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Contents

From Editor-in-Chief

Ivica Kuzmanić

Dear Readers,

You have before you the eleventh issue of the internationally double-blind peer-reviewed scientific journal Transactions on Maritime Science. It is published by the Faculty of Maritime Studies of the University of Split. As always, the Journal is published in the printed and electronic, open access form. Our desire is for our readers to have an easy access at minimum expense.

We are exceptionally pleased, and we take great pride in it, that we have been admitted to the prestigious Scopus database. Our year-long effort has finally paid off! This is a great step forward for our journal, as well as for the authors who publish their papers in it.

This issue brings seven papers from several scientific areas. The number of authors is high, 24 of those who have given their contributions to the papers before you. We are particularly happy to have published several papers by authors from Germany and Sweden, along with the ones presented before.

Far from underrating the contributions made by other distinguished authors, I would nevertheless like to take the liberty of recommending a paper entitled "Data Based Modelling of the Significant Wave Height in the Adriatic Sea", primarily due to the fact that the paper is excellent, and also because of the authors. We are dealing with three exceptionally promising scholars from the institution responsible for the publication of this journal, who obviously herald a bright future for the Faculty of Maritime Studies.

The "Contribution" section brings you the news from the International Maritime Organisation in London, reported by our associate Tatjana Krilić. All the news from the past six months has been brought.

You will also find some news with regard to the previous issues, as well as the enclosure containing the Decree of the Government of the Republic of Croatia, concerning the founding of the study of Military Maritime Studies with three study programmes: Military Nautical Studies, Military Marine Engineering, and Military Electronics.

We have also remained faithful to another area we wish to promote: the Croatian cultural heritage. Again a poem, this time written by Tašenka Matulović (neé Tabak) , born at Pitve on the island of Hvar. She has offered a valuable contribution towards the encounters of Croatian Chakavian poets of the island of Hvar, and is noted for her membership in several cultural institutions: Literary Circle in Split, Chakavian Association in Split, and, dating from 2016., Croatian Writers Society. The poem hereby translated, "Partenca" ("Departure"), has been retrieved from the collection entitled "Vrića puna misečine" ("A Bagful of Moonlight"). This contribution is presented in a bilingual form with the striking translation by Mirna Čudić. Readers of the electronic edition can listen to an impressive rendition of the poem by the author herself.

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

Data-Based Modelling of Significant Wave Height in the Adriatic Sea

Luka Mudronja, Petar Matić, Marko Katalinić

The paper deals with sea wave modelling based on available data acquired from a satellite-calibrated numerical model. The idea is to use an artificial neural network, as a flexible tool capable of modelling nonlinear processes, for significant wave height (SWH) modelling at a single point in the Adriatic Sea. The focus of the paper was not to develop a new type of ANN, but rather to use it as a modelling tool and identify the most significant input variables for SWH modelling in the Adriatic Sea, among the available data. Linear and nonlinear regression models were also developed for purposes of comparison of neural network performances with those of traditional data modelling methods. A total of 22 years of data were used - 20 years of data with a 6 h sampling step time, i.e. 30684 data samples were used to calibrate the models, while 2 years of data, i.e. 2920 data samples were used to test the models' performances. Simulation results proved the ability of an artificial neural network to model SWH with high accuracy based on available data. Furthermore, the artificial neural network model proved to be more accurate than traditional statistical models, especially when multiple input variables were used.

KEY WORDS
~ Sea wave
~ Data-based modelling
~ Artificial neural network
~ Regression analysis
~ Significant wave height

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1. INTRODUCTION

Sea wave modelling is challenging due to its complexity, since a variety of parameters influence the mathematical description of the sea surface. In wave modelling in the Adriatic Sea, Tonko Tabain defined the Tabain spectrum of waves in the Adriatic Sea (Tabain, 1997). Computer development enabled numerical modelling and the application of numerical tools such as SWAN (Ris et al., 1999) to play a significant role in the sea wave modelling process. However, the use of numerical models might be limited by their complexity, high computational requirements and the need for accurate bathymetric data (Peres et al., 2015).

The availability of measurements and significant data bases made data-based modelling a viable option. Regression analysis, briefly described in section 3.1 of the paper, is a common tool in modelling systems based on available data. However, it requires deciding on which variables should be included in the model, the form such variables should take and, most importantly, the assumption of the functional relationship between dependent (output) and independent (input) variables of the system. These issues could be avoided by using an alternative, more flexible data-based modelling tool, such as artificial neural networks.

Artificial neural networks (ANNs), briefly presented in section 3.2 of this paper, have the ability to approximate nonlinear functions, which makes them an interesting tool for nonlinear system modelling. In essence, ANNs represent an approach similar to regression analysis, a method using data collected from a process to calculate model parameters. While regression analysis requires the definition of a strict mathematical form of a model, a neural network has a more flexible structure allowing it to adapt to the data. Therefore, while expected to yield similar results in simple cases, neural networks are anticipated to perform better in more complex cases where multiple variables influence the output variable.

ANNs have already been used in ocean engineering mostly to model and/or predict significant wave height, as in (Zamani et al., 2009; Peres et al., 2015), peak wave period and, recently, wave energy flux, as reported in (Haddadpour et al., 2014). Input variables for sea wave modelling are usually wind speed and wind direction, with the previous values of the output variable also used as inputs. In paper (Peres et al., 2015), ANN was used to model significant wave height based on wind speed data, and the model was improved by expanding the input data set with more wind input points in the wave generation area. These predictions were used to fill-in the gaps in the significant wave height data series for three points in the Mediterranean Sea. In paper (Zamani et al., 2009), Kalman-filtering is applied to the ANN output to improve the network's prediction ability.

This paper examines the ability to apply feed-forward artificial neural network (ANN), known as multi-layer perceptron (MLP), to model significant wave height (SWH) at a single point in the Adriatic Sea, while examining the influence of different input variables.

Available data are presented in section 4.1 of this paper. In section 4.2, the results of correlation analysis are presented to pre-examine the influence of potential input variables on the output variable. In section 4.3, model-based experiments, used to determine the set of optimum input variables, are presented. For every ANN model, an appropriate regression model was also formed, and the comparison was made with the results presented and analysed in section 5. The conclusions, based on the comparison of neural and regression model performances with the actual values of the output variable, are presented in section 6.

2. SEA WAVE MODELLING

Wave modelling has a significant role in fields such as renewable energy planning, coastal engineering, naval architecture and maritime transportation. Sea surface waves are simultaneously an important energy resource that can be exploited by utilizing wave energy conversion devices (WEC) to generate electricity, and a threat to offshore installations and seagoing vessels owing to extreme loads capable of causing sudden structural collapses or "normal operation" long-term stress which can lead to fatigue damage. Detailed metocean studies facilitate the development of improved and safer designs by optimizing efficiency and minimizing risk.

Several methods can be applied to wave modelling, ranging from empirical to most sophisticated third-generation numerical models. Some examples of wave modelling approaches are as follows:

- modelling by formulated wave spectra function, e.g. Tabain spectrum, JONSWAP spectrum;
- numerical modelling with specialized software, e.g. SWAN, WAM, WAVEWATCH III (Ortiz-Royero and Mercado-Irizarry, 2008);
- modelling with wide-application tools, e.g. artificial neural networks.

Modelling with wave spectra function and specialized software are both well-known procedures for performing calculations in maritime transportation and naval architecture tasks in the Adriatic Sea (Katalinic et al., 2015). The use of numerical models might be limited by their complexity, high computational requirements and the need for accurate bathymetric data (Peres et al., 2015). The main goal of the present paper is to verify the application of a wide-range application tool, such as neural network, in wave modelling in the Adriatic Sea by examining available input variables for the case study.

3. MODELLING METHODS

As explained in (Rawlings et al., 2001), modelling refers to the development of mathematical expressions describing the behavior of a variable of interest. This variable is called the dependent variable and is usually denoted by *y*. Other variables which are thought to provide information on the behavior of the dependent variable are incorporated into the model as predictors or explanatory variables. These variables are called independent variables, and can be denoted by *x*, with additional notation as needed to identify different independent variables. In addition to dependent and independent variables, all models likewise involve unknown constants, called parameters, which control the behavior of the model. Since the modelling method should provide a way to determine the values of these parameters, the models' response should fit the available data. The basic idea of this paper is to use an artificial neural network as a modelling method in a case study and compare it with a traditional data-based modelling method, i.e. regression analysis.

3.1. Regression Analysis

The simplest linear model involves only one independent variable and states that the dependent variable changes at a constant rate as the value of the independent variable increases or decreases. Thus, the functional relationship between y_i and x_i is the equation of a straight line (Rawlings et al., 2001), described with (1) for the univariate case.

$$y_i = \alpha_1 x_i + \alpha_0 \tag{1}$$

The subscript *i* indicates the particular observational unit, the y_i and x_i pair of observations. The x_i stands for n observations of the independent variable, while y_i denotes the observations of the dependent variable. Therefore, a simple linear model has two parameters, α_0 and α_1, to be estimated from the data.

If there was no random error in y_i, any two data points could be used to obtain the values of the parameters. A random variation in a set of y_i values causes each pair of observed data points to give different results. Therefore, a method is needed that will combine all the information from the data into a single solution considered to be the "best" by some criterion. The least squares estimation, explained in (Rawlings et al., 2001), is frequently used for this purpose.

Models sometimes explain the behavior of the dependent variable by *k* independent variables. In this case, the linear model can be extended, as described in (2), for the multivariate case, and the problem is called multiple regression analysis. In this case, there are *k+1* parameters to be estimated, and the common least squares estimate can also be applied.

$$y_i = a_0 + a_1 \cdot x_{1i} + a_2 \cdot x_{2i} + L + a_k \cdot x_{ki} \tag{2}$$

More realistic and therefore more complex models use nonlinear relationships between the dependent variable and independent variables. The introduction of higher-degree polynomials, exponential and trigonometric functions increases the flexibility of the model. Generally, these models can be expressed with (3), where f_N stands for a nonlinear function.

$$y_i = f_N(a_{k+1}, x_{ki}) \tag{3}$$

Regression analysis requires the determination of the functional form of the model, which could cause errors. However, these decisions could be avoided by using an alternative, more flexible data-based modelling tool such as artificial neural networks.

3.2. Artificial Neural Networks

ANNs represent a simplified mathematical model of the process occurring in the brain of living beings. ANN is an artificial structure consisting of a number of interconnected artificial neurons, resembling the biological neural network in terms of information processing and storage, as described in (Haykin, 1999). Based on neuron type and their mutual connections, different ANNs have been developed over the last 50 years. So far, ANNs have been successfully applied to a large number of different computational problems such as pattern recognition, classification, function approximation, modelling and prediction.

A static feed-forward ANN called Multi-Layer Perceptron (MLP) is probably the most commonly used network architecture in most applications, especially function approximation, i.e. modelling and prediction. As briefly described in (Matić et al., 2015), MLP with m inputs, h hidden neurons and o output neurons, uses nonlinear sigmoidal activation functions in a hidden layer, which enables it to approximate nonlinear functions, i.e. model non-linear processes. Although the optimum number of layers was often the subject of research, two-layer structure was proven to be sufficient to approximate any practical function, given enough neurons in the hidden layer (Cybenko, 1989). Therefore, a two-layer MLP, known as universal approximator, was used in this research to form a neural model of significant wave height (SWH).

For a model structure to be defined, the number of inputs (Ni), the number of hidden neurons (Nh) and the number of output neurons (No) have to be determined. The determination of input variables is case-dependent, and is therefore discussed in more detail in sections 4 and 5 of this paper. The number of output neurones is determined by the number of output variables and depends on the modelling goal, i.e. the model's purpose. In this case, it is set to one neuron. Since the quality of the model is dependent upon the number of hidden neurons, it is inevitably a subject of research in the model development process.

Although defined by its structure, i.e. neuron number and type, ANN takes its final form only after the completion of the learning process. The procedure used to execute the learning process is called the learning (or training) algorithm. Its function is to modify network parameters in an orderly fashion to obtain the desired objective, i.e. minimize error between network output and the desired value. The basic algorithm developed for MLP network training is error backpropagation (EBP), which could be considered one of the most significant breakthroughs in the field of neural networks, as noted in (Matic et al., 2015). Although EBP algorithm is still widely used, many improvements have been made to the original algorithm to deal with the issue of its slow convergence. In this paper, a Levenberg-Marquardt (LM) algorithm, explained in (Hagan and Menhaj, 1994) and (Yu and Wilamowski, 2011), and Bayesian regularization (BR), explained in (Foresee and Hagan, 1997), were used to train the network. BR can be a useful tool for determining the sufficient number of hidden neurons, improving on the Levenberg-Marquardt (LM) algorithm, already proven to be the fastest and most appropriate algorithm for training networks, possibly containing hundreds of adjustable parameters (Beale et al., 2010). To determine the optimum number of hidden neurons, BR was used in addition to a set of experiments on training ANNs with varying numbers of hidden neurons.

Artificial neural networks (ANNs) have been explained in detail in (Haykin, 1999), or (Beale et al., 2010) which is more focused on the application of ANNs as a modelling tool. Explicit examples of application in sea wave modelling can be found in references stated in the introduction. The intent of this paper was neither to develop a new type of ANN, nor improve an existing one, but rather to explore the possibility of application of ANN in Adriatic Sea wave modelling, i.e. significant wave height (SWH).

4. CASE STUDY – ADRIATIC SEA WAVE MODELLING

The available data were obtained from an environmental monitoring company, *Fugro OCEANOR*, to be used in the *DATAS (Damaged Tanker in The Adriatic Sea)* project funded by the Croatian Science Foundation. The data were collected by satellite mapping between January 1992 - January 2016, with the time step of 6 hours, at 40 points in the Adriatic Sea. The calculations in this paper pertain to data from a single point in the Adriatic Sea with the following coordinates:

- latitude 42 N
- longitude 17 E

The chosen point is located on the busy merchant ship route between Otrant (SE entrance into the Adriatic Sea) and NE Adriatic ports (Rijeka, Venice, Koper). All data were divided into 12 classes of variables (Table 1, 1-12), the names, abbreviations and units of which are presented in Table 1. Additionally, the authors generated two more potential input variables from available data, namely wind time of duration (WTD) to account for past wind behaviour, and the wind quadrant (WQ) to simplify wind direction information (Table 1, 13-14).

Table 1.
Available data.

Class	Variable name	Abbreviation	Unit
01	Significant wave height	SWH	m
02	Mean wave direction	MDIR	° (degrees)
03	Peak period of 1d spectra	PP1D	s
04	Mean wave period	MWP	s
05	Significant height of wind waves	SHWW	m
06	Mean direction of wind waves	MDIRW	° (degrees)
07	Mean period of wind waves	MPWW	s
08	Sign. height of primary swell	SHPS	m
09	Mean direction of primary swell	MDIRS	° (degrees)
10	Mean period of primary swell	MPPS	s
11	Wind speed at 10 m height	WSP	m/s
12	Wind direction at 10 m height	WDIR	° (degrees)
13	Wind time duration	WTD	h
14	Wind quadrant	WQ	[1-8]

4.1. Data Analysis

Data analysis is performed to examine the relations between potential input and output variables. Although physical processes are mostly non-linear, linear measures, such as correlation analysis, are often used due to their simplicity. Non-linear methods, such as Mutual Information (Zamani et al., 2009), can also be used. However, these results are never taken unequivocally, i.e. the results of data analysis are considered to be merely an assumption, and should be verified by means of a model-based experiment. In this case, the correlation analysis was performed to examine the influence of potential input variables, thus providing an insight into the interdependence of input and output variables. Correlation analysis results presented in Table 2 are used to facilitate the selection of input variables.

Table 2.
Correlation analysis for potential input variables for the chosen point in the Adriatic Sea.

CC	WSP	WDIR	WQ	WTD	SWH_{t-1}
SWH	0.839392	-0.09057	-0.05716	0.171479	0.902132

Results from Table 2 suggest that SWH_t is strongly influenced by WSP_t and its own value from the preceding calculation step, SWH_{t-1}. Therefore, WSP_t and SWH_{t-1} are selected as the best potential inputs for the SWH model. These assumptions are validated by model-based experiments.

4.2. Model Formulation

Data sets obtained from Fugro OCEANOR and the DATAS project were used in the modelling process. From the available 22 years of data - 20 years of data were used to calibrate and 2 years of data to test the models. Sample rate, i.e. time step, was 6 hours, yielding 30683 samples for calibration and 2920 samples for model performance testing. Optimum input variables for modelling the current value of significant wave height (SWH_t) were identified by examining a set of potential input variables through a number of experiments. Since correlation analysis suggested that WSP_t and SWH_{t-1} were the best potential inputs for SWH modelling, experiments were performed as described in Table 3.

Table 3.
Experiment setup for optimum input variable identification.

i	**Formulation**
1	$SWH_t = f(WSP_t)$
2	$SWH_t = f(WSP_t, SWH_{t-1})$
3	$SWH_t = f(SWH_{t-1})$

Two models were formed for each experiment $i \in [1, 3]$, a neural network model (NNM_i), and a regression model (RM_i). The number of hidden layer neurons for the neural models was determined by experiments, where the number of neurons was increased from 10 to 50 with the step size of 10. The BR algorithm was also used to optimize the number of network parameters. Since training outcome is dependent upon the initial values of network parameters (w), multi-start was applied to bring the solution closer to the global minimum. This means that each network structure with different initial values of w parameters is trained P times, with the highest-ranking network selected as the representative model. $P = 10$ was used as the optimum number of consecutive network trainings based on a recommendation from (de Vos and Rientjes, 2005). In the regression analysis, for every RM_i, a number of polynomial functions were explored to obtain the optimum solution, found to be a simple quadratic function.

4.3. Model Evaluation

Graphical and numerical methods can be used to evaluate a model's performances. Graphical methods enable visual comparison of a model's response to actual values, offering a simple first impression of the overall quality of the model. Numerical methods measure the exact quantity of deviation of a models' response from the actual value by means of statistical measures of quality.

Numerical evaluation of data-based modeling in the field of hydrology was analyzed by LeGates and McCabe (1999), with the results applicable to this case study as well. The authors of (LeGates and McCabe, 1999) proposed a set of different measures to evaluate the quality of the model, and recommended that the set include at least one relative and one absolute measure. In the paper (Gupta et al., 1999) the application of Persistence Index (PI) is also recommended. Therefore, the quality of a model is established by means of the following measures, absolute: root mean squared error (RMSE), mean absolute error (MAE); and relative: Nash-Sutchllife coefficient of efficiency (NSC, or CE), percent bias (PBIAS), RMSE to standard deviation ratio (RSR) and persistency index (PI). RMSE, MAE, CE, PBIAS, RSR and PI measures are defined with expressions (4) to (9), in the corresponding order.

$$RMSE = \sqrt{\frac{1}{S}\sum_{s=1}^{S}(d_s - y_s)^2} \tag{4}$$

$$MAE = \frac{1}{S}\sum_{s=1}^{S}|d_s - y_s| \tag{5}$$

$$CE = 1 - \frac{\sum_{s=1}^{S}(d_s - y_s)^2}{\sum_{s=1}^{S}(d_s - \bar{d})^2} \tag{6}$$

$$PBIAS = \frac{\sum_{s=1}^{S}(d_s - y_s)}{\sum_{s=1}^{S}(d_s)} \cdot 100\,\% \tag{7}$$

$$RSR = \frac{RMSE}{STDEV} \sqrt{\frac{\sum_{s=1}^{S} (d_s - y_s)^2}{\sum_{s=1}^{S} (d_s - \bar{d})^2}} \quad (8)$$

$$PI = 1 - \frac{\sum_{s=1}^{N} (d_s - y_s)^2}{\sum_{s=1}^{N} (d_s - d_{s-1})^2} \quad (9)$$

RMSE, MAE and RSR values range from high (+∞) to 0, with lower values indicating lower errors. CE and PI values range from negative (-∞) to 1, where high positive values indicate a better fit. PBIAS measures the average propensity of the model for the calculation of output values (y) lower or higher than the measurements (d). The values of the criteria range from 0 to ± 100 %, with lower values being indicative of better model performance. Positive values indicate a model's bias toward underestimation, while negative values indicate bias toward overestimation.

In (Gupta et al., 1999) a satisfactory model is defined as the one with positive values of the PI coefficient. In paper (Moriasi et al., 2007), model classification is performed based on the values of CE, RSR and PBIAS quality measures. The same classification is presented in Table 4 and used in this paper to evaluate a model's performance.

Table 4.
Model classification based on CE, RSR and PBIAS values.

Model quality	CE	RSR	PBIAS
Very good	(0.75, 1.00]	[0.00, 0.50]	< ±10%
Good	(0.65, 0.75]	(0.50, 0.60]	[±10, ±15) %
Satisfactory	(0.5, 0.65]	(0.6, 0.70]	[±15, ±25) %
Unsatisfactory	≤ 0.5	> 0.7	≥ ±25 %

5. RESULTS AND DISCUSSION

The results of the numerical evaluation of neural and regression models for experiments 1 to 3 are shown in Table 5. Due to high CE values and relatively low values of RSR, RMSE and MAE measures, NNM_1 and RM_1 can both be noted to fairly model the system, with only the PI criterion measuring low negative value, indicating unsatisfactory model performances. Numerical evaluation of the models from experiment 2 is indicative of excellent model behaviour due to low RMSE, MAE, RSR and PBIAS values, and CE and PI measures yielding values close to 1. The NNM_2 model can be noted to score slightly higher than RM_2 by all numerical measures used. Numerical evaluation of the models from experiment 3 indicates satisfactory model behaviour by all measures used, with only PBIAS evaluating a NNM_3 better than RM_3. The overall comparison of the models' performances from Table 5 indicates that NNM_2 is the best model for representing SWH behaviour in the case study.

Table 5.
Numerical evaluation of the performance of models from experiments 1 to 3.

Model	Absolute			Relative		
	RMSE	**MAE**	**PI**	**CE**	**PBIAS**	**RSR**
NNM1	0.293	0.203	-0.178	0.791	2.918	0.52
RM1	0.293	0.204	-0.179	0.79	2.937	0.52
NNM2	0.126	0.083	0.784	0.962	0.147	0.2
RM2	0.136	0.091	0.745	0.955	0.232	0.216
NNM3	0.264	0.18	0.044	0.83	0.93	0.459
RM3	0.264	0.18	0.043	0.83	1.148	0.458

Models from experiments 1 and 3 tend to give best results if h = 10 neurons from the hidden layer are used. Models from experiment 2 tend to give best results if h = 20 neurons from the hidden layer are used. Optimum regression models are defined with expressions (10) to (12) for experiments 1 to 3, in the corresponding order, where y stands for SWH and x represents the WSP variable.

$$y_t = 0.0119 \cdot x_t^2 + 0.0126 \cdot x_t + 0.392 \tag{10}$$

$$y_t = -0.0288 \cdot y_{t-1}^2 + 0.6556 \cdot y_{t-1} + 0.084 \cdot x_t^2 + 0.0166 \cdot x_t + 0.1197 \tag{11}$$

$$y_t = -0.0255 \cdot y_{t-1}^2 + 0.9726 \cdot y_{t-1} + 0.0546 \tag{12}$$

The ordinate in Figures 1 to 3 represents significant wave height measured in meters, while abscissa represents time with a 6-hour step. For clearer presentation of the graphical evaluation, responses in Figures 1 to 3 are magnified, showing only model behaviour for sample 2740 to 2820.

Graphical evaluation of performances of models from experiment 1, presented in Figure 1, indicates consistent error in the range of low values of the SWH variable. Graphical evaluation also shows the model's tendency to predict sudden variable changes, causing numerical measures to have a negative impact on model's performances, although it is actually doing more than just modelling in some cases, it is predicting. This only underscores the importance of use of numerical and graphical evaluation in conjunction, to get a proper evaluation of models' performances.

Graphical evaluation of models' performances from experiment 2, presented in Figure 2, shows excellent correspondence of models' responses and actual data.

Graphical evaluation of models' performances from experiment 3, presented in Figure 3, suggests that lag effect is a problem preventing both models (NNM_3 and RM_3) from modelling sudden changes of the SWH.

6. CONCLUSION

Based on the results presented in section 5 it can be concluded that artificial neural networks can be successfully applied to significant wave height modelling in the Adriatic Sea. The models from experiment 1, using only WSP to model SWH, although being slightly under-rated by statistical measures of performance, have manifested an interesting ability to predict sudden changes of the output variable. This conclusion should be exploited in terms of SWH prediction in further research.

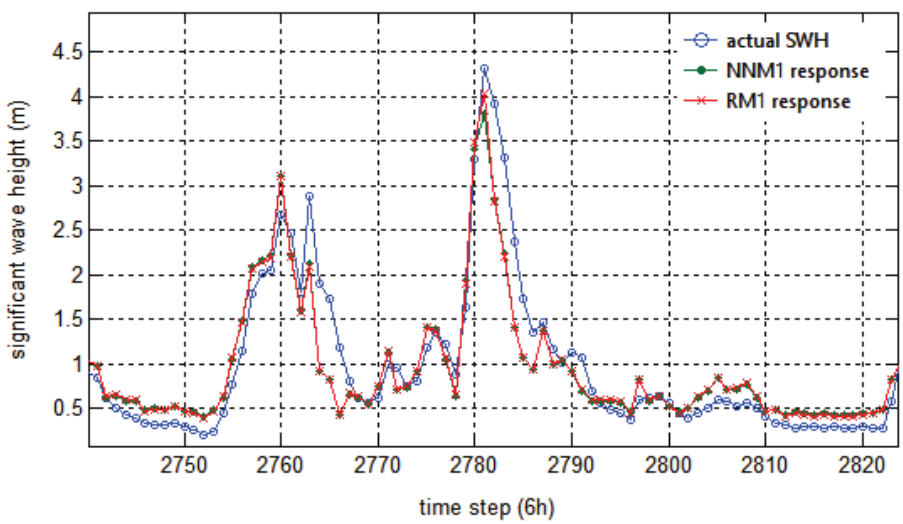

Figure 1.
Graphical comparison of model responses to actual SWH values from experiment 1.

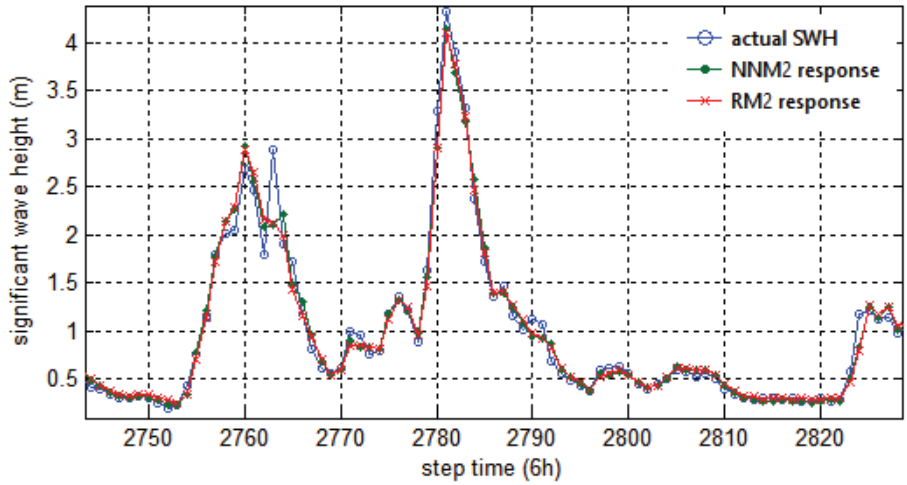

Figure 2.
Graphical comparison of models' responses to actual SWH values from experiment 2.

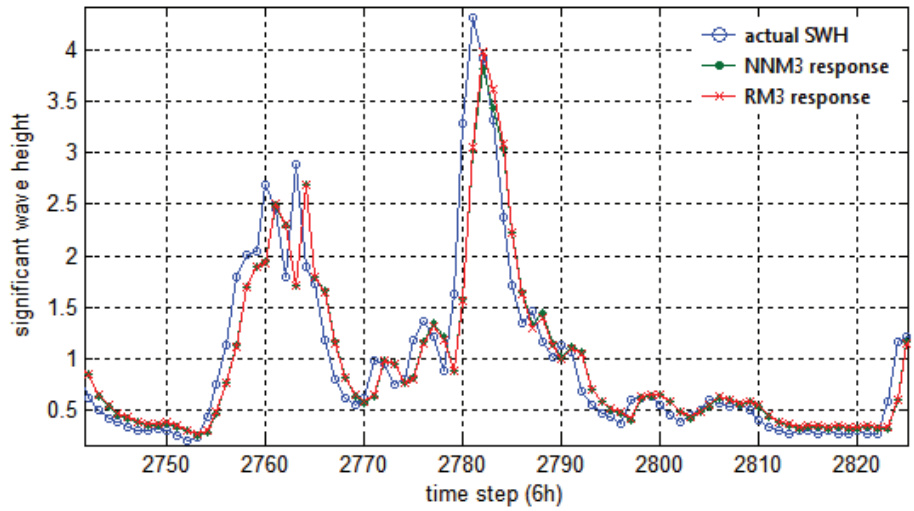

Figure 3.
Graphical comparison of model responses to actual SWH values from experiment 3.

In experiment 3, i.e. the case of SWH_{t-1} used as a single input variable, the issue of models' responses lagging behind the actual SWH can be noted. This lag effect suggests the inability of the models to account for sudden changes of the output variable at the right time. The use of an adequate input variable, such as WSP, would announce the change and correct the error. Therefore, the best results are obtained when WSP_t and SWH_{t-1} are used as inputs, as in experiment 2. In that case, NNM_2 produces slightly better results than RM_2, as can be seen from the numerical evaluation of the models.

Since the models performed equally in case of single input, and NNM performed better when two variables were used, neural network can be concluded to have certain advantages over regression in modelling complex processes where more input variables are expected to influence the output variable. Another advantage of a neural network is the simplicity of model formulation, which facilitates experimentation. As already noted, regression analysis requires the development of the optimum mathematical form, which is both time consuming and prone to errors. However, when neural network is used as a modelling

tool, the network learns the optimum function by itself, without any assistance from the model designer.

The work presented in this paper is the first step in the modelling and prediction of the state of the Adriatic Sea based on available data. Further research should include modelling of other sea state variables for different points in the Adriatic Sea and prediction ability investigation, as well as prediction horizon determination. The model to be obtained by further research should provide reliable information for ship response modelling purposes, with the final goal of route optimization in heavy seas. That model should help build an efficient, simple, real-time decision making tool that could be used for navigation in bad weather in the Adriatic Sea, based on easily measurable data, i.e. wind speed and direction.

ACKNOWLEDGMENTS

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Two-Stroke Low Speed Diesel Engine Simulation Model for NOx Analysis

Branko Lalić[a], Nikola Račić[a], Gojmir Radica[b]

All commercial marine engines have to comply with IMO regulations on emissions, especially of nitrogen oxides. This paper describes the gases produced in the combustion process in the diesel engine, and the manner of pollutant creation. Several models of slow-speed diesel engines have been developed and analysed. The characteristics of the simulation model are compared with the characteristics obtained on the testbed, and their differences considered. Using the term for the formation of NOx, as well as independently developed programs in MATLAB, the rate of nitrogen oxide formation was obtained as a function of excess air, pressure and temperature. The reduction of excess air increases adiabatic flame temperature and has an effect on NOx emissions. The obtained results are compared with the actual values measured on the testbed.

KEY WORDS
~ Marine two-stroke diesel engine
~ NOx emission
~ Internal combustion engine modelling

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1. INTRODUCTION

Exhaust gases from marine diesel engines are the primary source of emissions from ships and significantly contribute to environmental pollution due to the characteristics of the combustion process, typical for large marine two-stroke low speed engines and the use of heavy fuels. Ocean-going ships are the major contributors to global emissions of several hazardous air pollutants, such as nitrogen oxides (NOx), sulphur oxide (SOx), fine particulate matter (PM), hydrocarbons (HCs), carbon monoxide (CO) and greenhouse gas carbon dioxide (CO_2). These pollutants do not only have local, but global impact as well. While impact on local (or regional) air quality is mostly due to pollutants such as PM, NOx and sulphur, CO_2 has impact on global climate. The quantity of gases emitted from marine engines into the atmosphere is directly related to the total fuel oil consumption. Regulations governing air pollution from merchant shipping are developed at the global level. Since shipping is inherently international in character, having uniform regulations on issues such as air emissions from ships is vital. The shipping industry is principally regulated by the International Maritime Organization (IMO), an UN agency based in London, responsible for the safety of life at sea and the protection of the marine environment. IMO ship pollution rules are contained in the "International Convention on the Prevention of Pollution from Ships", i.e. MARPOL 73/78, **Annex VI** - the first set of regulations on marine exhaust emissions. This paper analyses the effect of modification of an engine's characteristics on nitrogen oxide emissions (Komar and Lalić, 2015). Scappin (Scappin et al., 2012) attempts to develop a correlation to predict thermal NOx formation in compression ignition (CI) engine fuelled with diesel and biodiesel. Attention was paid to both fuel properties and engine design factors. NOx emissions predicted by the correlation were found to be comparable to the actually measured emissions.

Saravanan (Saravanan et al., 2012) does something similar by developing a method for energy system analysis for low speed diesel marine engines to predict their performance and NOx emissions. The extended Zeldovich mechanism was used to predict the NOx emissions. An electronically controlled engine simulated to validate the model was found to be capable of predicting NOx emissions and specific fuel oil consumption with 95 % confidence intervals. However, Larsenb et al. (Larsenb et al., 2015) study looked into two-stroke diesel machinery for ships, with five varying configurations to explore the trade-off between increased NOx emissions and reduction in fuel consumption. By implementing a waste heat recovery system using an organic Rankine cycle and a hybrid turbocharger, fuel consumption decreased by up to 9 % and NOx up to 6.5 %. On the other hand, Andreadis (Andreadis et al., 2009) uses a large two-stroke marine diesel engine operating at full load to explore the pilot injection strategies using simulations of computational fluid dynamics along with an Evolutionary Algorithm. The solutions obtained were analysed and identified based on Pareto dominance. NOx emissions centred on early and late pilot injection improved. Guan (Guan et al., 2015) used a modular zero-dimensional engine model built in MatLab and Simulink environment to study the operation of large two-stoke marine diesel engines. Engine shop trial values were compared to the derived performance parameters of the engine, simulated under steady conditions, followed by the discussion of the operating strategies of the engine and their influence on CO_2 emissions and fuel savings. The purpose of the Varbantes (Varbantes et. al., 2012) research is to highlight the methods improving diesel engine efficiency. The purpose of control is the even distribution of load between the cylinders, providing the fuel equipment and main diesel systems are operating as usual. The power plant capacity, fuel efficiency and compliance with MARPOL environmental restrictions depend on it. In their previous studies, the authors (Radica, Račić) explored the possibility of increasing the efficiency of a low speed two-stroke turbocharged main diesel engine operating with waste heat recovery by combined heat and power production (Grljušić et al., 2014; Grljušić et al., 2015). Paper (Spahni et al., 2015) deals with a different concept realisation of Generation X-engines, namely (X-tra efficiency, X-tra manufacturing-friendly, X-tra reliability, X-tra environmentally-friendly). The differences between engines W-X35, W-X40, W-X52, W-X62 W-X72, W-X82 and W-X92 are due to differences in engine size, shipyard requirements or the availability of technical concepts.

