human factor must be acknowledged as equally important as all other business aspects - "the desired behavior and awareness in terms of cyber security therefore needs to be evaluated just like any other objective" (DNV-GL, 2016).

The latest regulation, which will certainly have a great impact on shipping companies, is EU "General Data Protection Regulation" (GDPR) which came into force in May, 2018. GDPR forces shipping companies to conduct an assessment of impact on personal privacy at any time when there is an increased risk of privacy violation. Companies are obliged to report any system violation within 72 hours in order to enable the entire industry to react quickly upon potential cyber-attacks (EUGDPR.org, 2018).

However, the insurance against the cyber related risks is still unrecognized for the maritime industry sector. The hull and machinery insurance (H&M) policies exclude cyber related risks by inserting relevant clauses, such as Cyber Attack Exclusion Clause (CL380), while Protection and Indemnity Insurance (P&I) offer pools with a limit of $30 million USD per ship in case of cyber-attacks which are not related to war or terrorist attack activities (Lagouvardou, 2018).

3. HISTORIC REVIEW OF MARITIME CYBER-ATTACKS

The exact number of maritime cyber-attacks is unknown and can be considered to be much greater than reported, as attacks are frequently unnoticed or companies do not want to publish such information in order not to endanger their business or frighten their customers.

In the recent era a set of attacks has resulted in data, system, and equipment breaches, as well as serious financial losses. Depending on the kind of attack, consequences vary from minor to moderate, such as in the case of data theft, while in the case of taking control over the whole system, for instance a vessel, they seem to be reaching catastrophic levels.

Large cargo shipments usually travel for weeks across the oceans before reaching their final destination, which makes them highly vulnerable to cyber-attacks as there is enough time to remove evidence of the crime (Jones, Tam and Papadaki, 2016).

The following is a list of the most important maritime cyber-attacks:

1. Few companies providing security onboard ships sailing through "High Risk Area" (HRA) were subject to hacker attacks back in 2011. Pirates successfully accessed sensitive data on vessels movement, their cargo and insurance. Using that, they were able to plan their further actions and request ransom. Those attacks had the same scenario – "key log" malwares were used to record each keyboard press, and send the logs further to pirates' e-mail addresses (Frodl, 2012).
2. Port of Antwerp in Belgium was under hacker attacks committed by sophisticated drug smugglers in the period between 2011. and 2013. Using malwares and, subsequently, on, other methods, the hackers were successfully finding out the location of cargo containers containing narcotics. Afterwards they used to send their own drivers to collect the goods before the real owner could come to pick up the container. The Port authorities realized that something was going on just after whole containers had started to disappear (Bateman, 2013).
3. Despite the fact that the main purpose of Automatic Identification System (AIS) is increase in safety, easier identification and communication at sea, a research (Balduzzi, Wilhoit and Pasta, 2014) shows that AIS has many deficiencies, especially in terms of cyber security because it is completely cyber unprotected. There were tests carried out to confirm such issues, during which false AIS symbols were generated on various locations around the world. The consequences which can result from a misuse of AIS are enormous.
4. A group of students successfully proved weaknesses and imperfections of Global Positioning System (GPS). In 2013 they hacked the GPS signal on a private yacht and distributed false position data to navigational equipment. As the track-pilot was active, automatic correction of course had been initiated in order to put the yacht back on route (Vaas, 2013).
5. Jamming of the GPS signal can cause a lot of trouble for navigation and positioning, both ashore and at sea. As GPS is under the control of the USA, the representatives of the White House issued a diplomatic warning to North Korea, due to a strong jamming encountered in Seoul. At that time the propagation of strong radio waves caused a lot of trouble to airplanes flying over the area affected (GPS World, 2016).
6. In 2014 hackers used malware to shut off an oil platform and completely disable it for a period of 19 days (Wagstaff, 2014).
7. In June 2017 the biggest container operator in the world "Maersk", suffered an enormous cyber-attack. "NotPetya" malware triggered a need for reinstallation of more than 4,000 servers and 45,000 PCs. The company was forced to transport, load, and discharge containers without the IT support for 10 days (Cimpanu, 2018).
8. Also, in the summer of 2017,"Svitzer" company was a victim of data theft – over 5,000 e-mails with personal data were redirected to outside addresses. More than 400 employees

were endangered. The problem arose 10 months before it was discovered and then fixed within 5 hours. The investigation confirmed that messages had been redirected to the outside addresses but, when the mailboxes become full, the e-mails were returning as non-delivered (Bogle, 2018).

