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April, 11th–12th 2019, Budva, Montenegro

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Assessment of The Port Costs on The Zagreb Pier in The Port of Rijeka

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ABSTRACT

Every sea port is an important link of the logistics chain, whose strength and development reflects the competitiveness of the traffic route. The growth of container traffic in the port of Rijeka imposes the necessity for further increase of the transhipment capacity. This has resulted in the construction of the new container terminal in the western part of the port of Rijeka, called Zagreb pier. That will enable the port of Rijeka to accept the latest generation of vessels and will represent additional container handling capacities of the existing Adriatic Gate Container Terminal. The capacity of the berths determines the throughput of the container terminal. The objective of this paper is the implementation of the queuing theory by which it can be determined the number of berths and cranes per berth with minimum costs for the expected container traffic. The optimal solution is obtained applying the model of total costs for the new container terminal in the port of Rijeka. This model can be used for any other container terminal under different specific conditions.

KEYWORDS: container terminal, queueing theory, total cost function & port costs

I. INTRODUCTION

Each port has its own specifics that are reflected in the development of the hinterland, adequate road infrastructure, railways and inland waterways. The port of Rijeka has an exceptionally favourable geostrategic position, but the spatial concept of the port of Rijeka is extremely complicated without leaving possibilities for expansion. The Project of the Container Terminal on the Zagreb pier is being developed by the Port Authority of Rijeka in order to exploit the advantages of the sea depth and the protected bay at the new terminal location. Consequently, the port of Rijeka will be equipped for the acceptance of the latest generation of vessels and for upgrading the container handling capacity of the existing Adriatic Gate Container terminal. In practice it is very difficult to determine and submit an optimal capacity of a port container terminal due to the oscillations of cargo transhipment conditioned by the irregular arrival of container ships to the terminal and irregular duration of operations with containers. The terminal should have spare capacity, but this would reduce the level of terminal utilization, and the share of fixed costs in terminal operations would increase. The goal of this paper is to demonstrate that applying the queuing theory it could be found the optimal capacity of the port container terminal, or a combination of the number of berths and cranes per berth with the minimum costs for the observed traffic. So, the optimal solution was received by applying a model of total costs that is based on the queuing theory. The function of the total costs was published by P. Schonfeld, and S. Frank in [1] for a container port with one berth. Later, in 1995 Z. Zenzerović [2] expands the model on the port with several berths and through graphics and calculations determines the change of each cost type, depending on the number of berths and cranes. Č. Dundović, and Z. Zenzerović in [3] present the model of costs for the general cargo port. With some modifications the same model has been applied on the real data for Brajdica container terminal of the port of Rijeka in [4]. Z. Zenzerović, S. Vilke, and M. Jurjević presented the function of total costs applying it on the port costs of the Brajdica container terminal in the port of Rijeka, where different variants were compared concerning number of berths and cranes taking into account the minimum port costs [5]. The model set in this paper can be used for any other container terminal under different conditions. The results obtained are a basis for bringing adequate business decisions for terminal operations. The model is tested on an example of the future container terminal on the Zagreb pier in the port of Rijeka.
II. APPLYING THE MODEL OF TOTAL COSTS AT THE CONTAINER TERMINAL ON THE ZAGREB PIER

A. Project of the Zagreb Pier Container Terminal

The increase of container traffic throughput in the Port of Rijeka calls for further development of the port handling capacity. Therefore, the planned construction of a new container terminal in the western part of the harbour area suggests itself a logical solution. The container terminal at the Zagreb pier which, when completely finished, will occupy an area of approximately 22 hectares, is conceived as a 680 m long pier with the terminal 300 m wide on average. The minimum planned depth of the sea alongside the pier is 20m. Two construction phases (stages) are planned for this terminal. The first includes 400 m long pier with the sea depth of minimum 20 m. The extension of the terminal to a total pier length of 680 m is foreseen in the second phase as a result of which the terminal would be capable of achieving throughput capacity of 500,000 TEU/year. The berth is dimensioned and designed to accommodate container vessels of the 366 m length, 51 m width and draft 15 m, which imposed the necessity for the installation of STS container cranes with the 22 rows outreach.

The construction of connector road D 403 and reconstruction of a shunting yard to meet the needs of container loading/discharge operation on the fringe of the terminal, would be undertaken concurrently with the construction of terminal. The financing arrangement to back up this project is a combination of the World Bank’s loan funds and private investment. Consequently, it is planned that the new pier construction should be financed by the funds received from the World Bank, while a public-private partnership should be used as a financing model for the development of infrastructure facilities at the existing part of the terminal. The same model is to be applied for the superstructure works and purchase of equipment. Due to the extremely difficult construction conditions, it was agreed to apply a method where both, designing and construction, would be included in the same contract, thus enabling contractor to choose, in terms of costs, the most favourable pier structure.

Construction of terminal at the Zagreb pier is planned as a joint investment project of the Port of Rijeka Authority and a future concessionaire to be selected in a public competition process. The contract for the design and construction of the first phase of the Zagreb pier was signed in April 2012 with the Italian consortium of the Grandi Lavori Fincosit Company, Nuova Co.Ed.Mar, Maltauro. The first phase of this project is worth 71 million EUR. The total investment, including terminal equipment, is estimated at EUR 300 million [11].
In accordance with its objectives to have the public competition prepared in compliance with the international practice in the field of public-private partnership, the Port of Rijeka Authority has engaged a consultant company, namely RMG Consult BV from Rotterdam. Construction started in August 2014.

B. Model of the Container Terminal Total Costs

The total cost model is presented with the function of total port costs that contains berths costs, costs of container cranes, costs of transport-handling equipment, crane operator costs, operator costs, stacking area costs, costs of ship stay in the port and cargo costs [4, 5].

The function of total costs of the container terminal system has the following form:

\[ C = C_b + C_d + C_{pp} + C_{id} + C_{ip} + C_{wh} + C_W + C_q \]  

(1)

where \( C \) is the symbol for total costs of the port container terminal expressed in money units in the observed time unit, e.g. in €/h.

The berth costs depend on the number of berths (\( S \)) and unit cost per berth (\( c_b \)), and are calculated with:

\[ c_b = \left[ B_b \frac{i(1+i)^N_b}{(1+i)^{N_b} - 1} + M_b \right] \frac{1}{365 \cdot 24} \]

(2)

\[ C_b = c_{b1} + c_{b2} \]

(3)

The total costs of container cranes depends on the number of berths (\( S \)), the number of cranes per berth (\( d \)) and costs per crane (\( c_d \)). The costs are obtained with the formulas:

\[ c_d = \left[ D_d \frac{i(1+i)^N_d}{(1+i)^{N_d} - 1} + M_d \right] \frac{1}{365 \cdot 24} \]

(4)

\[ C_d = S \cdot d \cdot c_d \]

(5)

The costs of transport-handling equipment depend on the number of transport-handling equipment (\( p \)) and unit cost per equipment (\( c_{pp} \)) and are calculated with the formulas:

\[ c_{pp} = \left[ P_{pp} \frac{i(1+i)^N_{pp}}{(1+i)^{N_{pp}} - 1} + M_{pp} \right] \frac{1}{365 \cdot 24} \]

(6)

\[ C_{pp} = c_{pp1} + c_{pp2} + c_{pp3} \]

(7)

Total costs of human resource contain total costs of crane operators (\( C_{id} \)) and total costs of operators (\( C_{ip} \)) that are calculated with the next formulas:

\[ C_{id} = \lambda \cdot d \cdot t_{id} \cdot c_{id} \]

(8)

\[ C_{ip} = n \cdot c_{ip} \]

(9)

Operating time for crane operators (\( t_{id} \)), or the duration of ship reload (h/crane/ship) is calculated with formula:

\[ t_{id} = \frac{x \cdot y}{d} \]

(10)

The stacking area costs present a product of necessary stacking area capacity (\( k_{wh} \)), size of stacking surface per container (\( a \)) and cost per unit of stacking surface (\( c_{wh} \)). The amount of costs is obtained by using the next formulas:

\[ k_{wh} = \lambda \cdot x \cdot t_{wh} \cdot f_s \]

(11)

\[ c_{wh} = \left[ W_{ho} \frac{i(1+i)^{N_{wh}}}{(1+i)^{N_{wh}} - 1} + M_{wh} \right] \frac{1}{365 \cdot 24} \]

(12)
The initial price during building the terminal consists of the values of water installation, rails, railroad
witch, TT network and asphalt surfaces. Because of the mentioned, the value of the complete stacking
surface is very high and will reflect on the amount of the total costs of the stacking area.

The costs of a ship at the container terminal \((C_w)\) are composed of all costs of the ship during stay at the
terminal, as the costs of the port taxes (taxes for using the operating costs, tonnage tax and lighthouse
tax), costs of piloting, costs of tugboat and costs of mooring and transport.

The costs that occur during ship stay at the container terminal cover several types of costs from which
some, considering the usage of the ship capacity, are seen as variable and some as fixed costs [10].

The fixed costs occur already with the existence of certain ship capacities regardless if the capacities are
used or not and usually are expressed in calculating daily fixed costs. The variable travelling costs of the
ship also occur during stay at the container terminal. Besides the costs of reload (stevedoring costs), all
other variable costs occur, directly or indirectly, in relation to reload, or during the ship stay in the ports.

The calculation of the total costs of a container ship is obtained with the formulas:

\[
C_{wh} = k_{wh} \cdot a \cdot c_{wh} \quad (13)
\]

\[
C_w = \left[ W_0 \frac{(1 + i)^n_w}{(1 + i)^n_w - 1} + M_w \right] \frac{1}{365 \cdot 24} \quad (14)
\]

\[
W_q = \frac{\rho^{s+1}}{\lambda(S - 1)! (S - \rho)^2} \left[ \sum_{n=0}^{s-1} \frac{\rho^n}{n!} + \frac{\rho^s}{S(1 - \frac{\rho}{S})} \right]^{-1} \quad (15)
\]

\[
W = W_q + \frac{1}{\mu} \quad (16)
\]

\[
C_w = \lambda \cdot W \cdot c_w \quad (17)
\]

The total cargo costs depend on the intensity of ship arrival into the port \((\lambda)\), duration of ship stay in the
port \((W)\), which among others depends on the number of berths, the number of cranes per berth and
amount of cargo \((Q)\), the number of containers on the ship and the costs per container \((c_Q)\).

Value \(W\) is one of the indicators of the port functioning obtained by applying the queuing theory, and
the way of calculating depends on the type of problem of the queue considering the elements that de-
termine the type of problem of the queue: distribution of ship arrival, distribution of serving time, serv-
ing discipline and number of berths. The types of queues M/M/1/∞ and M/M/S/∞ are used for this pa-
er since they are the most common cases of serving processes in port container terminals.

The total amount of cargo costs is calculated with the formula:

\[
C_Q = \lambda \cdot W \cdot Q \cdot c_Q \quad (18)
\]

III. CALCULATION OF THE OPERATING COSTS OF THE CONTAINER TERMINAL ON
THE ZAGREB PIER

The model of the total cost for the container terminal on the Zagreb pier is presented with the function
of total port costs that contains: berths costs, costs of container cranes, costs of transport-handling
equipment, crane operator costs, operator costs, stacking area costs, costs of ship stay in the port and
cargo costs.

The values are calculated for two berths and four cranes and an annual turnover of 200,000 TEU. Also,
two more variants are added containing a larger number of cranes in order to decide on the most suita-
ble combination of the number of berths and cranes, taking into account the criterion of least cost. The
calculation with an annual turnover of 400,000 TEU has also been presented. Based on the obtained
values, the optimal solution was chosen, which implies the least costs. Input data were used from the available sources [8-11].

A. Berth Costs
The container terminal on the Zagreb coast should have two berths and four container cranes. The ship's flow intensity is 331 boats per year (Sailing List 2017), and two ships can be tied to the Zagreb pier at the same time. The economic lifespan of the berth is estimated to around 50 years, the infrastructure interest rate is 5%, while for the value of the annual costs of berth maintenance is taken by experience 10% of the purchasing price.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Meaning</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial berth price</td>
<td>$B_0$</td>
<td>22,500,000 €</td>
<td></td>
</tr>
<tr>
<td>Economic lifespan of berth</td>
<td>$N_b$</td>
<td>50 years</td>
<td></td>
</tr>
<tr>
<td>Interest rate</td>
<td>$i$</td>
<td>5%</td>
<td></td>
</tr>
<tr>
<td>Annual maintenance cost per berth</td>
<td>$M_b$</td>
<td>2,250,000 €</td>
<td></td>
</tr>
</tbody>
</table>

Based on the input data given in Table I and formulas (2) and (3), berth costs ($C_b$) for the two berths amount 397.54 €/h.

B. Costs of the Container Cranes
For the container terminal at the Zagreb pier, four ZPMC (Shanghai Zhenhua Heavy Industries) container cranes with a 23 rows outreach are taken in calculation, where containers can be stacked in four heights.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Meaning</th>
<th>Amount for 4 cranes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial container crane price</td>
<td>$D_0$</td>
<td>24,000,000 €</td>
<td></td>
</tr>
<tr>
<td>Economic lifespan of container crane</td>
<td>$N_d$</td>
<td>10 years</td>
<td></td>
</tr>
<tr>
<td>Interest rate</td>
<td>$i$</td>
<td>5%</td>
<td></td>
</tr>
<tr>
<td>Annual maintenance cost per crane</td>
<td>$M_d$</td>
<td>2,400,000 €</td>
<td></td>
</tr>
</tbody>
</table>

The economic life cycle of the cranes is considered 10 years, interest rate (by experience) is 5%, and the annual maintenance cost per crane is (in practice) 10% of the purchasing price. For four container cranes cost obtained with formula (4) and (5) amount $C_d=628.78 €/h.$

C. Costs of transport-handling equipment
The equipment of the container terminal that would be used in transhipment operations for four cranes consists of four reachstackers, 12 forklifts, 12 tugmasters and 12 trailers (semi-trailers). The initial prices and costs of new transport-handling equipment have been taken into account. Thus, the initial price of the reachstacker is approximately 300,000 €, for a forklift 250,000 €, for a tugmaster 140,000 €, and for a trailer (semi-trailer) 35,000 €.

The economic lifespan of mechanization is considered 7 years; interest rate is 5% while 10% is taken from the purchasing price of the equipment to calculate the cost value for annual maintenance per equipment. With the formulas (6) and (7) cost calculation for transport-handling equipment of the container terminal at the Zagreb pier amounts 196.21 €/h.
TABLE III. Input Data for Transport-Handling Equipment

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Meaning</th>
<th>Reachstackers (4)</th>
<th>Forklifts (12)</th>
<th>Tugmasters (12)</th>
<th>(Semi) Trailers (12)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial price</td>
<td>$P_{0}$</td>
<td>Money</td>
<td>1,200,000</td>
<td>3,000,000</td>
<td>1,680,000</td>
<td>420,000 €</td>
</tr>
<tr>
<td>Economic lifespan</td>
<td>$N_{e}$</td>
<td>Time</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7 years</td>
</tr>
<tr>
<td>Interest rate</td>
<td>$i$</td>
<td>Percentage</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5%</td>
</tr>
<tr>
<td>Annual maintenance cost</td>
<td>$M_{m}$</td>
<td>Money</td>
<td>120,000</td>
<td>300,000</td>
<td>168,000</td>
<td>42,000 €</td>
</tr>
</tbody>
</table>

D. Costs of Human Resource

For the realization of ship’s transshipment process, the necessary number of port transport workers is nine workers and four crane operators.

TABLE IV. Input Data for Human Resources

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Meaning</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ship’s arrival intensity</td>
<td>$\lambda$</td>
<td></td>
<td>0.038 ship/h</td>
</tr>
<tr>
<td>Number of crane operators</td>
<td>$d$</td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>Number of reloaded container per ship</td>
<td>$x$</td>
<td></td>
<td>604 TEU/ship</td>
</tr>
<tr>
<td>Duration of one life cycle of crane</td>
<td>$y$</td>
<td></td>
<td>0.044 h/TEU</td>
</tr>
<tr>
<td>Interference coefficient</td>
<td>$f$</td>
<td></td>
<td>0.85</td>
</tr>
<tr>
<td>Unit cost for crane operator</td>
<td>$c_{U}$</td>
<td></td>
<td>5.86 €/h</td>
</tr>
</tbody>
</table>

If a month has an average of 182 working hours, the average gross salary of an operator per month amounts 1,067€, then the cost of one crane operator is 5.86 €/h. Costs of human resource on terminal Zagreb pier amounts 359.87 €/h, from which the costs of crane operators are 8.09 €/h and operators 351.78 €/h.

E. Stacking Area Costs

Based on the dimensions of 20' containers (width 2.64 m, length 6.6 m, height 2.64 m) the size of the stacking surface is 17.4 m²/TEU. Since the average number of containers stack into height is four, the necessary surface per container is 4.35 m²/TEU. The estimation of the economical life cycle of the stacking area is 100 years; interest rate for infrastructure is 5%, while the costs of annual stacking area maintenance are considered 0.5% of its purchasing price.

TABLE V. Input Data for Stacking Area Costs

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Meaning</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ship’s arrival intensity</td>
<td>$\lambda$</td>
<td></td>
<td>0.038 ship/h</td>
</tr>
<tr>
<td>Number of reloaded container per ship</td>
<td>$x$</td>
<td></td>
<td>604 TEU/ship</td>
</tr>
<tr>
<td>Stacking surface per container</td>
<td>$a$</td>
<td></td>
<td>4.35 m²/TEU</td>
</tr>
<tr>
<td>Initial price</td>
<td>$W_{0}$</td>
<td>Money</td>
<td>52,500,000 €</td>
</tr>
<tr>
<td>Interest rate</td>
<td>$i$</td>
<td>Percentage</td>
<td>5%</td>
</tr>
<tr>
<td>Economic lifespan</td>
<td>$N_{e}$</td>
<td>Time</td>
<td>100 years</td>
</tr>
<tr>
<td>Annual maintenance cost</td>
<td>$M_{m}$</td>
<td>Money</td>
<td>262,500 €</td>
</tr>
</tbody>
</table>

Cost calculation (formulas 11-13) for stacking area amounts 33,045 €/h, where cost per unit of stacking surface is 331 €/h.
F. Costs of the Ship Stay

The estimation of an economical life cycle of a ship is 30 years; interest rate is 5%, while the value of annual maintenance costs is considered 2% of the purchasing price of the ship.

<table>
<thead>
<tr>
<th>TABLE VI.</th>
<th>INPUT DATA FOR COSTS OF SHIP STAY</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Parameter</strong></td>
<td><strong>Symbol</strong></td>
</tr>
<tr>
<td>λ</td>
<td>Ship’s arrival rate</td>
</tr>
<tr>
<td>μ</td>
<td>Service rate</td>
</tr>
<tr>
<td>ρ</td>
<td>Traffic intensity</td>
</tr>
<tr>
<td>S</td>
<td>Number of berths</td>
</tr>
<tr>
<td>W</td>
<td>Average time of ship stay at the terminal</td>
</tr>
<tr>
<td>i</td>
<td>Interest rate</td>
</tr>
<tr>
<td>W₀</td>
<td>Initial ship value</td>
</tr>
<tr>
<td>Nₑ</td>
<td>Economical life cycle of ship</td>
</tr>
<tr>
<td>Mₑ</td>
<td>Cost of annual ship maintenance</td>
</tr>
</tbody>
</table>

With the input data and formula (14-17) it is obtained that the cost of a ship stay amounts 98.63 €/h.

G. Cargo Costs

For calculating all costs of the container terminal the cargo costs are taken into account considering that the interests of the cargo owner and port terminal are mutually interactively linked. The interest of the terminal is that the container dispatchment is as fast as possible, or that their retaining in the stacking area is as short as possible to make available space for a new cargo. The cost per container is obtained based on the calculations of costs of the standing of one container ship and its cargo. Cargo cost amount 414.15 €/h (formula 18).

<table>
<thead>
<tr>
<th>TABLE VII.</th>
<th>INPUT DATA FOR CARGO COSTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Parameter</strong></td>
<td><strong>Symbol</strong></td>
</tr>
<tr>
<td>λ</td>
<td>Ship’s arrival rate</td>
</tr>
<tr>
<td>W</td>
<td>Average time of ship stay at the terminal</td>
</tr>
<tr>
<td>Q</td>
<td>Average amount of cargo per ship</td>
</tr>
<tr>
<td>c₀</td>
<td>Unit cost per container</td>
</tr>
</tbody>
</table>

H. The Total Cost

The total cost of the container terminal on the Zagreb pier is obtained by summing all the previously calculated costs, following the formula (1). To find an optimal solution, or the optimal capacity of container terminal Zagreb pier, different variants are compared depending on the traffic and number of cranes per berth:

- Variant A – two berth, four cranes.
- Variant B – two berth, six cranes.
- Variant C – two berth, eight cranes.

In the Table VIII the cost amounts for each variant with an annual container traffic of 200,000 TEU are given. Based on the obtained values, taking into consideration minimum cost criteria and annual capacity of 200,000 TEU, it can be concluded that the optimal solution is the variant that include two berth and four container cranes. Although the total cost of the above variants do not differ significantly.
TABLE VIII. The Total Costs for Two Berths and Annual Capacity of 200,000 TEU

<table>
<thead>
<tr>
<th>Cost</th>
<th>Number of Cranes</th>
<th>d=4</th>
<th>d=6</th>
<th>d=8</th>
</tr>
</thead>
<tbody>
<tr>
<td>C_b</td>
<td>397.54</td>
<td>397.54</td>
<td>397.54</td>
<td></td>
</tr>
<tr>
<td>C_d</td>
<td>628.78</td>
<td>943.17</td>
<td>1,257.56</td>
<td></td>
</tr>
<tr>
<td>C_m</td>
<td>196.21</td>
<td>294.31</td>
<td>392.41</td>
<td></td>
</tr>
<tr>
<td>C_m+C_p</td>
<td>359.87</td>
<td>536.26</td>
<td>712.54</td>
<td></td>
</tr>
<tr>
<td>C_mm</td>
<td>33,045</td>
<td>33,045</td>
<td>33,045</td>
<td></td>
</tr>
<tr>
<td>C_r</td>
<td>98.63</td>
<td>65.18</td>
<td>48.58</td>
<td></td>
</tr>
<tr>
<td>C_e</td>
<td>414.15</td>
<td>273.72</td>
<td>204.01</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>35,140</td>
<td>35,555</td>
<td>36,058</td>
<td></td>
</tr>
</tbody>
</table>

The construction of the Zagreb pier container terminal provided an additional annual capacity of 500,000 TEU for the port of Rijeka. Due to various circumstances, this cannot be realized. Therefore, the annual capacity of 400,000 TEU would be taken into account for further calculation.

TABLE IX. The Total Costs for Two Berths and Annual Capacity of 400,000 TEU

<table>
<thead>
<tr>
<th>Cost</th>
<th>Number of Cranes</th>
<th>d=4</th>
<th>d=6</th>
<th>d=8</th>
</tr>
</thead>
<tbody>
<tr>
<td>C_b</td>
<td>397.54</td>
<td>397.54</td>
<td>397.54</td>
<td></td>
</tr>
<tr>
<td>C_d</td>
<td>628.78</td>
<td>943.17</td>
<td>1,257.56</td>
<td></td>
</tr>
<tr>
<td>C_m</td>
<td>196.21</td>
<td>294.31</td>
<td>392.41</td>
<td></td>
</tr>
<tr>
<td>C_m+C_p</td>
<td>367.96</td>
<td>544.86</td>
<td>721.51</td>
<td></td>
</tr>
<tr>
<td>C_mm</td>
<td>33,045</td>
<td>33,045</td>
<td>33,045</td>
<td></td>
</tr>
<tr>
<td>C_r</td>
<td>207</td>
<td>65.18</td>
<td>48.58</td>
<td></td>
</tr>
<tr>
<td>C_e</td>
<td>1,738.39</td>
<td>547.45</td>
<td>408.01</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>36,675</td>
<td>35,932</td>
<td>36,365</td>
<td></td>
</tr>
</tbody>
</table>

Taking into consideration the minimum cost criteria the optimal solution is the variant that include two berth and six container cranes with the annual capacity of 400,000 TEUs. With regard to the estimated future traffic at the Zagreb pier it is necessary to equip the container terminal, i.e. two berths of the terminal with an adequate number of cranes. For estimated traffic of up to 200,000 TEUs, there will be enough to install four cranes. Otherwise, for traffic up to 200,000 TEUs, it will be needed six cranes on two berths for optimal functioning of the terminal.