2. RESULTS AND DISCUSSION

2.1. The Formation of Thermal Nitrogen Oxides

Although nitrogen monoxide NO and NO_2 constitute the majority of nitrogen oxides NOx, nitrogen monoxide formed in combustion processes predominates. NO and NO_2 create nitric oxide N_2O, nitrogen trioxide N_2O_3 and N_2O_5 nitrogen peroxide which is present in much smaller quantities. Although the oxidation of molecular nitrogen is the basis for the formation of NO, if fuel contains a substantial amount of nitrogen, the oxidation of the nitrogen components of the fuel functions as an additional source of NO. Diesel fuels contain higher percentage of nitrogen than petrol. Since NO is the primary product (over 90 %) of combustion in diesel engines, its formation merits further clarification. The formation of thermal nitric oxide was described in (Heywood, 1988; McAllistar et al., 2011; Lalić et al., 2014; Lalić et al., 2016). The reactions required for the formation of NO from atmospheric nitrogen have been studied extensively. The following reactions show an almost stoichiometric combustion mixture of fuel and air to create NO from molecular nitrogen:

$$\begin{aligned} N_2 + O &\leftrightarrow NO + N \\ N + O_2 &\leftrightarrow NO + O \\ N + OH &\leftrightarrow NO + H \end{aligned} \tag{1}$$

This is often called the extended Zeldovich mechanism. Zeldovich was the first to recognize the importance of the first two reactions, while Lavoie added the third reaction which is of minor importance. The emergence of nitrogen oxides can be presented as shown in the following equation (McAllistar et al., 2011):

$$\frac{d_{xNO}}{dt} \cong 1.476 \cdot 10^{21} \cdot x_{N_2} \cdot x_{O_2}^{0.5} \cdot e^{\left(\frac{-67520}{T}\right)} \cdot \left(\frac{P}{R \cdot T}\right)^{0.5} \; ppms^{-1} \tag{2}$$

Where T is absolute temperature; x_{N_2} is mole fraction of nitrogen; x_{O_2} is mole fraction of oxygen; P is maximum pressure for the given temperature; R is universal gas constant (8314 $Jkmol^{-1}K^{-1}$). The greatest influences on the formation of thermal nitrogen oxide (NO) are local temperature in the combustion chamber (T_i), pressure (influenced by the concentration of ingredients), local air surplus (λ_i), retention time (τ_i) observed particles of composition in an area with conditions (T_i) and (λ_i). Figure 1 illustrates the dependence of nitric oxide (NO) formation speed on combustion temperature for a wide range of ratios of equality, and very small quantities of nitric monoxide (NO) are shown to be formed when combustion temperature is below 1800 K.

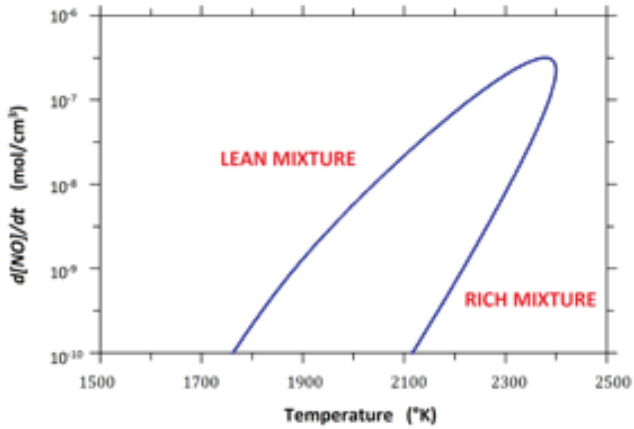

Figure 1.
Formation of nitric oxide (NO) in the function of mixture concentration and combustion temperature (McAllistar et al., 2011).

As shown in Figure 1, nitric oxide levels can be decreased by reducing the rate of reaction velocity, which lowers combustion temperature, and consequently, reduces oxygen *O* and nitrogen *N* levels. As for conditions of combustion in the engine, τ_{NO} is compared to the time it takes to change the conditions in the engine (equal or more), which means that the process is a kinetically controlled formation of NO.

$$\tau_{NO} = \frac{8 \cdot 10^{-16} \cdot T \cdot e^{\left(\frac{58300}{T}\right)}}{P^{\frac{1}{2}}} \; s \qquad (3)$$

Where τ_{NO} is time of NO formation expressed in seconds.

2.2. Low Speed Diesel Engine Model

This type of slow speed marine diesel engine is an open system with input and output streams. In order to simplify the simulation, the engine was treated as a closed system in which the state of equilibrium was assumed to change in control volumes (quasi stationary model), while unsteady gas dynamic effects were neglected. A set of mathematical equations represents the mathematical model of attributes of physical processes, including parameters obtained by measuring or estimating the physical model. The cylinder pressure, temperature and gas composition are assumed to be equal in all cylinder chambers. Weight losses due to leaks are taken into consideration in the high-pressure part of the process, while kinetic energy is ignored.

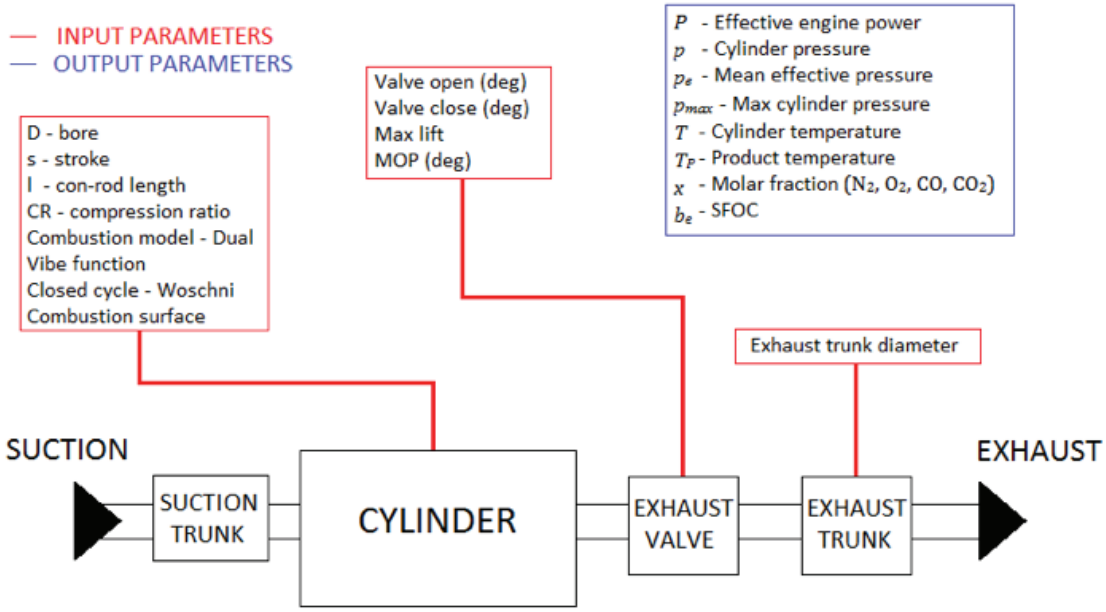

Figure 2.
Simplified working matter flows and influential model output parameters in low speed diesel engine.

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The heat in the cylinder is transferred by convection and later by radiation during combustion. Heat transfer coefficients are not the same throughout the cylinder, i.e. the temperature field is unsteady and inhomogeneous. Heat transferred to the cylinder walls is calculated for each crankshaft angle. Heat loss is described with Woschni's model, and the parameters of the law of combustion are determined by analytical form in the function of combustion according to Vibe (Radica, 2008).

2.2. Calculation of Nitrogen Oxide Emissions

Since the software package used was unable to simulate nitric oxide NO emissions, the estimated NO emissions needed to be calculated according to equation (2) (Benson, 1982). As M. Stoffels wrote in (Stoffels, 1999), the critical period of NO formation in diesel engines is marked by the moment of maximum combustion temperatures. The NO formation rate increases with the duration of combustion and growing pressure. Once maximum pressure is reached, the temperature of combusted gases decreases due to volume expansion and they begin to mix with cooler gases within the cylinder, resulting in decreasing NO emissions. The calculation of NO formation rate requires the establishment of the maximum temperature of combustion products. As stated in (Benson, 1982), the temperature of products will reach its maximum when there are no heat losses to the environment and when all the energy released in the combustion process is used to heat combustion products. This temperature is called the adiabatic flame temperature (T_{AFT}) and an analysis of combustion at constant pressure is used for its calculation. Adiabatic flame temperature for poor mixture (for equivalence ratio $\Phi \leq 1$) is (Benson, 1982):

$$T_{AFT} = T_R + \frac{\Phi \cdot f_s \cdot LHV}{(1 + \Phi \cdot f_s) \cdot \bar{c}_{p,P}} \tag{4}$$

Where T_R is absolute temperature of the reactants, Φ is equivalence ratio, f_s is stoichiometric fuel/air ratio, LHV is fuel lower heat value, and $\bar{c}_{p,P}$ is mean specific heat capacity of products. Compression temperature at the moment of fuel injection, used as the temperature of the reactants T_R, is easily determined from the temperature diagram in Figure 3.

Mean specific heat capacity of products $\bar{c}_{p,P}$ is taken as the average temperature of reactants and products, which is:

$$\bar{T} = \frac{T_P + T_R}{2} \tag{5}$$

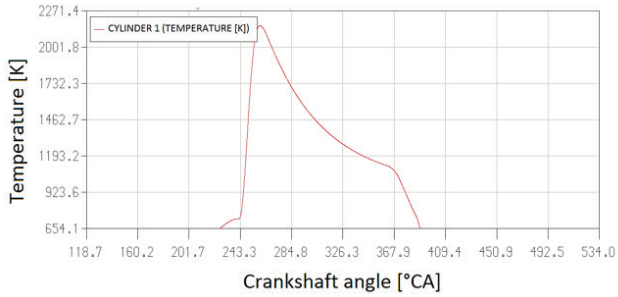


Figure 3.
Temperature in crankshaft angle function (MAN B&W 6S50).

The temperature of the reactants may safely be assumed to be equal to exhaust temperature, since its change would not significantly affect the specific heat capacity. Assume that the temperature of products T_P is 623 K, or 350° C. The average temperature of exhaust gas reactants and products ($\bar{T}$ = 675 K) can now be determined. The specific heat capacities of exhaust gas products for poor mixture are indicated in thermodynamics tables, i.e. Table 1.

Table 1.
Specific heat capacity of exhaust gas products.

Product	**Specific heat capacity** $kJkg^{-1}K^{-1}$
Water H_2O	2.13
Carbon dioxide	1.15
Oxygen O_2	1.05
Nytrogen N_2	1.12

The mean value of the specific heat capacity of products $\bar{c}_{p,P}$, can be calculated by entering the heat capacities of combustion products indicated in the table into the following expression (Guan et al., 2015):

$$\bar{c}_{p,P} = \frac{1}{N} \sum_{i=1}^{N} \bar{c}_{p,iP} = \frac{c_{p,H_2O} + c_{p,CO_2} + c_{p,O_2} + c_{p,N_2}}{4} \; kJkg^{-1}K^{-1} \tag{6}$$

Adiabatic flame temperature (T_{AFT}) largely depends on the relative air/fuel ratio and compression ratio, elaborated

in further text. The establishment of connection between adiabatic flame temperature and relative air/fuel ratio requires taking several relative air/fuel ratios into account. The ratios are obtained by calculating corresponding temperatures using the Matlab software package. Table 2 contains values required for the calculation of the adiabatic flame temperature. When these values are entered into Matlab, the values of the adiabatic flame temperature may be obtained depending on the relative air/fuel ratio. The dependence of adiabatic flame temperature T_{AFT} range on the relative air/fuel ratio is shown in Figure 4. The diagram in Figure 4 suggests that as the increase in air surplus reduces the T_{AFT}, calculated by expression (6), there is simultaneously a clear increase in real fuel/air ratio (Z), and a reduction in relative air/fuel ratio, i.e. an increase in fuel mass (mg) within the cylinder reduces the relative air/fuel ratio. The increase in fuel mass in the cylinder is accompanied by an increase in temperature, and therefore an increase in energy. The increase in temperature is justified due to reduced air surplus.

Table 2.
Values required for TAFT calculation (MAN B&W 6S50MC).

Parameter	Value
Temperature of reactants T_R	727 K
Relative fuel/air ratio λ	1.7 – 2.3
Stehiometric fuel/air ratio f_s	0.069
Fuel lower heat value LHV	42.7 $MJkg^{-1}$
Mean specific heat capacity of products $\bar{c}_{p,P}$	1.363 $kJkg^{-1}K^{-1}$

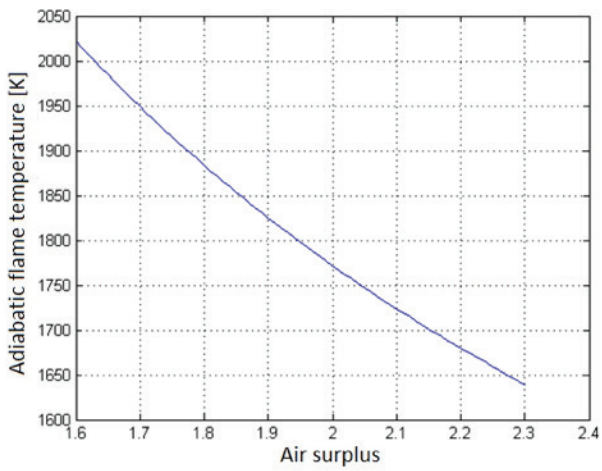
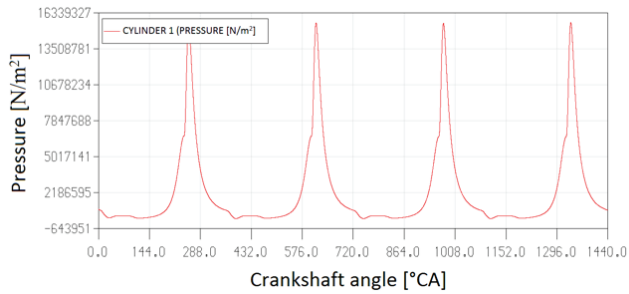


Figure 4.
Dependence of adiabatic flame temperature on air surplus (MAN B&W 6S50).

Figure 3, obtained from the software package, can now be related to the resulting adiabatic flame temperature range and indicates a range of crankshaft degrees (on the abscissa) required for the pressure values, mole fraction of oxygen O_2 and nitrogen N_2. Their values are shown in the diagrams in Figure 5. Matlab was used to calculate the values and tabulate the diagrams shown. Using the expression (2) for the rate of production of NO and expression (3) for NO formation time, NO emission can be obtained. The rate of NO production is given in ppm/s, and formation time in seconds, i.e. the product of these two expressions is the value of NO emissions at a given time:

$$x_{NO} = \frac{dx_{NO}}{dt} \cdot \tau_{NO} \quad ppm \tag{7}$$



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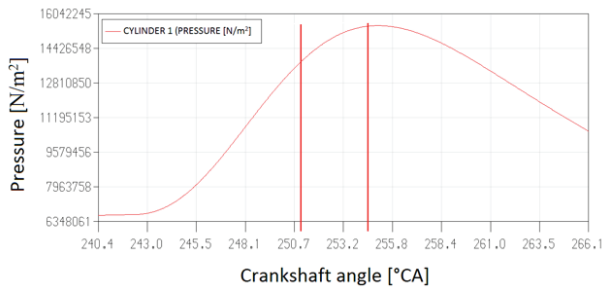

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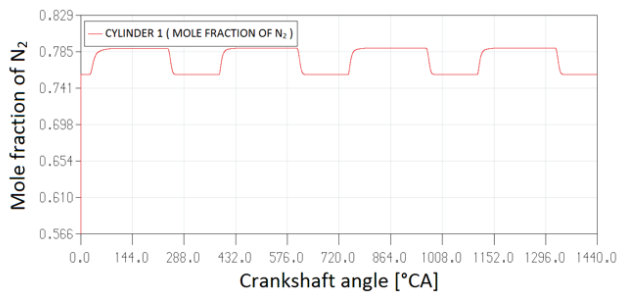

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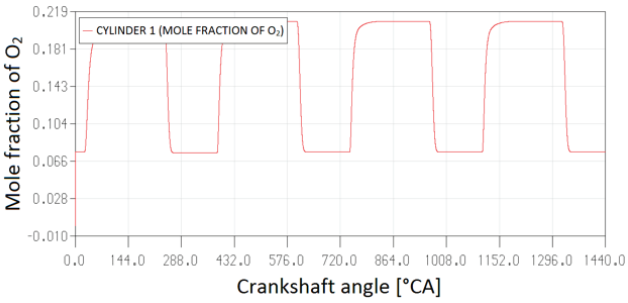

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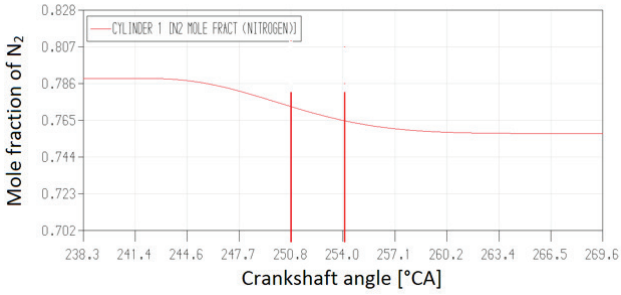

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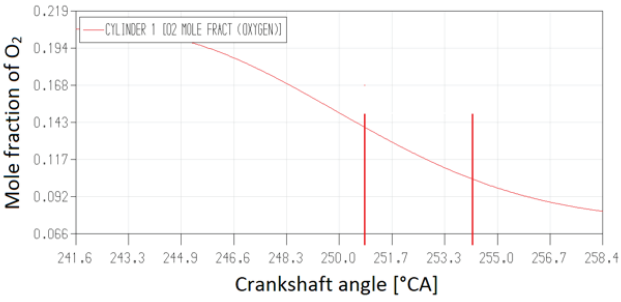


f)

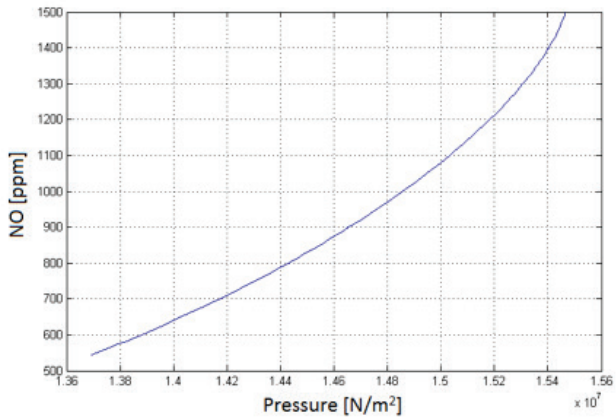
Figure 5.
Dependence of parameters on the crankshaft angle: a) cylinder pressure; b) cylinder pressure for T_{AFT} (within vertical lines); c) mole fraction of N_2; d) mole fraction of O_2; e) Value of nitroen in the cylinder for T_{AFT} range (within vertical lines); f) Value of oxygen in the cylinder for T_{AFT} range (within vertical lines).

When tabulated values of the model are entered in the expression (7), NO emission can be obtained, and shown as a function of temperature and pressure, Figure 6 a and b. The analysis will be conducted for two engines having the same characteristics, but different compression ratios and RPMs (crankshaft revolutions per minute). Since both engines are produced by the same manufacturer and are of the same type - MAN 6S50 MC - to prevent confusion they will be marked as:

Engine 1:
- Real compression ratio 13.21,
- RPM 121 min^{-1}.

Engine 2:
- Real compression ratio 13.54,
- RPM 110 min^{-1}.

So far, the analysed data pertains to Engine 1.



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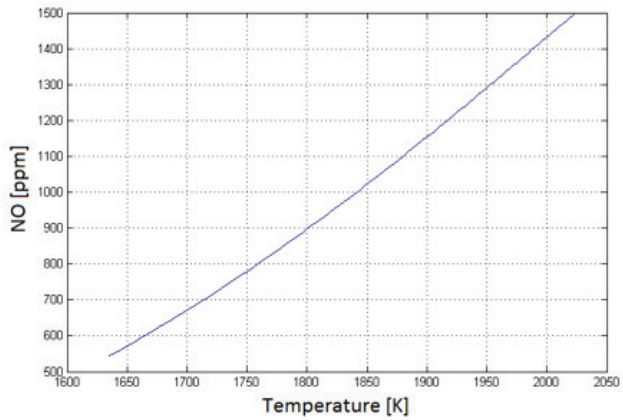
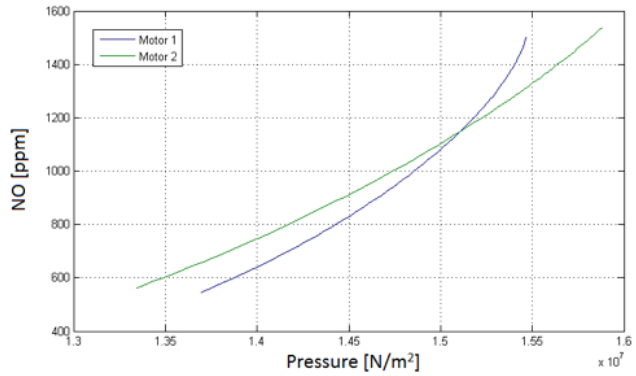


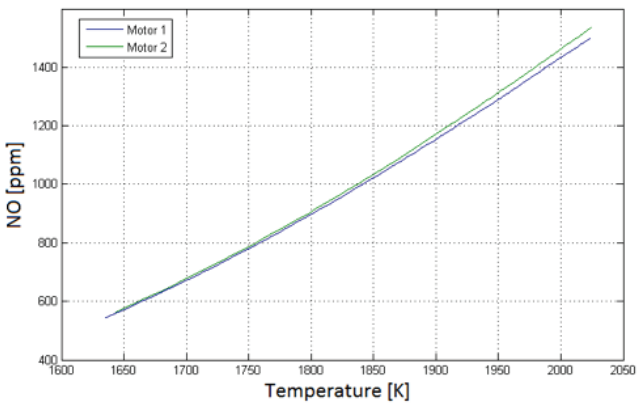
b)

Figure 6.
Nitrogen Oxide emission: a) as a function of pressure; b) as a function of temperature.

Comparison between Engine 1 and Engine 2 is illustrated in Figure 7. Values for Engine 2 are obtained as shown in the calculation procedure for Engine 1.



a)



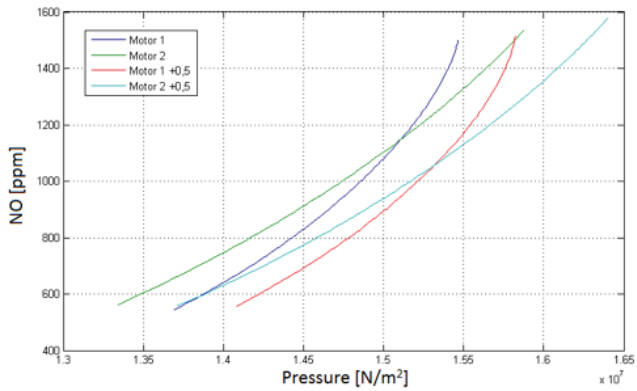
b)

Figure 7.
Nitrogen Oxide emissions: a) based on the pressures of engines no.1 & 2; b) based on the temperatures of engines no.1 & 2.

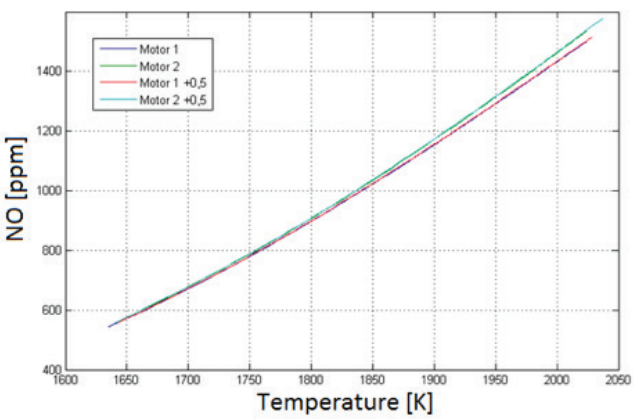
Evidence of traceability data has increased compression ratio for each engine by 0.5, which means:

- Engine 1: actual compression ratio 13.71, and
- Engine 2: actual compression ratio 14.04.

In Figure 8 all diagrams of engines with both initial and altered compression ratios are compared. Diagrams (b) and (c) illustrate the effect of compression ratio on NO emission volume. Compression temperature increases linearly with compression ratio increments, identified earlier in this paper as the temperature of the reactants T_R. Expression (6) suggests that the increment of reactant temperature also increases adiabatic flame temperature T_{AFT}. An increase in compression temperature is known to affect NO emission concentration. The preceding diagram shows that engines with different compression ratios have different NO emissions. Since NO emissions were higher in engines with higher compression ratios, cylinder pressure, which increases with the compression ratio, can be concluded to play an important role. Diagram (b) illustrates that higher temperatures cause greater deviation in the curve, i.e. an increase in NO concentration can be said to have occurred. This means that engines with lower compression ratios achieve their maximum pressure values, and hence their maximum NO concentration, earlier. The same conclusion can be drawn from diagram (c) in which the curves of Engine 1 and 2 are seen to intersect due to Engine 1 having a lower compression ratio and thus achieving its peaks, which are also lower, earlier (Lalić et al., 2016).



a)



b)

Figure 8.
Nitrogen Oxide emissions: a) as a function of pressure with initial and modified compression ratios; b) as a function of temperature with initial and modified compression ratios.

To further clarify the impact of pressure on NO emission formation, Figure 9 (a) depicts NO emissions as a function of pressure for a wider range of temperatures inside the cylinder,

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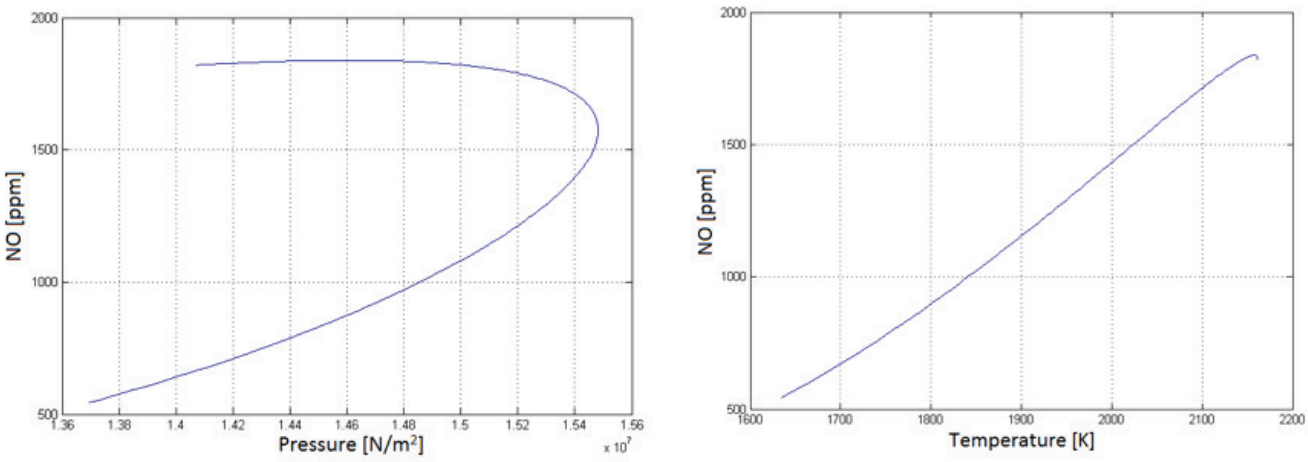
i.e. for a wider range of pressures. The diagram suggests that high emission depends on pressure, where the pressure drop is still at a slight increase due to the temperatures still being high. Emission curves can be seen to start to decline with sharper pressure drop, since after achieving maximum pressures, temperatures begin to fall, reducing emissions.



a) b)

Figure 9.
Nitrogen Oxide emissions: a) as a function of pressures; b) as a function of temperature.

The diagram in Figure 9 (b) likewise illustrates emissions for a wider range of temperatures inside the cylinder. At the very end of the emission curve where maximum temperature is reached, the beginning of emission decline can be observed. Huge impact of pressure are evident. Although temperatures in the cylinder are still high, nitrogen oxide emissions are lower due to low pressure and decreasing temperature (McAllistar et al., 2011).

3. EXPERIMENTAL SECTION

This section presents emission values obtained by test bed measurements of the MAM B&W 6S60MC engine, provided in Table 3.

Figure 10 shows the point on the simulation curve for the value obtained from the engine test bed at 100 % MCR.

Table 3.
Exhaust emission data obtained by testbed measurements.

Time	Power % kW	Speed % rpm	NOx ppm	CO Ppm	CO_2 %	O_2 %	HC ppm
10:27	25 / 2064	63 / 76.5	982	30	3.92	15.3	54
10:56	50 / 4720	79 / 96.2	1026	28	3.87	15.3	51
11:23	75 / 6580	91 / 109.8	1059	40	4.07	15.09	57
13:20	100 /8631	100 / 121	883	51	4.25	14.85	66

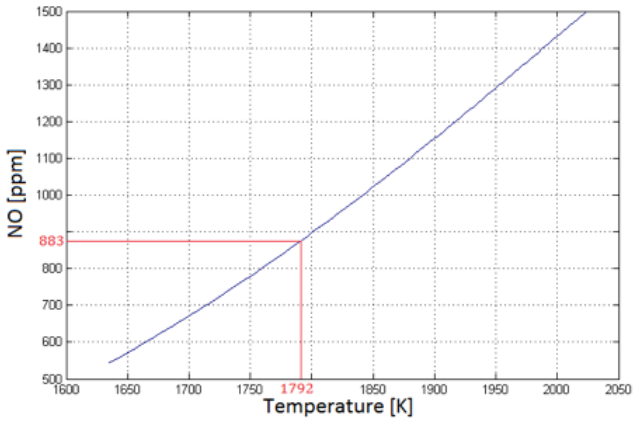


Figure 10.
Measured value in the NO emission diagram obtained by simulation model.

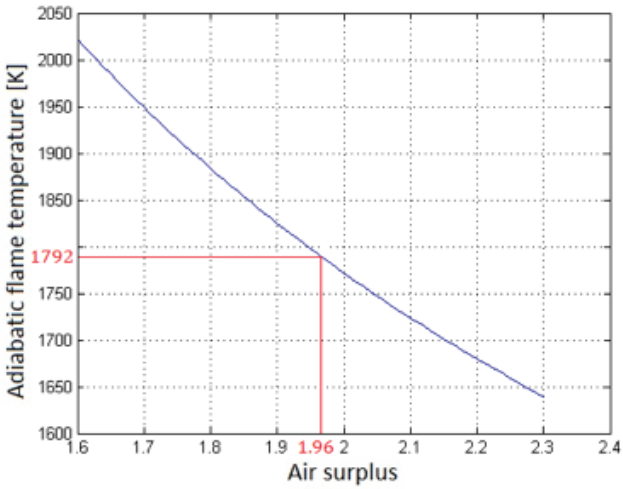


Figure 11.
Excess air for temperature indicated in measured values.

4. CONCLUSIONS

The need to preserve the environment is a major problem in the construction and production of slow speed diesel engines. Organizations such as the "IMO" and "EPA" set emission standards manufacturers are required to comply with. They must meet emission requirements while maintaining the same standard of performance. In this paper NOx emission was taken as the key parameter. Engine models were simulated, the obtained values analysed and compared with the actual tested values. In a developed computer program, NOx emissions were obtained by using simulated values and expressions for nitric oxides formation and compared with actual values. Air surplus, pressure, adiabatic flame temperature and compression temperatures were analysed to establish their effect on nitric oxides formation. The results showed air surplus reduction to increase temperature, since increased fuel mass (m_f) increases heat. The diagrams depicting NOx emissions as a function of temperature and pressure do not only show the strong influence of temperature, but also an area in which NOx emissions decrease in spite of high temperature. This phenomenon is interpreted as a critical period in NOx formation. The rate of formation increases with the duration of combustion and an increase in pressure in the cylinder. Once maximum pressure is reached, the temperature of combusted gases decreases due to their mixing with cooler gases, resulting in the decrease of nitric oxides emissions.

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Innovative Fast Time Simulation Tools for Briefing / Debriefing in Advanced Ship Handling Simulator Training and Ship Operation

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The innovative "Simulation-Augmented Manoeuvring Design, Monitoring & Control" system (SAMMON) based on Fast Time Simulation (FTS) technology was developed at the Institute for Innovative Ship Simulation and Maritime Systems (ISSIMS) of the Maritime Simulation Centre Warnemuende MSCW. The system consists of software modules for (a) Manoeuvring Design & Planning, (b) Monitoring & Control based on Multiple Dynamic Prediction and (c) Trial & Training. It is based on complex ship dynamic models for rudder, thruster or engine manoeuvre simulation under different environmental conditions.

It is an effective tool for lecturing and demonstrating ships' motion characteristics, as well as for ship handling simulator training. It allows the trainee to immediately see the results of the actual rudder, engine or thruster commands, without having to wait for the real-time response of the vessel. The Maritime Simulation Centre of AIDA Cruises at Rostock /Germany and the CSMART Center for Simulator Maritime Training of Carnival Corporation at Almere /NL have some experience with the use of this new technology to improve simulator training in Advanced Ship Handling Training courses.

Examples of its application in briefing / debriefing and introductory lectures for simulator exercises specifically for typical cruise ships with Twin-Screw and Rudder systems will be presented in the paper and at the conference.

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KEY WORDS

~ Fast-time simulation
~ Manoeuvre planning
~ Navigation Simulator Training

1. DESCRIPTION OF THE FAST TIME SIMULATION USE CONCEPT

1.1. Need for Fast Time Simulation (FTS) and Simulation Support

Ship manoeuvring is and will remain a human-centred process in spite of anticipated further technological development. The most important elements of this process are human beings and the technical equipment supporting their efforts. However, most of the work still has to be done manually since even today almost no automation support is available either for routine or complex manoeuvres. There is as yet no electronic tool capable of demonstrating manoeuvring characteristics efficiently or designing an efficient manoeuvring plan – even in briefing procedures for ship handling training, the potential manoeuvres have to be "guessed" and drafted on paper or described by sketches and short explanations. The impact of wind or current is rather vaguely estimated based on experience.