9. Another gigantic company "COSCO" was a victim of „NotPetya" malware in July 2018. During the attack, communication channels were disabled, first at port of Long Beach and then in the whole USA territory (Cimpanu, 2018).

4. ATTACK FORMS

The Classification society "Lloyd Register" in (Lloyd's Register, 2018) states that the number of cyber-attacks has increased by 27 % per year, while 86 % of companies were victims of cyber-attack during 2017. The same source states that 44 % of companies believe their IT system requires upgrade in order to meet cyber security requirements, especially because 39 % of those companies suffered attacks during 2017.

According to another research (IHS Markit, 2018), the most significant maritime cyber problems are manifested in one of the following forms:

1. „Phishing" is the most common form of cyber incident. Attacks can be classified in two groups – the first one known as social engineering and the second one based on malwares (Gupta et al., 2017). In the case of social engineering, the attackers try to cause harm via e-mail which seems harmless at a glance, or via fake web site. On the other hand, malware phishing uses malwares installed on client's PC.

This kind of threat is common onboard vessels in the form of e-mail. Usually e-mail contains a hyperlink to a fake web site where the user will, due to inattention or lack of knowledge, type personal details, such as username and password, to access their account. This usually happens when, due to being extremely busy, crew members do not pay attention to the e-mail content or the hyperlink.

2. Malware is a „computer code written to steal or harm. It includes viruses, spyware, and ransomware. Sometimes malware only uses computing resources (e.g. memory), but at other times it can record your actions or send your personal and sensitive information to cyber criminals" (Paulsen and Toth, 2016).

3. "Spear phishing" is a form of "phishing" and represents one way of unauthorized collection of personal and sensitive data. Hence the hacker performs a "spear phishing" attack in the following manner: he contacts person „A" inside the company, introducing himself as person „B", who is at the same time superior to person „A". He uses fake e-mail address, but very similar to the company official's one, attaching a file or a hyperlink to the e-mail. By clicking the file in the attachment or by opening the link, login details are shared, transactions are authorized, or whole company's network becomes infected. Therefore person „A" shares login details or passwords thinking that he is communicating with the superior.

4. Identity fraud – cyber-attacks can be aimed exclusively at stealing identity in order to use it for further crimes. Identity fraud is commonly committed by using „Trojan" malware.

5. Ransomware is a kind of malware. A seemingly normal and harmless e-mail can cause a lot of trouble. Ransomware is usually in form of „.pdf" or „.zip" files attached to e-mail. By opening these files the system is brought to danger as the malware initiates denial of access to document or to the system. The solution is in paying off ransom in order to restore access to files or system.

6. „Man in the middle" (MITM/MIM) is a kind of malware which relies on SSL/TSL protocol weakness, being correspondent in communication between two network users (Čekerevac et al., 2017; Mallik et al., 2019). In such a case, downloading of important data occurs while users can rarely detect it.

7. Data theft usually goes unnoticed or is discovered too late. Data is being copied or downloaded without authorization. Committing criminal activities by using ransomware and malware, unauthorized access results in data theft and data deletion in order to hide the traces or to cause a lot of harm to business (Borazjani, 2017). This is supported by the fact that over 50,000 e-mails of "Svitzer" company were subject to data theft back in the summer of 2017 (Bogle, 2018).