IV. CONCLUSION

The port system internal efficiency strongly depends of the development of port infrastructure, superstructure and port equipment. For optimal functioning of the container terminal it is especially important to define the capacity of the terminal that affects the possibility of achieving the production plan, and the realisation plan for port services. This paper shows the cost model that determines the combination of number of berths and cranes per berths with the least costs for the given traffic of the terminal. The cost model of the container terminal at the Zagreb pier is presented with the function of total port costs that contains the next costs: berths costs, costs of container cranes, costs of transport-handling equipment, crane operator costs, operator costs, costs of stacking surface, costs of ship stay in the port and cargo costs. Based on the obtained values, taking into consideration minimum cost criteria and annual capacity of 200,000 TEUs, it is concluded that the optimal solution is the variant that include two berth and four container cranes. In the second case, for the estimated traffic of more than 200,000 TEUs up to 400,000 TEUs, the optimal operation of the terminal with two berths and the minimum cost criterion would be the installation of six cranes. The application of cost model enables the adoption of appropriate business decision for any terminal in different working conditions.
REFERENCES


Role of Mathematics in Education of Nautical Engineer

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ABSTRACT
From a long time ago mathematics has been used in many technical fields, as well as maritime engineering, navigation in particular. Without the knowledge of mathematics, maritime engineering would not be possible in terms of ship stability and travel plans plotting. The influence of mathematics in navigation can be seen through the application of trigonometry and geometry in terrestrial and astronomical navigation and the calculation in the navigational charts construction. The development of mathematics has influenced the development of maritime engineering. Therefore, the assessment of the math courses is unavoidable in the education of any seaman. These courses represent the basis of all technical subjects that are of concern to any educated seaman, in this case, the sailor. This paper will try to present only some branches of mathematics with which a maritime navigator will have to deal with every day.

KEYWORDS: maritime, mathematics, education & nautical

I. INTRODUCTION
The relation between mathematics and nautical sciences goes deep in history. All navigation methods come from the main branches of mathematics that have developed through many civilizations. In this paper, the role of mathematics will be described not only in the branches of navigation but also in the development of maritime charts, chart projections and in the calculation of a ship’s stability. Namely, mathematics is applied wherever issues related to size, structure, space, or change occur. Mathematics plays a major role in the work of a seaman. Modern seamanship would not have been possible without the knowledge of mathematics; in the same way, there would not exist orthodromic navigation without the mathematical branch of trigonometry since equations for all elements in loxodromic and orthodromic navigation are derived through trigonometric relations. In order to understand this, it is important to explain the definition of terrestrial and astronomical navigation first. Terrestrial navigation includes methods by which the position of the ship and other navigational elements are determined by observing natural or artificial terrestrial objects or by measuring the depth of the sea. Astronomical navigation is a classic navigation branch that deals with questions and methods in which celestial bodies are used to determine and control the position of the ship in open seas.

II. MATHEMATICS IN THE EDUCATION OF NAUTICAL OFFICERS
Seafaring is the art of managing and manoeuvring a ship, her equipment and her crew. Maritime activities include the ability to navigate, steer, anchor, avoid collisions at sea, managing cargo, etc. For this reason, every seaman should, for the purpose and as a basis for the mentioned skills, know mathematics and know how to apply them in his/her work. Mathematics encourages people to think and develop their reasoning. As seafaring progresses, ships that are being built are getting bigger, faster, more agile and modern. It is therefore important to know how to apply mathematics, not only to facilitate the building of such ships, but also to facilitate their use. That is why it is said that mathematics is an important weapon in the hands of seamen. Mathematics, in the nautical training, is based on the adoption of a variety of mathematical subjects and the entire teaching material is impossible to enumerate. By learning these subjects, the student is ready to use the acquired mathematical knowledge in practice when completing his/her education.

The learning outcome in mathematics is that students adopt basic mathematical knowledge, skills and processes and establish and understand mathematical relationships. Students should be competent to solve mathematical problems and apply maths in different contexts, not only because of their practical
work but also because of the possibility of further education and advancement. Therefore, it is necessary to develop a positive approach to mathematics, the responsibility of the student for their success and progress and awareness of their mathematical achievements during the teaching lessons. By learning mathematics, students need to be competent for abstract and spatial thinking and logical inference in such a way that they can effectively apply mathematical knowledge, ideas and results using different presentations. The effective application of technology, as well as a solid basis for lifelong learning and continuing education, are acquired by learning mathematics.

Students often ask questions why maths are needed in seafaring. The answer is clear now. Mathematics is not only the basis for many technical subjects without which a nautical student sailor could not complete his/her education, but also serves to calculate and give solutions to uncountable situations in the life of a seaman. Navigational applications, ship’s stability, financial calculations, wave motions are only part of the problems that are solved by the use of mathematics. Improving the accuracy of navigation, the safety of the ship’s navigation, optimization of costs, and so on are still a part of seafaring that is impossible to approach without the knowledge of mathematics. Should it be put further?

Mathematicians seek samples and use them to create new assumptions. They check the accuracy of assumptions with the help of mathematical evidence. When mathematical structures are precise models of a real event, then mathematical calculation can provide an insight into the nature of the events or predict future similar events.

One of the navigational methods is the terrestrial navigation, the method of managing the ship using graphical and numerical task solving, observation of natural and constructed objects on the coast or at sea (sea lights, bell towers, pointed peaks, etc.) and sea depth measurement. In addition to the numerical resolution of tasks in terrestrial navigation, graphical views such as directions, curves and angles are used. Each seaman should know the definitions for course, azimuth, and bearing. The course is defined as the angle between the meridian direction and the heading; azimuth is the angle between the meridian direction and the azimuth line, and the bearing is the angle between the heading and the azimuth line. The use of curves in terrestrial navigation is read by using loxodromic and orthodromic navigation.

Mathematical calculations in seafaring are the starting point of all life stages of a ship. During the exploitation period, as part of the voyage plan, the seaman should determine the navigational route; and determining the position of the ship by astronomical navigation would be unthinkable without the knowledge of mathematics. The nautical charting is also based on mathematics. The list could go further on, as the roles of mathematics are multiple, not just for the tasks of a nautical officer, but in all maritime aspects. Therefore this paper will cover just a few elements of mathematics without which seafaring would not be possible.

A. Applications of mathematics in the projection of navigational charts
Cartographic projections are conditioned by the drawing of the meridian and parallel network that serve as the mathematical basis for chart making. It is considered that the Phoenicians used the charts for navigation, but the first written information on the use of nautical charts was made in 1270, when charts were called portolans, hand-drawn on parchment or leather. All cartographic projections, according to the deformations that occur when the spherical surface is displayed on a plane, are divided into: conformal (angles in the nature correspond to the angles on the chart), equivalent (preserved equality of the surface), equidistant (retains the same length but only in one direction) and arbitrary (all charts that do not fall within the afore mentioned categories).

The ideal chart would be conforming, equivalent and equidistant, but such a chart does not exist. Globus is the closest to the ideal solution as it meets all three conditions, but because of its size it is unsuitable for practical use. The Earth, as a ball or ellipsoid, can be projected onto a cylinder, a plane or a cone.
Cylindrical Projection

Cylindrical projections are those in which the Earth’s surface is projected onto a cylinder mantle. Depending on the position of the cylinder to the Earth’s axis, it may be: equatorial, transverse and oblique.

![Fig. 1. Cylindrical projections](image)

- a) equatorial (normal)
- b) transverse
- c) oblique

The angles on the chart do not match the angles in nature, so the chart is not conformal. In order for the chart to be conformal, the distance among parallels and meridians should be the same. The mathematical determination of the angles of the triangle of the cylindrical projection is based on trigonometric functions.

Projection on Earth:

\[
\tan K = \frac{dR}{d\varphi} = \frac{d\lambda \cdot \cos \varphi}{d\varphi} \tag{1}
\]

where:
- \(K\) – angle,
- \(R\) – separation,
- \(\varphi\) – latitude,
- \(\lambda\) – longitude

Projection on the cylinder:

![Fig. 2. Angle calculation for the projected triangle on Earth](image)

\[
\tan K = \frac{d\lambda}{d\varphi} = \frac{d\lambda \cdot \cos^2 \varphi}{d\varphi} = \frac{d\lambda \cdot \cos \varphi}{d\varphi} \cdot \cos \varphi \tag{2}
\]

How to get a conformal chart from a classic cylindrical projection was demonstrated in 1569 by Dutch cartographer Gerhard Kramer, called Mercator. Mercator retained part of the cylindrical projection, but the spacing between the parallels was not obtained by projection but by a mathematical calculation, assuming that the meridians also extend along the latitude.
\[
\begin{align*}
\cos K &= \frac{\Delta \varphi}{D} \\
\sin K &= \frac{R}{D} \\
\tan K &= \frac{R}{\Delta \varphi}
\end{align*}
\]

where:
- D – distance,
- \(\Delta \varphi\) – difference in latitude.

Conic Projection

Conic projections are developed when the surface of the Earth is projected on the cone mantle, where the cone touches the Earth in one parallel or cuts it in two parallels. Depending on the position of the cone axis in relation to the Earth axis, the conic projections can be: normal, transverse and oblique.

III. APPLICATIONS OF MATHEMATICS IN ASTROMICAL NAVIGATION

Astronomical navigation is a classic navigation branch which deals with issues and methods to be used with celestial bodies in order to determine and control the position of a ship in open seas. The adoption of astronomical navigation methods, and the aids used by the navigator, request the knowledge of part of general and spherical astronomy. Astronomy is the science that studies the celestial bodies, their position, motion, dimensions, distances and their past and future.

The branches of astronomy practiced in seafaring are the spherical and the practical astronomy. These two branches when combined are known by the name astrometry. Spherical astronomy studies the relative positions of celestial bodies projected on the imaginary celestial sphere and shows how these positions change under the influence of various causes. Practical astronomy deals with methods and instruments for determining the apparent coordinates of celestial bodies from perception, and determining the position of observers on Earth.

Astronomical navigation has in the past been more used to determine or check the position of a vessel in navigation than it is today. Today, astronomical navigation has been relegated by various satellite systems that show the precise position of the ship. The disadvantages of astronomical navigation are the time needed for a person to estimate the position of a ship through the height of a celestial body, and knowing astronomical calculations. To solve astronomical problems in navigation, it is necessary to master trigonometric functions.
Spherical trigonometry is used to solve spherical triangles through the application of goniometric functions. A spherical triangle is a figure in a sphere determined by three points lying on the same great circle. At the point where the two great circles intersect, a spherical angle is formed, called a “digon” or b-angle. The spherical length represents the smaller arc between two points on the great circle of the sphere. Every spherical triangle has an associated polar triangle (formed by constructing a triangle using the poles of the sides (great circles) of the triangle. The spherical triangles can be right-angled, quadrantal and oblique.

For right-angled spherical triangles it is considered that the cosine of a middle part equals the product of the cotangents of the adjacent parts or the sines of the opposite parts.

\[ \cos c = \sin(90^\circ - a) \cdot \sin(90^\circ - b) = \cos a \cdot \cos b \]  

(4)

A quadrantal spherical triangle can be solved by Napier’s rules provided any two elements in addition to the 90° side are known. The 90° side is omitted and the other parts are arranged in order in a five–sectored circle, using the complements of the three parts farthest from the 90° side. In the case of a quadrantal triangle, rule 1 above is used, and rule 2 subtracted: angle C (the angle opposite the side of 90°) is more than 90° when A and B are in the same quadrant, and less than 90° when A and B are in different quadrants. If the rule requires an angle of more than 90° and the solution produces an angle of less than 90°, subtract the solved angle from 180°.

Theorem of the cosines for angles:

\[ \cos a = - \cos \beta \cos \gamma + \sin \beta \sin \gamma \cos a \]
\[ \cos \beta = - \cos a \cos \gamma + \sin a \sin \gamma \cos b \]
\[ \cos \gamma = - \cos a \cos \beta + \sin a \sin \beta \cos c \]  

(5)

where:

\[ \alpha, \beta, \gamma \] – angles of the spherical triangle, \( a, b, c \) - sides of the spherical triangle.

The intercept method is the most used fix method in practice, although sometimes the Dozier method is used. Apart from those, there are other methods: Borda (latitude), Johnson (distance) and Sumner (sexant).

The intercept method was established by the French seaman Marcq de Saint Hilaire by the end of the XIX century. The method was globally accepted in the XX century and since then it has dominated over the others. The fix, according to this method, is obtained by the difference between the observed altitude and the calculated altitude, calculated with the aid of coordinates of the combined position and the direction of the azimuth. [3] Thus the intercept method is based on the correction of the coordinates of the different positions for the differences between the observed and calculated altitudes of celestial bodies in the azimuthal direction. The process for obtaining the fix is the following: the altitude of
A celestial body is measured and the time of the observation accurately noted with the aid of a chronometer. After this, this altitude is corrected by depression and refraction, obtaining the observed altitude (Ho), and the time of the observation is corrected by the chronometer error to obtain Greenwich Mean Time (GMT):

\[ UTC = t_k + St \]

where:
- \( UTC \) – Universal time,
- \( t_k \) – time noted in the chronometer,
- \( St \) – chronometer error.

For this GMT or UTC and with the help of the nautical almanac the declination and hour angle are obtained. The local hour angle will be calculated by adding the longitude to the hour angle at Greenwich. The local hour angle differs from the actual in a measure that is proportional to the error in geographic longitude.

With declination, geographic latitude and hour angle, the altitude of the celestial body is computed (Hc). The altitude is calculated with this expression:

\[ \sin H_c = \sin \varphi \cdot \sin \delta \cdot \cos \varphi \cdot \cos \delta \cdot \cos LHA \]

where:
- \( H_c \) – altitude
- \( \delta \) – declination
- \( LHA \) – local hour angle

This computed altitude is then compared to the observed altitude. The difference between Hc and Ho is called "intercept" and is the observer's distance from the assumed position.

\[ \Delta H = Ho - Hc \]

where:
- \( Ho \) – observed altitude,
- \( Hc \) – computed altitude.

The coordinates of the calculated position are corrected by the difference in altitude in the direction of the azimuth, so the calculation of the azimuth is needed.

\[ \cos \omega = \frac{\cos \delta - \sin \varphi \cdot \sin H}{\cos \varphi \cdot \cos H} \]

where:
- \( \omega \) – azimuth.

The azimuth is drawn on the chart from the assumed position. The assumed position was used for the computed altitude. The side of the horizon where the projection is found will define the local hour angle.

On a Mercator nautical chart from the assumed position the direction of the azimuth is drawn and on it the intercept is drawn.

The line of position is obtained when a line perpendicular to the azimuth direction is drawn at that point.

With two or more fix lines the position of the ship is obtained. The ideal angle between two lines of position is 90°, in case the same celestial object is used, then the lines of position should be calculated for a time difference.
The next mentioned method is the direct or Dozier method. This method, which helps to determine the ship's position by the resolution of the system of trigonometric equations, was developed by Charles T. Dozier in 1949. The fix with this method is obtained in such a way that two position circumferences are drawn, and the position is determined by one out of the two intersections of the circumferences. This method is called direct because the position can be obtained mathematically without a graphic representation.

From Fig. 5 it is possible to determine $S_1$ – terrestrial projection of the first celestial object, and $S_2$ – terrestrial projection of the second celestial object.

$$\Delta GHA = GHA_1 - GHA_2 = GHA_y + \lambda + (360^\circ - \alpha_1) - GHA_y - \lambda - (360^\circ - \alpha_2)$$

$$\cos LHA_1 = \frac{\cos H_1 - \sin \delta_1 \sin \varphi}{\cos \delta_1 \cos \varphi}$$

where:

$GHA$ – Greenwich hour angle,
$LHA$ – local hour angle of the celestial object.

Another method is the latitude or Borda. The main points of this method is that the terrestrial longitude is estimated, and the latitude computed for this longitude and the corresponding azimuth.

$$\cos (\varphi - x) = \frac{\sin Hp \cdot \sin x}{\sin \delta}, \tan x = \frac{\tan \delta}{\cos LHA}$$

$$\cos \omega = \frac{\sin \delta - \sin \varphi \cdot \sin Hp}{\cos \varphi \cdot \cos Hp}$$

It is also very interesting the Johnson method. This method gives the best results in the vicinity of the horizon, and it is not so accurate in the vicinity of the zenith.

$$\cos LHA = \frac{\sin Hp - \sin \varphi \cdot \sin Hp}{\cos \varphi \cdot \cos \delta}$$

$$\cos \omega = \frac{\sin \delta - \sin \varphi \cdot \sin Hp}{\cos \varphi \cdot \cos Hp}$$

Captain Thomas Sumner came by chance to the method of determining a position line with the aid of celestial objects, during a voyage from Charleston to Greencook in 1837. He calculated and plotted three positions which were in line (position line). From a geometry point of view, a line of position can be defined with two points, or one point and one direction. The line which passes through two points in a circumference is called secant; for this reason the Sumner method is called the secant method.
IV. APPLICATION OF MATHEMATICS TO TERRESTRIAL NAVIGATION

The term navigation comes from the Latin word navigation, which was formed by the words ship (lat. navis) and movement (lat. agar). Initially navigation meant ship management skills, while today it has a far wider meaning. Navigation can be defined as the science and skill of managing the ship in the shortest, safest and most convenient way.

Terrestrial navigation includes methods by which the position of the ship and other navigational elements are determined by observing natural or artificial terrestrial objects or by measuring the depth of the sea.

Mathematics plays a major role in the profession of the nautical officer. Without the knowledge of mathematics, modern seamanship would not have been possible, in the same way as without the mathematical branch of trigonometry there would not exist the orthodromic navigation since equations for all elements and loxodromic and orthodromic are derived from trigonometric relations.

Here must also be mentioned the mathematical forms for loxodromic navigation. The loxodrome is represented as a curve of spiral form, which passes through two points on the Earth’s surface, intersecting all meridians at the same angle. It approaches the pole, but never reaches it. The ship navigating with a loxodromic route between two positions on the Earth will always cut all the meridians at the same angle.

Looxodromic tasks can be represented graphically on Mercator nautical charts.

Fig. 6. Loxodrome and orthodrome routeing

The graphical way of dealing with loxodromic routeing is the easiest, but the disadvantage is that it is not a precise solution. Apart from the graphical way of solving the loxodrome routeing, there is also computing it. Looxodromic exercises can be completely defined by mathematical extracts from three loxodromic triangles.

The first loxodromic triangle or triangle of the course is obtained if from the starting point (P1) on the Earth a loxodromic rhumb line leading to the arrival position (P2) is defined.

As the first loxodromic triangle is defined as right-angled, the trigonometric rules apply.

\[
\cos K = \frac{\Delta \phi}{D} \\
\sin K = \frac{R}{D} \\
\tan K = \frac{R}{\Delta \phi}
\]  

(16)
The second loxodromic triangle or triangle of mean latitude is used in theory for defining the relationship between the separation and difference in longitude. In the practice it is not taken into account.

The following expression is obtained:

$$\cos \varphi_s = \frac{R}{\Delta \lambda}$$  \hspace{1cm} (17)

where:

$$\varphi_s$$ – mean latitude

From the given expression comes the final relationship for the separation and difference in longitude:

$$R = \Delta \lambda \cdot \cos \varphi_s$$  \hspace{1cm} (18)

The third loxodromic triangle or Mercator triangle is copied from the Mercator nautical chart where the loxodromic rhumb line is a straight line. The sides of the Mercator triangle are the differences of the enlarged latitude and the difference in longitude.

$$\tan K = \frac{\Delta \lambda}{\Delta \varphi_M}$$  \hspace{1cm} (19)

where:

$$\Delta \varphi_M$$ – difference of Mercator latitudes

The orthodromic is the shorter arc of the great circle that passes through two positions in the sphere and whose centre coincides with the centre of the sphere. In order to mathematically determine the elements of orthodromic navigation, the spherical trigonometry laws should be known as they will be applied to the spherical triangle. The great circles of the orthodromic spherical triangle are the geographical latitude for the starting and arrival positions, and the shorter arc of the orthodrome that links these two positions.

The orthodromic spherical triangle is formed by the meridians of the departing and arriving points and the arc of the orthodrome. The angles of the orthodromic spherical triangle are the initial course ($K_1$), the arrival course ($K_2$) and the difference in longitude ($\Delta \lambda$) which is represented by the angle at the pole.

When determining the expressions for the orthodrome distance and initial course, the cosine equation for the sides will be used.

$$\cos D_0 = \cos \psi_1 \cdot \cos \psi_2 + \sin \psi_1 \cdot \sin \psi_2 \cdot \cos \Delta \lambda$$

$$\cos D_0 = \cos(90^\circ - \varphi_1) \cdot \cos(90^\circ - \varphi_2) + \sin(90^\circ - \varphi_1) \cdot \sin(90^\circ - \varphi_2) \cdot \cos \Delta \lambda$$

$$\cos D_0 = \sin \varphi_1 \cdot \sin \varphi_2 + \cos \varphi_1 \cdot \cos \varphi_2 \cdot \cos \Delta \lambda$$  \hspace{1cm} (20)
where:
- $D_0$ – orthodrome distance
- $\Delta \lambda$ – difference in longitude

Since the cosine of the complement of the angle is the same as the sine of that angle, the ultimate expression for the orthodromic distance is used:

$$
cos D_0 = \cos \psi_1 \cdot \cos \psi_2 + \sin \psi_1 \cdot \sin \psi_2 \cdot \cos \Delta \lambda
$$

$$
cos D_0 = \cos(90^\circ - \varphi_1) \cdot \cos(90^\circ - \varphi_2) + \sin(90^\circ - \varphi_1) \cdot \sin(90^\circ - \varphi_2) \cdot \cos \Delta \lambda
$$  (21)

By applying the cosine equation for the angles, the value of the initial course can be determined. Attention should be paid to the fact that when applying the equation, only one angle is displayed - the opposite of the requested side. This element will be used when determining the initial course.

$$
cos \psi_2 = \cos \psi_1 \cdot \cos D_0 + \sin \psi_2 \cdot \sin D_0 \cdot \cos K_1
$$

$$
cos(90^\circ - \varphi_2) = \cos(90^\circ - \varphi_1) \cdot \cos D_0 + \sin(90^\circ - \varphi_1) \cdot \sin D_0 \cdot \cos K_1
$$  (22)

The final expression for the initial course is obtained by extracting:

$$
cos K_1 = \frac{\sin \varphi_2 - \sin \varphi_1 \cdot \cos D_0}{\cos \varphi_1 \cdot \sin D_0}
$$  (23)

The final course ($K_2$) can be determined in the following way:

$$
cos(90^\circ - \varphi_1) = \cos(90^\circ - \varphi_2) \cdot \cos D_0 + \sin(90^\circ - \varphi_2) \cdot \sin D_0 \cdot \cos K_2
$$  (24)

The orthodrome is represented as a curve that approaches the pole. The top position of the orthodrome is the point where the orthodrome is closest to the pole and it is called the top or the vertex (V). This position is defined by the coordinates of the latitude ($\varphi_V$) and the longitude of the vertex ($\lambda_V$). There are two cases for the vertex position, the first of them is when the vertex of the orthodrome is between the start and finish positions, and the other when it is not between the starting and arrival positions.

For the calculation of the vertex position coordinates, the Napier rule for right-angle spherical triangles should be applied. According to the rule, the Napier’s circle will be obtained.

With these elements, all other triangle elements can be calculated using Napier’s rules. By applying these rules, the geographic latitude of the orthodrome as follows:

$$
cos(90^\circ - \varphi_V) = \sin \psi_1 \cdot \sin K_1
$$  (25)

When determining the intermediate positions a rectangular spherical triangle is used, whose points are the closest point to the pole, the vertex and the observed waypoint. The geographic latitude of the waypoint will be the same to the left and to the right of the vertex, while the longitude difference is doubled.

When planning an oceanic navigation it is usually selected the shortest way. However, meteorological conditions sometimes do not allow following the shortest route. Because of this, sailing in practice is often neither loxodromic nor orthodromic, but a combination of both in accordance with weather conditions.

With the help of the Napier Rule the initial orthodromic course is determined, as well as the arrival orthodromic course and the initial and arrival subdistances, in the following way:

$$
cos D_{01} = \sin \varphi_1 \cdot \csc \varphi_G
$$

$$
cos D_{02} = \sin \varphi_2 \cdot \csc \varphi_G
$$

$$
sin K_1 = \cos \varphi_1 \cdot \sec \varphi_2
$$  (26)

where:
The total distance which the ship will cover under combination navigation can be calculated as:

\[ D = D_{01} + R + D_{02} \]  \hspace{1cm} (27)

where:
- \( D \) – total distance,
- \( D_{01} \) – initial subdistance (for the first orthodrome),
- \( D_{02} \) – arrival (for the second orthodrome).