However, new demands originating from IMO's e-navigation strategy to enhance safe, efficient and environmentally friendly navigation from berth to berth require the preparation of harbour approaches with complete berthing plans, especially by companies with high safety standards like cruise liners. These plans have to be agreed on by the bridge team, discussed and briefed with the pilot. Plan of potential manoeuvres needs to be developed – but only tentatively, by thinking ahead – by

putting it on paper or describing it with self-made sketches and short explanations. The plans are drawn up manually, either on paper charts or electronic chart interface printouts, since the tools providing support for manoeuvring planning have yet to be developed.

Ship Handling Simulation for simulator training has been proven to be highly effective. However, it is based on real time simulation, i.e. 1 second in computer calculation time represents 1 second in real world manoeuvring time. This means that in spite of all other advantages of full mission ship handling simulation, the process of collecting manoeuvring experiences remains utmost time-consuming. For instance, a training session for a berthing manoeuvre might take one hour – if the first attempt fails or an alternative strategy needs to be tried out, this second session takes an additional hour, which can hardly be considered efficient.

The Fast Time Simulation method will be used in the future to increase training effectiveness, as well as the safety and efficiency of real ship manoeuvring. Even when used on standard computers, it is capable of simulating a manoeuvre lasting about 20 min in 1 second computing time by using innovative simulation methods. Fast Time Simulation tools have been used in the research activities of the Institute for Innovative Ship Simulation and Maritime System ISSIMS at the Maritime Simulation Centre Warnemuende, which is a part of the Department of Maritime Studies of Hochschule Wismar, the University of Applied Sciences - Technology, Business & Design in Germany. They have been further developed by start-up company Innovative Ship Simulation and Maritime Systems (available at: ISSIMS GmbH Web page).

1.2. Overview of Fast Time Simulation (FTS) Software Modules

A brief overview of FTS tool modules is provided, together with their potential application:

SAMMON is the brand name of an innovative "Simulation Augmented Manoeuvring – Design, Monitoring & Control" system, consisting of four software modules for Manoeuvring Design & Planning, Monitoring & Conning with Multiple Dynamic Prediction and Simulation & Trial. The modules are as follows:

- Manoeuvring Design & Planning Module: designing ship manoeuvring concepts as a "Manoeuvring Plan" for harbour approach and berthing manoeuvres (steered by virtual handles on the screen by the mariner).
- Manoeuvring Monitoring & Conning Module with Multiple Dynamic Manoeuvring Prediction: monitoring of ship manoeuvres during simulator exercises or monitoring of real ship manoeuvres using bridge handles, simultaneous display of manoeuvring plan and predicted manoeuvres; calculation of various prediction tracks for full ship dynamic simulation and simplified route prediction, like Look Ahead for future ship motion.
- Manoeuvring Simulation Trial & Training Module: ship manoeuvring simulation on laptop to view and exercise the manoeuvring concept (providing it has the function of a monitoring tool; steered by virtual handles on the screen).

These modules are suitable for application both:

- in maritime education and training to support ship manoeuvring exercises by demonstrating and facilitating the explanation of manoeuvring technology details and, more specifically, to prepare manoeuvring training in the SHS environment, i.e. by developing manoeuvring plans in briefing sessions, supporting manoeuvring during the exercise run and assisting with replay analysis and in discussions on quick demonstration of alternative manoeuvres during debriefing sessions; and
- onboard to facilitate the manoeuvring of real ships, e.g. by compiling manoeuvring plans for challenging harbour approaches requiring complex berthing / unberthing manoeuvres, assisting steering by providing multiple predictions during the manoeuvring process and even by supporting result analysis, as well as for onboard training with the Simulation & Trial module.

SIMOPT is an FTS-based Simulation Optimiser software module for standard manoeuvre optimization and ship math model parameter modification applicable in simulator ships, FTS Simulation Training Systems and onboard SAMMON System applications.

SIMDAT is a software module for analysing simulation results obtained both from SHS or SIMOPT simulations and real ship trials: data on manoeuvring characteristics can be automatically retrieved and comfortable graphic tools are available for displaying, comparing and assessing the results.

The use of SIMOPT and SIMDAT modules for simulator ship model parameter tuning was described in earlier papers (Benedict at al., 2003; Schaub at al., 2015) as was the application of Multiple Dynamic Prediction & Control modules (Benedict at al., 2006) in onboard use as a steering assistance tool. This paper focuses on the potential of the SAMMON software to support the lecturing and briefing / debriefing process with elements specifically designed for simulator training in the framework of Advanced Ship Handling in Maritime Simulation & Training Centre MSTC of the AIDA Cruises Company at Rostock / Germany.

2. USE OF FTS FOR LECTURING AND FAMILIARISATION

2.1. Stopping – Using Speed Vector as Stopping Distance Indicator

One of the elements of simulator training courses is familiarisation with a ship's manoeuvring characteristics and

their practical application – Fast Time Simulation is a smart tool shortening and raising the successfulness of this process. The following example deals with a ship's stopping capability. Cruise ship "AIDAblu" was used in examples in this paper; her dimensions are: length Lpp= 244.6 m, beam B=32.2 m draft T= 7.00 m. She has two pitch propellers and two rudders, two thrusters at the bow and two at the stern.

To get an overview of the ship's stopping distances when navigating at several different speeds and with varying astern power, test trials could be conducted either with the Design & Planning tool (Figure 1) or with the SIMOPT and SIMDAT program (Figure 2).

The Planning tool (Figure 1) allows the ship to be placed in the ENC window, in an initial MP 0 position, where the initial speed can be adjusted using the handles in the right window. The ships can then be moved using the slider at the bottom of the ENC window, e.g. into a position after 1 min, where MP 1 is set.

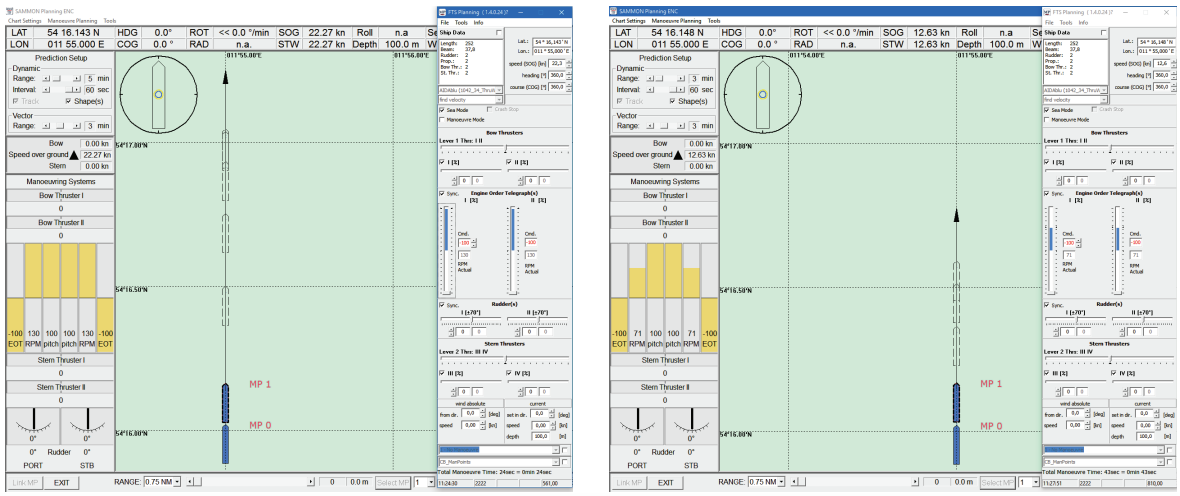

Figure 1.
Display of the Manoeuvring Design & Planning Module: Two stopping manoeuvres for AIDAblu at different speeds to full astern (EOT=-100 %):
• Left: crash stop from full ahead (EOT=+100 % for 22, 2 kn) at MP1
• Right: stopping manoeuvre from half ahead (EOT=+53 % for 12.6kn) at MP1.

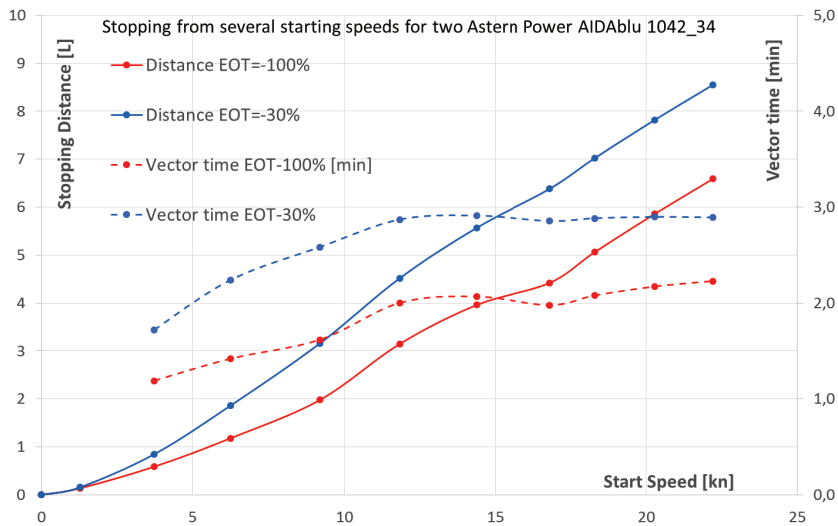

Figure 2.
Results of SIMOPT program for series of stopping manoeuvres for cruise ship AIDAblu (Computing time 17 seconds): Stopping diagram for distances (solid lines) and respective speed vector length times (dotted lines) (SIMDAT).

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Then handles are used to reverse the engine to EOT= -100 % and one can immediately see the ship's maximum stopping distance and stopping position in the ENC window.

In case of application of this stopping behaviour during voyage or in ports, visualising stopping distances in the ECDIS or RADAR could be helpful. The SAMMON Monitoring tool allows for high-level prediction of a ship's trail in case of change of the EOT or any other handle position after only 1 second (see Figure 15). Until this sophisticated dynamic prediction tool becomes available on the bridge, the speed vector can be used as an alternative.

The basic idea is to adjust the speed vectors' length to stopping distance: the required speed vector length can be easily calculated from the well-known formula speed = distance /time, i.e. time = distance / speed.

This equation helps us calculate Vector time:

tvector=Stopping distance / Starting speed,

e.g. Crash Stop Stopping Distance of 1600m, given the starting speed of 22 kn (12 m/s):

tvector= 1600 m / 12 m/s =138 s = 2.18 min.

If these calculations are performed for all stopping distances of the solid lines in Figure 2, we get the dotted graphs. The result is that vector time is 2.5 minutes (blue dotted line) for all crash stop manoeuvres (blue line) at Full Astern; this is illustrated in Figure 1 where the ship comes to a stop prior to the expiry of the 3 min speed vector. Therefore, the conclusion might be that setting the speed vector to tvector = 3 min would give us an extra safety distance – it would even allow stopping the ship with the astern power of a mere EOT= -30 %!

2.2. Effect of Rudders and Thrusters on Swept Path and Pivot Point

In many situations occurring in narrow fairways and limited space, the manoeuvring space and the swept path are of utmost importance. Figure 3 illustrates that the swept path in turning manoeuvres is much bigger in rudder than thruster manoeuvres.

If turning is achieved by means of a rudder, it produces a lift force similar to that of a wing of an airplane but in the horizontal plane: the force is pointing outward to port side. Then a drift angle ß sets in and the ship's hull starts to act like a "wing" with lift force to starboard at the fore part of the ship; this force generates the so called "unstable moment" trying to increase the drift angle. Therefore, when turning motion r develops, it causes centrifugal forces to act on the centre of gravity of ships and hydrodynamic masses. A damping force sets in due to rotation, acting like a "curved profile" and producing a moment in the opposite direction to balance the unstable moment in the circular motion. It has the same effect as "counter rudder", since it counteracts both the initial rudder moment and the unstable moment until an equilibrium is established in a steady state of circular turning.

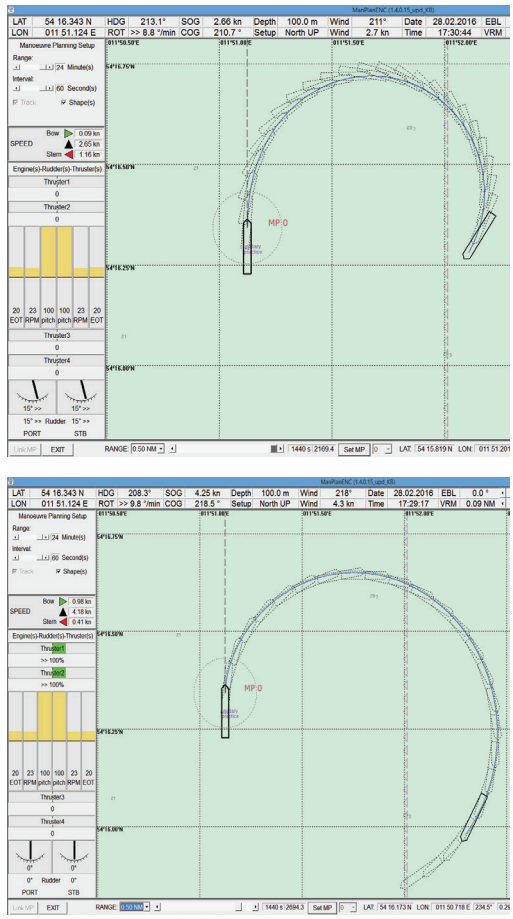

Figure 3.
Comparison of a ship's path when turning with rudders or thrusters, using SAMMON Design & Planning tool in forward motion at EOT=+20 % ahead:
- Top: turning with rudder STB 15°, thruster 0 %
- Below: turning with bow-thruster 100 % STB, rudder 0°.

The development of the Turning Circle Manoeuvre ends with a steady state, i.e. an equilibrium in balancing the transverse forces and moments.

If the ship starts turning with a bow thruster, there is no drift angle – it is not required (or even becomes negative if the thruster is too powerful!) to push the ship "inward" from its initial course because thruster force is already pushing it inward.

The drift angle and turning rate have an impact on the position of the pivot point (PP); the PP is located at the point in which crossflow speed (or the ship's transverse motion) is zero.

Where is PP and what affects its position? Figure 4 gives several examples of turning manoeuvres in ahead and astern motion and with rudder or thrusters. The following conclusions can be drawn:

- PP position is flexible and directly dependant on the ship's motion, i.e. the ratio between drift and turning. E.g. at the beginning of the turn it is located mid ship and starts moving forward as the drift sets in; it remains in the fore part, on average at 1/3 ship length behind the bow for rudder manoeuvres, i.e. aft for bow thruster manoeuvres.
- In case of wind, there might be wind drift in addition to the drift caused by rudder effect during turning, e.g. when turning in windy conditions: at the beginning of the turn, the pivot point is far ahead.
- The PP is not a suitable reference point for the discussion of acting forces due to its changing position – centre of gravity is preferable for understanding dynamic effects!

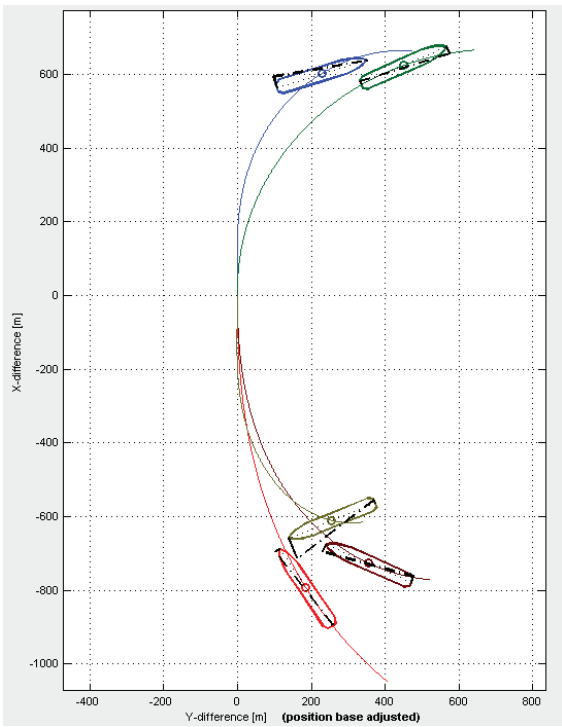

Figure 4.
Comparison of a ship's path and the location of the pivot point when the ship is turned with rudders or thrusters with SIMOPT & SIMDAT:
a) Forward motion engine ahead EOT=+20 %
  - Blue: rudder 20° STB, no thruster
  - Green: bow thruster 100 % STB

b) Astern motion engine astern EOT=-20 %
  - Red: rudder 20° STB
  - Brown: stern thruster 100 % STB
  - Grey: bow thruster -100 % PT.

- In case of small drift angles, since PP is at mid ship, only minimum manoeuvring space is required, i.e. minimum swept path.

More effects on ship manoeuvring characteristics studied by SAMMON, available in (Benedict at al., 2016) for wind & current and in (Benedict, 2016) for pivot point location and control.

2.3. Effect of Split Engines and Rudders for Twin Screw – Twin Rudder Ships

Many cruise ships and ferries have twin screw – twin rudder systems. Although these systems are normally continuously operated in synchronous mode during long voyage segments, when manoeuvring in ports, splitting the engines and propellers to allow their separate control might prove advantageous.

As seen in Figure 5, split engine manoeuvres can reduce the stopping distance:

Given the same speed with split engines, stopping distance at full astern is shorter, because one engine is already running astern, avoiding the reversing period altogether.

The split mode also has some advantages with respect to steering capability, since the rudder inflow from the ahead engine allows higher rudder forces to be used to stay on course (e.g. under strong wind) than when synchronised engines are used. In addition, turning can be improved as seen in Figure 6, leading us to the following conclusions: when split engines are used, the turning circle is smaller on the side where the prop is reversed, the ship reacts faster and has a smaller circular motion radius. Turning is likewise improved due to faster speed loss with split engines to that side, increasing the ratio of rudder forces to hull forces. However, if the ship is turning to the opposite side, the turning capability is reduced: this is why the ship needs the rudder angle of PT -4.4° to balance the ship already moving along a straight track – i.e. the effective rudder change is nearly 40° when turning STB, but only 30° when turning PT.

3. USE OF FAST TIME SIMULATION FOR SIMULATOR BRIEFING

3.1. Task Description – Introduction, Conventional Briefing and NEW CONCEPT

During the exercise briefing, a navigation officer gets information about the harbour area, the starting situation and the environmental conditions in the area, on a conventional sea chart illustrated in Figure 7. The objective is to bring the ship through the fairway channel of Rostock Port from the north, turn and head back through the channel to berth the ship port side at the passenger pier.

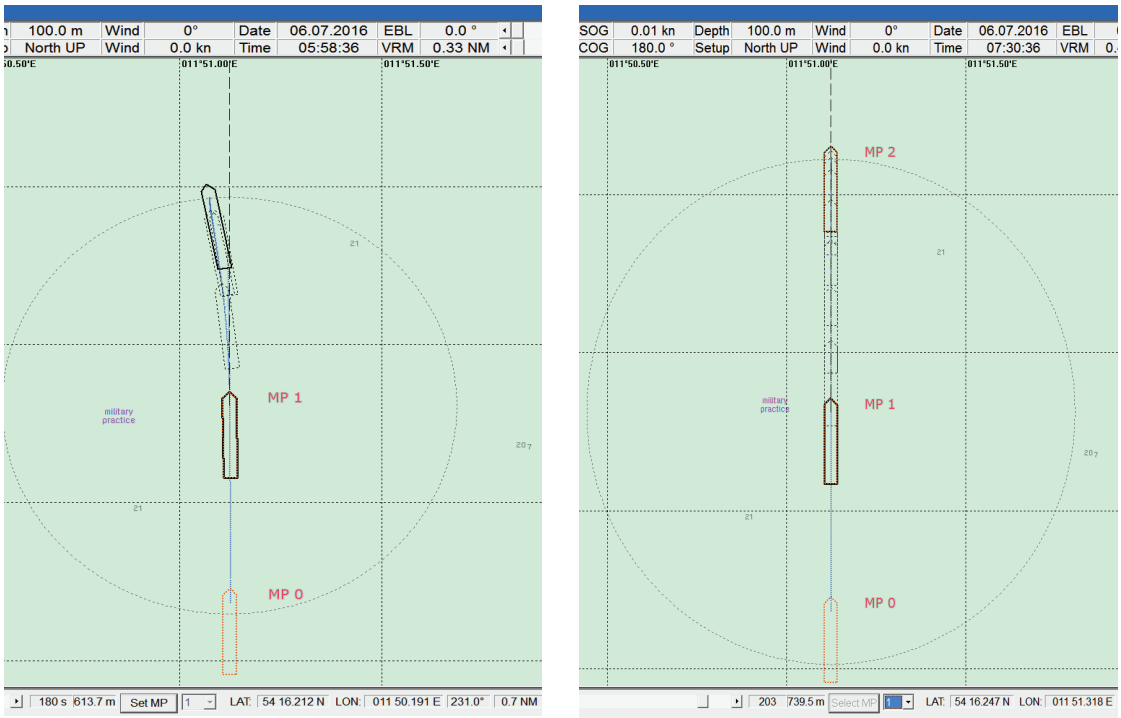

Figure 5.
Comparison of two different final situations after full astern to EOT =-100 %, with the same initial speed of 11.4 kn but different EOT settings:
- Left: from split engines STB +70 % & PT -20 %; Result: stopping distance = 0.33 nm
- Right: from sync engines, STB = PT =+48 %; Result: stopping distance = 0.40 nm.

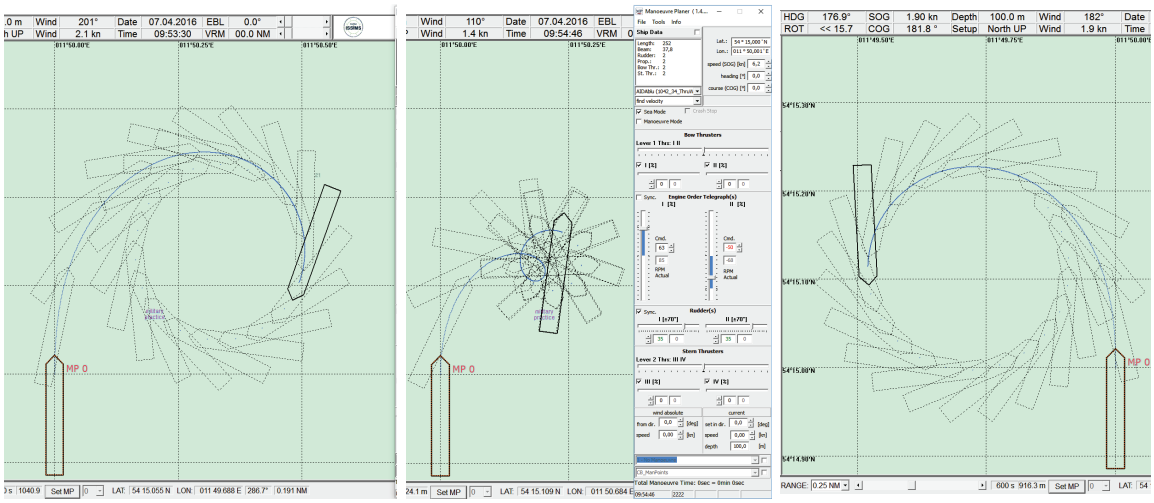

Figure 6.
Comparison of two turning manoeuvres beginning at the same initial speed of 6.2 kn, with constant speed rate on a straight track, to demonstrate the difference between sync and split engines:
- Left: standard turning manoeuvre with full rudders 35° STB, standard sync engines from EOT 30 % both STB and PT
- Centre: turning manoeuvre with full rudders 35° STB, split engines PT engine +63 % ahead, STB engine -50 % astern
- Right: turning manoeuvre with full rudders 35° PT, split engines PT engine +63 % ahead, STB engine -50 % astern.

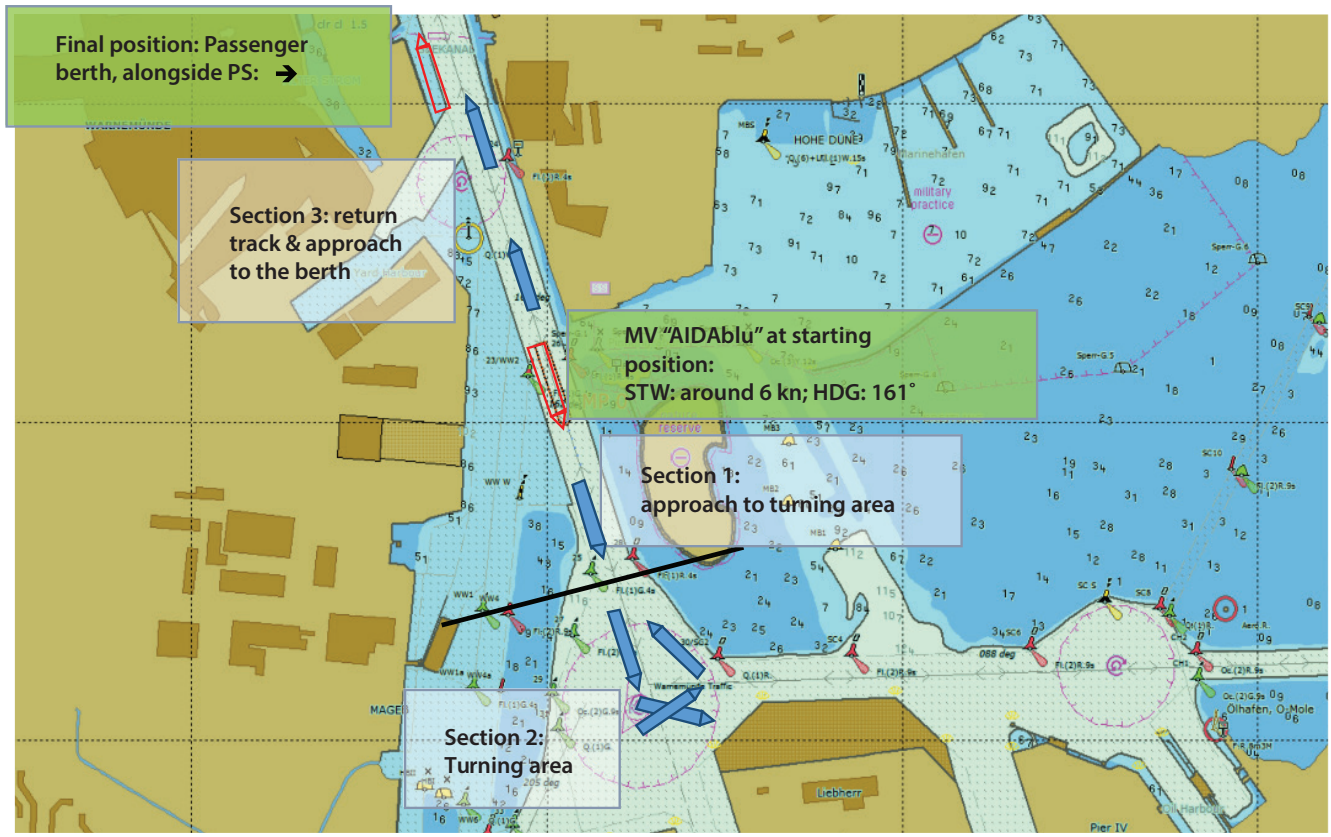

Figure 7.
Exercise area and environmental conditions in the Port of Rostock in a berthing scenario, divided into two manoeuvre planning sections and completed by guessing the desired positions of the ship (as contour).

The respective harbour area is divided into manoeuvring sections, with a specific goal:

1. Section 1: the ship's speed should be reduced until she is ready to be turned, SOG should be around 3 kn to be prepared for section 2.
2. Section 2: the ship should be turned and its course adjusted to re-enter the fairway in the course opposite to the final berth.
3. Section 3: the ship should be stopped and berthed.

In conventional briefing, only these rough indications of manoeuvring status can be used to develop a potential ship berthing strategy. In conventional berthing plans ship contours are positioned in WORD or POWER POINT drawings - the specific manoeuvres and engine rudder and thruster settings cannot be discussed in detail because specific manoeuvring characteristics can hardly be used in specific situations and real time simulation is too time consuming.

Fast time simulation allows the application of new individual exercise preparation methods with self-developed manoeuvring concepts:

- the Design and Planning tool allows us to develop a more detailed manoeuvring concept, i.e. the manoeuvring plan;
- the tool allows us to optimise the concept by several planning trials;
- pre-training using the Trial and Training Tool allows us to try out the concept on a laptop, in a real-time simulation.

3.2. Briefing by Means of the „Manoeuvre Planning & Design Module"

3.2.1. Basic exercise with no wind and no current

New fast time simulation allows us to compile a manoeuvring plan representing a detailed strategy with settings specific to positions called manoeuvring points MP. Some basic functions and interface displays for fast time simulation in the Design and Planning Tool are illustrated in the following figures. Figure 8 explains the method in a sea chart environment represented by an interface which is a combination of an

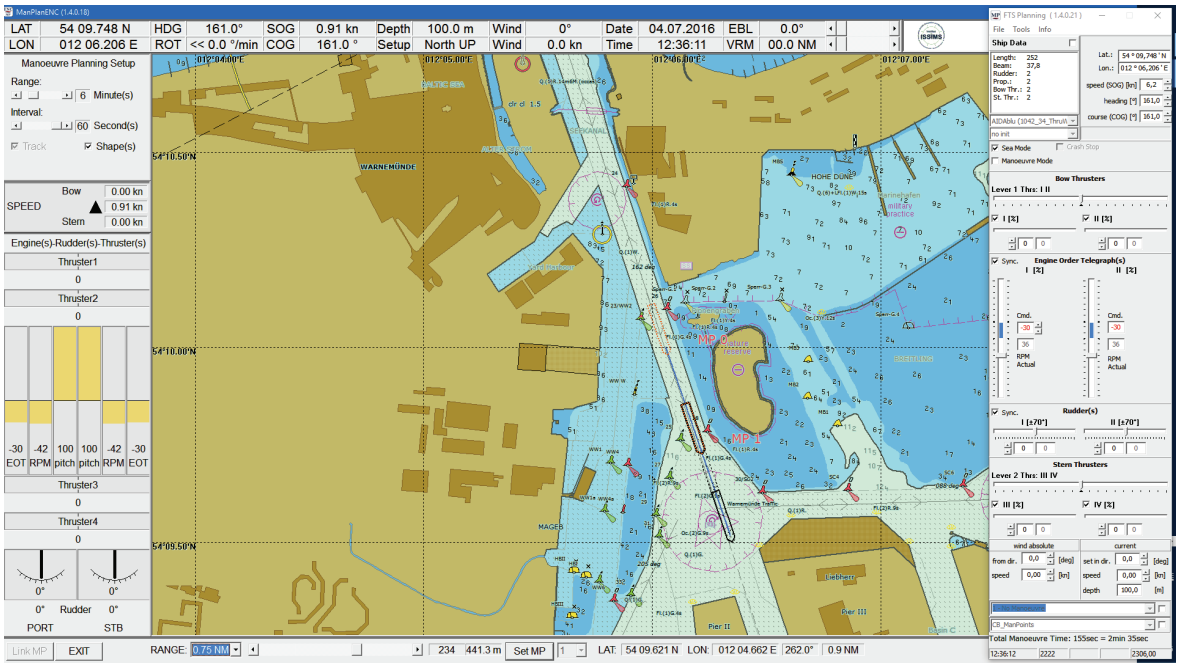

Figure 8.

Fast time planning on a sea chart: initial ship position MP0 and predicted stopping manoeuvre at MP 1: based on set handle positions, the prediction already shows the ship reducing speed.

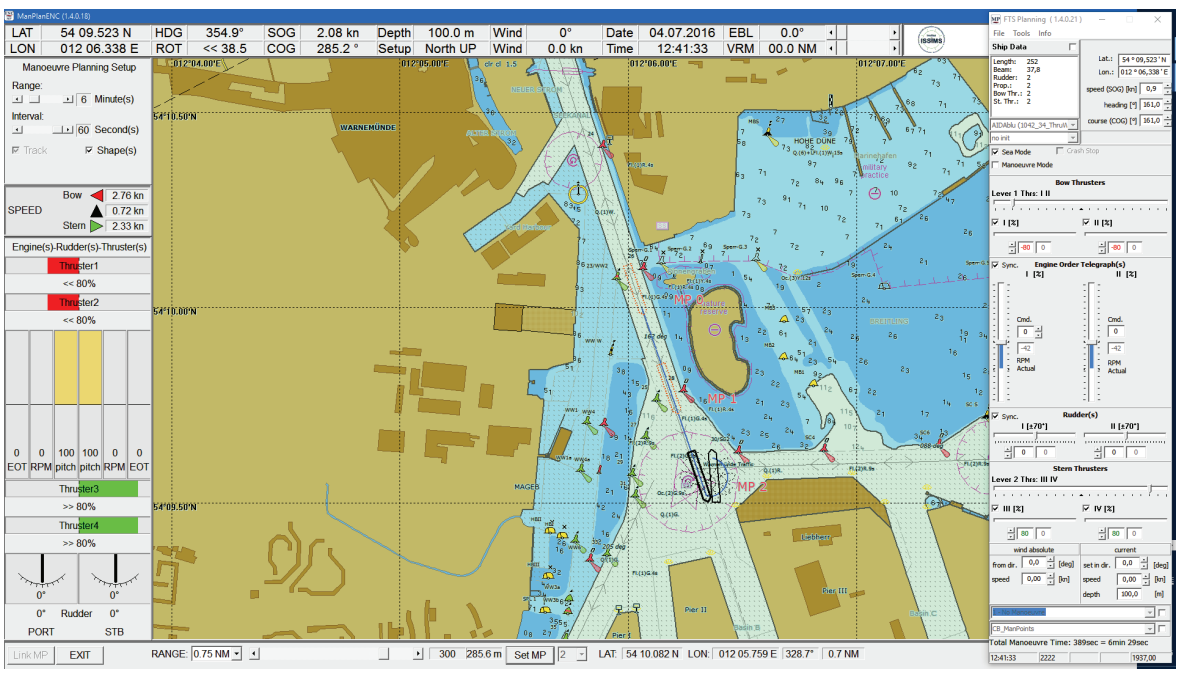

Figure 9.

Ship position at MP2 and prediction for the turning manoeuvre: the prediction shows the ship turning based on set handle positions of bow and stern thrusters operating at 80 %.

electronic navigational chart ENC window (centre), interface window of a ship's steering panel (right) used to adjust the controls to the selected manoeuvring point MP and interface displaying the status of the actual current ship manoeuvring controls (left) at the next manoeuvring point MP, indicated as a red ship shape in the ENC.