5. HOW TO SOLVE A PROBLEM?

Issuing the „Guidelines on Maritime Cyber Risk Management" the IMO responded to an increase in cyber-attacks by accepting the NIST framework containing of five elements: identification, protection, detection, response, and recovery (International Maritime Organization, 2017). Similarly, BIMCO (BIMCO, 2017) defines the circle process base d on theNIST approach (Figure 3).

Identification is a process of identification OF internal and external weaknesses or risks. It contains knowledge about: personnel and their abilities to recognize risks; systems; data and other elements that can cause a risk due to disruption of normal IT process within the company.

Detection means that it is necessary to conduct activities in order to spot the cyber threat as soon as possible. Hence, early threat detection leads to early detection of malicious intentions followed by on-time steps which will limit the consequences to the part of the system, protecting the rest of it.

Protection requires following of contingency plans in case of threat or incident, as well as procedures and measures to recover from the attack in good time.

Response to threats depends on the development and implementation of plans and activities which will restore the system upon cyber-attack.

Figure 3.
Cyber risk management (BIMCO, 2017).

Recovery is the last phase which requires implementation of measures to restore the system and the data which were under attack. This phase precedes the first one – identification of risks and weaknesses.

Notwithstanding the fact that these elements have a general character, they provide clear guidelines to companies which are free to create their own procedures and solutions in order to satisfy their own needs.

We believe that there are three basic considerations upon which cyber security measures must rely:

1. *Human resources* – personnel should be aware of risks and have adequate skills and qualifications. Also, employees should be familiar with the procedures, levels of authorization, physical security barriers, and they should be well trained in risk response.
2. *Technology* – adequate system design is a requirement. Software configuration should satisfy further inspection, verification, and testing processes.
3. *Processes* – include management of systems and networks, management policies and procedures, audits, contracts with third parties etc.

It is for these reason that the cyber security battle is not dependent solely on IT. Hence, it should start at the top of the company with implementation of cyber security procedures through the SMS. That is the most important precondition for the future plan development, education and training of seafarers, as well as for creating appropriate conditions for successful protection against attacks and threats.

Every single user onboard, as well as ashore at the company headquarters, should be limited with user rights with regard to some information, data, or parts of the system. The reason which lies behind limitation of access and user rights is mainly referred to steps made due to lack of knowledge or unintentionally, causing the system to become vulnerable and exposed to data theft or similar incidents.

IT network onboard is the crucial element of defense against cyber-attacks. However, the real disposition and protective measures onboard vessels are usually not as prescribed by international recommendations. Therefore the network configuration and its protective measures are of utmost importance, which can be achieved by following recommendations and company procedures. At first, the use of firewall to separate internal (safe) network from external (unsafe) network is crucial.

Performing of security assessment will enable the company to spot its weaknesses and vulnerabilities and to minimize them to the maximum extent. Based on the remaining and unsolved weaknesses and vulnerabilities, it is necessary to develop preventive measures, as well as recovery measures, in case of a successful cyber-attack.

In order to meet all of the afore mentioned requirements, it is necessary to monitor obeying the procedures, tasks and activities, as well as to monitor personnel behaviour in relation to the usage of IT resources.

Since there is an increasing number of systems onboard which are accessible from the company's headquarters, such systems should be treated with special attention, protected with additional procedures which will enable safe and secure access whenever it is necessary.

Implementation of anti-malware and anti-virus is a must, and there is no need to particularly underline it within this article.

It is very common for the whole systems to get infected onboard ship by using infected USB drives. This can be classified as user's insufficient knowledge. Companies should find a way to overcome such and similar occurrences – usually by implementation of online trainings provided by renowned companies „VIDEOTEL" or „SEAGULL", or even by classification societies. Tanker shipping companies have widely accepted newly introduced „OCIMF" requirements by using „Tanker management and self-assessment" (TMSA) tool (OCIMF, 2018). Employees' education expenses are negligible in comparison to the costs which may arise in case of a cyber-attack.