V. CONCLUSION

Mathematics appeared because of the practical needs of the people. This statement is definitely true since mathematics are important for calculations, comparisons, measurements, or time calculations. However, there is another important reason. Mathematics, just like poetry, painting, music, and art in general, has been born from human spiritual needs and his aspirations for cognition.

In the same way as the seafaring is unthinkable without the sea, building of modern ships is unthinkable without mathematical calculations. The role of mathematics in the design phase of the ship’s structure needs the use of Bonjean curves when calculating the geometric characteristics of the ship. And without the ship there are no nautical officers.

It was the objective of this paper to explain the role of mathematics in nautical education and performance. It has been explained how it can be applied in the design of navigation charts, as well as terrestrial and astronomical navigation. From the paper it can be concluded that the knowledge of mathematics in terrestrial navigation is necessary for defining the voyage plan, which suggests that mathematics is the foundation of safe ship management. In astronomical navigation, determining the position of a ship in open seas by means of the intercept method is unimaginable without the mentioned mathematical calculations. Apart from applications in navigation, mathematical expressions are also used for drawing and projection of nautical.

Mathematics are everywhere around us and follow us in all segments of the life although we are often unaware of it. The relationship between mathematics and seafaring is not twofold. Although mathematical problems can be solved even if seafaring as a technical branch and profession had not existed at all; maritime problems, especially in navigation, would be unsolved without the knowledge and application of mathematics. That is why in the education of every seaman, mathematics are represented in every exam of any subject. By learning and mastering mathematic lessons, the terms for abstract and spatial thinking are acquired, and the logical conclusion and the effective presentation and application of the same. Thus, the educated nautical officer provides a solid foundation for lifetime learning and continuing education and the ability to progress in his/her profession.

REFERENCES

Some Dynamic Load Aspects in Ship Navigation

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ABSTRACT

The paper presents an analysis of dynamic loads acting on a general cargo ship during the navigation. The ship route is set to be North Atlantic, between Western Europe and North America. Therefore, a data on North Atlantic wave statistics are used to obtain wave height, wave period and probability of wave direction acting on ship through the course. Maximum wave induced wave bending moment and shear force are calculated using short term probability analysis, with respect to the scenario that ship encounters two hour storm. In addition, the ship is subjected to long term probability analysis in which wave bending moment and shear force are calculated taking into account several storms during a longer period. Dynamic load results are compared to ones obtained according to IACS semi empirical formulas. Differences between “direct” versus “code” approach are highlighted and discussed. In addition, static loads are also calculated using longitudinal strength calculation. For the purpose of analyses, over the 30 separate direct load calculations has been performed.

KEYWORDS: long term probability, short term probability, ship dynamic loads, wave induced bending moment, wave statistics & IACS

I. INTRODUCTION

Loads that are having major influence on hull girder integrity are vertical bending moments and shear forces. Conventionally, they are taken as a summary of their static and dynamic, wave induced, components. Here, only global response loads are to be discussed, so high frequency dynamic loads such as vibration are not investigated. Still water loads, caused by uneven distribution of weight and buoyancy along hull girder, are obtained using direct longitudinal strength calculation method [1]. On the other hand, wave induced bending moments and shear forces are usually determined upon prescribed formulas given by Classification Societies or IACS standards [2, 3, 4, 5, 6]. These, relatively simple and commonly used equations account for the large ship statistics in a typical 20 – 25 year exploitation period. However, direct approach, although complex for everyday use, seems to be more within the practise (even mandatory) at present, thanks to modern software tools. This includes use of linear strip theory applied to ship motion analysis to calculate hull girder loads. The procedures are usually based on Salvesen, Tuck and Faltinsen equations of ship motions (STF) [7] or, somewhat less frequently, on those given by Tasai [8].

The paper predominantly analyses vertical wave induced bending moment and shear forces on a case study of a typical general cargo ship, calculated using direct approach. Maximum values are compared to ones obtained by IACS equations - as “code” values. Furthermore, a direct calculation of dynamic loads is performed based on short and long term wave statistics using ”in house” software developed at the Department of Naval Architecture - WIFM+ [9, 10] and commercial one – ShipMo [11]. Firstly, it is assumed that ship sails directly through the waves as this event is believed to be the worst one in case of ship global structure response analysis. Secondly, an analysis is made in order to model waves that are encountering the ship from all possible angles - as this happens to be more realistic case. Statistical theory employed in this paper is thoroughly explained in [7, 9, 10, 12], therefore, only a brief description and methodology will be mentioned in following chapters. For the purpose of analyses, over the 30 separate direct load calculations has been performed.

II. CASE STUDY

General cargo ship used in the analysis is designed to carry bulk cargo as well as containers. Particulars include: LOA = 103.5 m, B = 17.7 m, H = 10.4 m, C.L = 0.74, V = 15.5 kn. Ship is examined in two conditions: as fully loaded (4800 t of cargo, no ballast) and in lightweight (no cargo, but with 3092 t of ballast). Fully
laden ship has displacement of 7855.5 t and draught of 5.74 m, while in lightweight displacement is 6881.4 t and draught 5.12 m. Fig. 1 illustrates tank arrangement lateral plan made in AutoHydro [13], as well as sagging and hogging scenario for the two conditions. Weight and buoyancy distributions for both loading cases are shown in Figs. 2 and 3. Note the typical excess in weight in the midship due to fully loaded cargo and the vice versa picture in the case of lightweight. In Fig. 2, aft end of the ship presents local peak of the weight distribution due to engine and superstructure location. Furthermore, buoyancy overlaps weight on fore and aft ends as majority of the weight (cargo) is distributed at midship. In Fig. 3 buoyancy line is somewhat the same as in Fig. 2, although the values are lesser due to reduced draught. Weight peaks a bit at the aft, as in fully loaded case. Maximum weight on the fore end is a consequence of ballasted fore end of the ship in lightship (see also Fig. 1, hogging condition). Uneven distribution hereafter will naturally produce larger static bending moments.

III. STATIC AND WAVE INDUCED LOADS (IACS)

Diagrams and data for static and dynamic loads are presented on Figs. 4 and 5. \( M_s \) and \( Q_s \) for both cases are obtained using longitudinal strength calculation and therefore are directly derived from distributions shown on Figs. 2 and 3. Corresponding \( M_w \) and \( Q_w \) are determined upon IACS formula [6], as maximum ones that ship could experience in a lifetime. One could note that lightweight ship has larger maximum still water bending moment and shear force than fully loaded one, which obviously corresponds to the less homogeneous weight - buoyancy distribution. On the other hand, fully loaded ship has larger wave induced maximum bending moment (206815 kNm vs. 183575 kNm). Moreover, it has lesser maximum wave induced shear force (-5335 kN) than lightweight (5820 kN). These values are to be compared to the directly calculated ones in following chapters to investigate differences in approaches on a single case study.
IV. Wave induced loads (Head waves)

Apart from previous standard IACS calculations, the direct ones are also performed to acquire wave induced loads. But first, statistical theory of irregular waves and therefore some statistical parameters have to be briefly introduced in order to take into account wave randomness to structure response. For that reason, a mean square of wave free surface deviation \( \sigma_0 \) with regards to equilibrium is defined by:

\[
\sigma_0 = \frac{1}{N} \sum_{i=1}^{N} \xi_i^2 (t_i)
\]  

(1)

So, root mean square would be:

\[
\text{RMS} = \sqrt{\sigma_0}
\]  

(2)

If time added, (1) becomes:

\[
\sigma_0 = \frac{1}{T_M} \int_{0}^{T_M} \xi_i^2 dt
\]  

(3)

According to Parseval’s theorem [12] which states that \( \int_{0}^{T_M} \xi_i^2 dt = \frac{T_M}{2} \sum_{n=1}^{\infty} A_n^2 \), a mean square deviation transforms to \( \sigma_0 = \frac{1}{2} \sum_{n=1}^{\infty} A_n^2 \). Wave spectrum is defined by \( S_n(\omega_n) = A_n^2 (\omega_n)/2\Delta\omega_n \). Modelled irregular waves consist of infinite array of regular components with their own \( \omega_n \) and \( A_n \). Waves that correspond to the frequency that matches the highest \( S_n(\omega_n) \) carry the highest energy, as in Fig. 6. Over the past decades storms are measured and analyzed and therefore for fully developed waves, model of Rayleigh distribution has been adopted as most representative. Therefore, a standard one parametric Pierson – Moskowitz ITTC wave spectrum [14], based on Rayleigh distribution, is used here for wave modeling and is shown in (4) and on Fig. 6. This spectrum is to be used in analysis and is defined by just one parameter - significant wave height \( (h_{1/3}) \), for which the waves of 3 m, 5 m, 7 m, 9 m and 11 m are accounted for. Parameters in (4) is determined as: \( a = 0.0081\sigma^2 \) and \( b = 3.11/h_{1/3}^2 \).

\[
S(\omega) = \frac{a}{\omega^5} e^{-b/\omega^2}
\]  

(4)

![Wave spectrum](image)

WIFM+ program, based on STF equations [7] is used as a software tool for analysis. Program solves ship motion equations for combined heave and pitch, followed by numerical integration of wave loads, i.e. bending moment and shear force. Motions and therefore loads are modelled as sinusoidal with their amplitude and frequency (5). After solving STF equations and applying Newton’s second law to a ship segment - strip, a transfer functions are determined for bending moment and shear force. Thus, \( M_w \) and \( Q_w \) transfer functions are derived: \( \Phi_M(x, t) = A_M/A_T \) and \( \Phi_Q(x, t) = A_Q/A_T \). Afterwards, a wave spectrum (4) is modelled for different significant wave heights \( h_{1/3} \). Consequently, wave induced bending moment and shear force spectrum (6) is obtained and their amplitude RMS values (7) calculated. Steps are shown in (5-7).
Wave induced bending moment and shear force distribution along the ship length are presented in Figs. 7-10 for both loading conditions and in case of following significant waves acting on ship: \( \chi m \), \( \omega m \), \( \upsilon m \), \( \upsilon m \) and \( \upsilon m \). Waves are modelled as irregular. Larger significant wave height produces larger dynamic load. Significant wave height of \( \upsilon m \) is accounted as extreme one ship could probably encounter during particular navigation. It produced maximum bending moment of around \( \tau \tau \tau \tau \) kNm and maximum shear force of \( \chi \omega \) kN in case of fully laden ship and \( \tau \tau \tau \tau \) kN m (\( \chi \chi \tau \) kN) in lightweight ship condition. These values are much lower than those obtained by IACS, see Figs. 4 and 5. This is calculated for single developed wave spectrum and not for the whole possible spectra. Note that in this analysis head waves are considered as this is the worst case from bending moment stand point, while ship is at full speed (15.5 kn).

V. WAVE INDUCED LOADS – SHORT TERM STATISTICS (HEAD WAVES)

Next scenario would include more compound analysis as ship encounters typical two hour storm. Storm would produce a spectrum of waves. Dynamic loads are, again, analyzed via WIFM+ using the short term statistics [15]. Bending moment and shear force spectra are taken into account, so the storm specifics are modelled as follows: storm duration - \( T_s = 2 \) hours = 7200 s, frequency of the spectre - \( \omega = \sigma_1/\sigma_2 \), mean period of irregular waves - \( T = 2\pi/\omega \), mean square deviation - \( \sigma_0 = \int_0^\infty S(\omega)d\omega \), spectrum moment of first order - \( \sigma_1 = \int_0^\infty \omega S(\omega)d\omega \), spectre moment of second order - \( \sigma_2 = \int_0^\infty \omega^2 S(\omega)d\omega \). Therefore, the most probable maximum amplitude od \( M_w \) and \( Q_w \) for the storm is calculated according to:

\[
Q_w(x, t) = A_Q \cos(\omega t + \epsilon_Q(\omega, t)) \quad M_w(x, t) = A_M \cos(\omega t + \epsilon_M(\omega, t))
\]

\[
S_Q(\omega) = \Phi_Q^2(\omega)S_\omega(\omega); \quad S_M(\omega) = \Phi_M^2(\omega)S_\omega(\omega)
\]

\[
RMS(Q_w) = \sqrt{\int_0^\infty S_Q(\omega)d\omega}; \quad RMS(M_w) = \sqrt{\int_0^\infty S_M(\omega)d\omega}
\]
Since for the both load cases the difference in results is negligible, only fully loaded ship dynamic loads are given for the two hour storm. Figs. 11 and 12 represent wave induced bending moment and shear force for significant heights of 3-11 m at full speed of 15.5 kn, whereas Figs. 13 and 14 show the same loads for zero speed. Of course, here in paper, zero speed is taken for theoretical purposes to compare extremes (calculation is performed for 0 kn) since the ship will eventually have a few knots speed while navigation through the waves. $M_W$ and $Q_W$ in case of a storm are larger than ones obtained for just head waves (see Chapter IV). Naturally, one could assume that the captain would reduce the speed of the ship headed to large waves, so these results could be considered as extreme one and not so probable. On the other hand, if the ship stops the engines and experiences the storm, as in other extreme, it would experience much lesser loads. More realistic loads would, therefore, be somewhere in between these limits in which the speed is, to some extent, reduced. Moreover, this analysis is short term and the storm is modelled by one wave spectrum only. During the storm, mean height and mean wave period are constant. So, in order to compare results to IACS (which account to ship whole life), loads will be calculated using long term statistical analysis, considering ship 20 year of exploitation period.

$$M_W, Q_W = \sqrt{\frac{2\sigma_0 \ln \frac{T_s}{T}}{N}}$$

(VI. WAVE INDUCED LOADS — LONG TERM STATISTICS (HEAD WAVES))

In long term statistics, dynamic loads are analyzed through longer time frame which includes a group of different storms. Long term statistics is obtained by relating short term statistics to the tables that show the probability of wave occurrence on certain routes [15]. The probability of long term bending moment occurrence, hence, is described by:

$$p(M) = \frac{1}{N} \sum_i N_i \exp \left( -\frac{1}{2} \left( \frac{M_i - \mu}{\sigma} \right)^2 \right)$$

(8)
M_i represents the RMS value of wave induced bending moment for the sea condition “i”. The same relation is used for the probability of long term shear force occurrence. Henceforward, the first assumption is, again, the consideration that the ship encounters head waves. Calculation is performed using specialized commercial ShipMo software [11].

Figs. 15-18 illustrate long term wave induced maximum bending moments and shear forces (their RMS values) in case of full and zero speed of ship with head waves. Obviously, the full speed case gave larger values. However, the ship would always reduce speed in such condition, so the real value is somewhat between these two extremes. Diagrams also present IACS prediction of the maximum Mw and Qw for sagging and hogging condition, calculated according to standard procedure described in [6]. Horizontal axis shows probability of occurrence of the event. Probability of $10^{-8}$ corresponds to ship experiencing maximum value of predicted bending moment at least once in the lifetime – generally considered as 20 years [5]. This means that, according to IACS, the maximum bending moment in a lifetime is somewhat higher than 200000 kNm, and according to direct long term statistics - roughly 500000 kNm for $v = 15.5$ kn and 330000 kNm for $v = 0$ kn! The discrepancy is evident. The same goes for a maximum of shear force. Directly calculated maximum Qw is few times greater than IACS’ one. Note that shear force has two peaks (aft and fore), as could be seen on Figs. 8, 10, 12 and 14. Therefore, highest RMS value, which is here at fore peak location, is presented in the following diagrams.

Considering that IACS values are taking into account a ship lifetime dynamic, it would be expected that IACS line and RMS would cross at the $10^{-8}$ probability and not between $10^{-5}$ - $10^{-4}$ as happened. So, even thought the captain would reduce the speed of the ship, it would still produce much larger loads than IACS, according to directly calculated long term approach. The reasons for this could be various. Note that the analysed case is the worst one: ship is experiencing pitch and heave in head waves. Anyway, this analysis needs to be expanded to the more real scenario in which ship is encountering waves for the particular route while approaching from all possible directions.
VII. WAVE INDUCED LOADS – LONG TERM STATISTICS (ALL WAVE DIRECTIONS)

The analysis is extended taking into account several additional premises: ship has already defined route from Western Europe to Northern America; ship experiences waves from all directions; ship itself is changing the direction of navigation according the route. Presented are results for ship in full speed and when fully loaded. Wave statistics are obtained from Global Wave Statistics [15] where data are presented on annual wave height and period in specific zones and respective probabilities of their directions. Waves are directed from 8 angles, so the ship is assumed to encounter waves from direction as in Fig. 19. Calculations are performed using ShipMo [11].

Fig. 19. Ship navigation zone (left) and wave direction probability (right) taken from [14].

Probability of encountering maximum $M_{W}$ (or $Q_{W}$) for the ship that encounters waves from just one direction (out of 8) is defined in (8). Such value, let assume governed by the waves headed from North (N), is included in total probability of reaching maximum value of bending moment (shear force) by 12.81% (Fig. 20) - as this is the measured value of probability of waves headed from North. RMS that includes all wave directions and all wave direction probabilities, are shown in Figs. 20 and 21. Marks ($SW=0$, $W=0$, $N=0$, $S=0$, $NE=0$, $SE=0$, $E=0$) shows the wave – ship alignment, as in Fig. 19. Bolded line (all angles) is averaged line which took into account all wave – ship orientations. Apart form averaged results, figures show dispersion of RMS values in case of each out of 8 wave – ship orientations, where naturally, head waves present the extreme case. In this, most real and comprehensive analysis out of all investigated above, maximum $M_{W}$ would be 370000 kNm, whereas $Q_{W}$ peaks around 16000 kN in for fore location. Aft part shear force peak is not presented as the values are lesser. IACS and long term analysis (for all wave angles) are now comparable as both account for ship lifetime. Maximum IACS value is also illustrated on diagram to show the difference between code and direct approach, which is still significant.

VIII. CONCLUSION

Paper analyses different approaches in hull girder dynamic load analysis in case of typical general cargo ship navigating on a specific route with known wave spectrum data. In general, maximum lifetime wave induced bending moment and shear force are calculated according to IACS formulae which are the semi-empirical standard that accounts for large experience over the past several decades. On the other
hand, direct calculation approach with regard to actual wave data for the route, although complex, appears to come more in practise. Consequently, wave induced bending moments and shear forces are “directly” calculated according to realistic scenarios that ship is experiencing head waves and waves acting from all angles while navigating in storm and during its lifetime.

When all wave approaching angles are taken into account, calculated maximum values of $M_W$ and $Q_W$ with probability of $10^{-8}$ (20 years of service) are much greater than IACS predicted. However, it has to be noted that:

a) Ship would never navigate at full speed during the storm (or, even less, whole lifetime) – so realistically expected values are undoubtedly lesser;

b) Obtained results do not question the authority of the IACS formulas for general hull structure scantlings definition. In those procedures they are just one element of wider picture - proven to be proper upon long time record on ship response data. Their presumed probability of $10^{-8}$ should not be taken literally.

On the other hand, code values of $M_W$ are sometimes used for other purposes. In some fatigue analyses, where $M_W$ values with probability of $10^{-4}$ are required, they are mathematically converted from IACS code values – taking their probability of $10^{-8}$ as granted. According to research presented in this paper this could lead to significant underestimation actual loading.

In order to really outline future recommendations for calculating lifetime wave induced bending moment and shear force maximums one should make a more thorough analysis to account large database of ships.

ACKNOWLEDGMENT
This work was supported by Ministry of Education, Science and Technological Development (Project no. TR 35009) of Serbia.

NOMENCLATURE

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Definition</th>
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<tr>
<td>IACS</td>
<td>International Association of Classification Societies</td>
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<tr>
<td>STF</td>
<td>Salvesen, Tuck and Faltinsen equations of ship motions</td>
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<td>$A_M$</td>
<td>Wave induced bending moment amplitude</td>
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**REFERENCES**


Using Theory of Games When Choosing the Optimal Strategy for Improving the Energy Efficiency Ships

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ABSTRACT
Energy efficiency of ships has been the IMO topic of the day since issuing the Kyoto Protocol in 1997. All ships with gross tonnage of 400 and above have to meet MARPOL Annex VI requirements. The Companies create and develop their own strategies based on personal experience.

The article describes a method for evaluation of the energy efficiency of maritime transport in the spirit of the Kyoto Protocol of 1997, the Paris Conference of 2015 and IMO requirements to the Maritime industry. The assessment uses mathematical theory of games and makes it possible to quickly and easily select an appropriate vessel operating strategy in order to meet both the ever-increasing international demands and the efforts of the shipping companies to reduce fuel expenses.

KEYWORDS: Ship Energy Efficiency, Game Theory

I. INTRODUCTION
With this article, we would like to draw attention to the problem of calculating the energy efficiency of ships by the offshore industry. The problem that we are facing is the impossibility of assessing the methodology provided by the IMO as mandatory in RESOLUTION MEPC.212 (63) Adopted on 2 March 2012, GUIDELINES ON THE METHOD OF CALCULATION OF THE ATTAINED ENERGY EFFICIENCY DESIGN INDEX (EEDI) FOR NEW SHIPS. We will not quote the well-known formula here, but we would like to point out that it contains 20 variables, some of which are calculated on the basis of other variables. The situation is further complicated by the following note, which we will quote verbatim: "NOTE: This formula may not be able to apply to diesel-electric propulsion, turbine propulsion or hybrid propulsion systems".

Therefore, it is not possible to calculate the energy efficiency of these ships, and other specific ships due to the specificity of their use and the tasks they perform.

The methodology proposed here is a possible approach to tackling the problem and, hopefully, it will not only help to find a practical solution that will increase the energy efficiency of vessels not covered by the formula proposed by the IMO but will also lead to environment protection decisions.

II. APPLICATION OF THE MATHEMATICAL THEORY OF GAMES WHEN ASSESSING THE ENERGY EFFICIENCY OF SHIPS.
Theory of games is the theory of formal or mathematical models for making optimal solutions in situations of conflict and uncertainty.

All the phenomena and processes in which the participants have dissimilar interests and have ways to achieve their goals are to be considered conflicts.

Definition: Conflict is any phenomenon in which the following is known [7]:

- Who is involved?
- How does he/she participate?
- What outcomes may this situation have?
- Who is interested in these outcomes?
- What does this interest include?
The concept of "optimality" is one of the fundamental concepts. That is why optimality is a formal model in the theory of games and it includes within itself:

- Rationality;
- Profitability;
- Expedience
- Feasibility;
- Sustainability;
- Fairness.

When solving applied tasks, an optimum is chosen in the model which meets a pre-selected criterion and corresponds to the real perception of the optimality of the participants in the conflict [2].

A game is a system of the interacting parties, the behavior of each of the parties, the possible outcomes of the conflict, the interested parties, the latter are called a coalition of the interests and the preferences of each party over the set of situations. Therefore, the mathematical model should reflect the following factors:

- Parties to the conflict are actors capable of making a decision
- It is necessary to specify precisely what types of decisions each party may make.
- There are parties in the conflict who assert incompatible interests.
- It is necessary to describe the individual interests and objectives of the interested parties.
- Define the set of possible outcomes and evaluate their usefulness for the parties concerned [2].

The final issue, which we would like to address, is that it is not necessary for the objectives of the participants in the conflict to be incompatible (antagonistic). Significantly more frequent are the encountered situations where the interests of the parties coincide partially or almost completely. A conflict may arise rather because of non-matching positions and the multiplicity of interests, and not due to incompatible interests.

All this should convince us that this theory can play a significant role in determining the optimal strategy for offshore ship operation and in assessing their ships' effectiveness. And, in order not to dwell any longer on the theory of games, we would just like to emphasize that the theory of statistical games is of fundamental importance in the decision making theory.

**A. Applying the theory of statistical games in determining energy efficiency.**

To limit the number of possible strategies and to simplify the task, we will proceed from Nash's theorem: (John Nash).

"There is at least one equilibrium situation (in mixed strategies) in each non-cooperative game \( G = <B, A, L> \)" [5].

The company's pre-strategy can be selected by analyzing the situation using the theory of non-cooperative games [2] to assess the general strategy. We can illustrate this with an example.