The course of action will be illustrated by a series of figures to obtain a complete manoeuvring plan, including control actions required to be taken at designated manoeuvring points MP – first for simple conditions with no wind and currents to explain the fast time planning procedure:

In Figure 8, the initial position MP 0 is in the middle of the fairway, where the instructor has decided to position the ship. The ship has already been moved by using the slider at the ENC bottom to identify the next manoeuvring point MP 1: the stopping manoeuvres begin with EOT -30 %. Based on handle positions, the ship is already predicted to slow down.

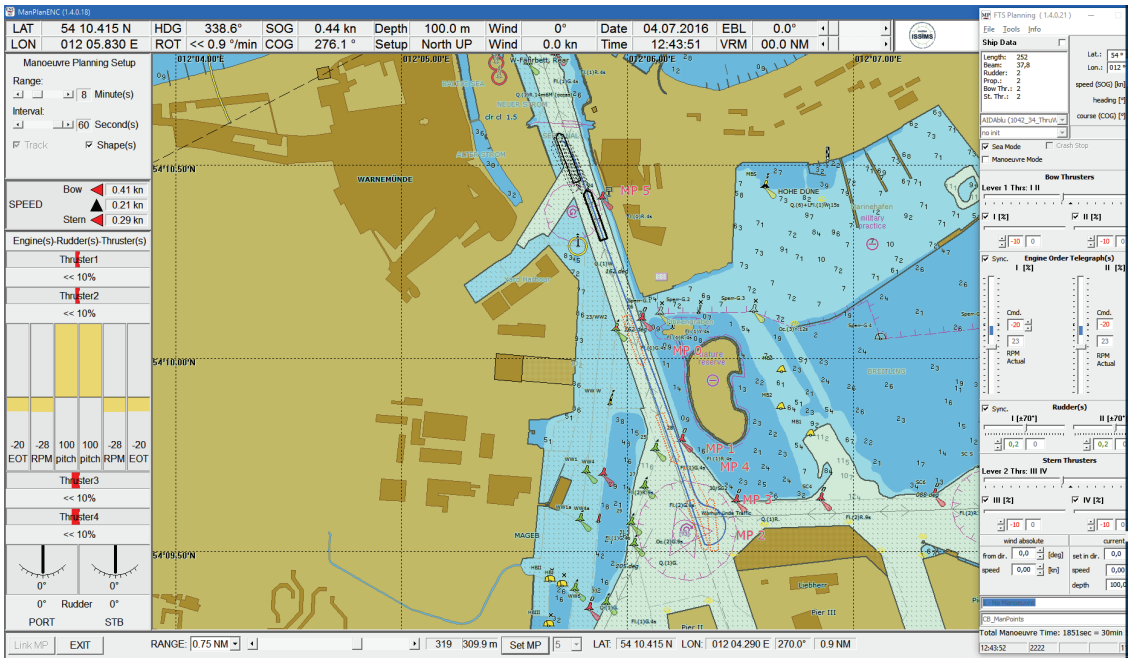

Figure 10.
Final part of the manoeuvring plan: the vessel is brought into a position parallel to the berth, to be pushed to the pier by thrusters from the next MP 6.

In Figure 9 the ship has almost come to a stop and turns by using the thrusters – the contour is moved to a position where the thrusters are stopped and the engines accelerate to return the vessel to the fairway in the opposite direction.

In Figure 10 the vessel is brought close to the berth and at MP5 the engines are reversed to reduce speed and stop the ship at a position parallel to the berth, to be pushed to the pier by thrusters from the next MP 6. The plan than requires an additional MP to reduce transversal speed shortly before berthing.

3.2.2. Advanced exercise with strong wind

The full potential of fast time simulation can be seen in difficult weather conditions. In Figure 11 the scenario has now to be re-enacted at 25 kn wind from 61°. The initial position is the same as in the previous example but the trainee's first task is to find the balance condition in the fairway: after several attempts, drift angle of about 16° and rudder angle of 3° were set and the ship contour was moved to the buoys at fairway entrance. The next manoeuvring segment requires stopping and turning: the left side of

Figure 12 clearly shows that if the ship were simply to stop here as in the previous exercise, she would drift heavily with the wind. Therefore, the engines are split to support turning by the STB engine, while the PT engine goes astern.

In the final part of the manoeuvre, the crucial segments are difficult to execute due to strong wind on the return track in the opposite course: in Figure 13 the ship enters the fairway from the south, with strong wind from the bow, requiring heading, course and rudder adjustment. Splitting the engines is advantageous since the rudder is more effective when one engine operates with more power. In addition, the ship is better prepared to

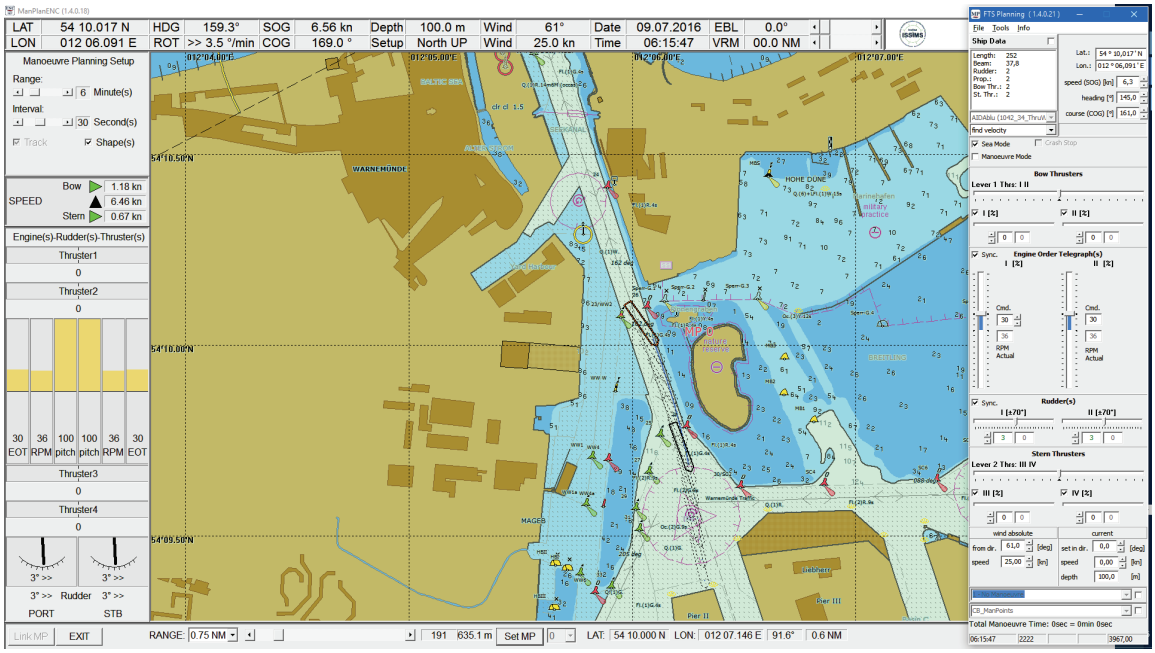

Figure 11.

Fast time planning on a sea chart under 25 kn wind blowing from 61°: initial ship position MP0 and future course prediction with drift angle.

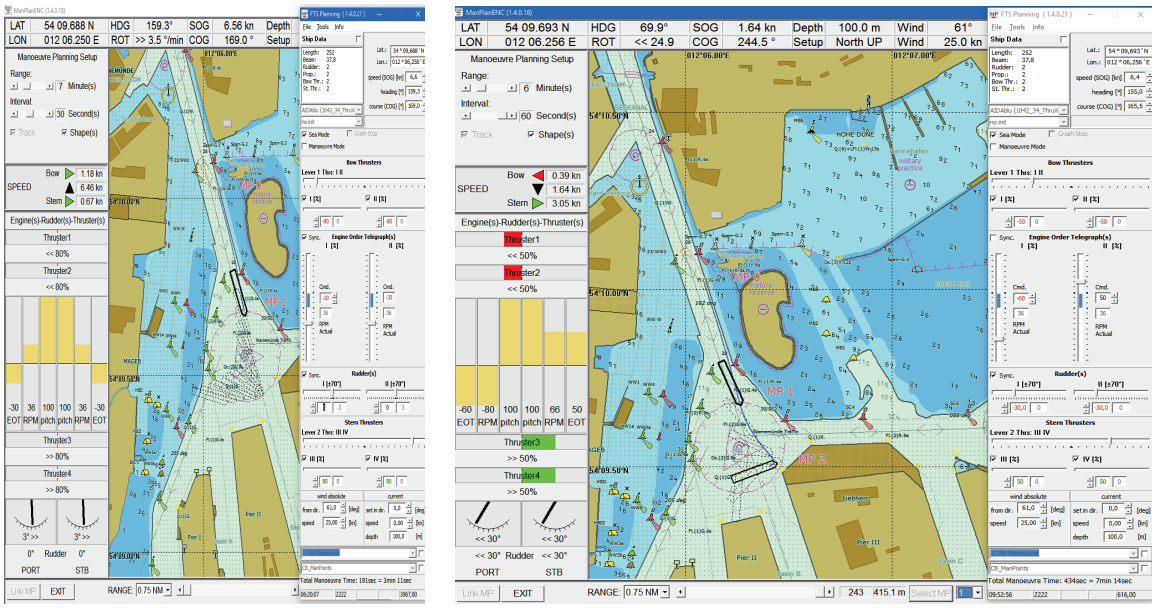

Figure 12.

Ship position at MP2 and turning manoeuvre prediction with two strategies:

- Left: turning with thrusters only (the same concept as without wind in Figure 9)
- Right: more powerful solution with split engines and rudder support.

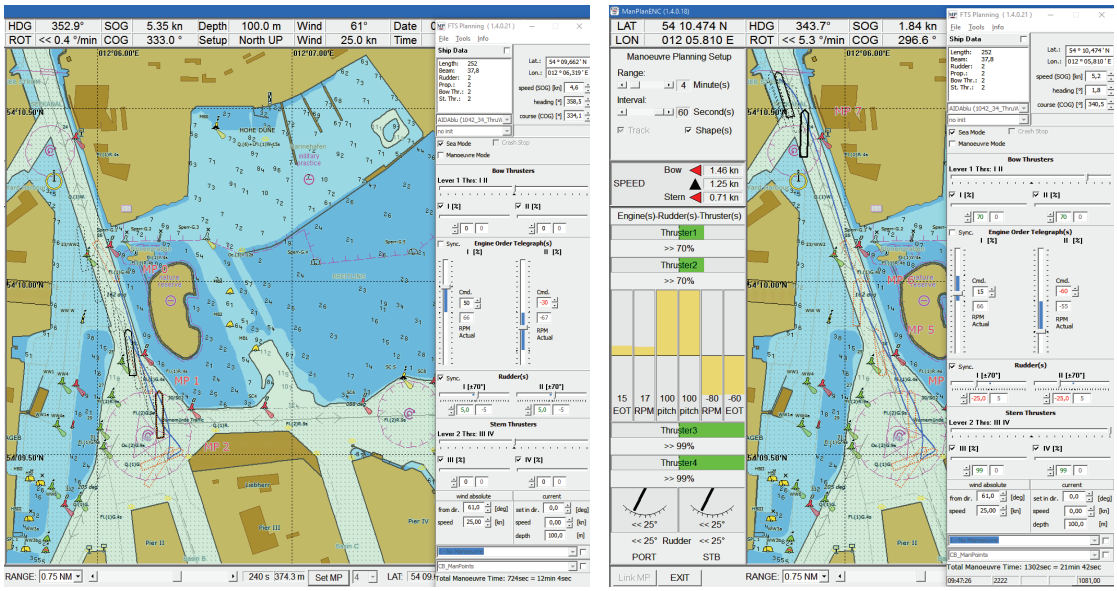

Figure 13.
Continued execution of the manoeuvring plan on the return track, in the opposite direction:
• Left: this time the ship enters the fairway from the south and heading, course and rudder are adjusted using split engines
• Right: the stopping manoeuvre intended to bring the ship into a position parallel with the berth.

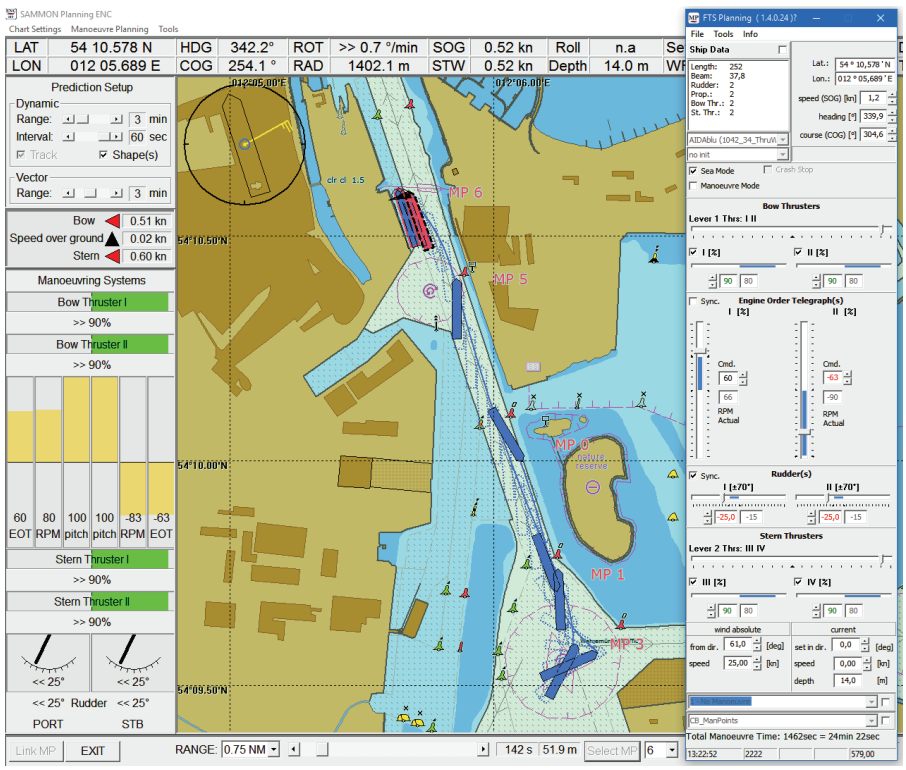

Figure 14.
Complete manoeuvring plan with the final berthing manoeuvre.

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stop since one engine is already going astern and there is no additional reversing time. On the right side of the figure, the stopping manoeuvre requires the trainee to bring the ship into a position parallel to the berth. In Figure 14 thrusters and rudders work at full power to counteract the wind for the final berthing, the approaching speed of the drift motion towards the pier is below 0.8 kn (for 30 kn it would be over 1.5 kn).

3.2.3. Briefing by means of the „Manoeuvre Trial & Training module"

The Trial & Training Tool is a desktop simulation tool for real time manoeuvring simulation illustrated in Figure 13. It has the same handle panel on the right side as previously seen in the planning tool. It contains conning information, together with prediction and is capable of displaying the planned manoeuvring track. The central window shows the ENC with motion parameters for longitudinal and transverse speed. The ship's position is displayed in the centre of the ENC as the ship's contour. Track prediction can also be indicated here either as a curved track or a chain of contours for the selected prediction time. Prediction parameters, like presentation range or interval, can be set in the control window on the left side.

In Figure 13 the scenario of navigation under wind is shown, with the ship just having entered the turning area and beginning to turn. The table at the top of the ENC shows planned manoeuvre control settings, with the planned track designated by blue colour.

4. EXECUTION OF EXERCISE AND DEBRIEFING WITH FAST TIME SIMULATION

4.1. Use of Simulation-Augmented Support with SAMMON Monitoring Tool in a Ship Handling Simulator

There are several ways to support execution and debriefing with FTS.

Support during exercise execution depends on the extent to which the trainee is allowed to use the new manoeuvring prediction technology during the exercise.

- At the lower end, multiple dynamic prediction can be used to gradually introduce the student to potential control options at his disposal, as a means of good visualisation of manoeuvre quality – in this case, only the learning process is supported since the new technology is still unavailable on conventional ships.
- At the highest level, the trainees are allowed to make full

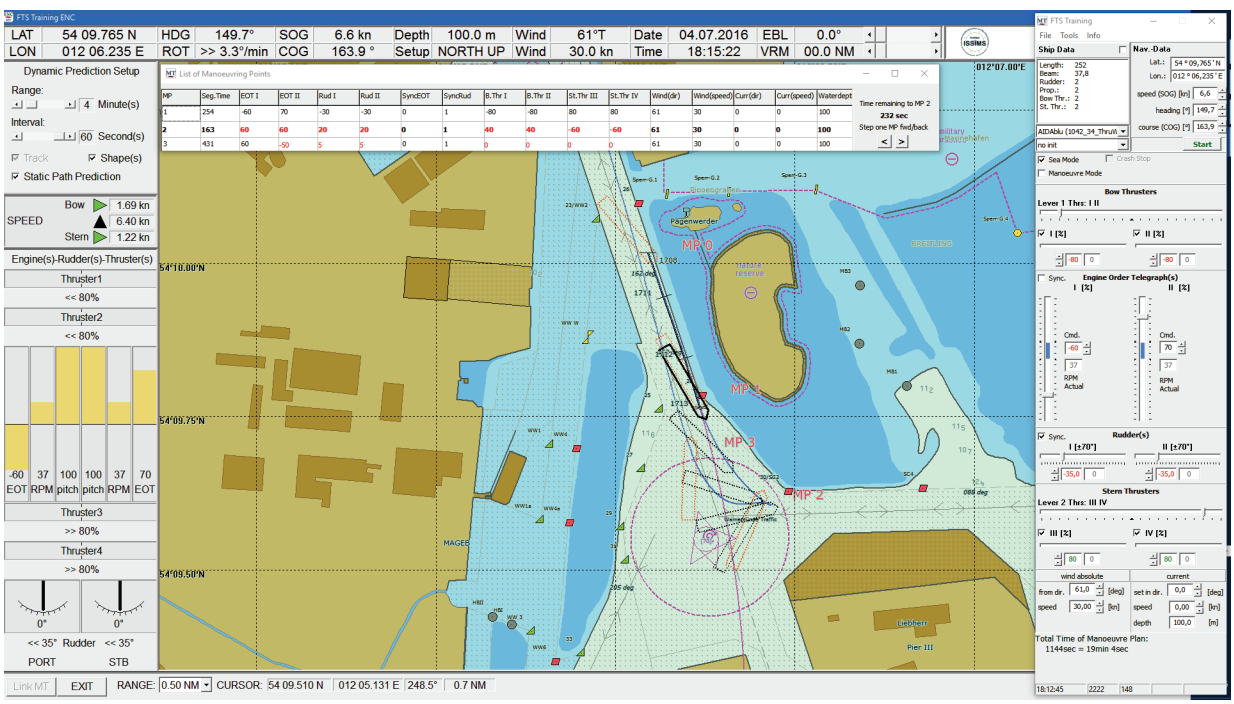

Figure 15.
SAMMON Trail & Training Tool: real time simulation and manoeuvring prediction integrated into ECDIS, with the comparison of full dynamic prediction (dotted ship contours) and simple static prediction (magenta curve), together with planned manoeuvring track (blue line) (same in Monitoring Tool, with the exception of the handle panel).

use of dynamic prediction and the prepared manoeuvring plan, they, as a rule, come closest to realizing the plan and get the best exercise results. The full use of prediction raises the safety and effectiveness even of advanced trainees

- Multiple dynamic predictions are always of great help to instructors (and peer students) because the chance for a trainee's action to be successful can immediately be seen and the exercise may be terminated earlier if it is obvious that the trainee will fail.

In the debriefing, fast time tools allow for an in-depth assessment of the quality of manoeuvring results:

- The assessment of results by comparison with the trainee's own concept or optimised plan can be shown in the replay function of the Monitoring tool, which can be used with the Multiple Prediction functionality; or in the SIMDAT tool for more detail, where the history of the trainee's actions can be presented graphically, e.g. for rudder, thruster and engine activities.
- Discussion of alternative manoeuvres at specific select situations can be supported by the Design & Planning tool; a particular situation is loaded during the exercise run and the manoeuvring handles are operated in several different ways.

Multiple prediction can be useful for manoeuvres during the exercise. In Figure 16 the setup is either explained by the instructor or laptop is brought to the simulator bridge (where the manoeuvring plan might have been developed), the prediction is controlled by the bridge handles. The same laptop with the Monitoring tool can also be placed at the instructor's station.

Figure 16.
Using Multiple Prediction in simulator training at the AIDA Cruises MSTC in Rostock:
• Left: portable setup for prediction display in the Monitoring tool on a trainee's laptop on the bridge - the prediction is controlled by the bridge handle via WLAN
• Right: prediction display in a debriefing session (left screen): dynamic prediction can be used even during fast replay to complement the simulator instructor display (right screen).

The benefits of FTS use are:

- Multiple dynamic predictions shown on the instructor's screen are always of great help to instructors and maybe even peer students looking over their shoulders to learn from the actions of the other trainees in charge on the bridge. They have a better overview of the current situation and the chances for a trainee's action to succeed can be seen immediately; the exercise can be stopped earlier if it is obvious that the trainee will fail.
- Multiple dynamic prediction can be used to gradually introduce the student to potential control options at his disposal, as a means of good visualisation of manoeuvre quality – in this case, only the learning process is supported since the new technology is still unavailable on conventional ships.
- If the trainees are allowed to make full use of dynamic prediction and the prepared manoeuvring plan, they, as a rule, come closest to realizing the plan and get the best exercise results. The full use of prediction raises the safety and effectiveness even of advanced trainees and can support the identification of the best performance.

4.2. Debriefing On the Exercise and Comparison of Results With the Manoeuvring Plan

There are several debriefing methods available after the training, using the FTS software. Whilst the Ship Handling Simulator (SHS) allows the training session to be additionally recorded using the „Monitoring & Manoeuvring Module", the training and planning procedure can also be saved in the „Trial & Training", as well as in the „Manoeuvre Design & Planning" modules. All files pertaining to planning and execution can be shown together, both in the form of the ship's track, and as diagrams for several parameters throughout the manoeuvring time in the SIMDAT program. The following figures illustrate some of the possible result display methods.

In Figure 17 two simulator results of trainees with a different level of preparation are compared mutually and with the manoeuvring plan of the second trainee. The achievements of the better prepared trainee are obvious – the actually executed track comes very close to the planned manoeuvre and the actions

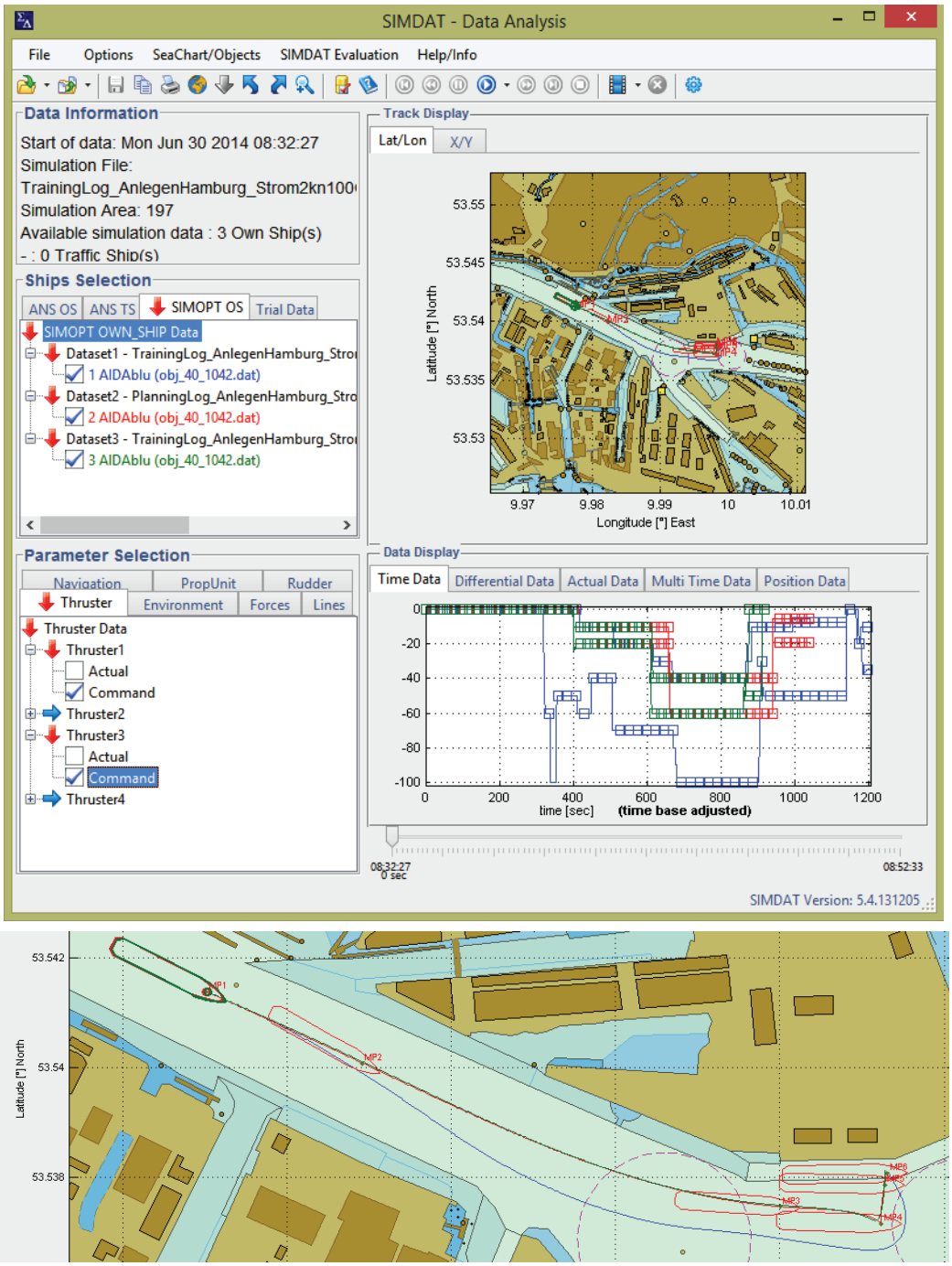

Figure 17.

Results from two manoeuvring exercises in SIMDAT interface (Top: "Track Display" with contours; Blow: „Data Display" of thruster activity history, Bottom: extract of sea chart from Track Display) and comparison with the prepared manoeuvring plan (below):

- Blue: run of the trainee without Fast Time Simulation support
- Green: run of the trainee with full support and pre-planning with the Design and Planning module
- Red: prepared manoeuvring plan with manoeuvring points MP.

of the controls also closely mimic the planned procedures. The use of the Fast Time Simulation tool in briefing and training not only reduces manoeuvring time; the thruster diagrams also show that a well-prepared manoeuvre can minimize the use of propulsion units, which makes the manoeuvre more efficient. Another great benefit of Fast Time Simulation is the opportunity to discuss alternative manoeuvres, the effects of and strategies of coping with different environmental conditions which might affect the ship unexpectedly at critical positions.

5. CONCLUSIONS / OUTLOOK

Fast Time Manoeuvring simulation has proven to be beneficial both for lecturing and training intended to improve ship handling knowledge and skills. The huge potential of this technology will be explored further, until it is incorporated onboard real ships. The majority of participants of ship handling courses hold that the Design & Planning module could be used for the compilation of a berthing plan onboard ships. There is high potential for optimisation, which would reduce manoeuvring time and fuel consumption /emissions. The FTS could also prove to be useful in various analyses (e.g. fairway layout, accidents) aiming to identify measures which would make shipping safer. Finally, the potential for real ship operation is obvious, e.g. for the information exchange between a pilot and the bridge team. The same tools may be applied to visualize intended plans of a pilot, monitor its conduction or discuss alternative maneuvering strategies and potentials threats respectively.

ACKNOWLEDGEMENTS

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Role of P&I Insurance in Implementing Amendments to Maritime Labour Convention 2014

Ranka Petrinović[a], Ivana Lovrić[a], Trpimir Perkušić[b]

Maritime Labour Convention (MLC), 2006 stipulates mandatory financial security for repatriation costs (*Standard* A 2.5), and contractual compensations related to death or long-term disability of seafarers due to an occupational injury, illness or hazard (*Standard* A 4.2) that is to be provided by the shipowner. However, financial security system set in the *MLC* was prescribed very broadly and insufficiently precise and, therefore, it opened a number of questions and doubts. Among others, the following questions are particularly interesting: what the legal nature of the *MLC* financial security is; from the insurance standpoint, whether this is life or accident insurance, or it is liability insurance; who has an insurable interest and what the nature of that interest is; which document proves fulfilment of *MLC* requirements. Due to the necessity of improving financial security provisions, in 2014 *Amendments to the MLC* were adopted that came into force in January 2017. Although the *MLC* does not explicitly prescribe a system of compulsory insurance, with the third injured party the right to a direct claim (*actio directa*) towards the liability insurer, marine insurance given its characteristic, appeared as a very suitable method of fulfilling *MLC* requirements – especially P&I insurance. All the clubs within the *International Group of P&I Clubs* have agreed to assist their members (shipowners) in complying with these additional financial security requirements under the *Amendments to the MLC* and issue *MLC Certificates* to their members. *MLC Certificates* refer to the *MLC Extension* Clause, 2016 and thus subject the insurance to conditions and limitations in the said clause. *MLC Extension* Clause provisions will be added to clubs *P&I Rules* which form the standard *P&I* cover.

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KEY WORDS
~ Maritime Labour Convention, 2006.
~ Amendments of 2014 to the MLC
~ Repatriation
~ Abandoned seafarers
~ Shipowners contractual liability
~ Financial security
~ P&I Clubs
~ MLC Extension Clause
~ Regulations on the implementation of the Maritime Labour Convention, 2006.

1. INTRODUCTION

Seafarer labour relations represent *specificum* among working relations in general. *International Labour Organization (ILO)* adopted a number of conventions and recommendations on the regulation of labour relations for seafarers. A big step has been made with the adoption of a single, coherent instrument in the form of the *Maritime Labour Convention, 2006*.[1] MLC embodies all relevant labour relations standards from previous international maritime labour conventions, with fundamental principles on labour relations in general found in other international labour conventions.

MLC was adopted at the 94th session of the *ILO*, held in Geneva, in February 2006, as a result of the work of *Special Tripartite Committee* comprised of government representatives, seafarer syndicate and shipowner representatives in order to further improve working and living conditions, social and other rights of seafarers. MLC entered into force in August 2013.

MLC significance, among other things, is the fact that it prescribes a system of protection of seafarers through the

1. *Law on ratification of the Maritime Labour Convention (Zakon o potvrđivanju Konvencije o radu pomoraca), Narodne novine, International Agreements No. 11/09.*

institution of financial security, which provides seafarers with an efficient way of exercising their rights. *MLC* stipulates mandatory financial security for repatriation costs[2] (*Standard* A 2.5), and contractual compensations related to death or long-term disability of seafarers due to an occupational injury, illness or hazard (*Standard* A 4.2) that is to be provided by the shipowner.[3]

Due to broad and insufficiently precise provisions on financial security, in 2014 *Amendments to the MLC* were adopted that came into force in January 2017. With the *Amendments'* entry into force, for the first time in maritime history the position of abandoned seafarers and their financial security are settled through mandatory international legislation.[4]

2. MARITIME LABOUR CONVENTION, 2006

2.1. About MLC

MLC consolidated and modernized the standards of 37 conventions and 31 recommendations, 68 in total that have been adopted since the year 1920 under the aegis of the *ILO*. In relation to the previous *ILO* conventions, the *MLC* enables the application of prescribed standards more effectively by stipulating obligations to the *MLC* state parties and port state inspections and not by making new, different requirements.

MLC Convention is structured according to the practice used by the IMO for their instruments. Therefore, the binding norms and recommendations are integrated into a single act. *MLC* consists of sixteen articles containing general provisions as well as the *Regulations* and the *Code*. Fundamental rights and principles as well as the *MLC* implementation and enforcement responsibilities for member states are given by the *Articles* and *Regulations*, while the *Code* contains details regarding the application of *Regulations*.

The *Code* consists of five *Titles* in which specific provisions are grouped by standard: *Minimum requirements for seafarers to work on a ship, Conditions of employment, Accommodation, recreational facilities, food and catering; Health protection, medical care, welfare and social security protection and Compliance and enforcement*. For each Title, there are general *Standards*, which are further specified in mandatory *Regulations* (part A of the Code) as well as *Guidelines* (part B of the *Code*) which contain recommendations for member states when implementing the *MLC* provisions into their national legislation. *Regulations* should in principle be implemented fully, while states are free to have different implementation measures from those suggested in the *Guidelines*.

Each member state has to ensure that ships flying its flag have *Maritime Labour Certificate* and *Declaration of Maritime Labour Compliance*. These certificates will be issued by the flag state of the ship as evidence of compliance with the *MLC*. Member state is required to exercise control over ships that fly its flag. Furthermore, ship subjected to the *MLC*, if in a port in *MLC* member state, may be inspected by the port state authority to determine its compliance with the *MLC*. The port state authority has the right of detaining the ship if the ship does not have *MLC Certificates*, and the conditions on board are not in accordance with *MLC* provisions. Port state inspections apply to all vessels over 500 gross tons, whether or not their country has ratified the *Convention*.

2.2. Amendments to MLC, 2014

The *2014 Amendments to the Maritime Labour Convention, 2006* (hereinafter also referred to as the *MLC Amendments* or the *Amendments*) entered into force on 18 January, 2017. The *MLC Amendments* relate to financial security of seafarers in cases of abandonment, and in the event of seafarers' death or long term disability due to an operational injury, illness or hazard.