There is also a need for introducing "Cyber Security Officer" (CySO) (Boyes, H. and Isbell, 2017). CySO should be delegated to perform cyber security assessment and to implement actual security plan, as well as to educate crew to respond to more and more frequent threats. Of course, CySO should be adequately educated and certified to conduct such a demanding task.

6. CONCLUSION

Cyber threats, vessels, port terminals and other maritime systems evolve simultaneously. Negative effects of cyber-attack are evident not only onboard the victim vessel, but in a much wider sector including shipping companies, port terminals, interconnection systems etc.

GPS signal jam causing the crude oil tanker to ground in dense fog is much more serious than the grounding itself, by far exceeding the average costs. In such a case, the oil spillage is bound to cause an ecological catastrophe. Apart from GPS imperfections and its misuse, this article has presented other unpleasant events with, in the majority of cases, serious consequences.

Apart from the great attention which is already being given to maritime cyber security, much more should be done. Regulation is just one step towards the goal achievement. However, the personnel seems to present an even bigger problem than the regulation itself, because it often happens that the crew onboard, with minimum or no knowledge about this matter, inadvertently perform some tasks, frequently resulting in the system being exposed and open to attack.

Awareness is a necessity in all business aspects – if there is no awareness among employees at the company headquarters, then all awareness onboard ship will not have a great impact. Sooner or later, the difference between successful and unsuccessful business companies will be in their sustainability in response to cyber-attacks.

Our future work will be aimed at improving the efficiency of seafarers' education related to minimizing the number of successful cyber-attacks onboard vessels. Special attention should be given to various forms of training which will become mandatory in the near future. The creation of comparative analyzes, assuming that companies abide by the new European Union "General Data Protection Regulation", should provide answers as to what extent the maritime industry has successfully responded to new form of war – cyber threats.

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CONTRIBUTION

Pjesme / Poems
Guidelines

ART

E MORTE KAPITÔN

Ive Kora

Kasîl je
tũji
i komũnski
grêb
u zrōkű
tamjôn
u dūšì
zêb.

Ùmro je
stõri Kapitõn.

Ćūtî je
da ga je živòt
obandunô.
Da nĩ ženê
ni ditèta,
da mu je
pod gòbu
tũjo koćèta.

Tūga je svè
inkrožãla
ko bršjõn.
Cêrti se rugãli
siromãhu
da je pjôn.

Dūšà mu
ćūtìla
vèli zvôn
dì ga zovè
dîn
dôn
dôn.

AND THUS DIED THE CAPTAIN

trans. by Mirna Čudić Žgela

The coffin
is someone else's
laid in the common grave.
Incense lingering
in the air
the soul filled with
anxiety and
chill.

The old Captain
is dead.

He felt
that life
had abandoned him.
That he was
wifeless
and childless,
that his body was laid
in someone else's bed.

The sorrow
pervades all
like ivy.
Some have mocked
the poor man
saying that he was drunk.

His soul
heard
the big bell
the death knell calling him
ding
dong
dong.

Kojô je
môra vìdit
kojê svè
krãje
a čèko je
nôjslãje
da mu
prìd noge
krĩž i velèta
ko bandîra
na jôrbul ventulô
i nestãje
ko za krmõn
morèta.

What seas
he had seen,
what
lands!
and he had waited
with a happy anticipation
for a cross and a veil
at his feet
to be flying
like a flag on his mast
disappearing
as the furrow
behind
the stern.

RJEČNIK

obandunàt	napustiti
gèba	grba, leđa
koćèta	starinska postelja
inkrožãt	prepletom učvristiti
bršjõn	bršljan
cêrti	neki, pojedini
pjôn	pijan
velèta	veo
bandîra	zastava
morèta	val od broad

MÒDRI GRÊB

Ive Kora

Kalôjte ôrgane
ne želĩn hi
čùt.
Plãče mi se,
dŕćen
ko prût….

Živòt
ko klûko
prèje,
zênso mõj.

Dôkle se
ne odmòto
nè znoš
za krôj.
I ne pènsoš
jē cilo
il je bŕž
retôj.