We shall analyze a game where each player has two strategies: strategy A - aggressive and strategy P - peaceful. We assume that it is better for the two parties to be peaceful, i.e. seek non-antagonistic decisions and actions rather than being aggressive - ready for "war" and not afraid of conflicts. If one player is aggressive and the other is peaceful that is good for the aggressor, and his profits are maximum and we estimate it at 3 points whereas the other party gets 0 points. If two aggressive strategies meet, both parties win something but lose more and the profits are appreciated as 1 point for each party. In the event that two non-aggressive strategies meet, losses (concessions) are also realized, but the profits are higher than those in the situation with two aggressors. Here the profits are estimated at 2 points for each party. The structure of winnings is presented by the following matrices:
The strategy of player 1 is expressed in the matrices of payment lines $H_1$ and $H_2$, and of player 2 - the matrix columns, respectively. The dominant strategies for each player are as follows - for the first player $A_1 - P_1$ (profit - $\chi p.$) and for the second player - $A_2 - P_1$ (profit - $\chi p.$). This condition, however, is a state of "war," which leads to mutual aggression and a condition profit of 1 point and loss of 2 points. The only equilibrium situation is $(P_1, P_1)$ - "peace" produces a better result for both players - $\phi$ points. Therefore, the non-cooperation behavior is detrimental to the common interest, and collective interests suggest the choice of peaceful strategies. At the same time, if players cannot exchange information, the most likely outcome is war. This game is known in the economic circles as "The Dilemma of the Prisoner" and gives us a basis for choosing a general strategy and from there we can limit the set of acceptable strategies and simplify the solution to the task.

A. Wald, the founder of statistical games, notes that all statistical models have the same structure, similar to a two-player strategic game: man (subject of governance) and nature (environment), using additional statistical information about environment strategies or the state of the economic environment $[\nu]$. Here we analyze a situation where we have an antagonistic game between two "players" - that is the environment and the offshore company. This game is slightly different from a standard antagonistic one for the following reasons:

- The environment cannot choose its optimal strategies because it is an unreasonable opponent and is not interested in winning the game, so the company plays against an imaginary opponent.

A reasonable partner (IMO) is involved on the side of the environment, who in turn also has its own strategy.

The environment has a random selection mechanism, which, with a certain probability, implements its various strategies. Since this mechanism has NOT changed for centuries, statistics can give us information about the probability distribution of its conditions $[1]$.

The following parameters with the following designations are introduced:

- $B$ – set of the of the state of the environment;
- $b$ - a separate state of the environment;
- $A$ – a set of the company’s decisions (strategies);
- $a$ - a separate decision of the company.

We assume that the set of states of the environment $B$ and the set of company decisions $A$ must be determined by the statistics presuming that they are measurable. Each distribution $\xi$ of set $B$ of the environment states assumed by the statistics before the experiment (the beginning of the game) is called the distribution of environment.

Assuming that the individual states of nature $b$ are random variables with distribution $\xi$, provided that the function has already been fixed, then the risk $R = R (b, \delta)$ becomes a random variable. Here, with $\delta$, we designate the mixed strategy of the subject in their statistical game with the environment. The risk is called Bayes’ risk of decision-making, taking into account (by statistical data) the distribution of the variable state of the environment.
We denote \( L(b, a) \) the function of the losses, and the game \( G = <B, A, L> \) is called a starting strategy game of the statistical decision-making task. Taking into account that in this game only the company deliberately strives for profit, then the solution is to seek an optimal strategy for the company, which is to achieve the optimal solution, complying with the limitations set by the partner of the environment – i.e. IMO. In case that we assume the state of the environment to be a random variable \( b \) with distribution \( \xi \) which also depends on the company's decisions (for example, in the case of uncontrolled air pollution with nitrogen oxides and CO\( _2 \) and the sea with petroleum products), we can also calculate the mathematical expectation of the risk in a distribution which risk is also a variable [7].

Taking into account that in the statistical game \( G = <B, A, L> \) only the subject (the company) deliberately strives for profit, then the decision of the statistical game is limited to the search for an optimal strategy for the subject, i.e. to the best functions of decision. It would be such a function \( \delta \) for which the risk \( R = R(b, \delta) \) is minimal, in an arbitrary state of the environment.

Typically, such a best function is rare to be found, since each state of the environment is characterized by a "best function" of its own.

The lack of the best decision function of a solution to all states of the environment requires the subject to use methods that provide optimal solution functions in the narrowest sense, i.e. when selecting certain criteria for optimality. The theory offers two approaches for determining optimal solutions that depend on the selected optimality criterion:

- Application of methods that relate the set of solutions to a subset of "good" functions.
- Application of methods that order the functions of the decision in accordance with the risk function, and the choice of the "best" functions is made using selected criteria for an ordering.

It should be noted that, having an evaluation criterion, we can choose the best solution, but there is no criterion for selecting the "best" criterion. Criterion selection depends on the goals, interests and experience of the subject (the company) [7].

**III. Conclusion**

The question of finding an optimal solution in terms of uncertainty and conflict is related to the answer whether there is an optimal solution to what is meant by "optimality"?

As noted in the previous paragraph, a unified form of optimality has not been developed. We have the perception and the knowledge about it, but this knowledge is not always applicable in practice. When we talk about something being "optimal" we usually have in mind three different forms of optimality:

- Benefit;
- Sustainability;
- Fairness.

The idea of benefit is the simplest. It consists in the strive of the participating parties to maximize profit or, ultimatelly, to minimize losses. Such situations are designated as Pareto efficiency. We can also find the benefit in the min-max principle.

Sustainability in non-cooperation games is realized in the disinterestedness (inability) of players to change the current situation. This is called "the principle of Nash equilibrium".

Fairness lies in the symmetrical form of the game. This means that the profits of the players are secured under all circumstances, the extra profits depend on their participation in the total profit.

In conclusion, we would like to conclude that the application of the theory of games is, in our opinion, fully applicable to assessing the economic efficiency of ships and to addressing environmental protection concerns. Though it may seem theoretically difficult, working with the theory of non-cooperation games is practically easy if we have the necessary statistical data and we have minimal skills to process...
the results. To understand the theory of games, we only need knowledge of algebra and minimal knowledge of mathematical analysis.

REFERENCES

Characteristics of The Eastern Adriatic Current in The Coastal Area Between Dubrovnik And Bar

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ABSTRACT

The research of sea currents in the Adriatic has a long history. Numerous methods of current measurements as well as indirect methods of current determination were applied. A large number of numerical models were developed to explore variability of the Adriatic current system at various space and time scales.

Direct long-term measurement of the sea currents in front of Dubrovnik in combination with the Princeton Ocean Model (POM) adapted for the whole Adriatic were used in this paper to describe a part of very stable Eastern Adriatic Current (EAC) in the coastal area between Dubrovnik and Bar where the coastline is generally oriented in the direction of NW-SE, without larger islands. It was found that at the current meter station with total depth of over 100 m off Dubrovnik, the current directions were dominantly between WNW and NW with very high stability factor, while the most intensive currents were recorded in WNW direction, parallel with the coastline. The maximum current flow near the surface was about 0.8 cm/s, while at the bottom it was weaker, about 0.3 cm/s. Intensity and stability of the East Adriatic Current flow in the area between Dubrovnik and Bar, as well as the existence of South Adriatic Cyclonic Gyre over the southern Adriatic Pit were confirmed also by the POM model results. Obtained results imply that all waste that reaches the sea in the coastal area southeast of Dubrovnik will likely pollute the whole area towards northwest.

KEYWORDS: currents, Eastern Adriatic Current, numerical model & Adriatic Sea

I. INTRODUCTION

In order to understand characteristics of the current field in a particular sea area, general outlines should be given about the main current generating forces. The main current generating forces are [1]: the force generated from horizontal differences in the sea density (gradient currents), tidal force causing tidal currents and wind drift force developed from the impact of tangential wind stress on the sea surface (drift currents).

Apart from generating forces, currents are also highly influenced by dimensions and topographic characteristics of the coast and the seabed of a particular basin.

To determine a current field at sea indirect and direct methods are used. Indirect method comprises distribution of some properties of sea water (for example temperature and salinity) to conclude on sea currents while direct method presents measurement of parameters needed for description of current field. Well known indirect method is determination of geostrophic currents from measured sea temperature and salinity, assuming that Coriolis force balances the horizontal pressure gradient [2].

For direct measurement of sea currents Lagrangian and Eulerian methods are usually applied. Lagrangian method includes spatial and temporal tracking of sea water particle (or tracers, drifters etc.) giving its trajectory. Eulerian methods include measurement of speed and direction at one position having as results stream lines at one point [3].

Indirect and direct methods were used to determine current field in the Adriatic paying more attention to the sea surface currents.

The first exploration of sea currents in the Adriatic was related to experience of sailors. Lorenz (1863) and Wolf and Luksch (1881) made a first set of “sea currents charts” based on spatial distribution of measured temperatures and salinities. Wolf and Luksch (1887) edited a chart of sea surface water circulation in the Adriatic Sea with set of cyclonic gyres and “recirculations” at the levels of the Palagruža Sill and south of the Istrian Peninsula [4].

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Direct measurement of sea currents in combination with indirect method of geostrophic approximation enabled making the “new” charts of the Adriatic surface currents. One of these charts was made by Zore-Armanda in 1967 [5] (Fig. 1). After Zore-Armanda the sea currents along the east Adriatic coast have prevailing NW direction, stronger in winter than in summer. Along the west Adriatic coast prevailing currents are SE directed, stronger in summer than in winter. Apart from strong seasonal variability, cross-currents in the area of Jabuka Pit and South Adriatic Pit can be noticed in charts, and there is some indication of circular circulation in the Northern Adriatic basin. However, it should be emphasized that sea currents in inner coastal waters are not shown in charts.

By implementation of Lagrangian method in current measurements using drifters, until lately, only surface currents were measured, although recently drifters which can be programmed to measure through water column are developed. The mean Adriatic surface circulation based on all drifter data for the period from 1990 to 1999 was derived by Poulain in 2001 [6].

According to Poulain, Lagrangian measurements confirmed the classical basin-wide cyclonic pattern in the Adriatic Sea, with recirculation (cross-circulation) in the vicinity of Jabuka Pit and the southern Adriatic basin as well as in the northern Adriatic basin.

Resultant surface circulation in the Adriatic may be explained as modification of gradient currents under the influence of tides and prevailing winds [7] as well as under the influence of some other phenomena and processes like seiches and inertial oscillations [8] and [9].

Development of numerical models in oceanography enabled exploration of acting forces and their influence on the sea current fields. In the last 30 years a large number of numerical models were applied for the Adriatic [4].

![Fig. 1. Sea surface currents in winter and in summer (from [5]).](image)

Eastern Adriatic Current (EAC) is a branch of the general Adriatic cyclonic circulation along the eastern part of the Adriatic Sea with dominant NW direction. It is well known that EAC varies seasonally, being strongest in winter and weakest in summer.

A very stable part of Eastern Adriatic Current in the coastal area between Dubrovnik and Bar will be described using long-term current measurements performed with Acoustic Doppler Current Profilers.
Characteristics of The Eastern Adriatic Current in The Coastal Area Between Dubrovnik And Bar

(ADCP’s). Current measurements were part of the scientific and research program – “The Adriatic Sea Monitoring Program” [10]. The measurements started in November 2007 and lasted until January 2009. Comparison between results of current measurements and numerical model will be presented too.

II. MATERIALS AND METHODS

The sea area off Dubrovnik, from an oceanographic point of view, is distinguished by a large depth gradient, which means that the sea depth rapidly increases with the departure off the coast (Fig. 2).

Currents were measured at station S20 (ϕ=42° 38.06’ N, λ=18° 02.66’ E, depth 105 m; WGS84) positioned at a distance of about 3 km off the coast (Fig. 2). In the winter ADCP was positioned at 105 m depth, while in the summer it was somewhat closer to the coast, at a depth of about 80 m (the station is therefore marked S20A). The measurements started on 28 November 2007 and lasted until 16 January 2009. Teledyne RD Instruments ADCP (Acoustic Doppler Current Profiler; Fig. 3) bottom mounted current meter was used with the vertical resolution of 2 m and sampling interval of 15 min.

Basic statistical analysis and spectral analysis of currents were applied [11]. Monthly and seasonal oscillations were described through the mean monthly current vectors and current roses.

Physical properties of the Adriatic for the period between 15 August 2007 and 15 November 2008 were calculated with Princeton Ocean Model (POM; [12]). POM is a three-dimensional nonlinear numerical model with complete hydro- and thermodynamics and turbulence closure submodel ‘Level 2 ½’ [13]. The equations which capture the model physics are the traditional equations for conservation of mass, momentum, heat and salt coupled with the equation of state [14]. The equation of state is a modified UNESCO form.

Adriatic-scale POM model had horizontal resolution of 2.5 km and covers the Adriatic basin with 108x320 grid points. Along the vertical 22 unequally spaced sigma layers were defined with increased resolution in the surface and bottom boundary layer. POM model was controlled by atmospheric, hydrological and tidal forcing. Atmospheric forcing for the Adriatic model adaptation included wind stress [15], surface heat ([16];[17];[18]) and water (E-P) fluxes calculated on the basis of the surface fields from the mesoscale model ALADIN [19] and instantaneous sea surface temperatures obtained by POM. Model domain contains 41 river discharges parameterized according to [20]. Climatological discharges were scaled according to realistic values from Neretva and Po Rivers [21]. Initial temperature and salinity fields were obtained by bilinear interpolation of the summer climatological fields into the Adriatic model domain, while velocity field was initialized with the state of rest. At the POM southern open boundary 7 harmonic constituents - M2, S2, N2, K2, K1, O1, P1 - are applied for denivelation and transport, while radiation condition is applied for three-dimensional current field.

III. RESULTS AND DISCUSSION

Time series of vertical profiles of mean monthly current vectors at station S20 (S20A) in the period between December 2007 and January 2009 are shown in Fig. 4. Predominant circulation is WSW-WNW, throughout the water column, except in May and June 2008 when speeds were less than 3 cm/s. Most intensive circulation was recorded in March 2008, with average (maximum) speed about 20 cm/s (95 cm/s) in the surface layer and 7 cm/s (40 cm/s) in the bottom layer, with a very high stability factor: about 95% in the surface layer, 70% in the middle layer, and 40% in the bottom layer (Table I). The weakest currents were observed in May 2008 (Table II). It can be generally concluded that circulation at station S20 is more intensive during the cold season (December to April) than during the warm one (May to November).

Statistical parameters of circulation at station S20 for March and May are given in Tables I. and II.
TABLE I. The statistics of the current flow at station S20 for March 2008. Vector and scalar means are given, together with the statistics of velocity magnitude (V) and the stability factor \( F \).

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<th>V-Dir (°)</th>
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<th>V-min (cm/s)</th>
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The most significant current energies at site S20 (Fig. 5) are recorded at long periods. Within subsurface layer (depth of 6 m) current energies are ten times bigger than in near bottom layer (depth of 100 m). Significant spectral maxima are pronounced at diurnal tidal period (larger near the surface) and at semi-diurnal tidal period (relatively larger energies near bottom).

Current rose in the surface layer shows that dominant current directions were between WNW and NW, while the most intensive currents were recorded in WNW direction, parallel to the coastline. In the bottom layer the currents were directed towards W and WNW, but also to the E direction, being a result of the tidal forcing (Figs. 6 and 7). Mean current vectors also show that the direction of the resultant vector throughout the most of the water column was directed towards WNW, due to the entering Adriatic NW current – East Adriatic Current (EAC) which embrace the whole water column in that area.

It can be concluded that current flow at S20 is stronger and with lower variability in the surface layer in comparison to the flow in the bottom layer. The recorded current flow is a part of the general East Adriatic Current which in front of Dubrovnik comprises the northern section of the South Adriatic cyclonic gyre.

Intensity and stability of the East Adriatic Current in the area between Dubrovnik and Bar is obtained by POM model too. Averaged model current fields for March 2008 (the most intensive circulation) and May 2008 (the weakest circulation) are shown in Fig. 8. It should be pointed out that the coastal area between Dubrovnik and Bar is generally oriented in the direction of NW-SE, without larger islands, which from the topographic and bathymetric point of view represents a significant condition for the intensification of the East Adriatic Current coming from the area of Otranto. The existence of the cyclonic gyre in the southern Adriatic is also evident in the modelled monthly average currents (Fig. 8). The presence of South Adriatic Cyclonic Gyre was obtained in almost all modelled monthly currents between December 2007 and January 2009 (not shown).
Fig. 4. Time series of vertical profiles of monthly mean current vectors at station S20 from December 2007 till January 2009 (from [10]).

Fig. 5. Total current spectrum in subsurface and near-bottom layer at the station S20 for time interval from 28 November 2007 to 20 July 2008.
Fig. 6. The distribution of current speed and direction at station S20 at depths of 6 and 100 m for 16 main directions (from 28 November 2007 to 20 July 2008; from [10]).

Fig. 7. The distribution of current speed and direction at station S20 at depths of 6 and 74 m for 16 main directions (from 21 July 2008 to 23 January 2009; from [10]).
Fig. 8. Mean monthly current fields for March 2008 (up) and May 2018 (down) at the depth of 5 m obtained by POM model.
IV. CONCLUSION

Characteristics of the Eastern Adriatic Current in the coastal area between Dubrovnik and Bar were explored on the basis of direct current measurement at the single station in front of Dubrovnik and numerical model simulations.

At the deep current meter station S20 with total depth exceeding 100 m off Dubrovnik, the predominant current directions were between WNW and NW with very high stability factor in the cold part of the year, while the most intensive currents were recorded in WNW direction, parallel with the coastline. The resultant vector almost throughout the water column was in WNW direction, which suggests that the inflowing Eastern Adriatic Current affects even the deepest layers of the sea. The maximum current flow near the surface was about 95 cm/s, while at the bottom it was weaker, about 40 cm/s. The most intensive circulation was in March 2008 while the weakest was in May 2008.

Results of spectral analyses of long-term measured currents off Dubrovnik have confirmed that East Adriatic Current can be explained as dominantly gradient current under the influence of tides and winds.

Intensity and stability of the East Adriatic Current flow in the area between Dubrovnik and Bar, as well as the existence of South Adriatic Cyclonic Gyre were confirmed by the POM model simulations.

It is important to emphasize that described current measurements and numerical model results indicate very important ecological consequence for the coastal area between Otranto Strait and Dubrovnik. The obtained results indicate that all waste (e.g. oil, communal waste or any other pollution) that reaches the sea in the coastal area southeast of Dubrovnik will likely pollute the whole area towards northwest.

REFERENCES


Cruise Ship Traffic in The Adriatic Sea: Environmental Impact

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**ABSTRACT**

Cruise ship traffic is a part of a shipping industry which is growing constantly, in a number of cruise ships and also number of persons on board them. Large cruise ships bring to the recipient country lots of benefits but at the same time they have negative impact on the environment. Adriatic Sea is closed type of sea and therefore is especially vulnerable to all kinds of pollution. The aim of this paper is to define all types of pollution from cruise ships that have environmental impact on the Adriatic Sea in respect to legal regulations for those pollutions.

**KEYWORDS:** cruise ship traffic, Adriatic Sea, pollution & environmental impact

**I. INTRODUCTION**

Cruise ship traffic is a part of a shipping industry which is growing constantly both in number of ships and their capacity. Although cruising tourism brings many benefits to the recipient country in economic and social scene at the same time it cruising industry can have negative environmental impact.

Cruise ships generate a number of waste streams that can result in discharges to the marine environment, including sewage, grey water, hazardous wastes, oily bilge water, ballast water, and solid waste. They also emit air pollutants to the air and water. These wastes, if not properly treated and disposed of, can be a significant source of pathogens, nutrients, and toxic substances with the potential to threaten human health and damage aquatic life [1].

Worldwide growth of cruise ship tourism is constantly increasing marine environmental contamination risks, frequently neglected by the tourism practices. Paradoxically, environmental degradation ultimately decreases the quality of resources tourism is dependent upon [2].

Because of their mobility, legal regulations of ships is specific subject. Therefore, literature on cruise tourism regulation is fragmented. Cruise mobility is considered an under-regulated activity, particularly when viewed from a state agency perspective. However, the regulatory voids in marine governance are increasingly tackled by international organisations and supranational authorities, such as the International Maritime Organisation (IMO) and the European Union (EU) [3]. Through annexes I, III, IV and V, IMO’s International Convention for the Prevention of Pollution from Ships (MARPOL) sets the international standards for controlling marine pollution from oil, solid and hazardous waste, sewage and air pollution. In the same way EU passed Biocidal product Directive 98/8/EC and Directive 2005/33/EC regarding sulphur content of marine fuels. Most recently, IMO passed Ballast Water Management Convention in 2018.

Adriatic Sea is semi closed type of sea with great dependence of its countries on tourism as part of economy. Cruise tourism is just one part in general tourism. Therefore, it is necessary to establish sustainable development of cruise tourism in Adriatic Sea so that negative impacts wouldn’t became greater than economic benefits.

**II. CRUISE SHIP TRAFFIC**

Cruising is a tourist journey of several days according to a specific cruise itinerary (detailed travel plan) [4]. The first cruise ships were built in the 1970s, however, their development began in the mid-1990s when the first cruise ship larger than the transatlantic Queen Elizabeth was built, cruiser Carnival Destiny. Since then, size of cruise ship has been constantly growing because the demand for such form of vacation is rapidly increasing.
A. Cruise ship traffic in world

At the beginning of 2010 world merchant fleet had 291 cruise ship with 15.2 mil. BT and the average size of 54047 BT [5] and currently there are 369 cruise ships [6]. Cruise ships are generally large ships. While they represent only 18 % in total number of passenger vessels at the same time they represent 93 % in total BT of passenger vessels [7]. Growth of cruise ship tourism in general is impressive - demand for cruising increased almost 50 % in five year period from 2000-2005 and then again by 50% in nine year period from 2005 to 2014 [5] and at last 20.5% in the last five years[8]. The cruise ship order book from 2018-2025 includes 50 new ocean-going vessels with average capacity of 4000 passengers [8] so the growth of cruise fleet is expected to continue in the same manner. Fig. 1 presents number of passengers on oceangoing cruise ships in last 20 years worldwide.

B. Cruise ship traffic in Adriatic Sea

Data on cruise ship traffic in the Republic of Croatia is officially monitored and published by the National Bureau of Statistics, since 2002. According to them, in 2018, there were 75 foreign vessels on cruise that arrived in Croatian seaports, which realised 693 journeys. More than 1.0 million passengers were on board and they stayed for 1 421 days in Croatia, that is, 2.1 days on average. Number of cruises, sojourns and number of passengers on board in the Republic of Croatia in the past 15 years is shown in Fig. 2.
III. CRUISE SHIP EMISSIONS, IMPACT AND REGULATIVE

The impacts of larger cruise ships on the environment can be compared with the impact of smaller cities. There are various sources for estimation of such environmental impacts, among which can be found: International Maritime Organization (IMO), Canadian Centre for Policy Alternatives - Nova Scotia (2000), The Ocean Conservancy (Cruise Control 2002) and Bluewater Network (2003 and 2006) along with many scientific articles covering this topic. The results of these surveys were used to illustrate the harmful effects of cruise ships and their tourists on the environment in general.

Cruise emissions cover a multitude of organic and inorganic wastes in gaseous, liquid and solid forms. Negative impacts of these emissions from cruise ships can be divided by the targeted environment: land, sea, and air (Fig. 3).

A. Land targeted emissions

Land targeted emissions means all waste generated on cruise ship that cannot be processed on board either because legal regulations or because lack of equipment on board ship. This waste is delivered ashore and must be processed further in local land facilities. This category comprises of solid waste, hazardous waste, ash, bilge water and rarely black water.

Cruise ships generate large amounts of solid waste which is very similar to communal waste. It can be divided in biological waste (food waste) and other waste that can be sorted and delivered ashore (plastic, glass, tins and paper). Daily accumulation of solid waste on board cruise ship is estimated to χ-ψ kg per passenger. However, cruise ship use incinerators for some of these waste, approximately ότ%. Product of incineration is ash that can also be delivered ashore but majority is dumped at sea.

Hazardous waste on cruise ships is a consequence of the work of photo laboratories, dry cleaners, photocopiers, printers, etc. Hazardous waste, also includes fluorescent lamps, protective paints and coatings, hospital waste, old medicines, cleaning agents, oily cloths etc. It is estimated that cruise ship produces ωω to όω litres of liquid hazardous waste per day [υτ].

Waste management is regulated by MARPOL Annex ω which entered into force in υύύό. The most significant feature is that all ships in international navigation certified to carry more than υω persons must carry a Waste Management Plan, to include written procedures for collecting, storing, processing, and disposing of waste. All waste generated on board must be delivered to the shore facilities where it can be recycled or properly disposed (unless it is incinerated onboard), except for food waste, which can be disposed of at υφ M from the shore. In relation to hazardous waste, MARPOL defines the prohibition of disposal of ‘harmful substances’ [11].