Standard A 2.5.2 established requirements which will enable providing a quick and efficient system of financial security to help the seafarers in the event of their abandonment. A seafarer will be deemed to have been abandoned where, in violation of the requirements of the *MLC Convention* or the terms of the seafarers' employment agreement, the shipowner fails to cover seafarers' repatriation costs, or leaves the seafarer without the necessary maintenance and support,[5] or in some other way severs his ties with the seafarer, including failure to pay the contractual wages for a period of at least two months.[6]

Each state party has to ensure that ships flying its flag have met the financial security requirements in *Standard* A 2.5.2 of *MLC*. Financial security system can be in the form of a social security scheme or insurance, national fund, or some other similar arrangements. The final form will be determined by the state party after consulting the shipowners and seafarers'

2. *The term repatriation implies shipowners' obligation to ensure a seafarer's return to his place of residence if during, or after the termination of his service on board, the seafarer was asked to leave the ship in some port which differs from the port of his boarding the ship. Shipowner will have to fulfill this obligation only if during, or after the termination of seafarer's employment agreement, seafarer was asked to leave the ship in a port other than the port of his boarding.*
3. *According to MLC, shipowner means the owner of the ship or another organization, or a person such as the manager, agent or bareboat charterer, who has assumed the responsibility for the operation of the ship from the owner and who, on assuming such responsibility, has agreed to take over the duties and responsibilities imposed on shipowners in accordance with this Convention, regardless of whether any other organization or persons fulfill some of the duties or responsibilities on behalf of the shipowner.*
4. *Petrinović, R., Lovrić,I. (2015: p. 163)*
5. *According to the Amendments to the MLC, Standard A 2.5.2, p. 5: Necessary maintenance and support of seafarers shall include: adequate food, accommodation, drinking water supplies, essential fuel for survival on board the ship and necessary medical care.*
6. *Ibidem, p. 2.*

associations. Financial security system has to provide every abandoned seafarer on a member states' ships, a direct access, sufficient coverage, and quick financial assistance.[7] The financial assistance will be granted promptly to the seafarer upon his, or his representative's making request, in which the justification of said entitlement must be explained.[8]

MLC, 2006 already contained a provision under which the shipowner had to provide financial security to assure compensation for contractual claims as set out in national law, seafarer's employment agreement or collective agreement.[9] *Amendments to the MLC* added a new provision which defines minimum requirements for these contractual compensations related to seafarers' death or long-term disability.[10]

According to the MLC Amendments, each state party ship that is flying its flag must carry on board a certificate or other document of financial security for repatriation costs and claims relating to death or long-term disability of seafarers, issued by the financial security provider. Certificates' copies have to be posted in a conspicuous place on board from where are available for seafarers to see.[11]

With the *Amendments*' entry into force, for the first time in maritime history the position of abandoned seafarers and their financial security will be settled through mandatory international legislation.

2.3. Amendments to Standard 2.5 - Repatriation

Repatriation is a way of solving specific problems that a seaman is faced with in case of abandonment, through rapid and efficient system of financial security. Shipowners need to implement financial security for the repatriation costs of seafarers. The financial security system has to provide any abandoned seafarer with a direct access (*actio directa*) towards the financial security provider and urgent financial assistance, sufficient enough to cover the basic needs, repatriation, and other justified costs, and with up to 4 months of outstanding wages and other entitlements which the shipowner owes the seafarer under the employment agreement, relevant collective agreement, or national law of the flag state.[12]

Financial assistance should be sufficient for the coverage of the seafarer's living costs, his essential needs from the day of the abandonment until his arrival home, including: food and water, clothing, accommodation, fuel for survival on board the ship, medical care and any other reasonable costs.[13]

Repatriation costs cover all reasonable costs or charges arising from the seafarer's abandonment including medical care, food, and accommodation from the time of leaving the ship until arriving home, and the seafarer's and his personal belongings' transport home, normally by air.[14]

If certain aspects of the seafarer's or his representatives' request need to be verified, it should not prevent the seafarer from immediately receiving requested financial assistance in a part which is recognized as justified.[15]

The *MLC* state parties require that ships flying its flag, carry on board a certificate or some other form of document, issued by the financial security provider, as evidence of placing the financial security for seafarers' repatriation under the *MLC Standard* A2.5. Certificate copy has to be posted on board the vessel in a conspicuous place for seafarers to see.[16]

According to *Appendix A2-I*, the certificate or other documentary evidence has to include the following information: ships name, port of registry, call sign and *IMO* number, then the name and address of the financial security provider, contacts for handling seafarers' requests, name of the shipowner, period of the financial security validity and an attestation from the financial security provider that the financial security meets the requirements of the *MLC Standard* A 2.5.2.[17] Certificate has to be written in English or accompanied by an English translation.[18]

2.4. Amendments to Standard 4.2 - Shipowners´ Liability

Amendments to the MLC stipulate a new provision to *Standard A 4.2.1 Shipowners´ liability* which defines minimum requirements for contractual compensations. The term *contractual* claim means any seafarers' claim related to death or long-term disability due to an occupational injury, illness or hazard as set out in the national law, seafarer's employment agreement or collective agreement.[19]

7. *Ibidem, p. 3 - 4.*
8. *Ibidem, p. 8. Standard A 2.5.2, p. 9 says: The financial security system has to be sufficient to cover: up to four months of outstanding wages and other entitlements due from the shipowner to the seafarer under their employment agreement, relevant collective bargaining agreement or national law of the flag state; all expenses reasonably incurred by the seafarer, including the cost of repatriation and the seafarer's essential needs, as: food, clothing, accommodation, drinking water, essential fuel for survival on board the ship, medical care and any other reasonable costs or charges from the act or omission constituting the abandonment until the seafarer's arrival at home.*
9. *MLC, Standard A 4.2, p. 1b.*
10. *Amendments to the MLC, Standard A 4.2.2 - Treatment of contractual claims, p. 1: The term "contractual claim" means any claim which relates to death or long-term disability of seafarers due to an occupational injury, illness or hazard.*
11. *Ibidem, Standard 2.5.2, p. 6 and Standard A 4.2, p. 11.*
12. *Amendments to the MLC, Standard A 2.5.2, p. 4 and 9.*
13. *Ibidem, Standard A 2.5.2, p. 9 (c).*
14. *Ibidem, Standard A 2.5.2, p. 10.*
15. *Ibidem, Guideline B 2.5.3 - Financial security, p. 1.*
16. *Ibidem, Standard A 2.5.2, p. 6.*
17. *Ibidem, Appendix A 2-I - Evidence of financial security under Regulation 2.5, paragraph 2.*
18. *Ibidem, Standard A 2.5.2, p. 7.*
19. *Ibidem, Standard A 4.2.1 - Shipowners´ liability, p. 8. For the definition of the term contractual claim, see Standard A 4.2.2 - Treatment of contractual claims, p. 1.*

The minimum requirements set in the new paragraph 8 of *Standard* A 4.2.1 are as follows: the claim for contractual compensation may be brought directly by the seafarer, his representative, next of kin, or his designated beneficiary. There can be no pressure to accept a payment which is less than the contractual amount. The contractual compensation will be paid in full and without delay, unless the nature of the seafarer's long-term disability makes it difficult to assess the full entitled compensation, than an *interim* payment or payments shall be made in order to avoid excessive difficulty to the seafarer. The seafarer will receive the payment without prejudice to his other legal rights, but the payment may be offset by the shipowner against any other seafarer's claims against the shipowner that the seafarer placed for the same incident.

Certificate or other document issued by the financial security provider will be used as evidence that financial security is in place. A copy of it has to be posted on board member state ships from where it is available for seafarers to see. The certificate or other documentary evidence of financial security has to be written in English, or accompanied by an English translation, and has to contain information required in Appendix A 4-I[20]: ship's name, port of registry, call sign and IMO number, then the name and address of the financial security provider, contacts for handling seafarer's requests, name of the shipowner, period of the financial security validity, and an attestation from the financial security provider that the financial security meets the requirements of Standard A 4.2.1.[21]

2.5. Declaration of Maritime Labour Compliance

Declaration of Maritime Labour Compliance will be of two parts - *Part I* and *Part II*. *Declaration of Maritime Labour Compliance - Part I* will be issued by the competent authority[22] and must be attached to the ship's *Maritime Labour Certificate*. Part I lists national requirements that embody the *MLC* provisions and confirm that the ship named in the *Declaration* is maintained in accordance with the *Convention*. *Declaration of Maritime Labour Compliance - Part II* lists measures adopted in order to ensure compliance, between inspections, with the requirements listed in *Part I*.

Declaration of Maritime Labour Compliance (Part I and Part II) issued from 18 January, 2017 will have to contain both standards:

- Financial security for repatriation (*Regulation* 2.5),
- Financial security relating to shipowner's liability (*Regulation* 4.2).

2.6. MLC Certificates

From 18 January, 2017 when the *MLC Amendments* came into force, the ships that are subject to the *MLC* will be required to display certificates issued by an insurer or other financial security provider, confirming that insurance or other financial security is in place for liabilities in respect of:

- outstanding wages and repatriation of seafarers together with incidental costs and expenses in accordance with *MLC Regulation* 2.5, *Standard* A 2.5.2 and *Guideline* B 2.5, and
- compensation for death or long-term disability in accordance with *Regulation* 4.2, *Standard* A 4.2 and *Guideline* B 4.2.

Certificate copies have to be posted on board all *MLC* member state ships and on board ships that will be calling ports situated in *MLC* member states.[23]

2.7. Implementation of the MLC in Croatian Legislation

MLC has left the national legislations to regulate the working and social position of seafarers in the spirit of their national legal and political system, and thereby meet the highest standards set by the *Convention*.[24] The Republic of Croatia ratified the *MLC* in February 2010, and harmonized its national legislation with its provisions. The Croatian legislator implemented the *MLC* provisions in the *Croatian Maritime Code* through amendments to the *Pomorski zakonik* from 2011 (hereinafter referred to as PZ, 2011).[25] Provisions which enable the implementation of *MLC Regulations* and *Standards* relating to repatriation (*Standard* 2.5) were incorporated to *PZ*, 2011. In doing so, article 139 a[26]

20. *Ibidem, Appendix A 4-I - Evidence of financial security under Regulation 4.2*
21. *Ibidem, Standard A 4.2.1, p. 11 and 14.*
22. *Competent authority is defined in Article II, p. 1 (a) of the MLC under which it means the minister, government department or other authority that has the power of issuing and enforcing regulations that will have the force of law.*
23. *International Labour Organization formed MLC database which contains ratification and implementation information of Maritime Labour Convention in all countries that have adopted the MLC Convention. MLC database can be found on ILO website, online at http://www.ilo.org/global/standards/maritime-labour-convention/database-ratification-implementation/lang--en/index.htm, [accessed 25 February 2017.].*
24. Petrinović, R., Lovrić,I. ibidem, p. 151.
25. Amendments to PZ (Zakon o izmjenama i dopunama Pomorskog zakonika), Narodne novine No. 6/11.
26. Ibidem, art 139 a says:
    (1) Shipowner will provide insurance or other financial security to cover repatriation costs for crew members.
    (2) Shipowner will ensure that relevant legislative provisions concerning the right of crew members to repatriation costs are available to crew members on all ships.
    (3) Relevant legislative provisions under paragraph 2 of this Article shall be made available in speaking, working language of the ship and in English.

and 1016 c are new, and were added to the *PZ*, and the existing articles 138[27] and 139[28] were amended.

According to *PZ*, the shipowner will be liable for damages related to death, personal injury, or deterioration of health of seafarers incurred while working or in connection with working on board, if the damage can be attributed to the shipowner's actions. The shipowner will not be liable for such damages if he can prove that he is not culpable, and the damage was caused without his fault.[29] Legislative solutions on the shipowner's liability for the death and personal injury of seafarers are based on presumed guilt (as a general principle), or on objective liability (in special cases[30]). Furthermore, liability insurance provisions in the *PZ*, stipulate seafarer's right as a third party, to a direct claim towards the insurance provider for the claims related to seafarer's death, personal injury or deterioration of health.[31]

According to the amendments to *PZ* from 2013[32] Minister of maritime affairs was obligated to adopt a regulation which would determine in detail how *MLC* provisions are to be implemented in the Croatian legislation, and thereby remove all doubts incurred by the lack of precision of *MLC* provisions on how financial security should be provided.

Pursuant to art 125, p. 5 of PZ, the Minister issued on 13 December, 2016 *Regulations on the implementation of the Maritime Labour Convention*, 2006 (hereinafter also referred to as *Regulations on the implementation of the MLC or Regulations*).[33] *Regulations* entered into force on 18 January, 2017, simultaneously with the *Amendments to the MLC*, and its provisions are in compliance with *MLC Amendments* provisions.

Regulations in detail regulate financial security for seafarers' repatriation costs and the contractual in accordance with the *Amendments to the MLC, 2014*. *Contractual claim* means any seafarer's claim related to the death or long-term disability due to an occupational injury, illness or hazard as set out in the national law, the seafarer's employment agreement or collective agreement.[34] According to the *Regulations*, the shipowner is obligated to provide financial security and ensure that the document[35] issued by the insurance or other financial security provider, is on board the ship, as evidence of having financial security in place. Such document should be placed in a prominent and accessible place for seafarers on board and contain the necessary information about the ship, shipowner and financial security provider as the document's period of validity. This document of financial security also has to contain an attestation from the financial security provider, that the financial security meets the requirements of the *MLC Standard* A 2.5.2[36] and *Standard* A 4.2.2.[37]

Insurance or other financial security set in place for contractual claims and repatriation of a seafarer should not cease before the end of the period of validity of the financial security unless the financial security provider has given prior notification of at least 30 days to the *Ministry of the Sea, Transport and Infrastructure*.[38] If a shipowner's financial security is to be cancelled or terminated, the shipowner has to notify the seafarers on board the ship of such cancellation as soon as possible.[39]

3. THE ROLE OF P&I CLUBS IN MLC IMPLEMENTATION

3.1. International Group of Protection & Indemnity Clubs and Maritime Labour Convention

International Group of Protection & Indemnity Clubs (hereinafter also referred to as the *Group*, or *IG*) is an unincorporated association of 13 principal underwriting

27. Ibidem, in art 138 after p. 1, p. 2 and p. 3 are added:
(2) Repatriation costs, referred to in paragraph 1 of this Article, shipowner may not collect from a crew member at the beginning of employment in the form of an advance, or from crew members entitled wages, except in a case of severe breach of the employment contract by the crew member.
(3) If the shipowner does not refund sums paid for crew member's repatriation under paragraph 1 of this Article, taking into account all applicable international standards, ships of said shipowner could be detained.
28. Ibidem, art 139, p. 3 is amended as follows: Crew members repatriation costs include accommodation, transport costs, wages and other entitlements from the moment of leaving the ship until the seafarers' arrival home at the place of his residence, including necessary medical care till the seafarer's medically fit for the return voyage home.
29. Pomorski zakonik, art 145, p. 1. Liability is joint for these damages and include the shipowner, manager, transport operator and the company.
30. Ibidem, art 145, p. 2 (damage caused by dangerous materials or activities and damage to the crew member incurred while working or in connection with working on board due to absence of safe working conditions).
31. Pomorski zakonik, art 743, p. 2 says: Only when specifically provided, as in the case of death, personal injury and crew members' deterioration of health, the damaged party may place an insurer a direct claim for compensation due to damages sustained by the event for which the insured is responsible, up to the amount of insurers' liability. In marine insurance, a direct action is provided only in two cases: compulsory insurance and claims of crew members due to death, personal injury or illness. For more see: Petrinović, R., Lovrić, I., (2015: p. 152).
32. Amendments to the PZ (Zakon o izmjenama i dopunama Pomorskog zakonika), Narodne novine, No. 56/13, art 125, p. 5.
33. Regulations on the implementation of the MLC, 2006 (Pravilnik o primjeni Konvencije o radu pomoraca, 2006), Narodne novine, No. 122/2016.
34. Ibidem, art 7, p. 1 and p. 2. The same definition of the term "contractual claim" is in Amendments to the MLC, Standard A 4.2.2 p. 1.
35. The document has to be written in English or accompanied by an English translation.
36. Regulations to the MLC, ibidem, art 5.
37. Ibidem, art 8.
38. Ministry of the Sea, Transport and Infrastructure (Croatian: Ministarstvo mora, prometa i infrastrukture) is the competent authority for MLC implementation in Croatia.
39. Ibidem, art 9.

associations and their affiliated associations and reinsured entity.[40] The *Group* is based at Peek House in London. Each club within the *Group* is an independent, non-profit mutual insurance association that provides cover for its shipowner and charterer members against third party liabilities relating to the use and operation of ships. Each club is controlled by its members through a board of directors. Together, these 13 clubs provide liability cover (protection and indemnity) for approximately 90 % of the world's gross tonnage.[41]

P&I clubs provide insurance for broader, indeterminate risks which marine insurers usually do not cover, or are reluctant to insure, such as third party risks. So, clubs provide cover for a wide range of liabilities, including personal injury to crew, passengers and others on board, cargo loss and damage, oil pollution, shipowner's liability after a collision, wreck removal and dock damage, and war risks. To members, clubs offer services and provide help with the legal issues, loss prevention and claims.[42]

On the issue of *MLC* implementation and certification, clubs within the *Group* cooperate and form unified decisions. In doing so, all clubs within the *Group* issue uniform *Circulars* of the same title and content. By way of *Circulars*, all members are informed on current proceedings and reached decisions. These *Circulars* give members guidelines on how to address certain issues. So, *Circulars* bear a very important function in dealings of *P&I* Clubs as they standardize the business practice in general and in our case, in *MLC* implementation. So, every club has issued several Circulars on the *MLC, Amendments to MLC* and the certification process. The *Group* did not act secluded, but has consulted a number of key states in order to establish a common approach in providing financial security according to the *MLC*, amongst 80 states which have ratified the Convention by now.

As already pointed out, the *MLC Amendments* aim at ensuring the financial security of seafarers by implementing new provisions on the protection of abandoned seafarers and the protection of seafarers injured in accidents at work.

All Clubs in the *Group* have agreed to provide their members with *MLC* certification. The club will issue its member two sets of *MLC* Certificates, for repatriation costs and contractual claims. The Certificates contain a provision which subjects the insurance to conditions and limitations in *Maritime Labour Convention Extension Clause, 2016* (hereinafter also referred as the *MLC Extension Clause, 2016*). *MLC Extension Clause* will be considered as an addition to the clubs *P&I Rules* that form the standard *P&I* cover.[43]

Should the *MLC* event occur, the club will directly indemnify the seafarer. The club has the right of indemnity from the member in respect of entitlements following abandonment, and on the basis that these new *MLC* liabilities do not fall within the *Group's* existing pooling arrangements.[44]

The *Group* plans to establish additional reinsurance for liabilities arising under the *MLC Extension Clause* and those falling outside its scope of coverage. All *Group* clubs have agreed to participate in this separate reinsurance arrangement that will address aggregation of risk in the event that a club becomes liable for members' financial default that resulted in seafarer abandonment. Reinsurance scheme will be placed in the near future, and should be enough for all members. But, there are indications that it would not be at the level capable to manage claims coming from a small number of fleets with exceptionally high crew numbers.[45]

3.2. Application Process for MLC Certificates at P&I Club

Every *IG* club has issued a similar announcement informing their members on the application process for *MLC Certificates*. The application process is basically the same in every *Group's* club. Club members (shipowners) using the Application Form, apply for *Certificates* on a basis of *per* vessel or *per* fleet.[46] After

40. Principal underwriting associations in the International Group of Protection & Indemnity Clubs are: American Steamship Owners; Skuld; Gard; Britannia; Japan Ship Owners'; The Swedish Club; UK P&I; West of England; London Steam-Ship Owners'; North of England; Shipowners' P&I; Standard Club; Steamship P&I; Sveriges Ångfartygs Assurans Förening, For more on the International Group on IG P&I website, online at: http://www.igpandi.org/, [accessed 14 February 2017.].
41. Ibid.
42. More on the P&I Clubs online at: https://en.wikipedia.org/wiki/Protection_and_indemnity_insurance, [accessed 13 February 2017.].
43. Each P&I Club in the IG announced in June 2016 Circular - Update on the Maritime Labour Convention (MLC). All Circulars are of the same content which says that the P&I Club will provide its member the financial security under the MLC by issuing MLC Certificates. More on The Shipowners Club website, online at: https://www.shipownersclub.com/publications/update-on-the-maritime-labour-convention/, [accessed 22 December 2016.].
44. Clubs within the IG agreed on the joint coverage of high risk claims. Pooling Agreement is in the joint interest of all clubs, as it reduces their risk exposure and provides a safer way of business, regardless of the fact that in ordinary line of business these clubs are competitors.
The Pooling Agreement explicitly defines which risks will the clubs jointly bear and which risks are excluded from coverage. The Pooling Agreement also defines in which ratio individual club will participate in covering the damage, arising from the realization of risk covered by the agreement. According to the terms of the Pooling Agreement, clubs have to share all qualifying claims in excess of $10 million. While the Group gives guidelines, coordinates and regulates the claims which are to be pooled. Also, if needed, the Group placed a reinsurance programme for support to claims sharing agreement. More on IG website, online at: http://www.igpandi.org/group-agreements, [accessed 22 January 2017.].
45. See Circular 16/16: Maritime Labour Convention, 2006 as Amended (MLC) on The Shipowners' Club web site, online at: https://www.shipownersclub.com/publications/maritime-labour-convention-2006-as-amended-mlc-financial-security-requirements/, [accessed 22 February 2017.].
46. See the Application Process for MLC Certificates on the UK P&I Club website, online at https://www.ukpandi.com/knowledge-publications/article/application-process-for-mlc-certificates-136479/, [accessed 22 February 2017.].

submitting the application to their usual underwriter in the club, the club will issue its member *MLC Certificates*. By returning the signed application, the member agrees to the undertakings contained in it, as well as the terms of the *MLC Extension Clause*, 2016.

From 18 January, 2017 when the *MLC Amendments* came into force, certificate copies have to be posted in a conspicuous place on board the ship, available to seafarers. *MLC Certificates* are provided by the *P&I* Club and there is no need to apply for state-issued *Certificates*. However, some flag states may require shipowners on their register to supply copies of *MLC Certificates* for their records, in which case shipowners are responsible for this process.

Clubs will keep records of issued *Certificates* to ships. These records will be available on the Club's website, thus providing flag states and port state authorities a reliable form of verification which ships have the needed financial security certification in place and which do not.[47]

P&I Club will issue its member two sets of *Certificates*:

- Certificate of insurance or other financial security in respect of shipowner's liability, as required under *Regulation* 4.2, *Standard* A 4.2, Paragraph 1 (b) of the *Maritime Labour Convention 2006. as Amended*, and
- Certificate of insurance or other financial security in respect of seafarer repatriation costs and liabilities, as required under *Regulation* 2.5.2, *Standard* A 2.5.2 of the *Maritime Labour Convention 2006. as Amended*.

3.3. MLC Extension Clause, 2016

Some liabilities in *MLC Certificates* fall within the scope of standard *P&I* cover for crew, but some of them do not, as they are new additional financial security requirements brought by the *Amendments to the MLC, 2014*.

Liabilities in respect of compensation for death or long term disability, repatriation costs and wages after a shipwreck, form a part of standard cover in the *P&I Clubs Rules*. However, there are other liabilities in *MLC Certificates* that are not normally covered by clubs *P&I Rules*. In particular, repatriation costs and wages arising from abandonment.

MLC Certificates contain a provision that names *Regulations* and *Standards* in the *MLC, 2006 as Amended*, to which the certificates apply. In this way, the certificates define their coverage. Furthermore, both *MLC Certificates* contain a provision which subjects their coverage to conditions and limitations in the *MLC Extension Clause*, 2016. According to *MLC Extension Clause*, the club will only pay the claims which fall within the scope of *Regulations* and *Standards* specified in *MLC Certificates* (paragraphs 1a, 1b). But, if such payments fall outside the scope of the standard cover, the members will be obliged to reimburse the club (*MLC Extension Clause*, paragraphs 2a, 2b).

The claims that fall outside the scope of *P&I* cover, neither will be part of pooling and reinsurance arrangements between the clubs in the *Group*. Nevertheless, the *Group* plans to establish reinsurance scheme for liabilities arising under the *MLC Extension Clause*. This additional reinsurance would also be for liabilities that fall outside its scope of coverage.[48]

According to paragraph 1(a, b) of the *MLC Extension Clause*, the *Association* will pay on the member's behalf under the *MLC as Amended, 2006* or domestic legislation of a state party implementing MLC:

- Liabilities and accompanying costs and expenses in respect of outstanding wages and repatriation of a seafarer in accordance with *Regulation* 2.5, *Standard* A 2.5 and *Guideline* B 2.5,
- Liabilities in respect of compensating a seafarer for death or long-term disability in accordance with *Regulation* 4.2, *Standard* A 4.2 and *Guideline* B 4.2.

If liabilities, costs or expenses payable under this MLC Extension Clause are also recoverable by any other separate insurance, social security scheme or fund, or any other similar arrangement, there will be no payment by this insurance to the extent that such claim is recoverable by that other insurance. In other words, this insurance will only pay the difference in compensation between the other insurance and this one (*MLC Extension Clause*, paragraph 3).

Members do not have to reimburse the Association for claims paid under paragraph 1 of the *MLC Extension Clause* if they are covered by the clubs' *P&I Rules*.

The member has to reimburse the *Association* for the claims paid under paragraph 1 of the *MLC Extension Clause*, but if the claim is covered by the club's *P&I Rules*, he will not have to reimburse the club. Therefore, the member shall reimburse the *Association* in full for the claims paid under paragraph 1(a) of the *MLC Extension Clause*, save to the extent that such claim is recoverable under Rule 2, Sections 2, 3, 4(A), or 6 of the club's *P&I Rules* (*MLC Extension Clause*, paragraph 2(a). In other words, the member will not have to reimburse the *Association* for those claims that were paid under paragraph 1 of the *MLC Extension Clause*, but are covered by the club's Rules. Rule 2, Sections 2, 3, 4(A), or 6 in the *P&I Rules* regulate the cover of liabilities, costs or expenses for injury or death of a seafarer, illness and death of seafarers, cost of repatriation and replacement cost of a seafarer with another seafarer, seafarer compensation for loss of employment due to actual or derived total loss of the ship.

Similarly, the member shall reimburse the *Association* in full for claims paid under paragraph 1(b) of the *MLC Extension*

47. Circular 16/16: Maritime Labour Convention, 2006 as Amended (MLC), ibidem.

48. Each P&I Club has posted specimens of MLC Certificates on their web page. More on the certification process, P&I insurance and reinsurance of liabilities, ibidem.

Clause, save to the extent that such claim is recoverable under Rule 2, Sections 2 or 3 of the clubs *P&I Rules* (*MLC Extension Clause*, paragraph 2(b)). Liabilities, costs or expenses for injury or death of a seafarer, as well as illness and death of a seafarer are regulated by Rule 2, Sections 2, 3 in the *P&I Rules*.

Liabilities, costs or expenses covered under paragraph 1(a) and paragraph 1(b) of *MLC Extension Clause* will be excluded from this cover if they contributed to, or were directly or indirectly caused by, or risen from:

- any chemical, biological, bio-chemical or electromagnetic weapon,
- the use or operation of any computer system, software programme, computer virus or any other electronic system with the intent of inflicting harm (*MLC Extension Clause*, paragraph 4(a, b)).

It wouldn't be of relevance if such liabilities, costs or expenses were incurred by, or caused by the neglect of the member or member's servants or agents.

War Risks are excluded from the *Extension Clause* cover and the insurance will terminate automatically if they happen. For the purposes of this insurance, war risks include the outbreak of war between the UK, USA, France, Russian Federation or People's Republic of China, and the requisition of the insured ship (*MLC Extension Clause*, paragraph 5(b)).

According to the paragraph 5(a) of the *MLC Extension Clause*, the *Association* may cancel this cover by giving the member 30 days' notice, due to the emergence of war risk.

Loss, damage, liability or expense arising from the requisition, or outbreak of war between the UK, USA, France, Russian Federation or People's Republic of China will be excluded from this cover (*MLC Extension Clause*, paragraph 5(c)).

Paragraph 6 in the *MLC Extension Clause* subjects this extension cover to the provisions of Rule 5(F) and 5(V) in the *P&I Rules* of a club. Rule 5(F) excludes from the cover nuclear risks and Rule 5(V) excludes liabilities, costs or expenses which could expose the club to state sanctions, restrictions, or penalties.

According to paragraph 7, cover under the *MLC Extension Clause* shall cease 30 days after giving the notice of termination. Disputes arising from, or in connection with this insurance are to be resolved in accordance with Rule 40 of the *P&I Rules* that determines the disputes are to be settled in court or arbitration in England (*MLC Extension Clause*, paragraph 8).

4. CONCLUSION

In order for seafarers to exercise their rights under the *MLC*, seafarer's right to a direct claim towards the liability insurer is of utmost importance, particularly when it comes to abandoned seafarers who have tried to reimburse their claims from the shipowner, but unsuccessfully. The best way of complying with the provisions on mandatory financial security in case of abandoned seafarers, and seafarers' death or long-term inability incurred while working, is through *P&I* liability insurance. Nevertheless, as outlined in the *MLC Convention*, this does not exclude the possibility of placing other suitable forms of financial security such as bank guarantees, social security scheme, state funds, and others,.

Owing to the fact that seafarer life is very specific and contains elements of common interest, the seafarer's right to life and physical integrity is especially protected. Hence, clubs' *P&I Rules* determined that a third party (seafarer) has the right to a direct claim towards the club for compensation related to death or personal injury. In such a case, the club has no right to call on a *pay to be paid* clause. Also, liability insurance provisions in the *Croatian Maritime Code (Pomorski zakonik)*, provided the right of a seafarer, as a third party, to a direct claim towards the maritime insurer for claims related to death, personal injury or impaired health. However, this applies only to physical damages occurred to seafarers. Other seafarers' rights could not be claimed directly from the insurer.

Clubs were explicitly opposed to covering the shipowners' liability in case of seafarers' abandonment. But, their reluctance changed significantly after the adoption of *MLC Convention* and especially *MLC Amendments* in 2014. Since the *MLC* comprehensively deals with seafarer rights, it became the perfect instrument to empower the provision on financial security for abandoned seafarers, which had previously existed only in non-binding international law (IMO resolution A.930 (22)). Mandatory financial security required by the *MLC Amendments* also applies to repatriation in the event of seafarers' abandonment (*Standard* 2.5.2).

A seafarer will be deemed to have been abandoned where, in violation of *MLC* provisions or the terms of the seafarers' employment agreement, the shipowner fails to cover seafarers' repatriation costs, or leaves the seafarers without necessary maintenance and support, or in some other way severs his ties with the seafarers, including the failure to pay contractual wages for a period of at least two months.

A number of ambiguities and the vagueness of *MLC* financial security provisions have been limited in business practice, especially thanks to *P&I* Clubs which have demonstrated their inevitability when it comes to protecting the interests of shipowners and their seafarers.

International Group of Protection & Indemnity Clubs is an unincorporated association of 13 independent, non-profit mutual insurance associations. Together, these 13 clubs within the *Group* provide liability cover (protection and indemnity) for approximately 90% of the world's ocean-going tonnage. The clubs within the *Group* jointly addressed the issue of *MLC* implementation, and afterwards the *Group* consulted a number

of key states in order to establish a common approach in providing financial security according to the *MLC*, amongst 80 states who have ratified the *Convention* by now.

All the clubs in the *Group* have agreed to provide their members with the *MLC* certification which confirms that the *MLC* financial security is in place. The club will issue its member two sets of *MLC Certificates*, for repatriation and contractual claims. *Certificates* contain a provision which subjects the insurance to conditions and limitations in the *MLC Extension Clause, 2016*. *MLC Extension Clause* will be considered as an addition to the clubs *P&I Rules* that form standard *P&I* cover. Should the *MLC* event occur, the club will directly indemnify the seafarer.

The clubs will keep records of issued *MLC Certificates* to ships. These records will be available on the clubs' websites, thus providing the flag states and port state authorities with a reliable form of verification as to which ships have needed financial security certification in place and which have not.

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Underwater ROV as Inspection and Development Platform

Marko Vukšić[a], Slaven Josipović[a], Ante Čorić[b], Ante Kraljević[a]

The successful business technical cooperation between the University of Split and the company PLOVPUT LLC yields a very usable, lightweight, maneuverable underwater Remote Operated Vehicle (ROV). The ROV is capable of diving down to 150 m depth. It can carry different remote controlled sensors and tools, and resolve challenging tasks. Primarily ROV's usage is to inspect underwater electrical installation. It is equipped with HD camera and LED lights. An umbilical cable is used to transfer data and electrical power from the surface to the underwater vehicle. The position control was realized using inexpensive PS2 joystick console. ROV's development was mostly carried out by the students of the University of Split (UNIST). The mechanical and electrical subsystems were built and tested at UNIST laboratories. In this paper, ROV mechanical and electrical systems are outlined and basic subsystems are presented.

KEY WORDS
~ Remote Operated Vehicle (ROV)
~ Power supply system
~ Control system
~ Arduino ATmega.

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1. INTRODUCTION

The Department of Professional Studies, University of Split, (DoPS UNIST), aims at enhancing human resources and increasing their capacity to participate in the development of advanced underwater systems. Along with the researchers, the students are highly encouraged to participate in the application of new and emerging technologies particularly during the final exam and diploma thesis preparation.

The main activities of the company PLOVPUT LLC. are the construction and maintenance of the lighthouses and other navigational equipment in the Adriatic Sea waters of the Republic of Croatia. Because of the need to improve the technology of maintenance and safety when performing these activities, the initiative for the development and prototype design of the remotely operated vehicle (ROV) emerged. Excellent business-technical cooperation of DoPS UNIST and the company PLOVPUT LLC. yields initiative to develop the low-cost ROV capable of fulfilling tasks that stand for company PLOVPUT LLC. The Company took over financing the prototyping, while the mentoring and professional support was offered by DoPS UNIST.

The need for a robotic underwater intervention comes in many forms and it is generally driven by specific tasks (Ferreira et al., 2014; Christ and Wernli, 2007). ROV is often used for the underwater tasks that are more safely and easily carried out without the presence of man, i.e. a diver. The principal objective of the new ROV is to serve as cost-effective inspection and development platform for the field-trials of the novel subsystems for the supervision of underwater electrical installations and cables.

The realized ROV is a result of a joint effort of the students from the Department of Electrical Engineering and students from the Department of Mechanical Engineering at DoPS UNIST.

The main effort of the mechanical construction development, testing and production was taken by the Mechanical Engineering Department students, that of the power

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and control systems development was taken by the Electrical Engineering Department students.

The realized ROV is controlled by the operator from the surface by means of the control unit and hand-held joystick that are connected to sub-sea module through umbilical cable. The PS2 joystick was selected because it is an easily adaptable and very intuitive tool for controlling objects in three axes. The umbilical cable consists of power cable, communication UTP cable and video cable.

ROV belongs to the middle-class submersible remote control vehicles, which is equipped with various sensors with the ability to dive up to a hundred and fifty meters. Because of its modular structural design it leaves room for various extensions and components (sonar, robot manipulator, a system of airworthiness compensation ...). It can be easily reconfigured in agreement with specific tasks.

The realized submersible module is equipped with a camera and a variety of sensors and optional tools. In order to illuminate the underwater environment, two high-luminosity dimmable LED lights were installed to illuminate the space in front of camera.

The ROV is equipped with a propulsion that has six degrees of freedom and ensures a precise position control in all three axes.