Mlôdi smo bîli.
Jemãli
u svè vìre,
ma ni godìšća
nīsù
za take
penšīrè.

Pènsoli smo
kojî će brôd
kojô jìta,
kojô nas
čèkoju môra
kojî krôj
svîta.

THE BLUE GRAVE

trans. by Mirna Čudić Žgela

Silence the organ
I do not want
to hear it.
I feel like crying,
I shiver
like a leaf ....

Life
is like a ball
of yarn,
old mate.

Until it is
unraveled
you know nothing
of the end.
You do not wonder
if it is whole
or perchance
a remnant .

Young were we.
Full
of faith,
young age
is not fit
for such
worries.

We thought
what ship,
what voyage,
what seas
lay ahead,
what endof earth
we were heading for.

Klãdili
smo se
kojî će
od nõs
prvî pasàt
Cobo de Hornos.

Dūšõn
i tîlon
ćũtin zêb….
U nãšoj
jubãvi
prvèga
vijãja
nõšo si
grêb.

We placed bets
which
of us
would be the first
to pass
Cape Horn.

I feel chill
in my soul
and body.....
In our
love
of the first
voyage
you found
your grave.

RJEČNIK

kalàt	skinuti
ôrgani	orgulje
klûko	klupko
prèja	pređa
pènsot	razmišljati
bŕž	možda
zênso	imenjak
pasàt	proći, prepoloviti
retôj	ostatak nečega
vìra	vjerovanje
penšĩr	misli, misao
jìta	određeno putovanje
vijôj	putovanje
jē	je li
zêb	zebnja

About ToMS: Ethics, Conflict of Interest, License and Guides for Authors

The Journal is published in English as an open access journal, and as a classic paper journal (limited edition).

ToMS aims at presenting the best maritime research primarily, but not exclusively, from Southeast Europe, particularly the Mediterranean area. Papers will be double-blind reviewed by 3 reviewers. With the intention of providing an international perspective at least one of the reviewers will be from abroad. ToMS also promotes scientific collaboration with students and has a section entitled Students' ToMS. These articles also undergo strict peer reviews. Furthermore, the Journal publishes short reviews on significant papers, books and workshops in the fields of maritime science.

Our interest lies in general fields of maritime science (transport, engineering, maritime law, maritime economy) and the psychosocial and legal aspects of long-term work aboard.

1. PUBLICATION ETHICS

Ethical Policies of ToMS

Plagiarism is arguably the most complicated ethical issue. Our policies define plagiarism as "taking material from another's work and submitting it as one's own." ToMS *holds authors — not the Publisher or its editors and reviewers — responsible* for ensuring that all the ideas and findings included in a manuscript are attributed to the proper source. We also refer to our role as steward of what constitutes ethical conduct. Ethical misconduct is the reason for our commitment to continue to strive to educate all the parties in the publishing process how to handle this matter. As a member of Crossref, ToMS has a powerful weapon – iThenticate system, which is not perfect.

"Even if there were reliable and sensitive plagiarism detection software, many issues would remain to be addressed.

For example, how much copying is legitimate? Clearly, the reuse of large amounts of others' text constitutes plagiarism. But what should one think about copying short passages from the author's own earlier work, such as commonly occurs in the Methods section? In the Nature article it is suggested that some journals set a quantitative limit whereby the amount of text that can be reused is limited to about 30 percent. This may be utilitarian, but it seems curious and arbitrary that 25 percent of copied text might be deemed acceptable whereas 30 percent might not. Indeed, two authors who copied the same number of words could find themselves on opposite sides of that border if one author simply was more verbose and thus diluted their plagiarized content below the threshold! No, this is not a simple issue at all." [cited from: http://newsletter.aspb.org/ethics.cfm]

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Faculty of Maritime Studies expects authors submitting to and publishing in its journals to adhere to ethical standards to ensure that the work they submit to or publish in the journal is free of scientific misconduct. Authors must:

- Take credit only for work that they have produced.
- Properly cite the work of others as well as their own related work.
- Submit only original work to the journal.
- Determine whether the disclosure of content requires the prior consent of other parties and, if so, obtain that consent prior to submission.
- Maintain access to original research results; primary data should remain in the laboratory and should be preserved for a minimum of five years or for as long as there may be reasonable need to refer to them. All authors of articles submitted for

publication assume full responsibility, within the limits of their professional competence, for the accuracy of their paper. Instances of possible scientific misconduct related to papers submitted to or published in the ToMS will be addressed by following the procedure outlined below.