Fig. 3. Negative impacts of cruise ship emissions divided by the targeted environment
Bilge water is oily water and it is explained in next chapter in detail.

B. Water targeted emissions

Water targeted emissions is all waste generated on cruise ships that legally may be dumped in sea. This category comprises of wastewater, ballast waters, food waste, ash from incinerators and biocides from antifouling systems.

Wastewater on the ship can be divided into sanitary and oily bilge wastewater. Oily bilge water is a mixture of water, oily fluids, lubricants, cleaning fluids and other similar wastes that are collected in the ship’s bilge tank and produced by main and auxiliary machinery, boilers and other mechanical machines. As oily water it is regulated in Annex I of MARPOL Convention. Oil, gasoline, and byproducts from the biological breakdown of petroleum products can harm fish and wildlife and pose threats to human health if ingested so it is not permitted to discharge bilge water unless water product after treatment in separator has less than υω ppm. However, oil in even minute concentrations can kill fish or have various sub-lethal chronic effects [υ]. Bilge water also may contain solid wastes and pollutants containing high amounts of oxygen-demanding material, oil and other chemicals. A typical large cruise ship will generate an average of 8 metric tons of oily bilge water for each φψ hours of operation.

Sanitary wastewater in order to increase efficiency and disposal is further divided into black water or sewage and grey water. Black water is discharge from all types of toilets and urinals and it is regulated by Annex IV of MARPOL Convention. Black water may host many pathogens of concern to human health, including *Salmonella*, *Shigella*, hepatitis A and E, and gastro-intestinal viruses. Sewage contamination in swimming areas and shellfish beds pose potential risks to human health and the environment by increasing the rate of waterborne illnesses [υφ].

Annex IV of MARPOL Convention is governing standards for the discharge of sanitary wastewater according to 3 areas of navigation: sea area in a distance until χ nautical miles from the nearest land (zone 2); sea area between χ and υφ nautical miles from the nearest land (zone χ); sea area beyond υφ nautical miles from the nearest land (zone ψ). For each of these zones Annex IV proscribes standards of quality for discharged wastewater. However, problem lays in the fact that international legislation treats merchant navy ships with usually χτ persons on board same as cruise ships where the number of persons on board may exceed ό,τττ people.

Generally, untreated black water can only be discharged in zone ψ at regulated rate of discharge. The quality of discharge wastewater in other zones depends on wastewater treatment system installed on board cruise ship. There are two types of sanitary wastewater treatment systems available: marine sanitation device, MSD and advanced wastewater treatment system, AWT. The main difference between them is in quality of effluent. MSD is smaller in size and it is designed for treatment of black water only, so ships with MSD always discharge untreated grey water while black water can be discharged treated beyond 3 M or untreated beyond υφ M. In addition quality of discharged BW treated with MSD is significantly worse than quality of treated wastewater from AWT [13]. On the other hand, AWT systems are large and expensive engineering plants. In most AWT systems black and grey water are collected and processed together through several treatment stages. Some final treatment stages like UV disinfection are optional so ships with AWT system can discharge: untreated sanitary wastewater, partially treated wastewater or treated wastewater.

Grey water contains water from sinks, baths, showers, washing machines, saunas, swimming pools, sinks and water generated from washing ship’s surface and it is not recognized as pollutant by IMO so it can be discharged untreated into the sea. Grey water contains an array of pollutants from the highly chemical (bleach, strong acids from some cleaning products giving water high pH) or strong alkalis (including many detergents, phosphates, whiteners, and foaming agents giving water low pH), to oil and grease, suspended solids and organic particles. In addition, degreasers found in washing up liquids and soaps strip the natural oils from fish gills making it difficult for them to breathe. In addition, researches have proven that untreated grey water contains bacteria and suspended solids concentrations equal to or exceeding black water [14].
One person on board produces 31.8 l/day of black water and 253 l/day of grey water [15].

Ballast waters on cruise ships is used for stabilization during navigation. Their impact on the marine environment is significant due to the transmission of invasive species. Shipping, including cruise ships play a major role in transporting species from one location to another. Ballast water discharge typically contains a variety of biological materials, including plants, animals, viruses, and bacteria. These materials often include non-native, nuisance, exotic species that can cause extensive ecological and economic damage to aquatic ecosystems [1].

IMO suggests that the consequence of ballast water is one of the most significant global ecological and economic risks so an International Convention for the Control and Management of Ships' Ballast Water and Sediments (Ballast Water Management Convention) was adopted in February 2004. The Convention entered into force in 2017 and it requires existing vessels to apply ballast water exchange until the renewal of their International Oil Pollution Prevention (IOPP) Certificate, after which they must meet strict ballast water quality standards. For new vessels (vessels constructed/keel-laid on or after 8 September 2017) Convention requires ballast water treatment system installed upon delivery [16].

Biocides in antifouling coatings on submerged ship’s hull are one of the main marine traffic environmental impacts recognized as a threat to the coastal environmental health. These coatings dissolve in the sea water, emitting in the surrounding environment their active ingredients, which are toxic to marine organisms and impair the function of different pathways crucial to their photosynthesis, reproduction, and/or growth [2]. Antifouling coatings are generally covered by IMO’s International convention on the control of harmful antifouling systems on ships of 2001.

Furthermore, EU parliament passed the Biocide Directive 98/8/EC that is expected to advance protection of the environment and humans [11].

The control of incineration content and disposal of ash remains a problem within the Mediterranean due to the lack of available enforcement. Incineration of plastic is a specific problem due to dioxin by-products and that incineration remains are dumped into the sea. Due to the concentration of various toxic substances, these ash remains can also be considered hazardous waste and it is the issue that requires more attention [11].

C. Air targeted emissions

Air targeted emissions comprises of all emissions from cruise ship resulting from fuel combustion and incinerators.

Cruise ships can be seen as floating cities with their own powerful power plants and they produce a range of emissions to the atmosphere like nitrogen, sulphur and carbon oxides (NOx, SOx and COx), and floating particles. The intensity of air pollution from fuel combustion depends on the activity of the ship and varies whether cruise ship is navigating open sea, manoeuvring or at berth. A cruiser with 3,000 passengers using fuel-efficient sulphur fuel can pollute more than 12,240 cars [10]. In cities like Vancouver, studies show that air pollution from ships contributes to the greenhouse effect in the city by 58% and that is involved in sulphur gas emissions with about 95%. So, a single day of a large cruise ship in harbour is equivalent to 2,000 cars and trucks per year by SOx emission [10]. Air pollution from cruise ships may have local, regional and global impact [17]. Local impact is contribution to the creation of smog that has an effect on human health (lung cancer, asthma) and cultural objects. It is estimated that 30% of smog on a global scale is derived from ships [11]. Regional effect is recognized through contribution to the creation of acid rain and change to the pH of water. Global impact implies climate change caused by greenhouse gases (primarily carbon dioxide, CO2). An average cruise ship produces around 169 kg of CO2 per passenger per day [3]. In addition, air pollution comes from incinerators in which larger cruise ships burn most of the mixed waste resulting in dioxin and thiophene emissions.

According the current legislation, ships trading in the special areas, the so-called SECA (SOx Emission Control Areas), have been allowed to use fuel with maximum 0.1% since January 1st, 2015. Out of the
SECA areas, the maximum sulphur limit has been reduced in MARPOL Annex VI from 4.5% to 3.5% since January 1st, 2012 and finally it will come to 0.5% starting from January 1st, 2020. Nowadays the EU Directive 2005/33/EC imposes the use of fuels with sulphur content of less than 0.1% by weight to all ships at berth in harbours [18]. The implementation of this directive will significantly decrease SO2 emissions in European harbours, however emission in open sea is still unregulated.

IV. ENVIRONMENTAL IMPACTS OF CRUISING TOURISM IN ADRIATIC SEA

The Adriatic Sea is considered as a closed type of sea and therefore it is especially vulnerable to all kinds of pollution. Tourism, as a strategic sector of the Croatian economy, is based on the purity of Adriatic Sea. The share of “sun and sea” as the dominant product of Croatian tourism has not fallen below 85% of the physical volume in the total Croatian tourism product for years. Croatia depends on tourism more than any other EU member country, even more than Malta, Cyprus and Greece, as proved by the data given in the foreign exchange revenue achieved by tourism in Croatia, which is the highest in Europe with 17 percent of Gross Domestic Product (GDP) [19].

The Adriatic Sea hosts high biodiversity, regions of cultural and historical significance, is politically stable and is easy to access. These features make the Adriatic an attractive region for cruising, Venice and Dubrovnik were ranked 3rd and 7th, respectively, in the leading Mediterranean cities visited by cruise passengers in 2010.

As it was demonstrated in this paper cruise traffic in the Adriatic is growing and special attention must be paid to its pollution. There are currently 275 large cruise ships (capacity more than 500 passengers) [6].

According to their capacity cruise ships can be divided into ten classes. Fig. 4 shows the distribution of the number of ships by class size in the global cruise fleet in 2016 and 2019 and in Adriatic Sea in 2016. It can be concluded that most ships generally fall into the category of large cruise ships in the class of 2400 - 3100. A small and extremely large ships are least represented.

Although all mentioned pollution also exist in the Adriatic the prime concern of this paper is sea targeted pollution. In that category main concern should be pollution with sanitary wastewater because, as it was already said, grey water isn’t recognized as a pollutant by IMO.

![Fig. 4. World and Adriatic cruise ship distribution](image-url)
All ships at sea generate sanitary wastewater. However, the problem is particularly pronounced on large cruise ships because with their capacity of persons carried they are the size of small cities. Wastewater on cruise ships is generated in large quantities. That is why the method of wastewater management on board and the quality of wastewater discharged into the sea is very important [19].

Generated grey and black water can be discharged arbitrarily if minimum requirements of Annex IV are respected. It means that there is a range of various operational modes i.e. scenarios that can be used while discharging wastewater. Actual data on cruise ship traffic in the Adriatic Sea in one year were obtained and discharged wastewater was simulated using evaluation model of wastewater pollution [20]. The results are summarized below.

Quality and quantity of discharged black and grey water was calculated for zone 3 (3-12 M from shore) of MARPOL Annex IV. Croatian zone 3 was further divided in 10 geographical areas shown in Fig. 5.

Two scenarios were considered. In both scenarios ships with AWT plant discharge treated wastewater (black and grey water) continuously while ships with MSD discharge treated black water and untreated grey water. Only difference in these scenarios is in MSD grey water discharges that were previously in zone φ (inside χ M from shore):

- Scenario 1: gray water is discharged continuously in the zone 2 in respect with MARPOL Convention
- Scenario 2: gray water is not discharged in zone 2. It is stored in holding tanks. Discharge begins with departure of the ship in zone χ which is usual practice of most cruise companies.

As results of these simulations quantity of discharged grey water were calculated in 10 geographical areas, Fig. 6.
It can be concluded that area of Mljet has biggest impact with grey water pollution. The concern only magnifies in context with Mljet’s position in relation to environmental sensitivity. The northwestern third of the island Mljet is occupied by the National Park Mljet, the oldest marine park in the whole Mediterranean. It stretches to 5375 hectares of protected land, including the sea belt 500 m from the shore. This area was declared national park in November 1960, and the sea part was added in 1997 [20]. In Mljet, great attention is paid to the preservation of the environment, and within the National Park it is strictly prohibited, among other things, any deterioration of the quality of the sea and its pollution.

The Mljet area is the critical area for pollution with sanitary wastewater from cruise ships. All ships moving from Dubrovnik to the north, either to Croatian or foreign ports pass in the proximity of the island of Mljet, Figure 7. Since Dubrovnik had 338 calls in the observed year, which is 24.2% of all calls in the Adriatic, it is clear that the traffic of cruise ships on this route is very pronounced. Bearing in mind that ships departing from Dubrovnik enter permitted discharge area just in front of the Mljet, the problem is even more pronounced.

![Figure 6. Quantity of discharged grey water in 10 geographical areas of Croatian territorial waters [20]](image6)

![Figure 7. Navigational routes in proximity of Mljet island [20]](image7)
V. CONCLUSION

Cruising tourism as a growing industry must carefully be monitored so that negative impacts through environmental pollution do not exceed economic benefits. There are various emissions from cruise ships that can be best divided according to targeted area. In this paper emissions from cruise ships were divided into land targeted emissions, water targeted emissions and air targeted emissions. Each emission was explained along with their impact on environment and regulations that covers that kind of pollution. As the Adriatic Sea is vulnerable to all kinds of pollution accent was made to water targeted emission, particularly grey water emission because it was recognized as the pollution not yet regulated by IMO. Simulation of discharged grey water in one year according to actual cruise traffic data showed that Mljet area is most endangered with pollution from cruise ship wastewater. In Mljet area National park “Mljet” is situated. It is the oldest marine park in the whole Mediterranean and it incorporates both land and sea. Therefore, a greater effort should be made to protect that sensitive and protected part of nature.

REFERENCES


Environmental and Social Impact Assessment in Coastal Zone

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ABSTRACT

Tourism must be sustainable and be in function of the quality of life, wellbeing of local community, and preservation of natural and cultural heritage. Direct pressures on coastal zones are related to infrastructure construction, waste and sewage, resource use, and wildlife interactions. Basic document that should steer tourism development in coastal area of the Republic of Croatia is Tourism development strategy whose adoption is subject to the obligation of implementing the SEA in course of drafting strategy proposal. With regard to individual projects that directly concern tourism development, the procedure of environmental impact assessment is carried out. Inclusion of the assessment of social impacts in the existing SEA and EIA procedures may significantly contribute to sustainable development. Proposed model for evaluating acceptable alternatives and their effects on the environment and society is social cost-benefit analysis. Useful environmental protection measure proposed is producing of environmental and sociological management plan.

KEYWORDS: environmental impact assessment, strategic environmental assessment, coastal zone & tourism

I. INTRODUCTION

Tourism is one of the leading economic sectors in the Republic of Croatia. Adriatic coast in particular is the main lure to millions of tourists. Therefore, particular attention should be paid to economic development of tourism that must be sustainable and in function of the quality of life and wellbeing of local community, preserving natural and cultural heritage and striving to establish mutual balance. Tourism involves travelling, relaxation and recreation, so one of the tourist offer types is recreation tourism which is for the most part associated with the use of natural resources of the Adriatic coast. Thus, tourism and nature & environment preservation may have mutually opposed requirements. While tourism on an annual basis tends to break the records in profit earned, nature and the environment should raise the chances for recovery.

The concept of tourism sustainability of a particular area implies maximum acceptable number of people (tourists staying in a particular area at the same time) which do not diminish the attractions of a tourist product and do not exert negative impact on natural and cultural environment as well as on the local community. Therefore, it is necessary to define tourist numbers that the area may sustain without compromising the balance in provision of the electricity, water, fuel, and with no excessive construction. In other words, the loads must not inflict adverse effects on the quality of living of the guests and local inhabitants.

The paper elaborates the impacts of tourism on coastal communities, legal framework in the Republic of Croatia with particular emphasis on the requirements which national tourism strategy should comply with concerning strategic environmental impact thereof. It also analyses the environmental impact assessment and social impact assessment procedures. Case analyses illustrate actual practice and quality of environmental reports. Integrating of social impact in environmental impact assessment procedures is proposed.

II. IMPACTS OF TOURISM ON COASTAL COMMUNITIES

Environmental impact of tourism may broadly be categorized as pollution, physical structures, beach and shore usage, interaction with wildlife, cumulative effects, and costs of environmental degradation [1]. Particularly pronounced are the problems of collection, treatment and disposal of solid and liquid
waste. Further problem are cruise ships calling at ports that have limited or inadequate waste and sewage handling facilities as well as poor supply services, leading to harmful emissions from auxiliary engines during their stay in the port. The yachts and small boats present an impact in the form of oil escapes from engines, action of anti-fouling paints, of propellers in shallow waters, and noise. Direct pressures on coastal zones are related to infrastructure construction (roads, parking places, airports, marinas, jetties, mooring, hotels), waste and sewage, resource use (fresh water, seafood) and wildlife interactions [2]. Coastal infrastructure necessary for coastal tourism change coastal landscape. Such a change from natural cover and agricultural use has significant implications for coastal ecosystems. Beaches are threatened by artificial structures, beach feeding, and ship anchoring. Interaction with wildlife ranges from diving, coral viewing, bird watching, marine mammals watching, to recreational fishing and hunting.

Tourism is a significant contributor to the increasing concentrations of greenhouse gases in the atmosphere. Conversely, climate change and natural disasters such as floods, wildfires, avalanches, droughts and diseases can have a serious effect on local tourism industry. Therefore the immense role of tourism industry in achieving climate resilience [3]. Climate change mitigation involves employing the resource hierarchy at all stages of the project (design, construction, operation and decommissioning) and through supply chains such as adopting alternatives to avoid GHG emissions, minimising energy use through energy-efficient design and energy conservation, employing renewables and low-carbon materials. Adaptation to climate change may include building adaptive capacity and resilience, provision and enhancement of green and blue infrastructure, water-efficient design and processes, design of buildings, plants and processes to reduce the need for cooling, and connectivity for biodiversity, among others [4].

Economic impacts can be negative as well. As tourist resorts become more crowded, the market becomes more of a mass market, with lower margins. In some areas, crowding was allowed to such an extent that the market has been depressed, and returns have become very low [1].

Besides ecological and economic, there are also community impacts such as transformation of the face of the community and lifestyles conflict arising from the competition for common resources and overlooked effect on future users. There are also economic impacts such as economic dependence, social layoff and unemployment, low-level jobs, import and export leakages, enclave tourism infrastructure costs, and vast use of resources [5].

Therefore, coastal zones in particular are under threat, often because of tourism. Coastal tourism requires to be managed in sustainable ways, considering interrelationships between local and non-local resource use, ecosystem change, and climate change.

III. LEGISLATIVE FRAMEWORK


A. Strategic environmental assessment

At the time of adoption of the Strategy in 2013, no strategic environmental assessment (hereinafter: SEA) has been undertaken therefor. The new strategy to be adopted for post-2020 period pursuant to Article 63 of the Environmental Protection Act [7] is subject to the obligation of implementing the SEA in course of drawing up strategy proposal. Throughout SEA procedure, the Ministry of Tourism finances the drafting of environmental report which is pursuant to Article 40 of the Environmental Protection Act elaborated by legal person authorized for environment protection tasks and who secured the approval for producing such reports from the ministry responsible for environment.

The content of environmental report is laid down in Annex I of the Regulation on strategic assessment of the impact of a strategy, plan and programme on the environment [8] (hereinafter: SEA Regulation). Environmental report must comprise the following: a. an outline of the contents and main objects of the
strategy, b. the aspects of the current state of the environment and likely evolution thereof without implementation of the strategy, c. the environmental characteristics of areas likely to be significantly affected, d. any existing environmental problems, e. the environmental protection objectives and the way those objectives and any environmental considerations have been taken into account during its preparation, f. the likely significant effects (secondary, cumulative, synergetic, short-term, mid-term and long-term, permanent and temporary, positive and negative) on the environment, including biodiversity, population, human health, fauna, flora, soil, water, air, climate, material assets, cultural and historical heritage, landscape and the interrelationship between those, g. the measures envisaged to prevent, reduce and abate adverse effects on the environment of implementing the strategy, h. the grounds for selecting reasonable alternatives dealt with, and i. separate chapter on appropriate assessment of acceptability of the strategy for ecological network insofar such is being carried out within the context of SEA procedure. The method of case-by-case examination and the criteria for determining the likely significance of effects on the environment are laid down in Annex III of SEA Regulation.

The Ministry of tourism is obliged to consider the results of SEA procedure implemented when adopting the tourism development strategy. The result of SEA is a. the method in which the environmental protection issues are integrated in the strategy, b. environmental protection measures and the method of monitoring the enforcement of measures, and c. the method of monitoring significant impacts on the environment.

B. Environmental impact assessment of projects

With regard to individual projects directly related to tourism development, the procedure of environmental impact assessment (hereinafter: EIA) is carried out pursuant to Annex I, while screening procedures are carried out pursuant to Annexes II or III of the Regulation on environmental impact assessment [9] (hereinafter: EIA Regulation). Apart from aforesaid, there is an option under Article 82, paragraph 1 of the Environment Protection Act providing that, insofar as project operator establishes that project type is included on the list of projects referred to in Annex II of the EIA Regulation, it may present to the Ministry the request for implementing the EIA procedure. The project that is related to tourism and for which the assessment procedure is carried out is golf course, while projects for which screening procedures are carried out are sport and recreation centres, tourist zones, ski slopes, thematic parks, camp sites and camp rest areas, as well as urban development projects (water supply systems, local roads, bike routes, etc.). The projects that are indirectly related to and significant for tourism development, for which the EIA procedure is undertaken are marine fish and shellfish farms, marine ports and airports, roads, railways, sewerage systems, etc. Those subject to screening procedures are food production and processing facilities, waste landfills, etc.

The assessment procedure is carried out based on environmental report the content whereof is laid down in Annex IV of the EIA Regulation. The report must consider the impacts on population, human health, biodiversity, fauna, flora, soil, land use, water, air, climate, landscape, material assets and cultural heritage as well as their mutual interaction, cumulative and transboundary impacts. Also considered are the impacts of polluting substances, noise, vibration, light, heat, radiation, as well as harmful effects resulting from waste disposal and recovery, and also the impacts due to susceptibility of projects to risks from major accidents and/ or disasters which are relevant to the project concerned.

The result of EIA procedure implemented are the protection measures for environmental components and the measures for diminishing the load on the environment, as well as the programme for monitoring the state of the environment. The environment protection measures and monitoring programme must be an integral part of documentation that ensues after the assessment, those being the location and building permit.

The screening procedure is carried out on the basis of a screening report. In such a procedure the significance of environmental impact is established, and should it be ascertained that significant environmental impacts are likely, the obligation to implement the EIA procedure is prescribed. Where established
that environmental impacts are not significant, the environmental protection measures may be prescribed as well as the environmental state monitoring programme, but no obligation to implement the EIA procedure is prescribed.

With regard to prescribed protection measures and the program of monitoring the state of the environment, Article 89a of the Environment Protection Act lays down the following: “The measures and/or monitoring programme of the state of the environment set out in the administrative decision on environmental acceptability of the programme or administrative decision under screening procedure constitute the compulsory content of master project which makes an integral part of the act approving the construction or other acts for implementing the project issued under lex specialis.”

C. Social impact assessment

The obligation to incorporate social impacts on local population or wider community is not specifically stipulated in law provisions, but freedom to consider likely impact in the part entailing consideration of impacts on local population is granted. The inclusion of assessment of social impacts into existing SEA and EIA procedures may significantly contribute to sustainable development advocated by EU as well as the Republic of Croatia. Such an approach comprehensively conduces to preventing the devastation of environment and biological diversity as well as to sustainable resource use, while strengthening economic, social and territorial cohesion.

Social impacts affecting people and communities in which they live as a result of a project involve changes to community values and/or the way the community functions, impacts on communities’ quality of life (air quality, noise levels etc.), impacts on their culture and history, impacts on exposure to hazards and risks, impacts on the access to control over resources, the access and quality of infrastructure, services and facilities, as well as economic well-being [10].

Potential difference in perception of sustainability in two national strategic documents is presented herein in the example of nautical tourism. In the Regional development strategy of the Republic of Croatia till 2020 [11] it is among others stated that maritime traffic is characterized by non-harmonized economic and tourist use of port areas as well as inappropriate maintenance and equipment of port areas according to category and designation of a port. Physical plans of the counties envisage the extension of existing and the construction of new reception capacities at about 300 potential sites with 33655 new berths planned, that being more than 150% of present capacities. On the other hand, pursuant to the Nautical tourism development strategy of the Republic of Croatia for 2009-2019 period [12], adopted is moderate scenario of nautical tourism development, or 15000 new berths are planned, that being based on established carrying capacity of the area, moderate annual growth rate and the principle of balanced regional development (subject to derogation by reason of recognizing the features of individual counties) aligned with the development of the supporting utility and other infrastructure and the needs of securing full employment of population.

It is interesting to note that nautical tourism is the only topic in the chapter on the development of tourist products in the Strategy where the term “environmental impact” is mentioned. Elsewhere in the document the only impact dealt with is the impact on the economy.