The entire system is controlled by the surface computer unit and electronic devices, which collect, organize, and send control information to the sub-sea computer unit via the cable using standard communication protocol,

The basic system requirements of ROV:

- Maximum diving depth: 150 meters;
- Maneuverability, six degrees of freedom;
- Total available power submersibles: 1,000 W;
- Standard equipment: Full HD camera, pressure and depth sensor, temperature sensor, penetration of water into dry housing alarm sensor, compass, accelerometer and gyroscope in three axes, surface video monitor;
- Controllability by handheld PS2 controller.

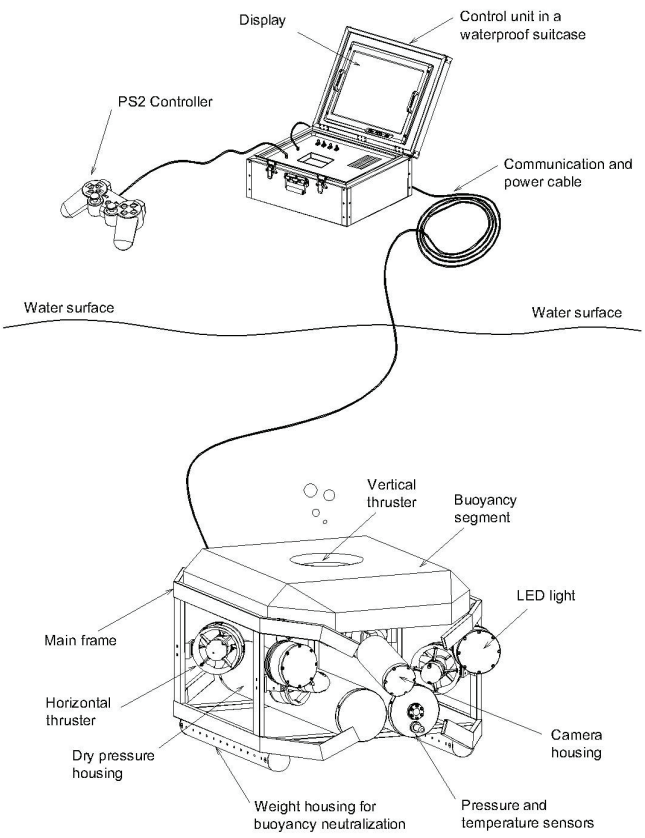

Figure 1.
ROV system.

2. MECHANICAL DESIGN

The underwater vehicle, described in this paper, is an observation class ROV, which is designed specifically for lighter usage with propulsion systems, to deliver a camera and sensor package to a place where it can provide a meaningful picture or gather data (Christ and Wernli, 2007).

ROV construction is self-sustained, stainless steel frame with a buoyancy block made of aluminum. The electrical equipment, camera and LED lights were installed into pressure vessels, sealed with non-transparent and transparent lids respectively. The construction is selected as passively stable. The buoyancy block in turn is designed as internally pressure-compensated vessel. The air pressure to the buoyancy block at sea level is 6bar, thus the net pressure to the block body at the depth of 150 m is 10 bar, reducing the possibility of the block compression.

The system is constructed with a high center of buoyancy and a low center of gravity, to give the camera platform maximum stability about the longitudinal and lateral axis. Roll and pitch movement is minimized by the design. Adjustable lead ballast system located at the bottom of the ROV frame is used to achieve neutral buoyancy, as the opposite uplift force is achieved by the buoyancy block located on the upper side of the ROV (More et al., 2010). The overall vehicle size and the main frame design is a product of optimal space usage around all the important components that include propulsion units, electronic vessels, LED lights, sensors and a camera.

All critical parts of the ROV were subjected to computer-simulated stress tests. This was done by the finite element method analysis using CAD software CATIA. All parts were subjected to pressure loads of 16 bar (150 m) as it is the depth rating (Dobrilo, 2011) defined in the initial requirements list.

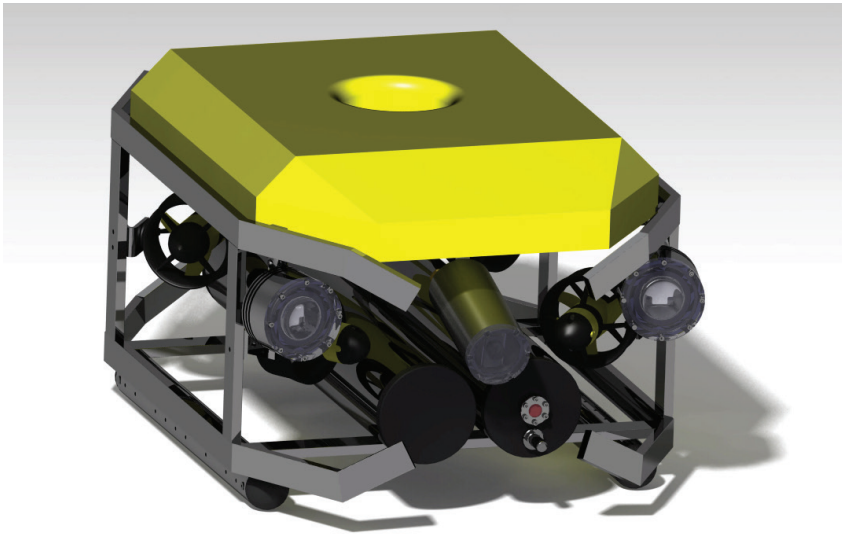

Figure 2.
ROV frame and vessels drawing.

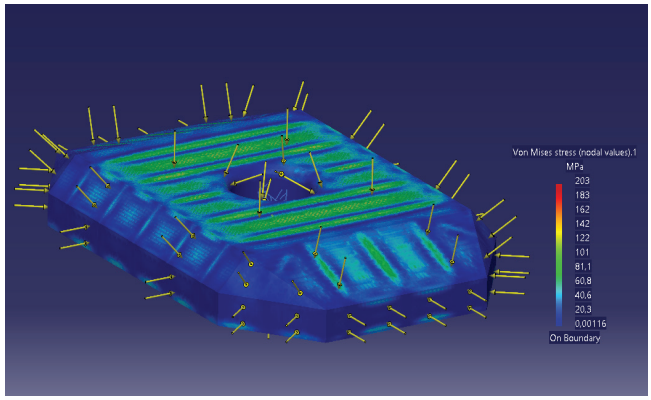

Figure 3.
Buoyancy block finite element method analysis using CAD software CATIA.

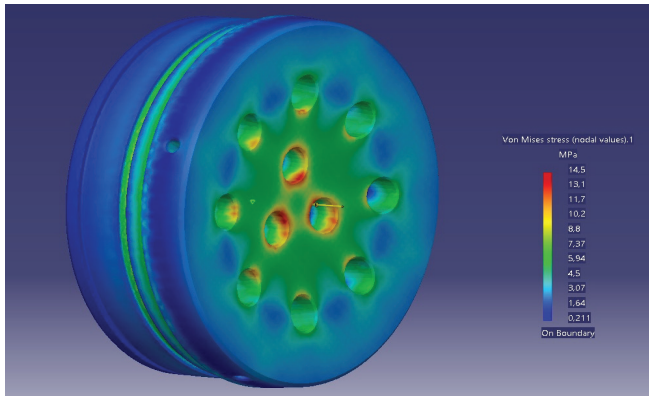

Figure 4.
Simulation of the pressure force applied to the vessel lid.

To achieve high thrust, precise positioning and movement in all directions for the five thrusters are used. The thrusters are DC brushless-motor-driven propeller type. The model used is Bluerobotics T200. Each thruster has the maximum power of 190 W at 12 VDC, and the current consumption of 25 A maximum. The maximum forward thrust force is 5.1 kg, and the reverse thrust force is 4.1 kg.

Two thrusters are used for the forward/backward thrust, two are for the lateral trust and one is used for the vertical thrust.

In this ROV design five Electronic Speed Controllers (ESC) are used to control the five thrusters, their speed and rotation. The thrust force is proportional to the average of the control voltage of the sub-sea microcomputer Pulse Width Modulated (PWM) output applied to the ESC. The ESC deals with the current up to 25 A and of 8-14 V voltage range. The five ESCs are located in the first pressure vessel.

To control thruster speed and rotation direction, the microcomputer program sets a width to the PWM pulses in the range from 1,100 to 1,900 µs. The pulse width of 1,500 µs represents neutral controller position and corresponds to zero thrust power. Lower and higher pulse width corresponds to the thrust power as represented in Figure 5. The rotation direction is also pulse-width dependent. If the pulse width is above the neutral point, the forward thrust is achieved. The pulse width of the 1,900 µs will provide the maximal forward thrust. If the pulse width is below the neutral point, the rotation direction reverses

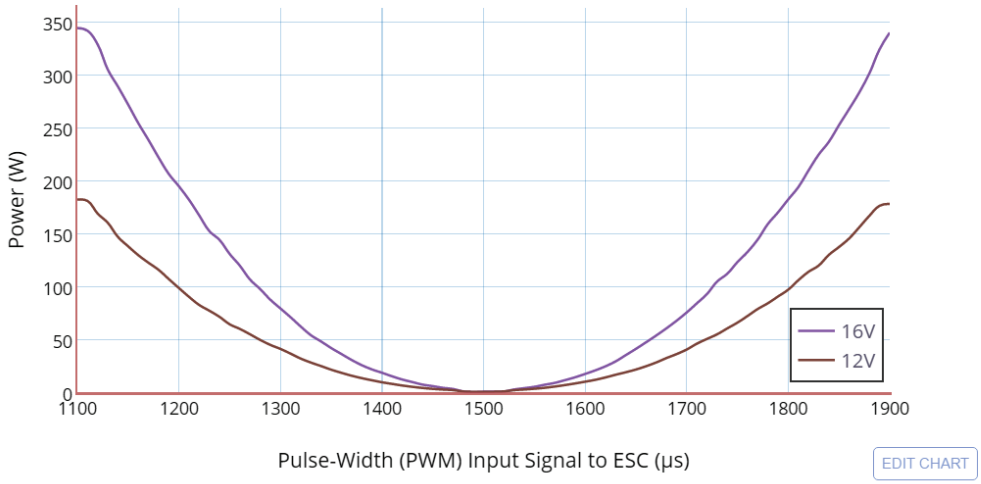

Figure 5.
Thruster power vs. PWM input to ESC.

and the thrust is backward-oriented. The pulse width of 1,100 µs will cause backward maximal thrust.

3. ROV CONTROL AND VIDEO SYSTEM

The control architecture (Figure 6) of the ROV outlined two main modules: the surface computer system and the sub-sea computer system. The computers used for the control system utilization are two Arduino class single board microcomputers (2549Q–AVR–02/2014 Datasheet) equipped with Ethernet shield and digital I/O shield (Figure 6). The aim of the microcomputers is to collect data from the control unit and sensors, and transfer it to the thrusters and the control unit respectively. The digital communication between the two microcomputers is realized using Ethernet network and Ethernet shield installed on board.

As the motion control interface, the PS2 compatible inexpensive joystick is selected to control the thruster power, thruster rotation speed, and rotation direction. Those parameters are determined by the position of the lever on the joystick and the appropriate buttons. The information from the joystick is transferred to the Arduino through PS2/USB interface.

Control knobs and levers on this joystick allow great versatility if additional functionalities are needed later on. The ROV's left and right rotational capability as well as its horizontal linear motion is determined by the position of the right and left levers respectively, while its vertical linear movement is determined by pressing the lever towards the base of the joystick. The joystick generates a series of numeric data corresponding to the positions of the stick and rotatable tab respectively. The data are further transferred from the surface microcomputer to the sub-sea microcomputer using Ethernet (Ferreira et al., 2014) and UDP protocol. UDP is simple "request-answer" protocol. The sub-sea Arduino sends request to the control Arduino. Upon receiving the request, the surface Arduino sends the answer that contains control data. If the data are not regularly received, the sub-sea computer continues to send requests. Similarly, the same process takes place in data transfer from the sub-sea microcomputer to the surface microcomputer.

There are two displays installed on the control box. The first one is a small LCD alphanumeric color display (Figure 8) used for the visualization of the real time sensor data. The second display is a standard 15" color display used for displaying video signal acquired by the sub-sea camera. The video signal transmission is realized by straightforward digital video streaming from the sub-sea camera to the display installed on the control box.

The ROV is equipped with five sensors. The sensors are connected to the Arduino analog inputs. The parameters of interest to be measured are depth, temperature and compass direction. To detect a leak in vessels, each electronic vessel has a pressure sensor which is also connected to the Arduino analog input.

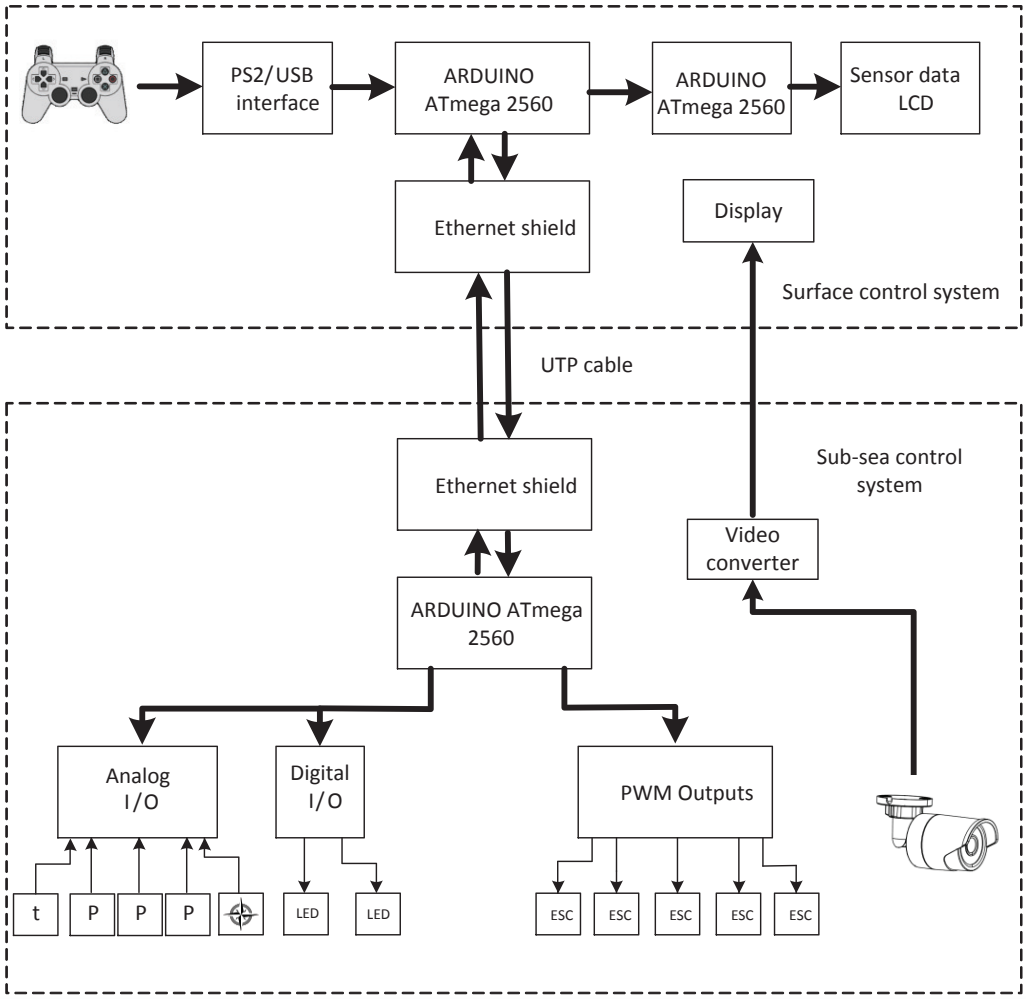

Figure 6.
ROV control and video system layout scheme.

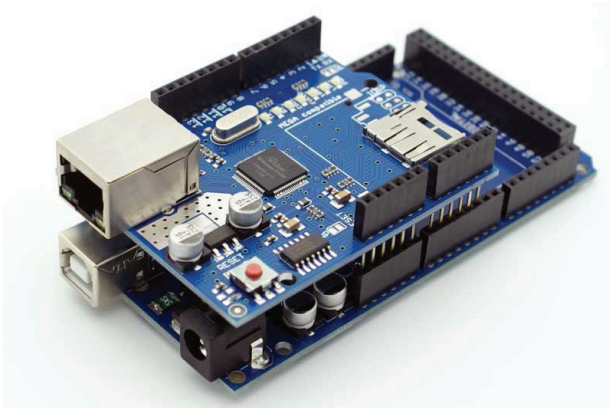

Figure 7.
Arduino ATmega single board computer.

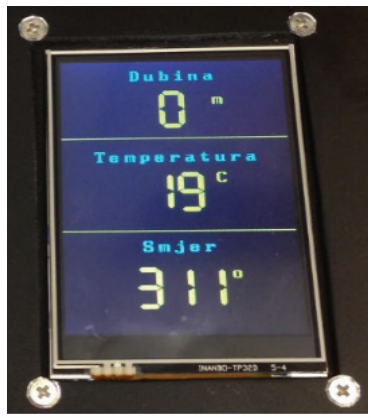

Figure 8.
Key parameters data LCD.

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4. THE ROV'S POWER SUPPLY SYSTEM

The ROV's power system is designed to deliver DC voltage to the control and sub-sea microcomputers, sensors, display, camera and five thrusters from 220V AC mains voltage (Figure 9). The power required by the electronic systems is moderate, and it is approximately 15 W. On the contrary, the power required by the five thrusters is significant. It is considered the worst case when four thrusters simultaneously operate at full power. In that case, the required power is little less than 1,000 W. In order to minimize the copper losses and copper cable cross section, the 100V DC link voltage is selected. Since the ESCs deal with voltage range of 8-14 V DC, each ESC and thruster are powered by dedicated 100/12 V DC/DC switch mode converter. The sub-sea electronics is powered by an additional sixth 100/12 V DC converter. All six converters are located into the second vessel. To obtain the desired power, the two 500 W switch mode AC/DC converters are connected in parallel and installed in the control box. An additional AC/DC converter with 12 V and 5 V outputs is used for powering the electronics. The display has its own embedded converter and is directly connected to the mains.

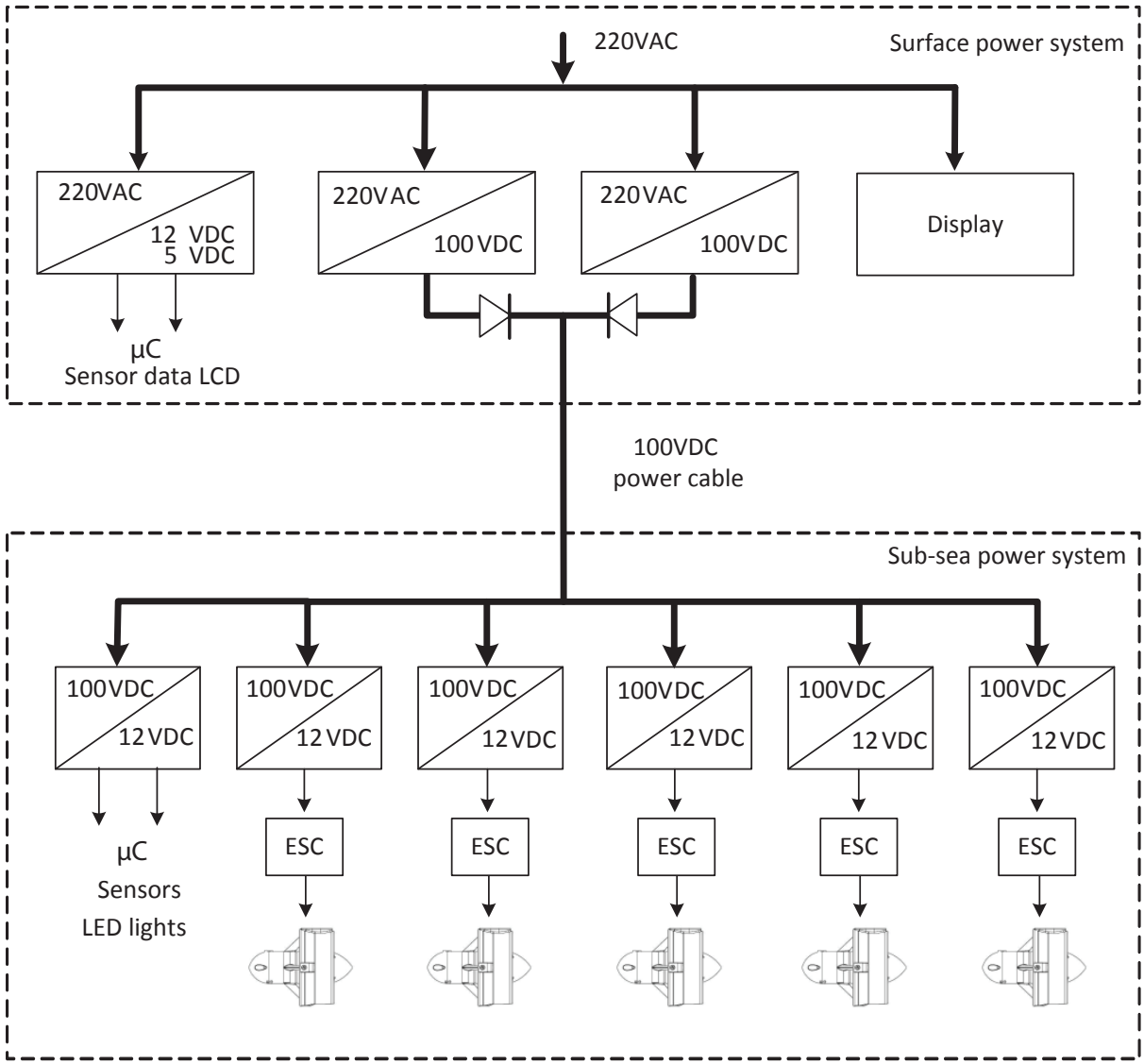

Figure 9.
Power system layout scheme.

5. DESIGN AND IMPLEMENTATION

Drawings and parameter calculation on the steel frame and aluminum buoyancy block were made in house, by the students in the Mechanical Department laboratory. Electronic components, microcomputer, ESCs, thrusters are off-the-shelf components bought on the market. The electrical project and software were written and tested by the Electrical Engineering department students.

The umbilical cable is composed of three different cables. Power cable, UTP cable, and video cable are merged together by plastic clips. The small, support, polyurethane blocks are installed along the cable set to achieve weight compensation and cable buoyancy.

Figure 10.
ROV frame, buoyancy block and vessels.

Figure 11.
ROV during wet testing at the University swimming pool.

The ROV has been wet-tested in the University swimming pool. After that, the ROV passed a few tests in the 150 m-deep sea. The ROV's size is 0.65 x 0.45 x 0.40 m, whilst the total mass, without the cable, is 15 kg.

6. CONCLUSION

In this project, the low cost Commercial off-the-shelf (COTS) components and in-house development were used to utilize the ROV capable of diving down to the depth of up to 150 m. The ROV shows excellent stability and maneuverability. The control software is also in-house-developed by students to meet the hardware needs.

It is a robust and modular underwater ROV with wide functionality. The ROV can be easily customized and deployed in a relatively short period of time.

The future work will be focused on the implementation of the robot manipulator arm and redesign of the umbilical cable. By using high-frequency power line communication system, a single pair of wires can be used to transfer both data and power at the same time. This will simplify the design and further reduce the cost and complexity of the umbilical cable. Such communication systems are under consideration.

The realized ROV platform will be used by the company PLOVPUT LLC. for the sub-sea power electrical cable inspection, and by UNIST as a demonstration of the advanced electrical and control systems.

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Mathematics as a Science and Marine Activity Follow Each Other Throughout History

Tatjana Stanivuk, Stipe Galić, Mia Bojanić

From the earliest beginnings to the present day, there has always been a strong link between mathematics and shipping. Both started developing at about the same time, fulfilling the basic human needs to act and to be creative. The shipping industry has developed throughout the history relatively in line with the development of science, but there have been periods of stagnation in times of great crises and wars. Mathematics, as one of the oldest sciences, is used for various calculations in shipping from shipbuilding to trade, transportation, and management. The safety of navigation, improvement of accuracy in navigation, optimization of costs, higher earnings and profits for ship owners and employees pose only a fraction of maritime affairs, hardly accessible without the knowledge and application of mathematics. Therefore, the aim of this paper is to examine closely the historical development of mathematics and maritime affairs, and to show how the knowledge of mathematics can become a powerful tool in the hands of a seafarer.

KEY WORDS
~ Mathematics
~ Maritime
~ Historical development
~ Seafarer education

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1. INTRODUCTION

The following paper is about mathematics and maritime affairs. Mathematics is an exact science which has evolved for thousands of years throughout history. Maritime activities, which are almost as old, allow a convenient and economical mode of transport of passengers and goods from one location to another.

The link between mathematics and maritime affairs is not reciprocal. While mathematical problems would be resolved even if the activity mentioned did not exist, without the application of mathematical models maritime affairs, as we know them today, would not exist.

An important fact is often forgotten: mathematical laws are all around us and follow us in all aspects of life, even though we often are unaware of them. Without a lot of mathematics, actions and processes, from the most basic to those complex ones, would not be possible.

The history and development of mathematics is not easy to summarize in a few pages, due to its being as old as humanity. The rapid development of modern science often leads us to the question of how it all started.

Maritime affairs stand out as a very important economic activity because they include all the activities related to the sea, thus contributing to the economic development and quality of our lives in general. The development, cohesion and progress of countries from the very beginning until the present day have largely depended on the use of sea routes. The importance of maritime affairs stems from the fact that the life and development of the modern world are directly conditioned by the international trade and transport of goods. Therefore, the sea as traffic route has a monopoly position.

Modern maritime affairs require an understanding of their formation and implementation, as well as the application of exact mathematical science in such a progressive and demanding

technological progress of electronic and IT devices, such as those used on board ships.

2. MATHEMATICS AS A SCIENTIFIC DISCIPLINE

2.1. Mathematics

From the practical point of view, mathematics is a science that studies amount (numbers), structure, space and change. There are different viewpoints among mathematicians and philosophers as regards the definitions of mathematics (Steen, 1988).

Statisticians-mathematicians look for samples, and use them to create new assumptions. They check the accuracy of assumptions with the help of mathematical tools. When the mathematical model of observed events has been built, its application can provide an accurate approximation of future similar events. Using uncertainties and logic, mathematics was created from counting, calculation and measurement, and the systematic study of shapes and movement of physical objects. People used mathematics even before the appearance of the first written records about it. Solving mathematical problems may require years or even centuries of uninterrupted testing and research.

Firm arguments first appeared back in the ancient Greek mathematics, most in Euclid's elements. Mathematics developed slowly until the Renaissance, when mathematical innovations along with new scientific discoveries led to a sharp increase in the number of mathematical discoveries whose increase has continued until today. (Đula, 2014; Ramana, 2007; Schleicher and Lackmann, 2011). Since the initial researches of Giuseppe Peano, David Hilbert and others, which were related to the axiomatic definitions in the late nineteenth century, it has become common to observe mathematical research as establishing the veracity through vigorous seizure of selected axioms and definitions. Galileo Galilei said: "*We can't understand the universe until we learn the language and grasp the symbols in which it is written*". It is written in the mathematical language, and the letters are triangles, circles and other geometric figures, without which it is impossible to understand a single word. Without them, man will wander as in a dark labyrinth. Carl Friedrich Gauss called mathematics "Queen of all the sciences". Benjamin Peirce claims that mathematics is "*Science that comes to the necessary conclusions*". David Hilbert said about mathematics: "*We are not talking about arbitrariness in any form. Mathematics is not like a game whose tasks are determined with arbitrarily written rules. In fact, it is a conceptual system of possessing internal necessity that may be so, and only so*." Albert Einstein said that "*As long as the mathematics laws are associated with reality, they are not certain; and as long as they are certain, they are not associated with reality*". French mathematician Claire Voisin states: "*There is a dose of creativity in mathematics, and that is all related to the movement that is being expressed*" (Devlin, 1996; LaTorre et al.; du Sautoy, 2010).

2.2. Geometry

Geometry (from the Greek: γεωμετρία; geo- "earth", -metron "measurement") is a branch of mathematics that deals with the problems of forms, sizes, and relations between figures, and properties of the space. In many early cultures, geometry appeared as an independent scientific discipline of lengths, surfaces and volumes. By the 3rd century B.C., geometry was in the axiomatic form, as formed by Euclid, whose work "*Euclid geometry*" set the standards for many future generations (Turner et al., 1998). Archimedes gave ingenious techniques for calculating the surface area and volume, which in many ways preceded today's integral calculus. The field of astronomy, especially because it is related to showing the positions of stars and planets on the celestial sphere and describing the interrelationship and movement of celestial bodies, served as an important source of geometric problems in the following 1500 years. In the ancient world, they were considered as part of quadrivium, a subset of seven liberal arts which every man was expected to know.

With the introduction of the coordinate system by René Descartes and the concurrent development of algebra, a new stage of geometry started, considering the fact that since then, the shapes such as a plane curve could be analytically presented in the form of functions and equations. This played a key role in the appearance of infinitesimal calculus in the seventeenth century. Furthermore, the prospect theory proved that geometry was not just the measurement of characteristics of bodies, and it represented the origin of projective geometry. The subject of geometry is complemented by studying the internal structure of geometric bodies, which are a result of Euler and Gauss, and the creation of differential geometry.

In Euclid's time, there was no clear distinction between the real 3D space and coordinate system. Since the discovery of non-Euclidean geometry in the nineteenth century, the idea of space underwent a radical change and posed the question: Which coordinate system best describes the real 3D space? With the advent of formal mathematics, "space" has lost its intuitive content, so that today we must distinguish between physical space, geometric space and abstract spaces. The modern geometry considers new types of space, more abstract than the famous Euclidean space with which they hardly have anything in common. These spaces can be supplemented with additional bands that allow observation of length. Furthermore, the modern geometry is strongly associated with physics. One of the newest theories of physics, string theory, also comes from geometry.

While the visual nature of geometry makes it more accessible than other mathematical branches such as algebra

or number theory, geometric language used within text differs significantly from its original meaning. Geometry is divided into planimetry, stereometry, trigonometry, analytic geometry and differential geometry (Hilbert, 1992; Kneebone, 1963; Renate et al., 2012).

2.3. Trigonometry

Trigonometry (from the Greek words *trigōnon* for triangle, and *metron* for measurement) is a branch of mathematics that studies the relationship between the length and angles in triangles. It was created in the 3rd century B.C. from the geometric study of astronomical objects.

The astronomers then first noticed that the side lengths of a right triangle and the amounts of angles between the relative sides had fixed relations, and that is, if at least one side and one angle are known, the values of all the other sides and angles can be determined through logarithms. These calculations were soon defined as trigonometric functions and are still the foundations of pure and applied mathematics: the basic method of analysing these, e.g. Fourier transformation, or wave equation, using trigonometric functions to understand the cycle changes through the application in many different fields such as physics, mechanical and electrical engineering, music and acoustics, astronomy, ecology and biology. Trigonometry is also the basis of various tests.

To put it simply, trigonometry is associated with planar rectangular triangles. The possibility of application of oblique triangles exists but, due to the fact that any non-rectangular triangle can be divided so as to create two rectangular triangles, most of the problems can be reduced to calculations of rectangular triangles. Therefore, most of the applications relate to rectangular triangle. One exception to this rule is spherical trigonometry, science that studies triangles on the sphere, the surface of constant positive curvature, in elliptical geometry (basic part of astronomy and navigation). Trigonometry on the surface of negative curvature is hyperbolic trigonometry. The basics of trigonometry are often studied at school as a separate subject, or as part of basic mathematics.

The number of applications of trigonometry and trigonometric functions is very high. For example, triangulation technique is used in astronomy to measure the distance to close stars; in geography it is used to measure distances between landmarks, and it is also used in satellite navigation systems. The sine and cosines functions are the basis of the theory of periodic functions, such as those that describe sound and light waves.

The fields in which trigonometry and trigonometric functions are used, are: astronomy, terrestrial navigation, music theory, sound synthesis, acoustics, optics, electronics, probability theory, statistics, biology, medicine, pharmacy, chemistry, theory of numbers, seismology, meteorology, oceanography, many physical sciences, land surveying, architecture, economics, computer science, cartography, crystallography and game development (Bojanić, 2014; Mura, 1993; Sorić, 2014).

3. MARITIME AFFAIRS

3.1. About Maritime Affairs in General

Maritime affairs are activities that can be defined in the broad and narrow sense of the term (Schleicher and Lackmann, 2011). In the narrow sense, maritime affairs refer to the art of navigation and management skills, and maneuvering ships. In the broader sense, maritime affairs include all the activities related to the exploitation of the sea and coastal zone, in the direct or indirect way. The activities implied by the term *maritime affairs* are: trade and shipping, shipbuilding, port activities, tourism, naval activities, and the maintenance of ports, canals and security infrastructure. In addition to the above mentioned, there are many activities that would not be possible to run without maritime affairs; fisheries, aquaculture, various forms of exploitation, such as the exploitation of oil and natural gas.

The basic prerequisite for the existence of maritime affairs are waterways, among which the most important is the sea. It links all the continents and represents the cheapest form of transport because the construction infrastructure of a waterway is not required.

The states that do not have access to the sea are in various ways dependent on the countries that do. Thus, a permission to use the transit ports is a solution to be provided with the best possible contracts.

Maritime affairs include the knowledge of different activities and development of specialized skills, such as navigation. It is necessary to know the International Maritime Code; time, meteorology and weather forecasting, handling of ships and boats, handling equipment on deck, anchors and cables, work with ropes, engines, communications, sailing, survival at sea, search and rescue. Also, among the essential activities on board, cargo handling equipment and handling of dangerous cargo, conduct in emergencies, especially fire-fighting, should be mentioned.

There are many opinions about when the development of maritime affairs started, but the only certain thing is that it has been developing since the beginnings of mankind, and has arisen from the need of people to exploit the sea and coastal areas (Schleicher and Lackmann, 2011). According to the archaeological findings, the first simple boats were built in the Neolithic period.

The chronological development of maritime affairs can be divided into four phases: the first stage is maritime affairs in the ancient times to the 6th century; the second phase includes the Middle Ages, from the 6th to the 15th century; the third phase is

the time of great geographical discoveries, from the 15th to 19th century; the modern era of maritime affairs covers the period from the 19th century to the present.

The first ancient civilizations that have developed maritime affairs were the Egyptians, Phoenicians, Cretans, and Greeks. After that, a significant role was played by the Romans, who were the only ones in history that managed to control the entire Mediterranean. Then began the development of shipping, shipbuilding, and fisheries. The most influential port of that era was Alexandria. In the ancient times, there were trade ships that sailed using wind power, and warships that were propelled by oars.