2. CONFLICT OF INTEREST

The authors, reviewers and other participant are obligated to clearly state possible conflict of interest. Editor-in-chief, senior editor and/or executive editors board decide on actions based on conflict of interest (COI).

Editors' Duty

Disclosure and Conflicts of Interest: The editor cannot use unpublished materials, disclosed in submitted manuscript for his/her own research, without prior written consent of the author(s).

If author(s) of submitted paper is a member of editorial board or editor-in-chief, the submission, review and decision process is carried by the highest ranking editor who is not the author.

Reviewers' Duty

All reviewers should have no conflict of interest with respect to the research, the authors and/or the funding bodies.

3. MALPRACTICE

Procedure for addressing allegations of scientific misconduct or other ethical violations

Scientific misconduct in publishing includes but is not limited to:

- Data manipulation;
- Data falsification;
- Fraud: fabricating a report of research or suppressing or altering data;
- Duplicate publication;
- Plagiarism and
- Self-plagiarism.

Procedure for handling allegations of misconduct

- All allegations of scientific misconduct or ethical violation will be referred to the editor for research integrity or to the editor-in-chief. All allegations should be made in writing.
- Editor for research integrity will report the case in the meeting of the Editorial board and recommend the actions in 30 days.
- Except redraw of the paper, punishment could be inclusion in the black list of the journal and prohibition of further publishing in ToMS.

Submission declaration

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Multiple, Redundant, or Concurrent Publications: Authors should not concurrently submit the same manuscript for publishing to other journals, or conference proceedings. It is also expected that the author(s) will not publish redundant manuscripts, or manuscripts describing the sameresearch in several publishing venues, after the initial manuscript has been accepted for publication.

Acknowledgement of Sources: Author(s) should acknowledge all sources of data used in the research and cite publications that have influenced their research.

Authorship of the Paper: Authorship should be limited only to those who have made a significant contribution to conceiving, designing, executing and/or interpreting the submitted study. All those who have significantly contributed to the study should be listed as co-authors. The corresponding author should also ensure that all the authors and co-authors have seen and approved the final submitted version of the manuscript and their inclusion as co-authors.

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The Journal is published in English as an open access journal, and as a classic paper journal (limited edition).

ToMS aims at presenting the best maritime research primarily, but not exclusively, from Southeast Europe, particularly the Mediterranean area. Papers will be double-blind reviewed by 3 reviewers. With the intention of providing an international perspective at least one of the reviewers will be from abroad. ToMS also promotes scientific collaboration with students and has a section entitled Students' ToMS. These articles also undergo strict peer reviews. Furthermore, the Journal publishes short reviews on significant papers, books and workshops in the fields of maritime science.

Our interest lies in general fields of maritime science (transport, engineering, maritime law, maritime economy) and the psychosocial and legal aspects of long-term work aboard.

6.1. Before you Begin

6.1.1. Ethics in publishing

For information on Ethics in publishing and Ethical guidelines for journal publication see Publication Ethics

6.1.2. Conflict of interest

All authors are requested to disclose any actual or potential conflict of interest including any financial, personal or other relationships with other people or organizations within three years of beginning the submitted work that could inappropriately influence, or be perceived to influence, their work.

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Submission of an article implies that the work described has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis or as an electronic preprint), that it is not under consideration for publication elsewhere, that its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere including electronically in the same form, in English or in any other language, without the written consent of the copyright-holder.