IV. Practice and Quality of EIA and Screening Reports

This part of the text analyses the quality of assessment carried out in the environmental report for tourist resort “Široki rat” and screening based on environmental report for bike trail “Umag – Špina”. Results of the analyses may also apply to other projects mentioned in Table 1, as the practice of drafting EIA/screening reports is harmonised. The table shows that projects are envisaged mainly in Istria and Split-Dalmatia County. In Istria county the majority of projects (3) qualifies for EIA procedure for golf courses, while in Split-Dalmatia county to EIA or screening for nautical tourism ports (8). Generally, in all the counties the majority of projects are associated with nautical tourism ports (18).
<table>
<thead>
<tr>
<th>County</th>
<th>City/municipality</th>
<th>Project</th>
<th>Procedure/year</th>
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<tbody>
<tr>
<td>Istria</td>
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<td>Golf course „Plava i zelena laguna“</td>
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<td>Tar Vabriga</td>
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<td>Vrsar</td>
<td>Golf course „Stancija Grande“</td>
<td>EIA 2016</td>
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<td>Pula</td>
<td>Reconstruction of nautical tourism port „ACI marina Pula“</td>
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<td>Umag</td>
<td>Bike trail „Umag – Spina“</td>
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<td>Umag</td>
<td>Golf course „Stancija Grande-Savudrija“</td>
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<td>Amusement park „Inspirir Fantasy Park“</td>
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<td>Littoral-Mountain</td>
<td>Mali Lošinj</td>
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<td>Nautical tourism port of „Nerezine“ marina</td>
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<td>Reconstruction of nautical tourism port „Novi Vinodolski“</td>
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<td>Pašman</td>
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<td>Tourist zone Zatoglav – Kalebova port</td>
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<td>Split-Dalmatia</td>
<td>Nerežišće, Brač</td>
<td>Nautical tourism port „Smrka“</td>
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<td>Nautical tourism port „Vela Luka“</td>
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<td>Selca, Brač</td>
<td>Nautical tourism port in Radonja bay</td>
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<td>Trogir</td>
<td>Reconstruction of nautical tourism port „Trogir service center“</td>
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<td>Korčula</td>
<td>Nautical tourism port „Otočac-Lučica“</td>
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<td>Baška Voda</td>
<td>Nautical tourism port „Baška Voda“</td>
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<td>Sućuraj</td>
<td>Port open for public traffic and nautical tourism port „Sućuraj“</td>
<td>EIA 2015</td>
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<td>Baška Voda</td>
<td>Nautical tourism port „Promajna“</td>
<td>Screening 2018</td>
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<td>Dubrovnik-</td>
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<td>Neretva</td>
<td>Dubrovnik</td>
<td>Nautical tourism port „Marina Gruž“</td>
<td>EIA 2013</td>
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<td>Tučepi</td>
<td>Reconstruction of the existing port and extenstion of nautical tourism port „Eco marina Tučepi“ and regulating bathing area with influx of Suhi potok torrent bed</td>
<td>EIA 2016</td>
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A. Tourist resort “Široki rat”

Environmental report [14] was produced for tourist purpose resort “Široki rat” in the City of Stari Grad on Hvar Island, Split-Dalmatia county, because project operator opted for drafting EIA report and pursuant to Article 82, paragraph 1 of the Act on environmental protection, for applying the EIA procedure irrespective of the fact that tourist resorts pursuant to Annex II of the Regulation imply screening procedure as set out in Annex II of the Regulation.

The EIA report assesses likely impacts on air, soil, natural assets and other environmental components. However, in this part of the paper, the analysis is made of the modality in which social impacts of planned tourist resort “Široki rat” on the environment have been identified. The impacts concern the following: demographic growth, direct and indirect economic impacts, and landscape.
Demographic growth

Section of the report related to the impact on demographic growth states that it is estimated that population of Stari Grad will grow at 5% rate during a period of 10 years from the year of developing of project concerned. The growth rate is estimated on the basis of employment potential in tourist resort and the development of ancillary activities. It is not based on clear data, but on subjective observations as stated in the following sentence: “Considered in absolute proportions it does not represent significant growth in population, but when present demographic characteristics and potential of Stari Grad are taken into account, the exhaustion of demographic reserves in emigration areas and the fact that specific needs for workforce reflect the continuity of seasonal migrations with very low probability of their transformation into permanent immigration, this estimate is realistic and easily achievable.” It is then stated that it will be necessary to create the atmosphere and experience that the guest is ready to pay for, that implying full shift in the way of thinking prevailing to date and the willingness to change and accept modern trends and technologies. Therefore, the recommendation for community members: “Mind-set change is an unavoidable process insofar as the inhabitants of Stari Grad (that in past years registers stagnation of tourist activity – decline in arrivals and tourist overnight stays) wish to benefit from or raise tourist income on which the development of project concerned may have an indirect impact. That also refers to local tourist institutions, political structures and civil society organizations, without which the implementation of innovative ideas are not feasible.” Furthermore, in wording of the environmental report it is presumed that “for the sake of developing the project concerned and job-related population inflow, the pressures on municipal infrastructure will increase, whereby long-term economic development and further increase of population will result in housing function growth and in boosting of daily mobility of workforce from the outskirts or other communities on Hvar Island, that having an impact on transformation of the entire urban zone.” Apart from aforementioned, it is presumed that “the arrival of guests having high purchasing power may provoke in local population the feeling of discontent or some other feeling for various reasons – ranging from dietary patterns and style to social customs, cultural needs of the guests, etc. Therefore, the integration of the project into local community is unavoidable.”

Economic impacts

In establishing the economic impacts of planned development of “Široki rat” tourist resort, identified is the increment of funds payable to municipal institutions resulting from obligations to pay public utility levies for developing the project concerned, as well as public utility and other charges throughout the operation. “It may be presumed that municipal budget will increase by 5-10% annually, and that will be a new source of continuous financial income from which the city and county may have significant economic also wider social benefits, rendering possible the reinvestment of new revenues in new city development projects. Indirect economic effect of the development of the project concerned on revenues of the City originates precisely from taxing the revenue of other employers – suppliers of goods and providers of services necessary for the project throughout its development and operation of the resort, that resulting in spill over of revenues of the project concerned for other activities.” Stated presumption on the increment of annual revenue is not reasonably argumented, or mentioned legal provisions incurring an obligation to pay various charges in realization of planned undertaking earnings are not specified.

Further economic impact is acknowledged through recruiting 280 persons in catering, commercial, service and recreation-associated jobs. “The work posts that will be created throughout development, but also during the utilization of project concerned shall boost the number of consumers and their purchasing power and render possible the improvement of personal standard and standards of living of the inhabitants. Insofar as we also consider the boost in employment resulting from the growth of intermediary activities, it is estimated that the development and operation of project concerned will increase the employment of population of Stari Grad City by 3-5%.” It is not clear on the basis of which parameters the data are produced stating that the number of inhabitants will increase by 5% in 10 years and that employment of population will increase by 3-5%, with 280 persons recruited.
Impact on landscape

The impact is recognized in deploying the buildings within the limits of project envelopment, as well as in their bearing on other facilities within the zone. “The buildings in terms of their height correspond to natural slope of terrain toward to coastline, thereby additionally achieving visual incorporation into surrounding landscape. Should upon producing of landscaping project specific characteristics of the site and wider area be acknowledged, with an emphasis on locally specific materials and autochthonous vegetation and with the aim that future tourist zone be as much as possible integrated into existing spatial context, negligibly negative impact on views in the landscape may be expected.”

The abovementioned two sentences quoted from EIA report are mutually contradictory. For planned project, it is established that the buildings correspond to natural slope of terrain, thus achieving visual integration. Next sentence questions such integration, but in such case that would mean that the project does not comply with input parameters from environmental report on the basis of which the procedure was carried out.

B. Bike trail “Umag – Špina”

With regard to bike trail “Umag – Špina”, City of Umag, Istria County, the environmental report [15] was produced with the scope of screening, pursuant to Article 78 of the Environment Protection Act, since the project is categorized in Annex II of EIA Regulation as urban development project.

The report assesses potential impacts on environment components such as the air, soil, natural values and other environment components. This paper analyses social impacts identified in environmental report for bike trail “Umag – Špina” which refer to population, traffic and infrastructure, landscape and habitats.

Impact on population

Identified is negative impact on population during construction and positive impact throughout the use. “Negative impacts during construction of project concerned may occur in the vicinity of housing facilities (initial 1040 m of route length) owing to: dust and exhaust gases emitted by construction machinery, elevated noise level owing to operation of construction machinery and hampered running of pedestrian traffic. The construction of bike trail shall have a positive impact on population, but also local tourist offer. That applies in particular when considered within the context of connecting the existing bike trail at southeast (project starting point) with the existing coastal promenade (pathway) at northwest. Thus the connection of two existing trails will be secured, providing bike trail by the very seaside. Along bike trail, pedestrian pathway 2 m wide is planned, thus achieving the connection of pedestrian traffic as well.”

The impacts are correctly identified, but opinion of the population concerning the project remain unknown.

Impact on traffic and infrastructure

The impacts on transport and infrastructure are considered during the construction of bike trail. “The impact on normal running of traffic may be incurred at local access roads due to entering and exiting of trucks and machinery from county road to the construction site and back. Also probable is the presence of dirt and other construction material on local roads as well as possible damages and occasional minor jams that may led to difficulties in running of the traffic. All those loads on traffic network and possible difficulties in running of the traffic are of limited duration and will be minimized by proper organization of the building site. Throughout the use of bike trail route, no negative impacts on the traffic and infrastructure are expected.” Conclusion that no negative impact on traffic and infrastructure is expected may not ensue from the impacts considered stating that traffic difficulties due to truck operation may arise.

Impact on landscape

The change of relief and anthropologically dictated elements are recognized as impacts on landscape. “Visual impact will result from the use of heavy machinery and excavation of surface cover that will temporarily impair landscape image of the space. Additionally, the impact will result due to organization and
operation of the building site (construction of temporary roads, storing construction materials, fuels). Fi-
nal development of the project will result in minor change in perspective of micro location because at the
points of minimum notches or earthworks the change in relief at micro level will arise, while promenade
route will visually be a new anthropologically dictated element on the part that follows natural terrain.”

Impact on habitats
The impact on habitats is recognized in the loss of areas that will be converted to bike and pedestrian
lane. “By construction of the very bike trail, a total area of about 23,200 m² in coastal belt will be con-
verted. About 1,430 m of the route follows coastal part that is under present anthropological impact
(Špina community development area and area of former cement kiln). The remaining land part of the
route follows dry eumediterranean grasslands, so that the development will lead to conversion of about
9,100 m² of habitat type concerned. A total of 400m of the route follows along the seacoast or across sea
surface.”

For the construction of bike trail, stone material will be backfilled on the seabed. “According to concep-
tual design and based on the depths indicated on nautical charts it will be necessary to backfill an area of
about 6,730 m² with a total of about 6 600 m³ of stone material. Major impact on natural habitats will
occur by backfilling on biocenosis of infralittoral algaes (initial layer several m from coastline) and in-
fralittoral fine-grained sands with more or less mud and the part of coastal habitats of supralittoral and
upper mediolittoral.” The destruction of habitats owing to backfilling of seabed is identified, but not
identified is modification of habitats and biocenosis in the part of the sea that will remain cut off. The
loss of habitats is justified by local character of the project compared to wide distribution of such
habitat types in that part of Istria.

V. PROPOSAL FOR INTEGRATING SOCIAL EFFECT IN EIA PROCEDURE

A. Environmental report for SEA

Compulsory content of SEA report should include concrete data on demographic development of the
area (number and composition of population, community development trends, etc.) for the areas where
projects are planned, or the analysis of present social/sociological problems that matter for tourism de-
velopment strategy. Also the analysis of the necessity for new or the reconstruction of existing infra-
structure (roads, airports, railway), and the needs for disposal of additional quantities of waste resulting
from planned tourist content. All aforesaid should be associated with positive and negative impacts on
human health, whereby health impacts may be expressed not only through the quality of environmental
components, but also through social standard, workposts, etc. One of appropriate models for establish-
ing the benefits and damages for the community is a cost-benefit analysis that would be adapted to
strategy-level purposes, or the analysis in which the benefits and costs are not expressed in monetary
units, because of value incommensurability [16], that is the difficulty to monetize intangibles like the en-
vironment [17]. Thus for instance the benefit could be expressed as anything that enhances people’s
well-being in the area of the project, that is on the basis of available data as to what could gratify the
population, while the cost would be whatever diminishes the well-being. That would be the first stage,
the second stage being placing an emphasis on sound organization of public consultation on SEA report
throughout which feedback information from population would be obtained as to whether their wishes
and desires for proper well-being have been recognized or should those be modified. Final third stage
would be the selection of appropriate alternative for tourism development on the basis of population
feedback analysis.

For instance, in the Strategy, one of the strategic goal is: “Continuous increase of the share of hotels and
boosting the quality of accommodation in campsites and households along with decline of their share in
the total accommodation capacity. The share of accommodation measured by the number of beds in ho-
tels increases from 13.1% in 2011 to 18.1%, while the share of campsites at the same time rises from
25.2% to 25.8%, and of private accommodation falls from 48.7% to 43.4%.” In future tourism develop-
ment strategy it would be useful to apply the cost-benefit analysis to consider and establish whether
strategic goal for people's well-being is indeed significant increase in hotel and campsite accommodation capacities, the construction of new tourist resorts or perhaps strategic goals could be considerable increase in the capacities of private accommodation and significant use of the existing abandoned settlements and individual facilities. Furthermore, it would be necessary to provide through appropriate cost-benefit analysis the elements for decision-making as to which tourist products such as nautical tourism (yachting and cruising), health tourism, cultural tourism, business tourism, golf tourism, biking, food and wine tourism, rural and mountain tourism, adventurous and sport tourism, eco-tourism, youth and social tourism would represent priority strategic goal or to provide the elements for ranking the priorities.

B. EIA report content

In description of the project in EIA and screening report it is necessary to specify concrete data concerning the number of employees in course of the construction and use of the project, and to describe in which manner the workers will be protected in their workplaces. Aforested should be substantiated by law provisions. In the description of variants it is also necessary to account for the number of employees and their safety at work.

In the chapter with project site description it is necessary to elaborate in detail the demographic characteristics of the area where the project is planned, the composition and number of inhabitants, to specify the feasibility of their participation in project realization, and also how planned project will affect their daily living habits and needs.

EIA or screening report should incorporate surveys of population which could be affected by the project, meaning that local community would be involved in project planning in their area at the earliest stage.

In the chapter on impacts it should be stated which social effects on the community in the area of planned project are expected. For instance, will their quality of life improve owing to new infrastructure (roads, airports, bike trails, etc.), necessary for realization of planned tourist facility or content. For modelling potential impacts it is possible to apply social benefit-cost analysis. The costs and benefits of tourism development can be measured with varying degrees of precision. For some tourist development projects, the benefits could be local income (wages, business profits, interest & rents) and local tax revenues (bed tax, property tax). The costs are support services such as parking lot expansion, resort rooms (amortized construction & operation), patrol car (amortized purchase & operation), police officer (benefits & salary), street repair (major cost usually for local government), the development of plan, preservation of heritage, environmental impact, and congestion at locality. Also, many important effects of tourism development cannot be considered in economic terms. Environmental costs and community resentment attributable to tourism are examples of negative items. Community members can determine appropriate weights for each plus and minus. There may not be agreement whether any one item is a plus or a minus (one person’s solitude is another’s loneliness) but all items should be consciously listed and net measured benefits calculated [18].

In the chapter on protection measures and monitoring programme, analysis should be made of law and subordinate law provisions, and in compliance therewith the protection measures referring to planned project listed, and where necessary additional measures prescribed as well. One of the measures should in any case also be the obligation of drafting the Environmental and social management plan (ESMP) during operation and maintenance as an integral part of project documentation on grounds of which construction and implementation of the project is approved.

With regard to comprehensive destination metrics, in 2013 the European Commission launched the European Tourism Indicator System [19] based on 27 core indicators and 40 optional indicators, subdivided into four categories – destination management, social and cultural impact, economic value, and environmental impact. Such criteria should obviously be considered at implementing the environmental and social impact assessment stage.
VI. CONCLUSION

Tourism is one of the leading economic sectors in Croatia and its impact on the environment and local communities may have significant adverse consequences. Therefore, particular attention should be paid to strategic planning of tourism development after 2020.

Tourism development must be contemplated as a function of the quality of life, well-being of local community, and the preservation of natural and cultural heritage. Strategic environmental assessment whose purpose is to examine the aforesaid should be undertaken in parallel with tourism development strategy. It is therefore proposed for the sake of decision-making on development alternatives or setting priority objectives in tourism development to utilize a model of identifying the benefits and damages for the community, that is cost-benefit analysis which is adapted to strategy-level purposes, meaning the analysis in which costs and benefits are not necessarily expressed in monetary units.

Particularly significant for the development of sustainable tourism in coastal area of the Republic of Croatia are also the considerations of acceptability for the environment and society of individual projects for which the environmental impact assessment / screening procedures are compulsory, such as golf courses, sport and recreation centres, tourist zones, ski slopes, thematic parks, campsites and camp rest areas, as well as the urban development projects (water supply systems, local roads, bike routes and similar), in addition to projects that are indirectly related to the development of tourism such as marine fish and shellfish farms, marine ports and airports, roads, railways, sewerage systems, food production and processing facilities, waste landfills, etc.

In order to introduce into environmental impact procedures the assessment of social impacts as well, certain parts of the EIA and screening reports should be complemented with data on the composition and number of inhabitants in the area of project development, how planned project will impact their daily living habits and needs, and the use of public spaces. Proposed model for evaluating acceptable alternatives and their effects on the environment and society is social cost-benefit analysis. Another useful proposed environmental protection measure is producing of the environmental and sociological management plan.

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Pollution of The Adriatic Sea by Chemicals Discharged from Vessels

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ABSTRACT
Biogeographical, physical and chemical characteristics combined with an exposure to the significant anthropogenic pressures make the Adriatic Sea one of the most endangered areas in the Mediterranean Sea. Commercial shipping presents a serious threat to the marine environment and all industry stakeholders put efforts in prevention of operational or accidental pollution. Chemical contaminants released from vessels have been identified as a cause for great concern. In this paper we present a systematic review of the Adriatic Sea status regarding chemical pollution and contribution of vessels to the burdening with chemicals. Knowledge gaps are identified and suggestions for further research are laid out. An analysis of existing legal instruments and proposal for additional prevention measures have been provided.

KEYWORDS: chemical contaminants, Adriatic Sea, shipping, legal instruments

I. INTRODUCTION
Due to unique combination of geographic, bathymetric, orographic and climatic characteristics the Adriatic Sea is a marine biodiversity hot spot [1], [2]. Unfortunately, as a result of numerous and intensive pressures its species are exposed to serious threats including habitat loss and degradation, pollution, introduction of alien species, over-exploitation and climate change [3]. Maritime transport is one of the human activities with large negative direct and indirect impacts on marine species. The effects of noise, collisions physical impacts, antifouling TBT paints, ship generated oil discharges, exhaust emissions, persistent organic pollutants, sewage, debris, and invasive species have been recorded in the Mediterranean Sea [4]. Consequences are observed particularly along traffic routes, harbours and other important commercial coastal areas located in the Adriatic Sea [5].

Seaborne trade continues to expand. As a result of the growth of the international trade the ship traffic showed a global fourfold growth between 1992 and 2012 [6]. According to projections for period between 2018 and 2023 world seaborne trade will expand at a compound annual growth rate of 3.8 percent [7]. Although the growth is reduced in the Mediterranean Sea, due to its sensitivity it could be expected that negative impact to the biota will be more pronounced. Therefore there is a need to decouple environmental pressures from shipping.

Volume of chemicals transported by sea globally also has increased in the period from 2000 to 2017 and further increase is expected in following years [7]. Many of estimated 2000 chemicals that are regularly transported by sea globally, either in bulk or in packaged form, have one or any of combination of properties such as explosivity, flammability, oxidativity, corrosivity, reactivity, carcinogenicity, toxicity, mutagenicity, genotoxicity, teratogenicity and pose a potential hazard to the humans and/or the environment [8]. Any substance other than oil which, if introduced into the marine environment is likely to create hazards to human health, to harm living resources and marine life, to damage amenities or to interfere with other legitimate uses of the sea, is classified as Hazardous and Noxious Substance (HNS) [9].

This paper reviews the Adriatic Sea status regarding contribution of vessels to HNS pollution. The issues and challenges related to the assessment of HNS hazards are discussed. An overview of legal instruments and problems with their implementation relevant for the Adriatic Sea is provided. Based on the presented analysis further research and measures have been proposed.
II. HAZARDOUS AND NOXIOUS SUBSTANCES IN THE MARINE ENVIRONMENT

To plan transport by sea appropriately, potential risks of discharged HNS to the receiving environment and to human health must be assessed. Risk assessment procedure includes hazard evaluation. Hazard evaluation for chemical substances carried by ships is performed according to procedures established by GESAMP [10]. The hazard profiles of substances, defined by their inherent properties, are obtained by collecting and analysing data on bioaccumulation and biodegradation, acute and chronic aquatic toxicity, acute mammalian toxicity (oral, dermal and inhalation exposures), skin and eye irritation and corrosion and long-term mammalian health effects (cancerogenicity, mutagenicity, reprotoxicity, sensitisation, aspiration, specific target organ toxicity (including neurotoxicity and immunotoxicity) and interference with other uses of the sea (tainting optionally), behaviour of chemicals in the marine environment and physical effects on wildlife and on benthic habitats and interference with coastal amenities). They are published at regular intervals and a “composite list” is available from IMO. Re-assessment of products following submission of new data or new scientific insights is performed if necessary. A hazard profile is used to assign HNS to pollution category (X, Y, Z or OS), which determines requirements for carriage, discharges of residues and other issues covered by MARPOL Annex II. Information obtained during hazard evaluation can be used for other purposes beside implementation of MARPOL, such as determination of potential ecotoxicological and physical hazards of the product which entered marine environment through accidental spillage or to assess impact of operational or continuous discharges from sea or land-based sources.

Behaviour of the chemicals in water, which also determines impact on human health and safety and biota, depends not only on their properties (e.g. solubility, density, vapour pressure), but also on environmental conditions (e.g. water temperature, water density, sea state, wind speed, water current) [11]. Different processes that can occur in various combinations involve evaporation, floating, dissolving and sinking. European Classification System [11] categorizes chemicals as members of 12 behaviour groups (gas, gas/dissolver, evaporator/dissolver, floater/evaporator, floater/evaporator/ dissolver, floater, floater/dissolver, dissolver/evaporator, dissolver, sinker/dissolver, sinker). The impact on the marine environment of chemicals belonging to different groups varies [12]. Aquatic organisms in the water column and the sediments are mainly exposed to dissolvers and sinkers. Floaters may endanger marine mammals, birds and benthic life forms along the coast. Gases and evaporators usually represent a low threat to the marine environment [12].

Due to a large number of chemicals with a wide range of properties, in comparison to ecological hazards involved in oil pollution, which are well recognised, the amount of information on HNS spills is much lower [8]. Therefore there is a possibility that associated risks can be underestimated or overestimated. There are number of issues and challenges related to the risk assessment procedure regarding HNSs. The knowledge about the toxic effects of HNSs on marine biota is still insufficient [12]. Many data related to HNSs are obtained from experiments conducted with freshwater organisms. However, depending on organism, its life stage, and various physico-chemical characteristics, toxicity effects can differ significantly and selection of relevant organisms for different habitats and experimental designs that would mimic actual environment is not an easy task. Moreover, data on the toxicity of individual chemical are inadequate for the complete understanding of possible consequences on biota since groups of HNS with common toxic mode of action can be present due to discharge from same or other sources (sea- and/or land-based). Temperature of the receiving sea water, which influences the decay rate of HNS, can differ significantly from temperature of test facility. Receiving marine environment is a complex system with many mutually dependent parameters influenced by natural and anthropogenic inputs and consequently change constantly. Regarding behaviour of the chemicals in the water, physico-chemical properties which determine categorization are measured in the laboratory using standard protocols and may differ significantly due to time factor and meteorological conditions during a marine accident [13]. An analysis of the 119 spill incidents that occurred worldwide from 1947 to 2011 has shown that although 90% of the involved 187 substances were X, Y or Z category most spills were poorly documented and information was mistreated [14]. Moreover, the impact of some HNSs was more serious than initially thought.
Taking into consideration aforementioned, there is a need to select contaminants which could pose a risk to the particular area. The prioritization procedure based on the following key risk criteria: (i) HNS volumes transported; (ii) reported HNS incidents in European waters; (iii) HNS physico-chemical properties and (iv) toxicity to marine organisms has been applied to obtain priority list of 23 HNS in EU Atlantic waters [12]. Since marine chronic toxicity data were lacking for most of the priority HNS, and for some of them only freshwater acute toxicity data were available, gathering of toxicological data had been recommended [12]. Following research data have shown that selected priority HNS can cause harm to biota. A study of acute and chronic toxicity of p-xylene to the amphipod *Gammarus locusta* has shown that chronic exposure may exert a significant impact in key ecological endpoints [15]. Another HNS identified as priority, acrylonitrile elicits important toxic effects in seabass [16]. Furthermore, effects of aniline, butylacrylate, m-cresol, cyclohexylbenzene, hexane and trichloroethylene on two ecologically relevant and phylogenetically different marine animals were investigated [17]. Data on fate, behaviour and weathering of 24 priority HNSs for the EU Atlantic ports were gathered and made available online for public use [18].