During the Middle Ages, especially after the discovery of the compass, maritime affairs flourished. Navigation was mainly based on the knowledge of the oceanographic characteristics and geographical features of the coast, with the help of nautical charts (terrestrial navigation).

During the great geographical discoveries, the focus of European and international maritime affairs moved from the Mediterranean to the Atlantic. The first Portuguese and Spanish colonies in the world were established, and it led to the development of intercontinental connections that changed the economic and social picture of the world and encouraged large population migrations.

3.2. The Development of Modern Maritime Affairs

At the very beginning of the development of maritime affairs, the main objectives were to find shorter and safer maritime routes, and to determine geographical location, and other important components of orientation and navigation, in the most reliable way (Poparić, 1932). One of the major issues in which all of Europe's leading scientists were engaged was the determination of longitude with direct application in maritime affairs. This problem was completely solved after 1728, when John Harrison invented the chronometer, clock that is accurate enough to be used as a portable time standard on vehicles, in this case on board a boat.

Great efforts were invested in finding the Northwest and Northeast Passages through the Arctic Sea, to cut the distance between Europe and the Far East and the Pacific coast of North America.

Although the knowledge of geographical and oceanographic features of newly discovered areas was much broader, the basic technology of maritime transport has not changed for thousands of years. The fixed assets were boats driven by sails.

The Industrial Revolution was characterized by the construction and application of the steam-powered ships. Steam-powered ships gradually replaced sailing ships because of better maneuverability capabilities and greater capacity, and also the ship's propeller appeared in 1827.

The excavation of the Suez Canal in 1869, and the excavation of the Panama Canal in 1914 had great significance for the development of modern maritime affairs.

Steamships allowed the establishment of a regular and relatively fast intercontinental connections in the passenger and freight traffic. With the tramp trade, liner trade also developed, which especially influenced the economic unification of certain parts of the coast. Great progress has also been made in the passenger maritime transport. In the 20th century steam-powered ships were gradually replaced with ships powered by diesel engines, and since the mid-20th century some warships and icebreakers have started using nuclear drive.

During the 20th century, freight traffic rapidly grew, especially the transportation of raw materials such as oil, coal, and iron ore. Therefore, larger ships were built, especially tankers and bulk-carriers, whose capacity exceeded 500,000 DWT.

Today, with daily developments in technology, new techniques are applied, integrated, and multi-modal transport develops, various specialized ships for the transport of general cargo (container, ro-ro ships, LASH ships) are built. Accordingly, ports and terminals also change.

4. MATHEMATICS AND MARITIME AFFAIRS

Applied mathematics is a branch of mathematics that deals with the application of mathematics in other scientific fields, inspires and finds use of new mathematical discoveries, which has led to the development of entirely new mathematical disciplines, such as statistics and game theory. Mathematicians also deal with pure mathematics, i.e. mathematics at the service of mathematics, without considering its application. There is no clear boundary between applied mathematics and pure mathematics, and often a practical application for discoveries that began as pure mathematics is found, e.g. in maritime affairs.

Maritime affairs can be defined as an activity including all actions either directly or indirectly connected with the sea. Maritime affairs include not only marine navigation and the conduct of ships, but they also combine the concepts of ships, workers, and companies across the shipbuilding industry to trade, transport and management. Mathematics, one of the oldest sciences, is used to calculate many, already mentioned items in shipping. The stability of a tossing boat, and financial budget applications in navigation are only a few problems that are solved with the help of mathematics. The safety of navigation, improving navigation accuracy, optimizing costs and how ship owners and employees in the maritime affairs make more revenue and profit, are only a fraction of maritime affairs which is

impossible to approach without the knowledge and application of both maritime affairs and mathematics.

Trigonometric functions appeared in the post-classical Greek period (2nd century B.C. – 5th century A.D.) from the requirements of astronomy. So, first appeared the practice, and then the theory: something was mathematically introduced because something was needed. It was only in the late Middle Ages and the Renaissance that the complete trigonometric theory was set up. In fact, even spheres were a lot more elaborated than plane trigonometry, and the latter was generally used only to the extent required to understand spherical trigonometry. The unknown dimension, tilt angle in mathematical and technical calculations can be determined using trigonometric functions, which is of great importance in solving a number of practical, and not just theoretical problems. Precisely, this importance is reflected in the application of trigonometric functions in the maritime affairs. Mathematicians took more than two millennia to make a leap from the definitions of trigonometric functions to their application, and it will take another two millennia until a similar leap occurs.

Differential equations as part of numerical mathematics, are mostly used for numerical finding and improving the algorithms for calculating the value related to mathematic analysis. In the maritime affairs they are widely used, but the most important is the application in the calculation of the movement of ship on the sea, or in the linear theory of waves. The main aim in maritime affairs is to transport cargo, and to deliver that cargo, ships need to withstand heavy seas, and stress and strain of construction on the waves. Differential equations are also an integral part of the loop of all computer software for navigation aids, such as radar, GPS, and alike.

Minor branches of mathematics are used by all the people every day, throughout life. Mathematics and solving mathematical problems stimulate human thinking, the development of logic and logical conclusions. The development of maritime affairs relies on vessels that are growing in size, as agile and fast as possible. In achieving this goal, mathematics has an important role. With the development and expanding of mathematical formulas, optimal goals in maritime affairs are reached.

It is simply impossible to list all the places, dates, parts where mathematics and maritime affairs meet. It is sufficient to say that there is an unbreakable bond between them, and that maritime affairs cannot do without mathematics.

5. CONCLUSIONS

Despite the fact that the foundations of mathematics were set up in ancient times, practical application in marine affairs (and consequently their further development) did not in the full sense come to life until the period of great discoveries, i.e. only when the economic point of view achieved its peak (oil, a large number of employees, huge amounts of money in circulation).

The availability of knowledge as a privilege of the minority caused the misconception and an often destructive access to it by the majority faced with the unknown. Throughout the history, it used to be a limiting factor in the development of science, in which mathematics was no exception either. In this context, trigonometry, with its invaluable application in the maritime affairs, can be taken as a good example.

Mathematical laws are all around us and accompany us in all the aspects of life, although we are often unaware of the fact. So, in shipping it should be emphasized that mathematical problems would be handled even if maritime affairs as human trade did not exist, but maritime affairs without mathematics, the way we know it today, would not be possible. The maritime sector underwent a historical development relatively in line with the development of mathematical science, but there were also periods of stagnation in times of major crises and wars.

Maritime training should be adapted to the modern maritime industry. With the development of technology, society and science, the differences that existed in the education of young seafarers in the past and at present are larger, but the essential role of mathematics in maritime affairs remains unchanged. Mathematics is applied throughout the world as an essential tool in many fields, including natural sciences, construction, medicine, finances and social sciences. Knowledge of mathematics is a fundamental tool in all technical sciences. In maritime affairs it starts from the most basic, construction of a ship, where different budgets are needed and present many mathematical dilemmas about only one question. This continues to calculating time, route, course, distance, position in navigation, to the budget related to cost-effectiveness of transportation of a certain cargo, or the stability of a ship. There are countless examples of routine, everyday actions that sailors in their work perform without having knowledge that the basis of all lies in mathematics.

The rapid development of information technology, e.g. in modern marine systems, requires well-trained seamen to familiarise with an increasing number of various programmes needed for a safe navigation. Today, when modern technology is advancing at high speed, and with the help of Internet, information is available at any time and any place, navigation has also been made much easier. Paper charts have been replaced by electronic charts with better marked routes, hazards and aids; position is calculated with the help of modern GPS devices. Any movement of the ship is planned in advance, as well as all the other activities related to cargo, crew and security. But a small thing, such as a voltage drop on board, or other emergencies lead back to the beginning: paper charts, drawing and calculating. Therefore, it is necessary to familiarise young seafarers through their education with the "alternative" and "outdated" methods of

navigation because, even if technology is considered reliable and accurate, one cannot always rely on it. After all, the background was human knowledge because without it, the development of technology would not have happened.

Options for a further development and improvement of maritime affairs are endless. Every day new ideas appear and are waiting for their realization. Still, maritime affairs are an activity for which it can safely be said that it will never disappear, because it is the most economical mode of transportation of different cargoes and passengers using all the waterways in the world without the need for construction of expensive infrastructure, which for example is required in rail or road transport.

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Information Model for Global Seaborne Shipping from 2010 to 2020

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The research has focused on the development of the global seaborne shipping market from 2010 to 2020. The analysis and assessment of the relevant variables of the model and the resulting growth rates have been aimed at a scientific formulation of the research findings and have been used to describe the most important theoretical principles governing the global seaborne shipping market over the defined period of time.

The basic hypothesis has been confirmed through the direct growth rates of the selected model variables. In this way a scientific confirmation of the hypothesis has been provided: "On the basis of scientific insights into the global seaborne shipping market, it is possible to suggest a new information model for the development of the global seaborne shipping market for the period 2010 – 2020."

KEY WORDS
~ Seaborne shipping
~ Freight rates
~ Shipbuilding
~ Economy.

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1. INTRODUCTION

Trends in seaborne shipping depend upon the rate of economic development, economic structure, and political situation in the countries that participate in the international maritime trade. The economic growth of the most developed countries is tightly related to the current state of the most cost-effective shipping routes. The busiest seaways follow the shorelines of Asia, Europe, and the eastern coastlines of the USA. The basic hypothesis of this research assumes that scientific insights into the global maritime market can enable the design of a new information model for the development of the global seaborne shipping market for the period 2010 – 2020. The research involves a number of scientific methods, among which the most relevant are analysis and synthesis, induction and deduction, descriptive, comparative, statistical, and mathematical methods, method of model drawing (growth matrix), and methods of proving and refuting.

Prior to drawing up a model for the global seaborne shipping market and calculating the relevant direct growth rates, the critical variables of the model need to be set. The design of the model is based upon the following variables: Global economy, Globalisation, Freight rates, Tanker trade, LNG trade, Bulk trade, Container trade, Passenger trade, Shipbuilding, and Innovations in maritime shipping. Values of the selected variables have been entered into the model on the basis of mental-verbal insights into the global maritime market. Calculation of the direct growth rates allows tracing of the changes in the variable growth intensity and structural relationships among the variables. Finally, a scientifically founded verification of the basic scientific hypothesis of this discussion is presented.

2. GLOBAL SEABORNE SHIPPING MARKET

Global seaborne shipping market can be defined as the global market of maritime shipping and shipbuilding. The demand on the global market of shipping capacity depends on the international seaborne trade, while the supply is defined by the world merchant fleet. In maritime shipping business, the main revenues are provided through freight rates, i.e. through the price of seaborne shipping service. This is the primary mechanism that encourages the shippers' investments in the business (Vidučić, 2011).

2.1. Global Economy

In the early 2010 the world economy stood better than expected, but gradually got weaker towards the end of the year. Deterioration of the global economy and adverse trends in Europe's economy affected the developing countries, but their growth rates remained high so that these countries became increasingly important for the overall growth of the global economy (Udruga pomorskih kapetana – glasnik udruge web page, 2012). However, predictions about the trends in global maritime shipping remain difficult and unrewarding (Glavan, 1992). A summary of forecasts for the global seaborne shipping leads to the assumption that the environment protection costs will increase due to construction of the eco-friendly tonnage, that the price of gas will affect the decisions associated with investments in alternative fuels, that the relationship between GDP and maritime shipping demand will change, and that the unexpected events (e.g. political circumstances, such as recent events in Russia and the Near East) will be crucial (DNV web page, 2015). Around 90 % of the foreign trade of the USA, European Union, and developed Asian countries is performed by sea and through seaports. As the global trade rises, the seaports handle more and more cargo. The trend will slightly grow by 2020. A study carried out by the Finnish Ministry of Transport and Communications in January 2005 predicted that the export from the EU to the fast growing economies (Russia, India, China, and other Asian countries) would triple, and the import would double by 2030 (not including energy products) (Kunda, 2013).

2.2. Globalisation

It is unrewarding to try to comprehend the overall impacts of globalisation but, looking from today's perspective, it is very likely that the effects might include "prevailing of the existing national borders, decline of sovereignty of the states-nations, and establishment of global and supranational associations that would take over the regulatory and other functions in the global economy and society" (Puljiz, 1998). Globalisation is a process developing beyond national borderlines, leading to economic, political, cultural, ecological, and information activities across the world and resulting in the global interdependence of the society. It strongly affects the development of maritime shipping in an interactive way. Maritime shipping might be regarded as an instrument of the process (Stopford, 2003). Global trends involve deregulation and abolition of national barriers, thus affecting seaborne shipping as well. The World Trade Organisation (WTO) has launched a process of liberalisation of trade and deregulation of maritime shipping. The liberalisation has resulted in the increased use of flags of convenience, open registers of shipping, and outsourcing. Specialisation in individual segments of seaborne shipping enables the outsourcing and off-shoring of management functions in all geographic combinations. The process of globalisation has encouraged the transfer of registryof vessels, from national to open registries. It is assumed that half of the world merchant fleet flies flags of convenience. Future agreement on free trade between the USA and EU is also part of the globalisation process. The agreement will increase the flow of goods by sea, across the Atlantic Ocean (European Commission home page, 2015).

2.3. Freight Rates

The global crisis that started shaking the worldwide economy in 2008 was the most severe crisis since the Great Depression in the 1930s. It hit hard the seaborne trade. Freight rates plunged, banks reduced financing of the maritime trade, orders were cancelled, and a number of renowned shippers disappeared from the market (Stopford, 2009). Most shippers responded by using economical sailing speeds and adjusted their shipping schedules accordingly. Reduced fuel consumption helped to mitigate huge oscillations in fuel prices on the global oil market. The economical speed is about 20 % less than the full speed used before the economic crisis (Mitrović, 2006). The year of 2010 experienced low freights and surplus shipping capacity. However, by the end of that year the global exchange of goods increased by 5% and was 6 % higher than before the crisis. The worldwide tonnage grew by 9 %, i.e. 120 million dwt. By February 2012 the downward trend in freight rates continued and reached only 36 % of the rates before the crisis, while the price of second-hand vessels fell by 3 %. In February 2012, heavy fuel oil prices reached record values, skyrocketing to over 700 USD/t. The combination of high fuel prices and low freight rates caused financial troubles for all shippers. Due to requirements for finding balance between the worldwide tonnage and shipping demand, changes for the better are expected in the years to come. In 2013, the highest growth of freight rates was experienced in bulk and container trade. Seaborne trade in 2014 was better than ever but the shippers coped with surplus capacities of the ships that had been commissioned by 2008, in the time of high freights, and with reduced demand from China. In February 2015, the Baltic

Dry Index (BDI) that follows the freight rates of dry bulk cargo such as coal, iron ore and grain over 20 shipping routes, reached the all-time low of 509 points. In March 2015 the freight index rose by 1 point to 598 points (a 0.17 % increase) in the segment of Panamax and Supramax ships, while for Capesize ships the index rose to 455 points, i.e. by 7 points or 1.56 %. Daily earnings of Capesize ships carrying 150.000 tons of bulk cargo, such as iron ore, rose from 2800 US dollars to 4320 USD. [17] The growth of national and international maritime trade is expected by 2017, and this should result in higher rates (Zelenika, and Pupovac, 2000). They will probably grow slowly through 2016 and 2017, but are expected to increase considerably afterwards (Hellenics Shipping News web page, 2015). TRANSvisions forecasts that by 2050 the freight rates will have reached higher values than in 2009.

2.4. Tanker Trade

Tanker trade did not experience major employment problems in 2010 because Asian economies continued to grow (somewhere even above 7 %). The economies of the USA and EU were also on their way of recovery. The development of the tanker trade was affected by the general growth of the worldwide economy during 2013. The key factors included high oil prices (averaging more than 100 USD per barrel for the third year in a row), demography, geopolitical uncertainty, energy efficient technologies, and changes in supply/demand related to traditional US markets. In 2013, lower amount of crude oil was imported in the USA, while the country exported more refined oil products at the same time (Columbia River Log Scaling & Grading Bureau home page, 2015). Fast growing economies, like China and India, have become major importers of oil, with immense plans regarding the expansion of their refinery capacities. All these factors positively affected the development of tanker shipping (Cerović and Bašić, 2008). Towards the end of 2014 the prices of newbuild tankers slightly decreased (the three-month trend) and were around 0.5 – 1 % less than in August 2014. Tanker freight rates were falling since October 2014, from an average of 80,000 USD/day (Suezmax and VLCC tankers) to around 44,000 USD/day for Suezmaxes and 55,000 USD/day for VLCCs, whereas in Aframax segment, the rates dropped from 60,000 USD/day to about 32,000 USD/day. Meanwhile, freight rates in product tanker segment were growing since October 2014: for MR Handymax tankers the rates increased from 20,000 USD/day to 23,000 USD/day, for Handysize tankers from 22,000 USD/day to 29,000 USD/day, and for Panamaxes from 22,000 USD/day to 25,000 USD/day. In the segment of 20,000 dwt chemical tankers fitted with stainless steel tanks, the freight rates remained stable in 2014 and early 2015, amounting to around 14,000 USD/day. (Hrvatska brodogradnja jadranbrod d.d. home page, 2015). It is expected that the near future will see a slight growth of tanker trade, with crude oil supply increased by 1.2 % and oil product supply increased by 3.6 %. The USA is expected to remain the key player on the market. Other essential aspects include the expected reduction of export from North Africa due to civil unrests and relatively poor infrastructure. The major shipping routes are expected to change: the currently prevailing shipments from West Asia and West America are likely to be outnumbered by shipments from North America towards Asia, especially China. The latter will undoubtedly continue to diversify its sources of supply. Such forecasts imply the shifting of tanker trade growth from the developed towards the developing economies (Intertanko home page, 2015). The world orderbook for 2015 contains 937 tankers with approximately 75 million dwt, which presents about 15 % of the current tanker fleet. In early 2015, the prices of newbuildings dropped slightly (the three-month trend) and were by around 1 % lower than in November 2014. The reduction was most obvious in the segment of MR tankers (51,000 dwt) – they were cheaper by 1.1 %. (Ostojić, 2014). According to the forecasts of the World Research Institutes from New York, oil production will continue to grow until 2020. After that, the production will be decreasing. Tanker trade market has been under tremendous pressure due to various events associated with oil exploitation and product refinement, so that it is very unrewarding to predict future trends. However, it is expected that this market will remain balanced until 2020, with oil supply mainly running through pipelines from the Near East, Africa and Russia. It is also expected that the import into China and India will be higher in 2020 than it was in 2012 (DNV home page, 2015).

2.5. LNG Trade

During 2010, about 340 LNG carriers performed more than 4000 voyages. In 2011 LNG carriers were busier than in 2010. Nevertheless, the major issue in this segment is whether it is possible to employ these vessels more efficiently in order to, at least, equalise the time when they sail loaded with the time when they fly light. If this could be achieved, the market would not need additional LNG ships until the end of the decade. These vessels are so expensive (currently 200 - 220 million USD for a standard newbuilding) that any decision on commissioning a new ship requires careful reconsideration. In early 2012 there were around seventy newly commissioned LNG vessels and they drove the trade quite close to a glut of LNG tanker capacities. In 2013, global production of natural gas increased by 1.1 %. The USA remained the leading producer. LNG trade growth almost came to a halt as the increased import in America, China, and South Korea was relatively neutralised by cheaper import into France, Spain, Ireland, and Great Britain (RS Platou Economic Research AS, 2014). It is expected that the export of natural gas running through pipelines from the Near East, Africa, and Russia into China and India will increase. Still, it is difficult to predict the

future trends on the LNG market. For instance, fifteen years ago it was forecasted that the USA would import 40 million cubic meters of LNG in 2010. As the year of 2010 was passing, it turned out that the import reached only half of what had been expected. More moderate forecasts predict that the US export of LNG will considerably drop due to political reasons and the nation's own demand for gas. In other words, over the next ten years the US annual export of LNG will not exceed 40 percent of Qatar's current annual export. Even these forecasts are considered as very optimistic. (Tijardović, 2012).

2.6. Bulk Trade

Trends in bulk shipping present the backbone of the international seaborne trade. Presently, the demand is growing rather fast. Following the worldwide 2008-2009 economic crisis, freight rates in the bulk segment plunged in 2010 (DNV home page, 2015). In 2013, bulk shipments amounted to 6.7 billion tons, a 5.5 % increase compared to 2012. There is a wide range of importers on the market. The most important include Argentina, Australia, Brazil, Canada, Indonesia, South Africa, and the United States of America. However, there are smaller importers emerging on the market, as well as new suppliers, such as Liberia, Peru, and Sierra Leone, taking their market share. In the world orderbook for 2015 there are altogether 1,958 bulk carriers with around 163 million dwt (21 % of the current fleet), including 351 orders placed for Capesize vessels (over 100,000 dwt), i.e. 22 % of the current fleet of Capesizes, 400 orders placed for Panamaxes (65,000 – 100,000 dwt), i.e. 17 % of the current Panamax bulk fleet, and 644 orders placed for Handymax ships (40,000 – 65,000 dwt), which represents 27 % of the current Handymax fleet (Hrvatska brodogradnja jadranbrod d.d. home page, 2015). By 2020, the economies of China, India, and Brazil will continue to strengthen the bulk fleet due to high growth of their annual GDPs. Over the next five years it is expected that China will need bulk carriers for importing raw materials from distant sources. The trade between Africa and Asia will intensify, resulting in the growth of the bulk market. Building of bulk carriers having the capacity over 200,000 dwt is expected. The increased demand of the world elementary industries for coal as the basic energy product results in the increased share of the tramp trade. It is expected that the demand in the segment of tramp trade will grow more intensely than the demand in other market segments (Hrvatska brodogradnja jadranbrod d.d. home page, 2015) .

2.7. Container Trade

Five years ago the container seaborne shipping fleet amounted to 450,053 dwt. Four years ago the fleet capacity rose to 474,846 dwt, while three years ago the container trade capacity amounted to 507,453 dwt. The trend of growth is obvious. After a period of stagnation, it is expected that the container trade market will grow by 6.7 % in 2015. According to the results produced by the research carried out by Clarkson Company, from 1st April 2011 to 31st March 2014 there were 291 orders for post-Panamax and large container ships placed worldwide. It is interesting to note that only five orders were placed with South Korean shipbuilders. The trend started in 2011 by the Maersk Company placing ten orders for super-large container carriers having an average capacity of 18,270 TEU. The United Arab Shipping Company, which provides shipping services for six Near East countries, including Kuwait, placed orders for six 18,000 TEU and eleven 14,000 TEU carriers at the end of 2014 and in early 2015. Meanwhile the Canadian company Seaspan commissioned fifteen 14,000 TEU and twelve 10,000 TEU carriers and plans to purchase 20 more mega-carriers by early 2016. Asian shippers follow the trend. However, it is worth noting here that South Korean shippers did not place orders for large vessels, except for Hyundai Merchant Marine which commissioned five 13,100 TEU container carriers, whereas Hanjin Shipping, the largest South Korean shipping company, did not place any order (UNSCIMEDIA homepage, 2015). Presently, the worldwide orders amount to 3.39 million TEU, i.e. 18.4 % of the current capacity, which is the lowest ratio since 2000. According to the 2015 data, APM Maersk operates most of container carriers – 608 vessels. The Mediterranean Shipping Company, with 505 container carriers, is the world's second-largest shipping line in terms of container vessel capacity. CMA CGM Group has 459 vessels, Evergreen Line 199, Hapag Lloyd 184, Cosco Container 160, PIL (Pacific International Line) 150, CSCL 141, Hamburg Sud Group 114, while MOL operates 112 vessels (Statista – The statistics Portal homepage, 2015). Currently the busiest container routes run from Asia to Europe (14.1 %), from Asia to North America (13.8 %), North America – Asia (7.4 %), Europe – Asia (6.4 %), Europe – North America (3.8 %), and from North America to Europe (2.8 %). By the year of 2020, further strengthening of the Asian and European markets, employment of larger vessels, and new Panamax standards of 12,500 TEU are expected. Vessels whose capacities are less than 1000 TEU will represent a negligible share of the market. It is also expected that, over the next five years, only 4 or 5 out of ten major container shippers will survive.

2.8. Passenger Trade

Passenger trade has considerably recovered after the 2009 depression caused by global recession. The number of passengers booking cruise travels increased steadily, from 15.62 million in 2007 to 21.12 million in 2013. The worldwide cruise ship fleet grew from 2012 to 2013 by 3.3 %, reaching 20.9 million dwt. Global cruise industry earned 36.27 billion USD in 2013. In the period from 2016 to 2018 the Royal Caribbean International is planning to invest in a newbuild cruise ships more than any other shipper (Cruise Industry News, 2015). As the number of passengers

increases every year, it is expected that their number will amount to 24 million by 2018. North America is the leading cruise market. Mintel estimates that the value of the North American market will reach almost 50 billion USD by 2018. Australia is emerging as the second-largest market. Investments in cruise ships will amount to 12 billion USD over the period 2015-2018 (Ship Cruise home page, 2015). China signed the Memorandum of Understanding with the American cruise shipping company Carnival Corporation with the purpose of transfer of know-how and in order to enable China to build large cruise ships. According to Chinese forecasts, by the year of 2020 China will have become one of the major markets for these vessels, with around 4.5 million passengers. The two largest cruise shipping companies, Carnival Corporation and Royal Caribbean Ltd share 71.7 % of the overall revenues from cruise tourism. It is expected that 19 new cruise ships will contribute towards 64,300 passenger capacities by 2018 (Ship Cruise home page, 2015).

2.9. Shipbuilding

There is no telling how many shipyards there were in China, the world's major shipbuilding power, in 2010. Estimations range from 850 to 1500. More than 100 Chinese shipyards were able to produce vessels larger than 30,000 dwt. It was customary to place an order for a newbuilding before a shipyard even existed, because the state provided guarantees. In 2010 there were 400 new buildings worldwide (Izvješće Tankerske plovidbe d.d., 2009). Labour costs in most shipyards currently range from 500 to 1000 USD/CGT. Shipbuilding countries having labour costs over 1000 USD/CGT produce differentiated vessels (cruise ships in Germany, warships in the USA) or disappear from the shipbuilding market (Denmark) (CESA web page, 2010). The world fleet increased by 65.9 million dwt in 2014. When observing the growth over the longer course of time, it can be noticed that the 2014 growth was lower than usual. The 2008 global crisis strongly affected the industry and caused a five-year depression. The trend changed in 2013 and in February 2015 the world orderbook continued to grow. Presently, there are 6.371 orders for newbuild vessels having around 112 million compensated gross tons (cgt), or around 18 % of the current fleet. The quantity of newly ordered ships in the first three quarters of 2014 was larger by 2 million cgt compared to the same period in the previous year, i.e. 2105 ships with 36 million cgt were ordered. The quantity of the delivered ships within the same period was somewhat smaller: the delivered vessels had 28.4 million cgt, which implies a trend of lower demand for newbuild ships, i.e. stagnation on the global market. China ranks first in the number of orders placed for newbuildings and their overall tonnage. This is the first time that South Korea is not ranked first (Research and Markets, 2015).

Table 1 shows that bulk carriers make over 50 % of the world's newbuildings ordered at the end of 2014. Presently, there are about 800 shipyards in China. The designed shipbuilding policy, aimed at solving the overcapacity problems, and at preserving the industry in line with the market principles, will result in the survival of around 50 shipyards. These measures will mostly affect small and middle-sized shipyards. The financing of shipbuilding presents the toughest obstacle to entering the market of high-tech vessels (Vidučić, 2011).

Table 1.
World orderbook, November 2014.
Source: http://www.hb.hr.

Ship type	Quantity ordered	DWT
Bulk carrier	2028	170 mil
Tanker	933	74 mil
Container ship	452	39 mil
LPG carrier	368	18 mil
Cruise ship	28	6 mil

The year of 2013 was a milestone in the market of newbuild and second-hand vessels. From the very beginning of that year it was clear that the activities would intensify on the market due to a drop in the yen and, more directly, due to increased activities on the bulk shipping market. Dramatic changes resulted in filling the orderbooks until the beginning of 2016. The data provided by Intermodal show that more than 2000 orders for newbuild ships were placed in 2013 (Columbia River Log Scaling & Grading Bureau home page, 2015). New regulations regarding the environment protection have been imposed causing an increased demand for new types of vessels able to reduce fuel consumption considerably (Mitrović, 2005).

Commissioning and deliveries of vessels able to reduce their direct harmful impact on the environment will intensify by 2020. These "green" ships are relatively cheap due to the situation in the shipbuilding industry (decline in European shipbuilding and blooming shipbuilding in Asia). Moreover, they are economical because they reduce fuel consumption, which is the highest single operating cost in maritime shipping. Despite the excess capacity of the world fleet, vessels of the new generation have been commissioned. The trend is likely to gradually displace standard vessels out of the market (DNV home page, 2015).

2.10. Innovations in Maritime Shipping

All tanker shippers had to replace their single-hull ships with double-hull tankers by 2010. In 2012, international

regulations required a reduction in sulphur content in fuel to 3.5 %, whereas in 2015 the sulphur content in fuel will have to be further reduced to 0.1 % at the US eastern shores, the North Sea, the Baltic, and the English Channel (La Manche). It is expected that the issues regarding the change of fuel will be solved by 2020. The problems include the loss of propulsion, fluctuation of ship speed at lower loads, difficulties in starting and reversing operations, and inability to reach full speeds. It is expected that, as from 1st January 2020, the sulphur content in fuel will decrease by 0.5 % globally. Alternative means of reducing sulphur emissions will be allowed, including scrubbers and exhaust gas purification systems (DNV home page, 2015). According to DNV Shipping 2020 report, more than 1 in 10 newbuildings will be delivered with gas fuelled engines, the demand for marine distillates could be as high as 200-250 million tonnes annually, newbuildings in 2020 will emit up to 10 to 35 % less CO2 than today's ships, the Energy Efficiency Design Index (EEDI) will be a driver for more than half of the reduction, and ballast water treatment systems will be installed on at least half of the world fleet (EMSA home page, 2015). The recommendations for the shippers adjusting to market changes until 2020 include the optimisation of ship management (passage planning, impact of weather conditions), continuous market monitoring, introduction of cold standby regime during cargo operations and when in port, whenever possible (power supply from ashore), setting and monitoring the efficiency parameters, use of new and more efficient hull paints, replacement of old and worn-out machinery and equipment with new energy-saving products, optimisation of the overall supply chain and fleet distribution (cooperation with cargo suppliers, charterers and agents), implementation of the policy of replacing older ships with eco-friendly vessels, ordering newbuildings that feature efficient construction qualities, suitable selection of human resources, detection of defects and shortcomings and the introduction of necessary changes in the organisation structure of the shipping companies, preparing "green passports", employment of new technologies that are more efficient in terms of energy and ecology (WHR, BWM and equipment, etc.), reduction of fossil fuel consumption and use of alternative sources. Shippers should introduce these guidelines in their development plans (EMSA home page, 2015).

3. DESIGNING THE INFORMATION MODEL FOR GLOBAL SEABORNE SHIPPING MARKET 2010-2020

Quantification of the information model for global seaborne shipping market 2010 – 2020 will result from the qualitative research. The assessment of the variables of the model will take into consideration synergetic effects of the following scientific aspects: scientific theoretical aspects of the individual model variables, values and importance of variables of the model in the observed period, i.e. from 2010 to 2020. The design of the information model for global seaborne shipping market 2010 – 2020 is based on the previously set variables. The variables that are considered critical are: Global economy, Globalisation, Freight rates, Tanker trade, LNG trade, Bulk trade, Container trade, Passenger trade, Shipbuilding, and Innovations in maritime shipping.

It is asserted that the global seaborne shipping market consists of "n" inter-reliant elements. The value of an individual model variable is expressed as y_{if} and y_{it-1} of the *i* variable in the period *t* and *t-1*. An increase of the input value of the *i* variable of the model is expressed as:

$$\Delta y_{it} = y_{it} - y_{it-1} \tag{1}$$

(Vidučić, 2007). An indirect growth rate of the *i* variable, in relation with *j*, is defined as the relation among the input growth of the *i* variable of the information model, Δy_{it}, and the input value of the *j* variable of the model in the period *t*, that is, the indirect growth rate is expressed by the equation:

$$r_{ijt} = \frac{\Delta y_{it}}{y_{it}} \tag{2}$$

where: *i, j*=1, …, n, whereas $y_{it-1} \neq 0$.

The indirect growth rates can be expressed in a form of the growth matrix of the model variables:

$$r_t = \begin{bmatrix} r_{11} & r_{12} & L & r_{1nt} \\ r_{21} & r_{22} & L & r_{2nt} \\ L & L & L & L \\ r_{n1t} & r_{n2t} & L & r_{nnt} \end{bmatrix} \tag{3}$$

where *t*=1, …*t*;

The variables on the main vertical refer to direct growth rates (*i* = *j*). The variables in the *i* row refer to the input growth in the *i* variable in relation to inputs in other variables. The variables in *i* column refer to the value growth of the input in all variables of the model in relation to the input of the *i* variable in the period *t*. Therefore, each variable in the growth matrix is represented by one row and one column, with elements expressing indirect or relative growth relationships. Other rows and columns refer to other variables of the information model for global seaborne shipping 2010 - 2020. If only the direct growth rates are analysed, then the growth of a variable is expressed irrespective of the growth of other variables. By expressing the direct and indirect rates, it is possible to follow both intensity changes of the growth of variables and their structural relationships at the same time.

The quantification of the above mentioned variables, on the index scale from zero to 100, has been performed on the basis of mental-verbal insights into the worldwide maritime shipping market. Zero is the value of the model variables which corresponds to the situation on the seaborne shipping market in 2008, when the global crisis – the most severe crisis since the Great Depression in the 1930s – shook worldwide economies. The value 100 corresponds to the situation on the maritime shipping market before 2008, i.e. when the freight rates index reached its record high. The model comprises the variables quantified for the year 2010, as well as the expected values of the variables for 2015 and 2020.

Table 2 shows the growth value of the model variables: 1. Freight rates (50), 2. Innovations in maritime shipping (30), 3. Bulk trade (25), 4. Container trade (20), 5. Global economy (20), 6. Passenger trade (20), 7. LNG trade (10), 8. Shipbuilding (10), 9. Globalisation (10) and 10. Tanker trade (10).

The research has provided the direct growth rates of the model for global seaborne shipping market 2010 – 2020 (Table 3). The model has provided both direct and indirect growth rates of the individual variables. Because of limited space, the indirect growth rates will not be elaborated in this paper.

Table 2.
Values of the variables of the information model for global seaborne shipping market from 2010 to 2020.