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6.2. Guidelines for Authors: Manuscript Preparation and Submission

6.2.1. Organization of the manuscript

First (title) page

The first page should carry:

a. the paper title;

b. full names (first name, middle – name initials, if applicable), and last names of all authors;

c. names of the department(s) and institution(s) to which the work should be attributed. If authors belong to several different institutions, superscript digits should be used to relate the authors' names to respective institutions. Identical number(s) in superscripts should follow the authors names and precede the institution names;

d. the name, mailing address and e-mail of the corresponding authors;

e. source(s) of research support in the form of financial support, grants, equipment or all of these.

Last page

The last page should carry:

a. ethical approval, if required;

b. authors' declarations on their contributions to the work described in the manuscript, their potential competing interests, and any other disclosures. Authors should disclose any commercial affiliations as well as consultancies, stock or equity interests, which could be considered a conflict of interest. The details of such disclosures will be kept confidential but ToMS urges the authors to make general statements in the Acknowledgement section of the manuscript.

c. a list of abbreviations used in the paper (if necessary);

Other pages

Each manuscript should follow this sequence:

- title page;
- abstract;
- text (Introduction, Methods, Results, Conclusions/ Discussion);
- acknowledgments;
- references;
- tables (each table complete with title and footnotes on a separate page);
- figures and figure legends, and the last page.

6.2.2. Text organization and style

6.2.2.1. Abstract

The second page should contain the Abstract. ToMS requires that the authors prepare a structured abstract of not more than 250 words. The abstract should include (at least) four sections: Aims, Methods, Results, and Conclusion, not necessarily separated.

Aim. State explicitly and specifically the purpose of the study.

Methods. Concisely and systematically list the basic procedures, selection of study participants or laboratory/ experimental/simulation setup, methods of observation (if applicable) and analysis.

Results. List your primary results without any introduction. Only essential statistical significances should be added in brackets. Draw no conclusions as yet: they belong in to the next section.

Conclusion. List your conclusions in a short, clear and simple manner. State only those conclusions that stem directly from the results shown in the paper. Rather than summarizing the data, conclude from them.

6.2.2.2. Main text

Do not use any styles or automatic formatting. All superscripts or subscripts, symbols and math relations should be written in MathType or Equation editor.

Introduction

The author should briefly introduce the problem, particularly emphasizing the level of knowledge about the problem at the beginning of the investigation. Continue logically, and end with a short description of the aim of the study, the hypothesis and specific protocol objectives. Finish the section stating in one sentence the main result of the study.

Results

Key rules for writing the Results section are:

a. the text should be understandable without referring to the respective tables and figures, and vice versa;

b. however, the text should not simply repeat the data contained in the tables and figures; and

c. the text and data in tables and figures should be related to the statements in the text by means of reference marks.

Thus, it is best to describe the main findings in the text, and refer the reader to the tables and figures, implying that details are shown there. The formulations such as "It is shown in Table 1 that the outcome of Group A was better than that of Group B" should be replaced by "The outcome of Group A was better than that of Group B (Table 1)."

The need for brevity should not clash with the requirement that all results should be clearly presented.

Discussion/Conclusions

The discussion section should include interpretation of study findings in the context of other studies reported in the literature. This section has three main functions:

a. assessment of the results for their validity with respect to the hypothesis, relevance of methods, and significance of differences observed;

b. comparison with the other findings presented in the relevant literature; and

c. assessment of the outcome's significance for further research.

Do not recapitulate your results, discuss them!

6.2.2.3. Tables

Information on significance and other statistical data should preferably be given in the tables and figures. Tables should not contain only statistical test results. Statistical significances should be shown along with the data in the text, as well as in tables and figures.

Tables should bear Arabic numerals. Each table should be put on a separate page. Each table should be self-explanatory, with an adequate title (clearly suggesting the contents), and logical presentation of data. The title should preferably include the main results shown in the table. Use tables in order to present the exact values of the data that cannot be summarized in a few sentences in the text.