Regarding acute effects on human health top 20 priority HNSs for EU Atlantic Region has been established [19]. Toxicity of the HNS under investigation, potential to reach local population on shore, the shipping crew and emergency responders and annual tonnage shipped were used to assess risk. To the best of our knowledge, there is no research on selection of the HNSs relevant for the Adriatic Sea. The risks associated with a potential HNS spill along the Italian coastline have been assessed [20]. However, only Italian ports were considered and hazard was assessed for a group of HNSs according to HNS classification adopted by the IMDG Code.

HNSs discharged by ships are only a fraction of chemicals entering marine environment. A list of 276 substances emitted from sea-based sources (with shipping as a source of 32% of the identified substances) with a special focus on the European environment has been created based on a review of the peer-reviewed papers and books, reports, assessments and proposals from regional sea conventions, research projects, conference proceedings, and other relevant literature [21]. That is only a fraction of chemicals that enter marine environment from land and atmospheric deposition. Therefore it is important to perform research on distribution and fate of contaminants with common toxic mode of action with selected HNSs to obtain areas where such substances could accumulate and exhibit synergistic toxic effects, which depends on sources and transport. For example, a study on distribution and fate of emerging (fragrances, UV filters and endocrine disruptors, nonylphenol izomers) and legacy contaminants (PAHs, PCBs, DDTs,) along the Adriatic Sea showed that they accumulate preferentially in the northern Adriatic [22]. However, fragrances and UV filters were significantly present in the southern Adriatic.

### III. PREVENTION OF, PREPAREDNESS FOR AND RESPONSE TO MARINE POLLUTION FROM SHIPS

Regional Strategy for Prevention of and Response to Marine Pollution from Ships (2016-2021) (Strategy), adopted by the Contracting Parties to The Convention for the Protection of Marine Environment and the Coastal Region of the Mediterranean of 1995 (Barcelona Convention) defines 22 specific objectives which, if achieved, will meet the general objectives: prevention of pollution from ships; prevention of maritime accidents; and preparation for response to major pollution incidents [23]. Ratification of relevant international maritime conventions related to the protection of the marine environment is listed as first of the specific objectives, and it is stated that is expected to be accomplished by end of 2018 [23]. An implementation and full compliance with provisions of the MARPOL and its six annexes is requested. As can be seen from Table 1 as at 18 October 2018 relevant MARPOL annexes are ratified by all countries located around the Adriatic Sea except Bosnia and Herzegovina. However, the standards set out in MARPOL are often not complied with, and it is well-known that illicit discharges regularly happen [23].

Beside lack of adequate facilities in ports and cost-savings, mere convenience on behalf of the ship’s crew and/or operator have been recognised as a cause for illicit releases. Therefore there is a need to raise awareness about impact of marine pollution. In order to change inappropriate on-board practices environmental information messages must be shaped to the existing attitudes, values, and perceptions. Furthermore, they have to be understandable, relevant, and personally important [24].
A growing number of different chemicals entering the sea from various sources and growing tonnage of the operational discharges of HNS residues due to the growth in ship traffic raise concern about impact of substances which bioaccumulate, biomagnify and exhibit acute or chronic toxicity. For example, Şanlıer [25] has proposed that maritime authorities reconsider the requirements of MARPOL related to the control of discharges of residues of HNSs (Annex II, Regulation 13). In our opinion, characteristics of the Adriatic Sea and its maritime traffic justify analysis to consider implementation of a total ban on discharges, at least for areas obtained as vulnerable by analysis mentioned in previous section.

Despite all prevention measures, incidents can happen. The key international convention developed for ensuring an adequate level of response capacity and a mechanism for international cooperation and mutual assistance is IMO’s Protocol on Preparedness, Response and Co-operation to Pollution Incidents by Hazardous and Noxious Substances, 2000 (OPRC-HNS Protocol 2000) [26]. Presently, as seen from Table 1 only Albania and Slovenia are parties to the OPRC-HNS Protocol 2000. The Protocol concerning Co-operation in Preventing Pollution from Ships and, in Cases of Emergency, Combating Pollution of the Mediterranean Sea the Prevention and Emergency Protocol to the Barcelona Convention, adopted in 2002 (Prevention and Emergency Protocol 2002), similarly as OPRC-HNS Protocol 2000, recognizes the importance of sub-regional, bilateral and multilateral, agreements for cooperation in accidental marine pollution preparedness and response [26]. Prevention and Emergency Protocol 2002 has to be ratified by Albania and Bosnia and Herzegovina to accomplish this objective of the Strategy.

An analysis of EU Member States’ Policies and Operational Response Capacities for Hazardous and Noxious Substances Marine Pollution from 2013 performed by EMSA assessed the knowledge and capacity to response to HNS spills as limited [27]. Similar results have been obtained by analysis performed at the regional level. Therefore enhancing the level of pre-positioned spill response equipment under the direct control of the Mediterranean coastal States, encouragement of the participation of the regional scientific and technical institutions in research and development activities, facilitation of transfer of technology and increasing as much as practical, the level of knowledge in the field of preparedness and response to accidental marine pollution by oil and other harmful substances are among specific objectives of the Strategy. Another objectives directly related to the HNSs are provision of the reception facilities in ports, improved follow-up of pollution events as well as monitoring and surveillance of illicit discharges, improvement of the level of enforcement and of the prosecution of discharge offenders, establishment of procedures for the designation of places of refuge in order to minimise the risks of widespread pollution, improvement of the quality, speed and effectiveness of decision-making process in case of marine pollution incidents through the development and introduction of technical and decision support tools, revision of the existing recommendations, principles and guidelines, and to develop new ones aimed at facilitating international cooperation and mutual assistance within the framework of Prevention and Emergency Protocol 2002 and strengthening the capacity of individual coastal States to respond efficiently to marine pollution incidents through development of sub-regional operational agreements and contingency plans. The Agreement on the Sub-regional Contingency Plan for prevention of, preparedness for and response to major marine pollution incidents in the Adriatic Sea has been signed by Croatia, Italy and Slovenia in 2005 [28] within the framework of the Barcelona Convention and in accordance with Article 17 of the Prevention and Emergency Protocol 2002 and with the technical assistance of the Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea (REMPEC). The Agreement and the Plan are not into force since Italy have not ratified it [28]. On the other hand, Albania and Montenegro fulfilled the criteria and it can be expected that the Agreement will be extended [29].

Finally, a comparison between the previous Strategy for period from 2005 to 2015 and current Strategy reveals that all specific objectives directly related to HNSs defined 13 years ago were not completely accomplished and they are, together with a new one, regarding sharing of knowledge, stated in the
TABLE I. Status of Conventions and Protocols—Ratification by State. Authors according to [26]

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
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<td>yes</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>Bosnia and Herzegovina</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td></td>
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<tr>
<td>Croatia</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Italy</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Montenegro</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
<td></td>
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<tr>
<td>Slovenia</td>
<td>yes</td>
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current Strategy. This fact indicates that inadequate human and financial resources had been allocated to carry out necessary tasks and that issues related to the HNS pollution remain actual.

IV. Conclusions

The Adriatic Sea ecosystem is threatened by numerous anthropogenic pressures, including maritime traffic, which contributes to the pollution by HNSs. To improve knowledge on HNS hazards there is a need to select priority HNSs and perform research on their properties, tailored to relevant biota and water characteristics.

Further studies on environmental status with a focus on contaminants with common toxic mode of action with selected HNSs are needed to detect possible vulnerable areas and consider potential banning of the operational discharges to improve maritime eco-efficiency.

Raising awareness of impact of HNSs could help to prevent illicit discharges. Research on appropriate framing of scientific results and usage of new communication tools is needed to provide information in a way that will motivate crew members.

Preparedness and response to HNS spills in the Adriatic Sea it could be improved by further efforts on international cooperation and mutual assistance.

REFERENCES


Analysis of Stator and Rotor Windings of Induction Motors

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ABSTRACT
In the predesign stage of the induction motors it is very important to choose a suitable winding structure with optimal characteristics: maximum value of the main winding factor, minimum space harmonics content, and minimum differential leakage coefficient.

In the paper, these characteristics are used in order to sort out some different winding layout and to find the best stator winding structure of the motor, including the motors with phase number higher than three (multiphase windings). These multiphase windings must be deeply analysed because the winding characteristics can improve significantly the motor performance in different applications (electric vehicle, electric aircraft, electric ship propulsion, locomotive traction, etc.).

On the other side, the rotor winding of induction motor is a cage winding in majority with many bars short-circuited by end-rings. The number bars in the case of symmetrical cage (healthy cage) or the number of broken bars in the case of faulty cage influence the rotor space harmonic and the distribution of bar currents in the cage. To study these effects, in the paper is presented an experimental model that provide many practical possibilities to analyse the cage windings of induction motors and to measure directly the bar currents in both steady-state or dynamic behaviour. This model helps us to understand better the electromagnetic phenomenon in the rotor cage of induction motor.

KEYWORDS: induction motors, winding analysis, winding factor, magnetomotive-force (mmf) & space harmonics content

I. INTRODUCTION
Three-phase induction motors are nowadays a standard for industrial electric drives. Robustness, reliability, cost and low maintenance are some the reasons for use these motors in many applications.

The electrical machines designer knows very well that the winding arrangement strongly and directly affects the machine performance. So, in the predesign stage, it is very important to choose a suitable winding structure with optimal characteristics. There are different machine designs with various winding structures and different pole/slot number combinations. Even if the pole/slot ratio is fixed, there is the possibility to choose the number of layer and the coil pitch.

That is why the windings performances analyses or winding layouts optimization in electrical machines area are becomes again a very important and timely subject in this field [1 – 9]. The paper [10] analyses the impact of different space harmonics caused by air-gap MMF distribution on the rotor losses and highlights that the sub-harmonics have a dominant effect and are the main causes of rotor losses. Also, in order to reduce the space harmonic content and improve the winding performance, the papers [6, 7, 8] propose to use different number of conductors per machine slots (unequal-turn coils); the authors in [8] propose a design program flowchart to optimize the turn number of the coils.

The number of phases of the induction motors is not limited to three. The performances of the motors can be improved if these motors are designed with more than three phases. A variety of the multiphase motors has been implemented [11 – 15]. At present, the motors with multiphase windings become more and more significant in different applications, including ship propulsion [16, 17], thanks to its performances.
From the classical theory it is known that the winding performances are represented by some characteristics: the main winding factor, the harmonic content (amplitudes of each MMF space harmonic) and differential leakage coefficient. These characteristics are generally used in the predesign stage in order to sort out the different winding layout and to find the best winding structure.

This paper aims to help the machine designer to select the proper winding configurations and to sort out the best winding layout, using free available software. The first part of the paper presents some results obtained with this application for some cases of stator windings, in order to highlight the advantage of the proposed method. In the second part is presented a prototype model that provide many possibility to experimental analysis of the rotor winding (rotor cage) of induction motor and to measure directly the bar currents in both steady-state and dynamic behaviour. Moreover, the prototype allows analysing the rotor cage in healthy and faulty conditions.

II. STATOR WINDINGS

A. Analytical method for winding analysis

The classical method based on star of slots and Fourier-series expansion of the air-gap MMF wave is used to compute the winding characteristics. The method has been implemented on computer [18] for quickly find the values of the main winding factor, relative harmonic content and differential leakage coefficient. The proposed application becomes a helpful tool in the design process and can be applied for any type of multiphase windings layout (with $m \leq 7$ phases) irrespective of number of layers or number of conductors per slot.

Because the winding coils are placed inside the stator slots the magnetomotive-force is a stepped curve with the steps situated exactly in the slot axes. That means that the effect of slotting is disregarded. In consequence, the both MMF and air-gap flux density curves are not sinusoidal waves.

Due to the discrete position of the winding coils inside the slots, the air-gap MMF is:

$$F(k) = \sum_{\lambda=1}^{k} A(\lambda)$$

where: $A(\lambda)$ is the total current intensity (at the instant of time) within the $\lambda$-order slot and $F(k)$ is the air-gap MMF in the axis of $k$-order slot. From this equation the MMF stepped curves can be described by a matrix that has a number of elements equals to the slot number of the stator.

Firstly, on define this phase current matrix $A$ that consist of $Z$-number of elements equal to slot number of the machine. Each element of this matrix is equal to per unit filling degree of the corresponding slot and the sign ($\pm$) is assigned according to “go-side” or “return-side” of the coils. To understand how we can write the matrix $A$, in Fig. 1 it is presented one case of phase winding arrangement (only first phase) for a three phase induction motor.

For this case the corresponding matrix is: $A=[2, 2, 1, 0, 0, 0, -1, -2, -2, 0, 0, 0, 1, 2, 1, 0, 0, 0, -1, -2, -1, 0, 0, 0, 0]$. The first slot is completely filled by two sides of two different coils; so, the first matrix element has the value “2” that means 100% slot filled. The third slot includes only one coil side and thus the corresponding matrix element has the value “1” that means 50% slot filled.
Secondly, knowing the current distribution matrix of one phase, using (1) one can obtain the elements of 
\[ \text{MF}_1 \] matrix corresponding to the phase "1," at the time \( t=0 \).

Finally, the resultant air-gap MMF curve is the sum of all the magnetomotive-forces (at the instant of 
time) corresponding to the each phase.

According to the above remarks, the air-gap MMF space distribution at the instant of time can be con-
sidered as a mathematical function and can be expressed as the following stepped function:

\[
F(\theta) = \begin{cases} 
\text{MF}(1), & 0 \leq \theta < \alpha \\
\text{MF}(2), & \alpha \leq \theta < 2\alpha \\
\text{MF}(3), & 2\alpha \leq \theta < 3\alpha \\
\ldots \\
\text{MF}(Z), & (Z - 1)\alpha \leq \theta < 2\pi
\end{cases}
\]  

(2)

where: \( \alpha = \frac{2\pi}{Z} \) is the angular displacement between two adjacent slots considering a regular distribu-
tion of the slots.

The function described by (2) can be easy expanded as a Fourier series in order to assess the MMF space 
harmonics. In the general case of a periodical function \( F(\theta) \), the very well-known harmonic relations of 
Fourier-series expansion are:

\[
F(\theta) = \sum_{\mu=1}^{\infty} \left( A_{\mu} \cos \mu \theta + B_{\mu} \sin \mu \theta \right) = \sum_{\mu=1}^{\infty} M_{\mu} \sin \left( \mu \theta + \beta_{\mu} \right)
\]  

(3)

where \( M_{\mu} \) and \( \beta_{\mu} \) are the amplitude and the initial phase of the harmonic of \( \mu \)-order:

\[
M_{\mu} = \sqrt{A_{\mu}^2 + B_{\mu}^2}; \quad \beta_{\mu} = \arctan \frac{B_{\mu}}{A_{\mu}}
\]  

(4)

with the assumption that there is no constant term in this series. In the particular case of step function 
(2) the amplitudes \( A_{\mu} \) and \( B_{\mu} \) from (3) can be expressed using the elements of resultant \( \text{MF} \) matrix as fol-
ows:

\[
A_{\mu} = \frac{1}{\mu \pi} \sum_{i=1}^{Z} \text{MF}(i) \left[ \sin(i \mu \alpha) - \sin((i-1) \mu \alpha) \right]; \quad B_{\mu} = -\frac{1}{\mu \pi} \sum_{i=1}^{Z} \text{MF}(i) \left[ \cos(i \mu \alpha) - \cos((i-1) \mu \alpha) \right]
\]  

(5)

The differential leakage reactance coefficient can also be calculated by means of harmonic amplitudes 
with the relation:

\[
\sigma_0 = \frac{\sum_{\mu=1}^{\mu_{\text{max}}} M_{\mu}^2}{M_p^2} - 1
\]  

(6)

where \( M_{\mu} \) and \( M_p \) are the amplitude of \( \mu \)-order harmonic and respectively of main harmonic \( \mu=p \).

More details about this application (namely Fast MMF) one can find in [18].

B. Applications with the Software Fast MMF

The program FastMMF allows the calculation of winding characteristics on the basis of the star of slots 
theory and Fourier-series expansion of the air-gap MMF wave according to above considerations in this 
paper. The program starts with input data which are the number of pole pairs, the number of slots, the 
number of phases, and phase current matrix.

In that follows are presented summary only the results for three cases with different winding arrange-
ment and different number of phases.
**Case 1:** Three-phase winding; 5 pole-pairs; 12 slots; phase current matrix $A=(0, -1, 2, -1, 0, 0, 1, -2, 1, 0, 0)$

**Numeric Results**

- Filling of the slots: 2 2 2 2 2 2 2 2 2 2 2 2
- Differential leakage reactance coefficient = 0.967301
- Main winding factor = 0.933013
- Amplitude = 0.712769 p.u.

The order and the amplitude of each MMF Space Harmonic:

- $1$ = 35.90 %
- $5$ = 100.00%
- $7$ = 71.43 %
- $17$ = 29.41 %
- $19$ = 26.32 %

The resultant MF-matrix (air-gap MMF wave), p.u.:

- $0.50$ - $1.00$ - $1.00$ - $0.50$ - $0.50$ - $0.50$ - $1.00$ - $1.00$ - $0.50$ - $0.50$ - $0.50$ - $0.50$

**Graphical Presentation**

![Graphical presentation](image)

Fig. 2. Graphical presentation of the results in the **Case 1:** Magnitude of few MMF space harmonics and resultant MMF stepped function (curve)
Case 2: Five-phase winding; 9 pole-pairs; 20 slots; phase current matrix $A = (1, -2, 1, 0, 0, 0, 0, 0, 0, -1, 2, -1, 0, 0, 0, 0, 0, 0, 0, 0)$

**Numeric Results**

- Filling of the slots: $2 \ 2 \ 2 \ 2 \ 2 \ 2 \ 2 \ 2 \ 2 \ 2 \ 2 \ 2 \ 2 \ 2 \ 2 \ 2 \ 2 \ 2 \ 2 \ 2 \ 2 \ 2 \ 2 \ 2 \ 2$
- Differential leakage reactance coefficient = 1.098098
- Main winding factor = 0.975328
- Amplitude($\theta$) = 0.690045 p.u.

- The order and the amplitude of each MMF Space Harmonic:
  - $1$ : 22.58 %
  - $-9$ : 100.00 %
  - $11$ : 81.82 %
  - $-29$ : 31.03 %
  - $31$ : 29.03 %

- The resultant MF matrix (air-gap MF wave), p.u.:
  1.00 -1.00 0.81 -0.81 0.31 -0.31 0.31 -0.31 0.31 -0.31 0.31 -0.31 0.31 -0.31 0.31 -0.31 0.31 -0.31 0.31 -0.31

**Graphical Presentation**

![Graphical presentation of the results in the Case 2: Magnitude of few MMF space harmonics and resultant MMF stepped function (curve)](image-url)
Case 3: Seven-phase winding; 3 pole-pairs; 14 slots; phase current matrix \( \mathbf{A} = (1, 0, -1, 0, 0, 0, -1, 0, 1, 0, 0, 0) \)

**Numeric Results**

- Filling of the slots: 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
- Differential leakage reactance coefficient = 0.165488
- Main winding factor = 0.974928
- Amplitude(3) = 1.448203 p.u.

The order and the amplitude of each MMF Space Harmonic:

- 3: 100.00 %
- 11: 27.27 %
- 17: 17.65 %
- 25: 12.00 %

The resultant MF-matrix (air-gap MMF wave), p.u.:

\[ 1.22 \ 1.22 \ -0.68 \ -1.52 \ -0.00 \ 1.52 \ 0.68 \ -1.22 \ -1.22 \ 0.68 \ 1.52 \ 0.00 \ -1.52 \ -0.68 \]

**Graphical Presentation**

Fig. 4. Graphical presentation of the results in the Case 3: Magnitude of few MMF space harmonics and resultant MMF stepped function (curve)
III. Rotor Windings

A. Symmetric Cage Model

In general, induction motors have in the rotor a cage winding with n-bars shortcircuited by end rings. The majority of classical analytical methods replace the n-bar cage winding with an equivalent three phase winding. However, if the actual bar currents are to be calculated, existing analytical models consider the cage winding made of a network of nodes and loops (Fig. 5). The unknowns in these models are either the bar currents (Fig. 5.a), or the fictitious loop currents (Fig. 5.b).

![Fig. 5. Mesh circuit model of a cage rotor with n-bars.]

Also, the cage winding may be replaced by an equivalent poliphasic two layer windings when the fictitious loop currents in Fig. 5.b become real currents in tooth-wound shortcircuited equivalent coils (Fig. 6).

![Fig. 6. Equivalent winding of a cage rotor]

The rotor bar current produce one’s own MMF wave in the air-gap that is again a stepped curve with many space harmonics. The number of rotor slots affects the harmonic content of this MMF wave. For example, at two pole pairs, the $\sigma_0$ – coefficient have the values like in Table I, for different number of rotor slots.

<table>
<thead>
<tr>
<th>Rotor slot number</th>
<th>12</th>
<th>24</th>
<th>28</th>
<th>32</th>
<th>36</th>
<th>40</th>
<th>44</th>
<th>48</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma_0$ – coefficient</td>
<td>9.65</td>
<td>2.31</td>
<td>1.69</td>
<td>1.29</td>
<td>1.02</td>
<td>0.82</td>
<td>0.68</td>
<td>0.57</td>
</tr>
</tbody>
</table>

B. Experimental model [19, 20]

A wound rotor three phase IM was used to build the inverted motor prototype: 3kW; 2p=6 poles; Z1=27 slots in the rotor (primary); no skewing in stator and rotor.

The now stationary (cage) winding has Z2=36 cage bars ($\alpha=30^\circ$) with $\Phi 7$ mm diameter, connected together by two brass end rings. First end ring is placed inside the motor (Fig.7.a). The cage bars are longer than the laminated core stack, traverse the motor frame through 8 mm diameter insulated holes (Fig.7.b) and thus the second end ring is outside the motor, to allow room for individual bar current sensors.

The 12 LEM HTY 100-P current sensors have been mounted on cage bar outside the motor frame, for easy access. The data acquisition and processing system that carries current sensor outputs has a sampling rate of 50000 samples/s for each channel; that means 1000 samples per each period at 50 Hz fundamental frequency.
C. Test Results

The test results have been obtained at steady state standstill. The inductor (rotor in our case) was fed through brushes and slip rings with symmetric 50 Hz currents at low voltage, because of the limit-current of the LEM current sensors. Again, 12 bar currents have been acquired simultaneously.

In the case that the cage has a certain fixed position with respect to the inductor, the instantaneous recordings of 12 bar currents (corresponding to one pole pair) show various amplitudes. Ten successive bar currents waveforms are illustrated in Fig. 8.

Not only the amplitudes are different but the phases shift differs even for two adjacent bars (left and right).
So, the bar currents system, at least at standstill, is not symmetric. A phasor diagram of the 12 measured currents shows clearly the asymmetry (Fig. 9).

![Fig. 9. The phasor diagram of 12 successive bar currents at standstill.](image)

Moreover, the bar currents depends at standstill of the rotor position. Fig. 10 shows this dependence.

![Fig. 10. Ten successive bar current amplitudes variation versus bar position covering about 60° mechanical degrees.](image)

The cage of the experimental prototype was made in such a way that each bar could be directly disconnected from the cage ring mounted outside the machine. Thus, at standstill, for a many cases of interrupted bars, the current in the vicinity of the fault have been measured [19].

The rotor position has also a notable influence on bar currents in the case of broken bars. The larger the number of broken bars, the larger the currents in the bars adjacent to the defect is (up to 100% for 4 broken bars and up to 64% for 2 broken bars, related to symmetrical cage).