Variables of the information model for global seaborne shipping from 2010 to 2020		Inputs y			Growth
		2010	2015	2020	2010/20
1.	Global economy	60	70	80	20
2.	Globalisation	70	75	80	10
3.	Freight rates	20	40	70	50
4.	Tanker trade	70	75	80	10
5.	LNG trade	60	65	70	10
6.	Bulk trade	40	45	65	25
7.	Container trade	50	60	70	20
8.	Passenger trade	65	75	85	20
9.	Shipbuilding	60	65	70	10
10.	Innovations in maritime shipping	50	60	80	30

Table 3.
Growth rates of the information model of the global seaborne shipping market from 2010 to 2020, on the index scale from zero to 100.

Model variables	1	2	3	4	5	6	7	8	9	10
1	**25,0**	25,0	28,6	25,0	28,6	30,8	28,6	23,5	28,6	25,0
2	12,5	**12,5**	14,3	12,5	14,3	15,4	14,3	11,8	14,3	12,5
3	62,5	62,5	**71,4**	62,5	71,4	76,9	71,4	58,8	71,4	62,5
4	12,5	12,5	14,3	**12,5**	14,3	15,4	14,3	11,8	14,3	12,5
5	12,5	12,5	14,3	12,5	**14,3**	15,4	14,3	11,8	14,3	12,5
6	31,3	31,3	35,7	31,3	35,7	**38,5**	35,7	31,3	35,7	31,3
7	25,0	25,0	28,6	25,0	28,6	30,8	**28,6**	23,5	28,6	25,0
8	25,0	25,0	28,6	25,0	28,6	30,8	28,6	**23,5**	28,6	25,0
9	12,5	12,5	14,3	12,5	14,3	15,4	14,3	11,8	**14,3**	12,5
10	37,5	37,5	42,9	37,5	42,9	46,2	42,9	35,3	42,9	**37,5**

According to Table 3, the direct growth rates of the model variables, on the index scale 1-100, are ranked as follows: 1. Freight rates (42.9), 2. Bulk trade (38.5), 3. Innovations in maritime shipping (37.5), 4. Container trade (28.6), 5. Global economy (25.0), 6. Passenger trade (23.5), 7. LNG trade (14.3), 8. Shipbuilding (14.3), 9. Globalisation (12.5) and 10. Tanker trade (12.5).

Direct growth rates of the model variables will have higher values than their growth (see Table 2, growth 2010-2020), due to synergetic interrelation of all the variables (see Figure 1), as follows: Freight rates (growth 50 ↔ direct growth rates 71.4); Bulk trade (growth 25 ↔ direct growth rates 38.5); Innovations in maritime shipping (growth 30 ↔ direct growth rates 37.5); Container trade (growth 20 ↔ direct growth rates 28.6); Global economy (growth 20 ↔ direct growth rates 25.0); Passenger trade (growth 20 ↔ direct growth rates 23.5); LNG trade (growth 10 ↔ direct growth rates 14.3); Shipbuilding (growth 10 ↔ direct growth rates 14.3); Globalisation (growth 10 ↔ direct growth rates 12.5) and Tanker trade (growth 10 ↔ direct growth rates 12.5).

It is obvious that the greatest difference between the growth value and the value of direct growth rates will change the ranking of the variables compared to the ranking according to the values of their direct growth rates: 1. Freight rates (21.4), 2. Bulk trade (13.5), 3. Container trade (8.6), 4. Innovations in maritime shipping (7.5), 5. Global economy (5.0), 6. LNG trade (4.3), 7. Shipbuilding (4.3), 8. Passenger trade (3.5), 9. Globalisation (2.5) and 10. Tanker trade (2.5).

Taking into account all that has been discussed, it can be concluded that the direct growth rates of all variables of the model for global seaborne shipping market 2010 – 2020 have realistic chances to be implemented. In this way the scientific confirmation of the hypothesis of this research has been provided: on the basis of scientific insights into the global seaborne shipping market, it is possible to suggest a new information model for the development of the global seaborne shipping market for the period 2010 – 2020.

4. CONCLUSION

By the early 2020, the content of sulphur in fuel should be reduced to 0.5 % globally, depending on feasibility studies and tests that have to be carried out by the end of 2018 at the latest. The feasibility tests refer to manufacturers" abilities, i.e. whether the production is able to meet the requirements and demand regarding low-sulphur fuels. If the tests produce negative results, the implementation of the regulations will have to be postponed until 2025. Fuel change is associated with a number of potential problems that require careful consideration.

The research has confirmed the initial hypothesis stating that "on the basis of scientific insights into the global seaborne shipping market, it is possible to suggest a new information model for the development of the global seaborne shipping market for the period 2010 – 2020." The design of the model for global seaborne shipping market 2010 – 2020 has been based on the most relevant variables, including: 1. Global economy, 2. Globalisation, 3. Freight rates, 4. Tanker trade, 5. LNG trade, 6. Bulk trade, 7. Container trade, 8. Passenger trade, 9. Shipbuilding and 10. Innovations in maritime shipping.

The quantification of the model has been performed on the basis of scientific and theoretical aspects of the mental-verbal insights into individual variables and their importance within the observed period, from 2010 to 2020. The research produced direct growth rates of the variables on the index scale from 1 to 100: 1. Freight rates (71.4), 2. Bulk trade (38.5), 3. Innovations in maritime shipping (37.5), 4. Container trade (28.6), 5. Global economy (25.0), 6. Passenger trade (23.5), 7. LNG trade (14.3), 8. Shipbuilding (14.3), 9. Globalisation (12.5) and 10. Tanker trade (12.5).

Taking into consideration all that has been discussed, it can be concluded that the direct growth rates of all variables of the model for global seaborne shipping market 2010 – 2020 have realistic chances to be implemented. This also means that the hypothetical values of all variables of the model have been set realistically.

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CONTRIBUTION

News from IMO
News
Pjesma / Poem
Guidelines

CONTRIBUTION

News from IMO

Tatjana Krilić

This contribution presents a compilation of information on current work of selected IMO bodies in the period preceding the publication of this issue of ToMs. The outcome of IMO bodies responsible for safety and environment protection has been covered, aiming at informing readers on the decisions taken, as well as on the IMO instruments and/or their amendments that have entered into force.

KEY WORDS
~ IMO
~ Safety
~ Environment protection

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INTRODUCTION

Within its mandate, IMO provides the forum for cooperation among Governments in the field of international shipping regulations relating to technical matters. Within this framework, this year's World Maritime Day theme, which is "*Connecting Ships, Ports and People*", should contribute to building on the long standing effort of Member States towards the achievement of those objectives.

The 70th session of the Marine Environment Protection Committee (MEPC) met in London at the IMO Headquarters from 24 to 28 October 2016 and the 97th session of the Maritime Safety Committee (MSC) was held from 21 to 25 November 2016. Selected decisions and outcome of discussions of the MEPC and MSC have been presented in this review, along with amendments to the mandatory IMO instruments that entered into force since the last issue of ToMS.

Whilst news presented in this contribution only highlight the selected topics, complete information on the outcome of various IMO bodies is available in their reports, which can be found on the Organization's IMODOCS website (http://docs.imo.org). More information and highlights on the work of the Organization can be found on its public website (http://www.imo.org), including press briefings and meeting summaries available in “Media Centre” area. In addition, most of the Organization’s technical and operational data, some of which is available to the public, is stored in the Global Integrated Shipping Information System (GISIS), which is also accessible via a public website (https://gisis.imo.org/Public).

70th session of the Marine Environment Protection Committee (MEPC 70)

Adoption of mandatory data collection system for fuel oil consumption

The MEPC adopted mandatory MARPOL Annex VI requirements for ships to record and report their fuel oil consumption. Under the amendments, ships of 5,000 gross tonnage and above will be required to collect consumption data for each type of fuel oil they use, as well as other, additional, specified data including proxies for transport work. The aggregated data will be reported to the flag State after the end of each calendar year and the flag State, having determined that the data has been reported in accordance with the requirements, will issue a Statement of Compliance to the ship. Flag States will be required to subsequently transfer this data to an IMO Ship Fuel Oil Consumption Database. IMO will be required to produce an annual report to the MEPC, summarizing the data collected.

Roadmap for reducing GHG emissions approved

The MEPC approved a Roadmap for developing a comprehensive IMO strategy on reduction of GHG emissions from ships, which foresees an initial GHG reduction strategy to be adopted in 2018.

Energy efficiency of international shipping

The energy-efficiency regulations require IMO to review the status of technological developments and, if proven necessary, amend the time periods, the EEDI reference line parameters for relevant ship types and reduction rates.

Whilst the review is ongoing, updated guidelines for calculation of the EEDI were adopted, as amendments to the 2014 Guidelines on the method of calculation of the attained EEDI for new ships.

IMO was the first Organization to adopt, in 2011, energy-efficiency measures that are legally binding across an entire global industry. Energy-efficiency design standards for new ships and associated operational energy-efficiency measures for existing ships became mandatory in 2013, with the entry into force of the relevant amendments to MARPOL Annex VI. Data received by the IMO Secretariat identifies that so far more than 1,900 ships have been certified as complying with the new energy efficiency design standards.

2020 global sulphur cap implementation date decided

In a landmark decision for both the environment and human health, 1 January 2020 was confirmed as the implementation date for a significant reduction in the sulphur content of the fuel oil used by ships.

The decision to implement a global sulphur cap of 0.50 % m/m (mass/mass) in 2020 represents a significant cut from the 3.5 % m/m global limit currently in place and demonstrates a clear commitment by IMO to ensuring shipping meets its environmental obligations.

Adoption of other amendments to MARPOL

The MEPC adopted the following with an expected entry into force date of 1 March 2018:

- Amendments to MARPOL Annex I to update Form B of the Supplement to the International Oil Pollution Prevention Certificate, in relation to segregated ballast tanks;
- Amendments to MARPOL Annex V related to products which are hazardous to the marine environment (HME) and Form of Garbage Record Book. The amendments provide criteria for the classification of solid bulk cargoes as harmful to the marine environment and are aimed at ensuring that such substances are declared by the shipper if they are classed as harmful and are not discharged.

Implementation of the BWM Convention - Revised Guidelines for approval of ballast water management systems adopted

The Committee welcomed the news that the conditions for entry into force of the International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM Convention), 2004, were met on 8 September 2016 and consequently the treaty will enter into force on 8 September 2017.

The MEPC adopted revised *Guidelines for approval of ballast water management systems* (G8), which update the Guidelines issued in 2008 and recommended application of the revised Guidelines (G8) as soon as possible. The Commitee agreed that BWMS installed on ships on or after 28 October 2020 should be approved taking into account the revised guidelines. Systems installed prior to that date could be approved using the existing guidelines or the revised guidelines.

The revision to the guidelines updates the approval procedures for ballast water management systems (BWMS), including more robust test and performance specifications as well as more detailed requirements for type approval reporting and control and monitoring equipment, among others. The approval should take the form of a Type Approval Certificate for BWMS, specifying the main particulars of the BWMS and any limiting operating conditions.

It was also agreed that the approval process should be made mandatory and the MEPC instructed the IMO Secretariat to prepare the *Code for approval of ballast water management systems* as well as draft amendments to the BWM Convention making the Code mandatory, for circulation with a view to adoption following entry into force of the Convention.

The MEPC also further discussed a number of issues in relation to implementation of the BWM Convention, including the roadmap for data gathering and analysis of experience gained with the implementation of the BWM Convention, as well as developing guidance on contingency measures under the BWM Convention and amendments to the Guidelines for risk assessment under regulation A-4 of the BWM Convention (G7), and made pertinent decisions.

With regards to the dates of implementation of the BWM Convention, the proposed draft amendments to regulation B-3 of the Convention relating to the time scale for implementation of its requirements had been previously approved at 69th session of the Committee (MEPC 69) for circulation upon entry into force of the Convention, with a view to subsequent adoption. The draft amendments would provide for compliance with regulation D-2 (Ballast water performance standard) of the Convention by a ship's first renewal survey following entry into force, however, an alternative proposal put forward at this session would be debated at the next Committee session (MEPC 71) in mid-2017.

The Committee granted Final Approval to one BWMS that makes use of active substances and Basic Approval to one system and noted that the total number of type-approved BWMS stands now at 69.

97th session of the Maritime Safety Committee (MSC 97)

Adoption of amendments

The MSC adopted the following amendments, which are expected to enter into force on 1 January 2020:

- Amendments to SOLAS, including amendments to regulation II-1/3-12 on protection against noise, regulations II-2/1 and II-2/10 on firefighting and new regulation XI-1/2-1 on harmonization of survey periods of cargo ships not subject to the ESP Code;
- Amendments to the 2008 International code on Intact Stability (IS Code), relating to ships engaged in anchor handling operations and to ships engaged in lifting and towing operations, including escort towing;
- Amendments to the International Code for Fire Safety Systems (FSS Code), clarifying the distribution of crew in public spaces for the calculation of stairways width;
- Amendments to the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code), aligning the wheelhouse window fire-rating requirements in the IGC Code with those in SOLAS chapter II-2.

The MSC also adopted the following amendments, which are expected to enter into force on 1 July 2018:

- Amendments to the International Code on the Enhanced Programme of Inspections during Surveys of Bulk Carriers and Oil Tankers, 2011 (2011 ESP Code).
- Amendments to the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) and its related STCW Code, to include new mandatory minimum training requirements for masters and deck officers on ships operating in Polar Waters; and an extension of emergency training for personnel on passenger ships.

Interim recommendations on the safe carriage of industrial personnel adopted

The MSC adopted Interim Recommendations on the safe carriage of more than 12 industrial personnel on board vessels engaged on international voyages.

Governments are invited to apply the Interim Recommendations, pending the planned development of the new chapter of SOLAS and the draft new code addressing the carriage of more than 12 industrial personnel on board vessels engaged on international voyages.

Offshore industrial activities covered by the Interim Recommendations would include the construction, maintenance, operation or servicing of offshore facilities related, but not limited, to exploration, the renewable or hydrocarbon energy sectors, aquaculture, ocean mining or similar activities.

Goal-based standards

Whilst making progress on the proposed amendments to revise and update the GBS Verification Guidelines, based on the experience gained during the initial verification audits, the MSC agreed a revised timetable and schedule of activities for the implementation of the GBS verification scheme, to include a 31 December 2017 deadline for the receipt of rule change information and request for new initial verification audits, if any.

At its last session, the MSC confirmed that ship construction rules for oil tankers and bulk carriers submitted by 12 classification societies conform to the goals and functional requirements set by the Organization for new oil tankers and bulk carriers set out in the International goal-based ship construction standards for bulk carriers and oil tankers (resolution MSC.287(87)), which were adopted in 2010.

Updated SafetyNET and NAVTEX manuals

The MSC approved amendments to update the International SafetyNET and the NAVTEX Manuals, which will be issued as MSC circulars, replacing versions issued in 2010 and 2011.

SafetyNET is the international automatic direct-printing satellite-based service for the promulgation of Maritime Safety Information (MSI), navigational and meteorological warnings, meteorological forecasts and other urgent safety-related messages to ships, as well as search and rescue (SAR) information. NAVTEX provides coastal shipping, via terrestrial means, with similar messages by automatic display or printout from a dedicated receiver.

STCW Manila 2010 – transitional arrangements clarified

The MSC noted that the transitional arrangements for implementation of the 2010 Manila amendments to the STCW Convention and Code end on 1 January 2017. However, there was concern that some Parties may not be in a position to issue STCW certificates in accordance with the requirements of the Convention by 1 January 2017. It was agreed that a practical and pragmatic approach should be taken during inspections, for a period of six months (i.e. until 1 July 2017), to allow flexibility in cases where seafarers are unable to provide certificates that were issued in compliance with the 2010 Manila Amendments and related circular was issued (MSC.1/Circ.1560).

Amendments to mandatory IMO instruments that entered into force

Inter alia, the following two new codes took effect upon entry into force of related amendments to relevant conventions on 1 January 2017:

Polar Code - International Code for Ships Operating in Polar Waters took effect upon the entry into force of the amendments to SOLAS 1974, introducing new Chapter XIV, and related MARPOL amendments. Its requirements, specifically tailored for ships operating in polar environments of Arctic and Antarctic waters, go above and beyond those of existing IMO conventions such as MARPOL and SOLAS, which are applicable globally and will still apply to shipping in polar waters.

IGF Code - International Code of Safety for Ships using Gases or other Low-flashpoint Fuels took effect upon the entry into force of the amendments to SOLAS 1974, along with the new training requirements for seafarers working on those ships.

News

1. NEWS

The IEEE Spectrum magazine published an interesting article of relevance for the future of maritime traffic (see: http://spectrum.ieee.org/transport/marine/forget-autonomous-cars-autonomous-ships-are-almost-here and https://doi.org/10.1109/MSPEC.2017.7833502). It questions the purpose of mariner education in the face of imminent development of autonomous ships. Starting from the premise that 75 %-96 % of marine accidents are caused by human error, it can be surmised that if the human factor is removed, the number of accidents would drop to 4 %-25 %. Insurance company expenses, material damage suffered by maritime companies, environmental pollution and human casualties would all be reduced.

Tremendous developments will be made during our lifetime. River/fjord-size commercial operation of autonomous (robotic) ships/vessels is expected to occur within the next couple of years. Robotic oceangoing cargo ships are anticipated to become commonplace within 10-15 years. According to Rolls-Royce (http://www.rolls-royce.com/~/media/Files/R/Rolls-Royce/documents/customers/marine/ship-intel/rr-ship-intel-aawa-8pg.pdf), the next steps are:

- Remotely operated local vessels by 2020,
- Remotely controlled unmanned coastal vessels by 2025,
- Remotely controlled unmanned ocean-going ships by 2030,
- Autonomous unmanned ocean-going ships by 2035.

This would suggest that classic maritime jobs will soon become obsolete. However, some jobs still come to mind:

- Virtual Reality Control (VRC) Designer,
- Virtual Reality Control Developer,
- Virtual Reality Control Operator,
- Neural Interface Maintenance Technician,
- Computer Controlled System Maintenance Technician,
- Distant Communication Officer,
- Distant Steering Officer, and similar.

2. PREDICTING AN AUTONOMOUS FUTURE

Reprinted with permission from: http://www.wartsila.com/twentyfour7/innovation/predicting-an-autonomous-future

Seeing into the future might appear to be merely wishful thinking, or something possible only in science fiction. However, Wärtsilä's latest systems launch, SmartPredict, does precisely that; it tells the captain of a ship exactly what is happening during its manoeuvring operations, and what will happen if nothing is done to change its position.

Unprecedented input

Prediction systems have been around for some years already, and as such are not new. The aim of all these systems is to enable safe navigation between ports, and specifically to reduce the risk of accidents occurring within the ports. Two basic approaches have been used in developing these systems, based on dynamic and purely kinematic prediction models; the latter being concerned only with the motion without reference to the forces causing such motion. The simplification of these early prediction systems allows restricted use only.

In developing SmartPredict, Wärtsilä's Dynamic Positioning (DP) unit has sought to overcome the inadequacies of the conventional systems available on the market. The biggest challenge to achieve this has been to utilise all of the parameters used for automated control by the DP system, and to adjust them for the motion characteristics of the vessel. The limited usability of most conventional systems is a result of the limited input they receive. Table 1 compares the input and modeling from traditional systems to those of the new Wärtsilä system.

The Wärtsilä SmartPredict module takes advantage of the DP system's built-in mathematical model to provide advanced motion prediction capability for the vessel. The input to the control algorithm takes consideration of the vessel's current position and heading, as well as the velocity and rate of turn with

all associated accelerations. Furthermore, the manual commands from the coordinated control joystick (3 axis), and environmental input from the onboard wind sensor(s) are included in the total equation. The overall level of input is, therefore, unprecedented in prediction systems, and all of these factors are continuously evaluated to provide a constant update of the vessel's path.

What Where and When

In addition to displaying the vessel's predicted future position and heading, SmartPredict uses proven DP analysis algorithms to evaluate the forces affecting the vessel, thus providing truly advanced motion predictions. What is more, the system comes with a configurable prediction time display. In other words, the system provides the operator with information regarding not only what is happening and where it is happening, but also when it might happen.

The Wärtsilä user interfaces provide a simple, intuitive display whereby the operator can toggle on or off the 'ghost ship' indicators for the predicted positions. The time steps for the predictions can be assessed from the display. SmartPredict is fully compatible with the Electronic Chart Display & Information System (ECDIS) overlay function in Wärtsilä systems and provides clear indications of potential dangers during manoeuvring operations. This immediately increases both the safety and the efficiency of the vessel's movements.

While the initial development of this capability is aimed primarily at cruise ships and passenger ferries, it has obvious relevance also to any vessel that regularly needs to perform challenging manoeuvres. Development is also underway that will allow display of the 'ghost ship' indicators on other displays within the Wärtsilä Nacos Platinum family of navigational and control systems. This will enable the power of SmartPredict to be available even when using manual controls.

Future potential

Dynamic Positioning systems date back to the 1960s, which was when the DP industry as such was born. The evolution began, however, during the 1970s when the first commercial systems were introduced. The development during this phase included the introduction of modern control theories with mathematical modelling of the system. It was during these years too that concepts such as redundancy and feed forward became standard. The huge strides in computer technology from the 1980s onwards, however, enabled completely new DP capabilities. New functions were added to take advantage of the greatly improved processor power, while the user interfaces were also modernised.

Wärtsilä's SmartPredict system now represents the beginning of the new evolution, which will inevitably lead to greater vessel automation. The technology is moving beyond merely maintaining station and onto better and smarter DP systems providing dynamic control. More and more operators are today looking for the safety and reliability of automatic operations. This means that each phase of vessel control will need to be validated and proven in order for true vessel autonomy to be possible. However, without question, SmartPredict is an important first step in the direction of achieving fully autonomous ship manoeuvring.

3. OTHER NEWS

EU ship recyclers have joined voices to promote clean and safe practices (see link: http://www.shipbreakingplatform.org/platform-news-eu-ship-recyclers-join-voices-to-promote-clean-and-safe-practices/).

An interesting news is the re-emergence of Somali Pirates (see link: http://www.marinelink.com/news/floating-pirates-somali423505).

4. CONSTITUTION OF SPECIAL CURRICULUM "NAVAL SHIPPING" IN THE REPUBLIC OF CROATIA

The Government of the Republic of Croatia on its 26th session, held on 26 March 2017, accepted the Draft decision on initiating the procedure of the constitution of the special curriculum "Naval Shipping" at the University of Split. The performance of the curriculum will start in the academic year 2018/2019, and will take place at the venue of the Croatian Military Academy "Dr Franjo Tuđman" and the University of Split components (Faculty of Maritime Studies, Faculty of Electrical engineering, Mechanical Engineering and Naval Architecture, and Faculty of Humanities and Social Sciences), which will jointly carry out the curriculum. Hereafter, there is the Government exposition of the reasons for the establishment of the studies, which is publicly available on the Government web pages: https://vlada.gov.hr/sjednice/26-sjednica-vlade-republike-hrvatske-20304/20304.

Explanation

The constitution of the special curriculum "Naval Shipping" has been initiated to achieve a uniform education of maritime officers for all the state bodies participating in the area of maritime safety. It is the prerequisite of their integrated activity in the protection and promotion of the national interests of the Republic of Croatia at sea.

To acquire the necessary competencies required of maritime officers, the Croatian Military Academy "Dr Franjo Tuđman" and the Croatian Navy in cooperation with the University of Split and

the Faculty of Maritime Studies, Faculty of Electrical engineering, Mechanical Engineering and Naval Architecture, and Faculty of Humanities and Social Sciences, as components of the University of Split, have started to elaborate on the integrated undergraduate and graduate university studies "Naval Shipping".

The concept of the integrated studies "Naval Shipping" is planned to comprise three directions: "Naval Nautical Studies", "Naval Marine Engineering", and "Naval Electronics". The studies would last for ten semesters, i.e. five years. On the completion of the studies, the students would acquire the title of the Master of Naval Shipping, direction of Naval Nautical Studies, Naval Marine Engineering, or Naval Electronics.

The curriculum contents would mainly be carried out in specialized lecture rooms of the barracks "Sveti Nikola – Lora" in Split, and partly at the facilities of the University of Split components. The accommodation and meals would be provided in the dedicated object within the above mentioned barracks.

The main learning outcomes are determined as acquaintance with and understanding of the professional and scientific principles and standards important for the maritime profession, as well as of maritime disciplines essential in the process of ship exploitation: navigation, manoeuvring, maintenance, cargo handling, and other specific procedures regulated by the International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers, as well as other international and national standards.

In each direction, the performance of 71 courses has been planned, of which 55 courses are common to all the directions. The structure of the studies has the following important characteristics:

- The first two years of study are common to all the three directions
- The third and fourth years consist of 50% of common and 50 % of elective courses (elective courses are compulsory for certain directions as well as for the Ministry of the Interior requirements)
- The fifth year is common to all the three directions
- The military camps and navigational practice are also part of the study plan and curriculum.

Considering that the Ministry of the Sea, Traffic and Infrastructure, Ministry of the Interior, and other national authorities participate in the protection of the Adriatic along with the Croatian Navy and the Coast Guard of the Republic of Croatia, by such an integrated university study it is possible to carry out common education of maritime officers required by all the national authorities.

The general competencies acquired by the cadets on the completion of "Naval Shipping" studies are equal to those acquired at other maritime universities. Beside the general competencies, the cadets also acquire specific competencies within the scope of the Coast Guard of the Republic of Croatia, Ministry of the Interior, use of marine combat systems and alike, as well as the competencies required for work in Harbourmaster's Offices, Search and Rescue Service, and in the Vessel Traffic Monitoring and Information System. They also acquire additional competencies for a successful work and performing tasks in the national authorities for which they are educated. It is at the same time an excellent nursery from which it will be possible to grow and develop high-quality reserve maritime officers.

ART

PARTÊNCA

Tašenka Matulović-Tabak

DEPARTURE

trans. by Mirna Čudić

Nikud se nismo moràli mìcat
lomìt se di svoga nî,
mèst šporkìcu dālèkega svîta
iz ové biliné, vedriné, čistoće,
iz tišiné,
iz lipoté.

Mogli bi smo sômo uprâvit
nojoštrìju pûntu ōtòka
po jôkemu vìtru,
pùknit konopé
i zaplutàt, zabordižàt.

Nâši kampanèli bìli bi jôrboli,
lancūnì po terâcan, jìdra.
Svi bròdi išli bi sa bônde,
náše tìčice, sve bèštijice i raci
išli bi s nâmin.

Svi bismo na vàs glôs kantâli
kako oduvìk u procesjūnù.
Svi bi se mênduli rascvâli,
i zavonjâli zimurâdi.

Bili bismo plovéća lanterna,
vélika zvîda Stvorìteja,
njegòvo nasmîjano oko
jer se smìlovala dici otòka.

We did not have to go away
toil bitterly in a foreign land, with no one close to our heart,
sweep the dirt of the remote world
away from this whiteness, serenity, purity,
away from this tranquillity,
away from this beauty.

We could have just turned
the sharpest cape of this Island
in the face of a gale,
severed the ropes
and floated, drifted, steering forward.

Our bell-towers would have been our masts,
sheets hung on balconies our sails.
All the boats would have sailed at our side, escorting us,
all our birds, little animals, and crabs
would have accompanied us.

We would have all sung our throats out
as we once used to in processions.
All the almond-trees would have blossomed,
and rosemary would have spread its scent.

We would have been a sailing lighthouse,
the great star of the Creator,
His smiling eye
because it took pity upon the Island's children.

RJEČNIK

partenca	odlazak
di	gdje
ni	nema
šporkica	prljavština
upravit'	usmjeriti se prema
punta	rt
po jokemu vitru	po jakom vjetru
puknit'	puknuti, odriješiti
zabordižat'	okrenuti se u jedrenju
kampanel	zvonik
jorbol	jarbol
lancun	plahta
tičice	ptičice
beštijice	životinjice
s namin	s nama
na vas glos	iz svega glasa
kantat'	pjevati
kako oduvik	kao oduvijek
prešešjun	procesija
menduli	bademi, bajami
zavonjat'	zamirisati
zimurad	ružmarin
lanterna	svjetionik

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]

Expectations for publishing in ToMS

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:

- 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

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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5.1. Duties of the Authors

Reporting Standards: Authors should accurately present their original research, as well as objectively discuss its significance. Manuscripts are to be edited in accordance to the submission guidelines of the proceedings.

Originality: Authors must ensure that their work is entirely original.

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.

Data Access and Retention: Authors should retain raw data related to their submitted paper, and must provide it for editorial review, upon request of the editor.

Disclosure of Financial Support: All sources of financial support, if any, should be disclosed.

Fundamental errors in published works: When an author discovers a significant error or inaccuracy in his/her submitted manuscript, the author must immediately notify the editor.

5.2. Duties of Reviewers

Confidentiality: Manuscript reviewers, the editor and the editorial staff must not disclose any information regarding submitted manuscripts. All submitted manuscripts are to be treated as privileged information.

Acknowledgement of Sources: Reviewers of manuscripts must ensure that authors have acknowledged all sources of data used in the research. Any similarity or overlap between the considered manuscripts, or with any other published paper, which is in personal knowledge of reviewer, must be immediately brought to the editor's notice.

Standards of Objectivity: Review of submitted manuscripts will be conducted objectively. The reviewers shall express their views clearly, with supporting arguments.

Promptness: If a reviewer believes it is not possible for him/her to review the research reported in a manuscript within the designated guidelines, or within stipulated time, he/she should notify the editor, so that the accurate and timely review can be ensured...

Conflict of Interest: All reviewers should have no conflict of interest with respect to the research, the authors and/or the funding bodies.

5.3. Duties of the Editor

Publication Decisions: Based on the editorial board's review, the editor can accept or reject the manuscript or can send it for modifications.

Review of Manuscripts: The editor ensures that each manuscript is initially evaluated by the editor, who may make use of appropriate means, to examine the originality of the contents of the manuscript. After the manuscript passes this test, it is forwarded to two reviewers for double-blind peer review, and each of whom will make a recommendation to publish the manuscript in its present form or to modify or to reject it. The review period will be no more than30 days.

Fair Review: The editor ensures that each manuscript received is evaluated on its intellectual content without regard to authors' sex, gender, race, religion, citizenship, etc.

Confidentiality: The editor must ensure that information regarding manuscripts submitted by the authors is kept confidential.

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).

6. GUIDELINES 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.

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.

6.1.3. Submission declaration

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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This policy concerns the addition, deletion, or rearrangement of author names in the authorship of accepted manuscripts:

Before the accepted manuscript is published in an online issue: Requests to add or remove an author, or to rearrange the author names, must be sent to the Journal Manager from the corresponding author of the accepted manuscript and must include:

a. the reason the name should be added or removed, or the author names rearranged and

b. written confirmation (e-mail, fax, letter) from all authors that they agree with the addition, removal or rearrangement. In the case of addition or removal of authors, this includes confirmation from the author being added or removed. Requests that are not sent by the corresponding author will be forwarded to the Journal Editors and to the corresponding author, who must follow the procedure as described above.

Note that:

- publication of the accepted manuscript in an online issue is suspended until authorship has been agreed.

After the accepted manuscript is published in an online issue:

Any requests to add, delete, or rearrange author names in an article published in an online issue will follow the same policies as noted above and result in a corrigendum.

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You are requested to identify who provided financial support for the conduct of the research and/or preparation of the article and to briefly describe the role of the sponsor(s), if any, in study design; in the collection, analysis and interpretation of data; in the writing of the report; and in the decision to submit the article for publication. If the funding source(s) had no such involvement then this should be stated.

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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:

a. the word "Figure", followed by its respective number;
b. figure title containing major finding (e.g. Manuscripts which follow Guidelines for Authors had higher acceptance rate, and not Relationship with manuscripts style and their acceptance rate).

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.

Graphs, charts, titles, and legends in accepted manuscripts will be edited according to ToMS style and standards prior to publication.

Preferred format for graphs or charts is xls. Graphs and charts saved as image (raster) files such as JPG, TIF, or GIF and imported or copied/pasted into Word or Power Point are not acceptable.

The resolution for photographic images should be at least 300 dpi, and minimum image width should be 6 cm. Please submit files in RGB format. For published manuscripts, image files will be posted online in their original RGB format, maintaining the full color of your original files. Note that we will still need to convert all RGB files to CMYK for printing on paper and color shifts may occur in conversion. You will not receive a CMYK proof. You can view an approximation of print results by converting to CMYK in Adobe® Photoshop® or Adobe® Illustrator®.

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.

6.2.2.6. Acknowledgments

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.

6.2.2.7. References

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.

Examples for reference section:

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

Donoho, D., Duncan, M. R., Huo, X. and Levi, O., (1999), Wavelab, available at: http://www.stat.stanford.edu /_wavelab/, [accessed 12 August 2011.].

Unknown, Wavelab, available at: http://www.stat.stanford.edu /_wavelab/, [accessed 12 August 2011.].

ToMS home page, available at: http://www.toms.com.hr, [accessed 12 July 2012.].

Books

Mallat, S., (2009), A Wavelet Tour of Signal Processing, 3rd Edition, New York: Academic Press.

Chapter in book

Hymes, D.H., (1972), On Communicative Competence, in: Pride, J. B. and Holmes, J. (eds), Sociolinguistics, Selected Readings, pp. 269-293. (Part 1 if exists), Harmondsworth: Penguin.

Šoda, J., Beroš, S.M., Kuzmanić, I. and Vujović, I., (2013), Discontinuity Detection in the Vibration Signal of Turning Machines, in: Öchnser A. and Altenbach, H. (eds), Experimental and Numerical Investigation of Advanced Materials and Structures, Advanced Structured Materials (serial name if applicable), 41 (volume number if applicable), pp 27-54. (part if applicable), Heidelberg: Springer., https://doi.org/10.1007/978-3-319-00506-5_3

Conference proceedings

Łutowicz, M. and Lus , T., (2013), Effect of Loss of Cylinder Pressure Indicating Channel Patency on Parameters Values Obtained from Indicating Graph, Proc. 5th International Maritime Science Conference, Solin, Croatia, April 22 – 23, pp. 382-389., available at: http://www.pfst.hr/imsc/archive/2013/IMSC2013_proceedings.pdf

Kingsbury, N.G. and Magarey, J.F.A., (1997), Wavelet Transforms in Image Processing. Proc. First European Conference on Signal Analysis and Prediction, Prague, Czech Republic, June 24 – 27, Birkhauser, pp. 23 – 24., available at: http://www.sigproc.eng.cam.ac.uk/~ngk/publications/ngk97b.zip, [accessed 12 August 2011.].

Regulations, standards or legal acts:

Constitution of the Republic of Croatia, (2010), Narodne novine, 2010(76), pp. (if known).

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 Open journal system.

Manuscripts can also be submitted to:

Editorial office
Transactions on Maritime Science,
Faculty of Maritime Studies,
Ruđera Boškovića 37,
21000 Split, Croatia
www.toms.com.hr | office@toms.com.hr