Avoid repetitive words in the columns: these should be abbreviated, and their explanations given in the footnotes. Present data either in a table or a figure.

Each column heading for numerical data given should include the unit of measurement applied to all the data under the heading. Choose suitable SI units.

Place explanatory matter in footnotes, not in the heading.

Explain in footnotes all nonstandard abbreviations that are used in each table.

6.2.2.4. Figures

Figures should be numbered in sequence with Arabic numerals. Legends to figures should be listed on a separate page, in consecutive order. Minimum resolution for all types of graphics is 300 dpi and 600 dpi is recommended. The legend of a figure should contain the following information:

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Use simple symbols, like closed and open circles, triangles and squares. Different types of connecting lines can be used. The meanings of symbols and lines should be defined in the legend.

Each axis should be labeled with a description of the variable it represents.

Only the first letter of the first word should be capitalized. The labeling should be parallel with the respective axis. All units should be expressed in SI units and parenthesized. Make liberal use of scale markings.

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6.2.2.5. Authorship statement

All contributing authors must fill out and sign these statements and submit them to the Editorial Office. Accepted manuscripts will not be published until signed statements from all authors have been received.

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Technical help, critical reviews of the manuscript and financial or other sponsorship may be acknowledged. Do not acknowledge paid services, e.g. professional translations into English.

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References cited in the manuscript are listed in a separate section immediately following the text. The authors should verify all references. Usage of DOIs is mandatory.

Examples of citation in text:

It is well known fact (Strang and Nquyen, 1997; Antoniou, 2006) that FT is not an appropriate tool for analyzing nonstationary signals since it loses information about time domain.

First group of authors (Vetterli and Gall, 1989) proposed Multiresolution Signal Analysis (MRA) technique or pyramidal algorithm. Second group (Crochiere et al., 1975; Crochiere and Sambur, 1977) proposed subband coding algorithm. Legal acts are cited as in example: The Constitution of the Republic of Croatia (Constitution of the Republic of Croatia, 2010) is the main legal source for this subject matter, as well as any other subject matter relating to the Croatian legal system. References from the Web are cited in the text as (Author(s) last name, year of origin if known (year of accessed in other cases). If the author is unknown, such as in case of company web page, instead of author's name, title of the web page is used.

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Journals

Petrinović, R., Wolff, V. S., Mandić, N. and Plančić, B., (2013), International Convention on the Removal of Wrecks, 2007. – a New Contribution to the Safety of Navigation and Marine Environment Protection, Transaction on Maritime Science, 2(1), pp. 49-55., https://doi.org/10.7225/toms.v02.n01.007

Pennec, E. and Mallat, S., (2005), Sparse Geometric Image Representations with Bandelets, IEEE Transactions on Image Processing, 14(4), pp. 423 – 438., https://doi.org/10.1109/TIP.2005.843753

Web links

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6.2.2.8. Supplementary materials

Supplementary materials are optional. Authors can submit different types of materials which will be available on-line.

6.2.2.9. Language

Authors may use standard British or American spelling, but they must be consistent. The Editors retain the customary right to style and, if necessary, shorten texts accepted for publication.

This does not mean that we prefer short articles – actually, we do not limit their size - but rather a resection of the obviously redundant material.

The past tense is recommended in the Results Section.

Avoid using Latin terms; if necessary, they should be added in parentheses after the English terms. Real names rather than “levels” or “values” should refer to parameters with concrete units (e.g. concentration).

6.2.2.10. Abbreviations

Only standard abbreviations and symbols may be used without definition and may be used in the title or the page-heading title.

Non-standard abbreviations should not be used in the title or page-heading title. They must be explained in the text in the following way: the term should be written in full when it appears in the text for the first time, followed by the abbreviation in parentheses; from then on, only abbreviation is used in the text. This applies separately to the Abstract and the rest of the text.

6.2.3. Submission of manuscripts

Paper submission via ToMS web page Open Journal System.
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