The paper [21] proposes a fast estimation method of cage currents distributions for one or more broken bars. Simplified analytical expressions of currents in bars that are adjacent to the defect are in fact derived in [21]. Such expressions may be useful in real-time defects estimation, in simplifying diagnosis methods and in the preliminary design of induction motors.
IV. CONCLUSIONS

Electric drive systems for marine propulsion are becoming nowadays very competitive, thanks to increased life costs, simpler ship construction and improved reliability. On the other hand, multiphase induction motors offer many advantages for naval propulsion compared to three phase motors: fault-tolerant operation, higher efficiency and increased power in the same frame, lower pulsating torque, a great variety of operation modes (multipole-pair operation, current harmonics injection). That is why the winding performances analysis of the induction motors or winding layouts optimisation becomes a very important and timely subject in this field.

To help the designers in this problem, the authors introduce free software for the performance analysis of winding layouts for induction motors. The proposed application becomes a helpful tool in the pre-design stage and can be applied for any type of single or multiphase winding layout irrespective of number of layer or number of conductors per slot.

Moreover, this application can be used for analysis of rotor winding in the case of symmetrical/healthy cage, or faulty cage rotor in order to better understanding of the electromagnetic phenomenon in the induction motor and to optimize the cage structure.

REFERENCES


Autonomous Systems & Ships - Training and Education on Maritime Faculties

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ABSTRACT
The technologies for the autonomous, remotely controlled and operated ships already exist. Optimum integration of different technologies in a reliable and cost efficient way achieving any degree of ships autonomy is a challenge. No matter how futuristic it is, there are indications that the first autonomous ships for international trade will get underway till 2030. Accordingly, there will be a need for a new and educated crew to manage and operate autonomous ships. The use of on board autonomous systems will completely change the education programs at the maritime faculties. It is necessary to monitor the development of autonomous systems through the educational plans and programs. Education of the faculty teachers and students is crucial to respond the requirements of autonomy on board. Regardless of ships autonomy degree, human knowledge and expertise will be requirement always.

The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW), which strictly prescribe educational programs for maritime faculties, left the place for an improvement and implementation of new teaching contents. Article IX - Equivalents of STCW Convention state:
“The Convention shall not prevent a national government from retaining or adopting other educational and training arrangements, including those involving sea-going service and shipboard organization especially adapted to technical developments and to special types of ships and trades, provided that the level of sea-going service, knowledge and efficiency as regards navigational and technical handling of ship and cargo ensures a degree of safety at sea and has a preventive effect as regards pollution at least equivalent to the requirements of the Convention”.

KEYWORDS: autonomous ships, training, education, maritime faculties, STCW convention & students

I. INTRODUCTION
Current situation in international shipping is characterized by an accelerated technological development affecting the traditional and basic concept of ship control and management. Modern information and communications technology shall provide a good foundation for the automation of ship systems. Advanced digitalisation further encourages the use of automation and autonomy on worldwide shipping. The diverse capabilities of new and advanced technologies provide solutions that contribute to the development of unmanned ships and fully autonomous ships. Although the development and self-use of autonomous ships is expected in the next decade, it is certain that the transition to autonomous ships and unmanned ships will not happen all of a sudden. It is logical that there will be a transitional period when autonomous and conventional ships (with crew) will perform transport over sea together. As such maritime traffic will be a major challenge, particularly with regard to the safety and efficiency of maritime traffic flows. Demand for future maritime personnel will be marked by various factors. It is obvious that the world trade of goods will grow together with world maritime transport. This will result in the growth of ship productivity, high-performance workforce and new technologies on ships with a high level of automation and autonomy [1]. High level of automation and autonomy will force the naval industry to reduce crew number on board and finally introduction of unmanned vessels.

Term „unmanned ship” refers to a ship without a crew. Depending on the level of autonomy, the ship can be operated remotely from one or more coastal centres (SCCs), or the ship performs operations completely autonomously without a human factor [2].
Definition / types / types of autonomous ships [3]:

- **Autonomous:**
  - the system can control ship and make decisions without presence of a human factor,
  - the use of artificial intelligence can help to make the necessary decision-making system,
  - they can be with or without crew.

- **Unmanned:**
  - The crew is not physically present on board,
  - They can be fully autonomous or remote controlled.

Autonomous means that the ship can perform a set of defined operations without or with reduced attention from a bridge crew. This does not necessarily mean that no human is present. Unmanned means that there is no human present on the ship’s bridge to perform or supervise operations. Crew may still be on board the ship. Maritime Autonomous Surface Ship (MASS) has already been suggested as a general term for autonomous ships [4].

![Fig 1. Classification of autonomous maritime system and autonomous ship types [4]](image)

According to Industry Code of Practice - Maritime Autonomous Surface Ships up to 24 metres in length are classified as:

<table>
<thead>
<tr>
<th>TABLE 1. Classes of MASS</th>
<th>Class of MASS</th>
<th>Characteristic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ultra-light</td>
<td>Length overall &lt;7m and maximum speed &lt;4kts</td>
</tr>
<tr>
<td></td>
<td>Light</td>
<td>Length overall ≥ 7m to &lt;12m and maximum speed &lt;7kts</td>
</tr>
<tr>
<td></td>
<td>Small</td>
<td>Length overall ≥ 12m to &lt;24m</td>
</tr>
<tr>
<td></td>
<td>Large</td>
<td>Length ≥24m (and 100 GT)</td>
</tr>
<tr>
<td></td>
<td>High-Speed</td>
<td>Operating speed ( V ) is not less than ( V = \frac{7.19 V}{1/6}\text{kt}, ) where ( V = ) moulded displacement, in cubic meters, of craft corresponding to the design waterline</td>
</tr>
</tbody>
</table>

With current concept of education at Maritime faculties it is hard to keep up with enhanced technology on ships, and by that, demand for educated personnel is higher than they can provide. Even newer study programs after a few years becomes obsolete. One of the reasons that forces the maritime industry to develop unmanned ships and autonomous ships is currently insufficient number of skilled and educated personnel. That’s why it is necessary to adapt existing and develop new curriculums for maritime students in time so they can catch up with the development of ship autonomy.

Why autonomy?:

- the crew is less exposed to danger,
- less environmental pollution,
- lower costs due to damage,
- lower costs in general?,
- less emission,
new types of ships and the concept of management,
no crew accommodation = less fuel consumption + more cargo space,
no crew costs,
no security equipment required etc.

All of this will enable a new concept of maritime transport. It’s believed that autonomous ships will be cheaper, safer and more environmentally friendly. In a decade, unmanned ships could become a reality on world seas according to the world-famous Rolls-Royce manufacturer [5]. In order to be able to carry out its primary business, maritime transport of goods, it is necessary to develop a support system for such ships. There is a need to develop a terminal for the reception of such ships, Shore Control Centres (SCCs) for monitoring and control, communication (ship-boat, ship-ship, etc.), and a training program.

Maritime faculties are trying to follow the development of new technologies. Although education programs are strictly related to the STCW convention, it is necessary to improve the curricula so students can be more competitive on the market and adapt more quickly to technological progress.

It is necessary to make every effort in order to reduce the gap between technological advances in marine and education staff for advanced ships. A similar problem occurred with the expansion of ships for liquefied natural gas transport. In a short period of time there was a larger number of such ships, but the development of inland terminals for the reception of such ships is retarded and still lagging behind. Demand for educated and skilled personnel for this type of vessel is growing, which means that the education system cannot meet the needs of that demand.

For wider application of autonomous ships i.e. Ocean sailing in maritime transport it is necessary to simultaneously develop onshore infrastructure (ports and terminals) as well as educational programs at universities that will “produce” adequate staff to manage / control such ships.

**II. AUTONOMOUS SHIPS DEVELOPMENT TIMELINE**

The development of autonomous ships is mentioned already in the 70s in the book “Ships and shipping of tomorrow”, where future officers will carry out their duties from the land office, while ships will be operated by a computer. In order to develop a highly reliable plant and a very high automation system in the maritime area, a project was implemented in Japan 1983-1988. called "Ultra-Automatic Ship Project". The aim of this project was to develop systems of highly automated operating systems that will integrate sea and land sides with elements such as open sea shipping, port entry, berth, anchoring, cargo handling and more. Such a system was supposed to manage unmanned ships and received support through land-based systems that are all connected via satellite. By the end of the 90s, these systems were simulated on the computer. The Project of the Korean Research Institute of Ships & Ocean Engineering (KRISO) focused on Autonomous Unmanned Surface boats for Maritime Surveillance and Supervision. Main scope was to deal with issues of technology development and exploration in the areas of ship and ocean technology, maritime traffic, marine equipment and so on. 2012 The Maritime Unmanned Navigation project has been launched through intelligence in networks (MUNIN). The purpose of this project is to explore the technical, economical and legal feasibility of unmanned ships, with the aim of developing and confirming the concept of autonomous ships defined as vessels driven by automation systems but controlled remotely from the control office by land-based operators. The new concept of unmanned ships presented as ReVolt 2013 by DNV-GL is based on ships in coastal navigation under controlled conditions. A 60m fully autonomous battery powered vessel was created to reduce emissions. The Centres for Autonomous Maritime Systems and Operations (AMOS) was established in Norway in 2013 with the aim of developing a world centre for autonomous maritime systems and operations. 2015 Rolls-Royce launches the Advanced Autonomous Waterborne Applications Initiative (AAWA) project to analyse and optimize technology for autonomous ships, prepare for new safety and security issues, global legal rights and new economic and business models. The Lloydsregister 2016 has released instructions for cyber-enabled ships, or ships with embedded systems that will, with the development of IT technology, officers on shore, or without human factor, control and monitor vessels. 2017.
Tokyo-Mitsui O.S.K. Lines, LTD launches the development of a technology concept for autonomous vessels that will provide reliability, safety and efficient trans-oceanic transport. At the end of 2017, Rolls Royce demonstrated the first commercially operated remote-controlled vessel. That same year, Kongsberg launched the Hull to Hull (H2H) project, focusing on the need for sailing in the vicinity of other stationary or mobile vessels and facilities. 2017. Korea successfully tests the first unmanned ship on real sea conditions. 2018. The MV COSCO Shipping for container ship Aries 20000 TEU becomes the first vessel to be enrolled for power management according to Lloyd’s registry for cyber-enabled ships. In mid-2018, Wilhelmsen and KONGSBERG team up to take the following steps for autonomous ships. In the same year, 2018 Rolls-Royce and AXA Corporate Solutions signed Letter of Intent (LOI) to develop the necessary products for autonomous ships. April 2018. The IMO takes the first steps to integrate autonomous vessels into the IMO. September 2018 DNV GL announces directions for autonomous and remote ship management November 2018. Japan is preparing for testing the first autonomous tug [6].

![Fig. 2. Development of autonomous ships - timeline](image)

According to the IMO, levels of autonomy are defined as [7]:

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

According to the Lloyd’s Register, levels of autonomy are defined as [8]:

- AL0 – No autonomous functions. All operations are manual.
- AL1 – On-ship decision support. Data will be available to crew.
- AL2 – Off-ship decision support. Shore monitoring.
III. AUTONOMOUS SHIPS – KEY QUESTIONS

In the process of accepting and developing autonomous ships, different ethical questions will arise which need to be answered. The questions will be raised due to the special circumstances that may occur in shipping industry. Such issues should be treated seriously and with a high degree of responsibility. There will be many cases where it is difficult to find a best solution, similar to the "Trolley problem".

In original version of this problem, five people will die in fast trolley, unless somebody press the switch that will change the trolley direction to the other rail. In this case only one person will die. If question is raised, will you press the switch, most of the people will answer yes. At the same time, people will refuse to accept responsibility to stop the trolley by pushing somebody off the bridge on the rails, which is another known case of "Trolley problem". It is difficult to answer this kind of questions. There is no ethical general consensus on this matter.

However, it is important discuss such and similar problems, if this kind of problems and decisions would be delegated to autonomous ships in the future. Various ethical issues related to autonomous ships is imperative and requires unified guidelines that would be accepted globally.

Dilemma

An autonomous ship going straight is about to collide with a fishing boat with ten crew aboard (boat A). At the right side is a fishing boat with only one crew on board (boat B). What would you do if you are controlling the ship?

1st choice
Keep original course and collide with boat A.

2nd choice
Avoid boat A and collide with boat B.

3rd choice
Make a fast turn to avoid both boats at the risk of capsizing.
Except ethical questions, there are many other important questions which need to be answered. Questions such as [10]:

- What technology is needed and how can it be best combined to allow a vessel to operate autonomously and miles from shore?
- Is the Maritime Industry ready for change?
- What do we mean by ‘Autonomy’?
- Is it all about Manned and/or Unmanned?
- What are the true benefits of Autonomy?
- What is the timeline for Autonomy in the Maritime Sector?
- Is there a risk that we will lose sight of safety and efficiency in our pursuit of Artificial Intelligence and Autonomous Systems?
- Is the research and development work for Autonomous Systems having an unexpected benefit for ‘conventional’ manned vessels?
- What skills, knowledge and experience will we need in the future?
- How can an autonomous vessel be made at least as safe as existing ships, what new risks will it face and how can they be mitigated?
- Are autonomous ships legal and who is liable in the event of accident?
- How will decisions be made when the system needs to be judged between feeling and optimal cost?
- What about the countries that are not developed, how they will follow such development? etc.

IV. NECESSARY EDUCATION, TRAINING AND SKILL FOR AUTONOMOUS SHIPS OPERATIONS

Education related to autonomous ships is a challenge. Due to interdisciplinary of ships autonomy projects various skills and knowledges are required, such as:

- navigational equipment for the ship autonomy,
- ships autonomy systems,
- E-navigation,
- autonomy software’s,
- technology for ship remote operations,
- internet of Things (IoT),
- cyber security,
- universal and global legal maritime regulations etc.

Ship autonomy will not rapidly change maritime faculty’s educational concept in the near future. Years will pass until autonomous ships become global trend. It is necessary to improve faculty’s curriculum constantly, due to increase in development of new technologies and the ships autonomy levels [11].

Ship autonomy development encourage maritime faculties to introduce basic knowledge’s on new technologies. It is important to familiarise students with general concepts of automation, levels of autonomy and to prepare them for the future employment.

A crew who manages or monitors Shore control centres must have a new level / level of ability to collect and analyse large amounts of data. This will certainly be an attractive opportunity or challenge for some seafarers, but for others this can be a burden for additional education, training and new certification (certificates) to be acquired.

Shore control centre operators, as new type of employment, must be able to collect and process large amounts of data. This kind of jobs will be opportunity and challenge for the ship officers, despite requirements for additional education, training and certification.

Employment in Shore control centre will improve seamen’s social and family life. Most probably, that will be reason for increase in demand for this kind of employment.
As ship design becomes increasingly sophisticated, new generation naval architects, engineers and technicians will develop. Cyber security and new occupations related to cyber security management is additional opportunity and challenge for the new generation’s employment. All this will affect the educational institutions as well as maritime faculties, legal regulation, economic efficiency and port operations worldwide [12].

According to existing IMO regulations for minimum manning level, unmanned ships / autonomous ships / MASS (Maritime Autonomous Surface Ship) cannot be classified as “seaworthy”. Current definitions under the COLREG, SOLAS and STCW conventions will remain an obstacle to the development and application of ship autonomy on the open sea unless amended or supplemented.

To determine the knowledge, skills and education for autonomous ships, it is important to point out differences between the traditional seamanship’s and the one that will be performed in Shore Control Centres.

The STCW Convention defines the seaman as a person who is employed or seeks the job of a Master, Officer or Crew member on board [13]. The MLC Convention defines the seaman as a person employed in any rank on board, and that the Convention applies to that ship [14]. Above mentioned Conventions are not applicable for Shore control operators. The regulations of these conventions imply that a seafarer is working on a ship.

Exigency for certain qualifications, competences and certifications of Shore control operators are obvious. That is why new educational programs need to be developed for persons operating such ships.

Art. IX of the STCW convention has granted the national governments of the contracting possibility. The article stipulates [13]:

“The Convention shall not prevent a national government from retaining or adopting other educational and training arrangements, including those involving sea-going service and shipboard organization especially adapted to technical developments and to special types of ships and trades, provided that the level of sea-going service, knowledge and efficiency as regards navigational and technical handling of ship and cargo ensures a degree of safety at sea and has a preventive effect as regards pollution at least equivalent to the requirements of the Convention”.

Governments and maritime colleges have the ability to adapt existing and develop new programs for education and training for autonomous ships. Although, this possibility leaves room that each member state of convention develop their specific plans of education for autonomous ships. Small difference between faculty curriculums will always exist, but unification in global educational process is crucial if negative effects on operations with autonomous ships want to be avoided.

For example, safety, security and certification standards for the Shore control operators may vary from country to country. Accordingly ship owners will establish Shore control centres in countries with lower level of standard. So unification of education will be crucial to keep the high safety and security standards security at a high level.

To identifying the required skills for autonomous ship operators, following should be considered [15]:

- the size of the Vessel, e.g. vessels under 24m in length,
- the Class of the Vessel - see MCA Guidance on Vessel classification and certification,
- the areas of operations,
- type of cargo.

Owners operating autonomous ship should [15]:

- provide for safe practices in MASS operations and a safe working environment,
- continuously improve safety management skills of personnel operating MASS vessels, including preparing for emergencies related to both safety and environmental protection,
• comply with all mandatory rules and regulations,
• ensure that applicable code, guidelines and standards recommended by IMO, Flag States, Classification.

A. Present impact of autonomous ships on maritime education and training
We can say that we are in the transition from the second to the third degree of automation and the current training is done in accordance with this, even though demand for well trained personnel is always greater than the supply.

With the development of navigation technology, it is also necessary to master it. At present, navigation technology is divided into automated navigational tools such as the ARPA (automatic radar position system), GPS (global position system), ECDIS, a communications system like GMDSS, and the UMS unmanned engine system, where then number of crew is reduced due to automation.

According to this current / future seafarers will need to overcome not only basic knowledge and navigation technology, but also new knowledge and technology that is adaptive to the existing technological level, i.e. education should focus on ship automation systems, equipment and so on.

Further, as technology is rapidly evolving, it will be necessary to acquire greater knowledge and understanding of the new modern equipment and technology and not just the basic maritime knowledge. Such knowledge requires knowledge of logic, i.e. education will focus more on science, technology, engineering, mathematics and computing. Along with this, traditional seafaring education will continue.

B. Impact of Remote Control vessels on maritime education and training
Progressing to the next degree of autonomy, the number of crew on board will be considerably reduced, and the manner of performing the obligations will be changed also. Education needed for personnel training for the needs of autonomy will be focused on mastering knowledge and technology based on autonomous ships and managing the technology. The scope of knowledge will increase and there will be more education about knowledge related to information technology, advanced automation systems, remote management systems, etc. Traditional naval knowledge will not be enough.

C. Impact of autonomy with human factor on maritime education and training
Since this is the fifth degree of autonomy the vessel will be completely unmanned, and will be controlled and operated through a qualified offshore operator. That is why such a qualified person needs to have expanded and deeper knowledge about information and automation technology. Education will, besides theoretical knowledge, be more based on a practical part such as simulator training.

Fig. 5. Knowledge based on autonomy level
Some colleges have already started with new curriculums and study programs in terms of the ship's autonomy. In addition to study programs, various workshops, summer schools, scientific meetings, etc. are organized.

The emphasis is on [16]:

- to test the security of the maritime industry,
- to connect the cybersecurity community to the Maritime industry, to learn from each other's experiences,
- to better improve our understanding of the risks within the industry,
- design in maritime environment,
  - marine hydrodynamics fundamentals of marine hydrodynamics, equilibrium and stability,
  - system approach and design in maritime engineering,
  - underwater robotics - design and system optimisation,
- decision-making autonomy and cyber-security,
  - robotics examples and problems inherited from the maritime environment,
  - decision-making autonomy USV guiding, practical examples, algorithmic and implementation,
  - location/navigation in maritime environment inertial navigation, introduction to Kalman filtering,
  - cyber-security - historical context, issues related to cyber-security, brief history of cryptology,
- exploitation of Autonomous maritime systems,
  - maritime environment maritime transport systems and activities - meteorological constraints for autonomous systems,
  - risk analysis applied to maritime autonomous systems,
  - exploitation and main characteristics of autonomous systems - main missions of autonomous maritime systems,
- Regulation, strategy and innovation,
  - regulation general introduction to maritime law. International organisations,
  - industrial organization applied to the maritime field and autonomous systems,
  - Innovation economy applied to the maritime field and autonomous systems, basic concepts of innovation economy.

V. CONCLUSION

The International Maritime Organization (IMO) is the best place to develop a plan for education and training for a new type of seafarer. For now, small shifts within the IMO are visible on this issue, and as far as legal regulation is concerned, almost nothing has been done. For the time being, the IMO has organized a working group dealing with regulations on unmanned ships and some details are expected to be known within 2 to 4 years. It will probably take another five years to make such regulations come into effect. Taking into account the specific skills and competences that an operator in the Coastal Control Centres (SCC) must have, these people should have a combination of maritime and IT skills, as well as complete understanding and knowledge of the operation to manage unmanned ships.

Requirements for qualifications and training of operators in coastal centers must be regulated by a special rulebook. While there is no any regulation for operators in coastal centres, it would be wise to apply existing conventions as if they were working on a ship.

One of the main problems of applying the STCW Convention to unmanned ships is the requirement to hold a guard. The STCW convention was created to enhance the safety of human life on the sea by introducing unified regulations on training, certification and keeping watch on the ship.

A person who manages a ship by land is not subject to these regulations because they relate only to persons working on a ship. This does not mean that anyone can work in Coastal Centres (SCCs) and manage
unmanned ships. It is clear that new regulations have to be adopted or existing STCW conventions adjusted to ensure that the safety of such ships is maintained at a high level.

So it is necessary to adopt a global and unified rules for training, education, certification and watchkeeping, taking into account all the opportunities and challenges that ships without crew provide. It is unrealistic to expect such rules to be introduced in the first years of the development of such ships. Certainly, it is necessary to keep and apply the existing STCW convention regulations until a new or amended rulebook is issued.

With the development of marine autonomy, new models of simulators that will meet the requirements of the new maritime concept need to be developed. Thus, Kongsberg has already developed a simulator to test all aspects of marine autonomy under various traffic, load and weather conditions. Kongsberg have modelled the complete sailing area and will connect the autonomous ships control system to the simulator. The simulator will provide the sensor input to the autonomous control system, and will also have a full and very detailed model of the ship including all the ships dynamics. This will allow you to test all aspects of sailing and emergency situations in a completely safe environment. A built-in simulator can also be used for prediction purposes when the ship is operational [17].

At the end it is important to point out a few important conclusions:

- autonomous ships are not a thing of the future - small autonomous vessels are already a reality,
- fully automated vessels reduce risk in some areas, including keeping seafarers out of harm’s way, but may increase it in others,
- interaction between manned and unmanned vessels is likely to be a major point of risk,
- existing conventions and regulations will need to be updated,
- while autonomous merchant vessels are unlikely to be a reality for many years yet, onboard systems are increasingly becoming automated, which demands a new set of skills and aptitudes from seafarers.

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Challenges of Marine Education with Implementation of Modern Technologies

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ABSTRACT
Modern technologies are undoubtedly changing the way we comprehend our outside world. Digital revolution introduces new possibilities of changing everyday tasks. On the vessel, new advanced technologies are making way for improvements and beneficial cost effective management. As the time changes, more and more companies are accepting these improvements. Furthermore, some of them also invest in innovative projects. Those projects include information technologies, digitalization, new fuel, cloud computing, block-chain technologies as well as education.

To put education into the perspective of the modern day society it is clear that maritime and shipping industry have to change according to it. On the other hand, educational institutions have to adopt new advanced scientific breakthroughs and implement them into their educational system. With that in mind, today’s students have to learn for the future. That means that the educational institutions have to prepare them for the future endeavours in the maritime industry, whether they will be employed on the different types of vessel or on shore.

Study programmes with universities ought to be more flexible in order to implement innovative technologies and concepts. This can be achieved with better connection between universities, government institutions and maritime industry.

KEYWORDS: maritime education, modern challenges, autonomous vessels & maritime industry

I. INTRODUCTION
This scientific work will analyze correlation between growing trend of modernizing technologies and education that has to be up to date. Modern times require modern solutions. It is well known that maritime transport makes more than 90% of worldwide trade.

In the second chapter it is clear that modern technologies make the very foundation of this scientific work because the education must be built on today’s view of the futuristic technologies that might be implemented into the maritime industry in the relevant near future. Many companies are testing and trying to implement different types of advanced technologies. Some of which are already implemented such as are prototypes of autonomous vessels and digitalisation.

Third chapter describes current state of educational system and proposals for improvements that should be implemented in order for students and future seaman to be more qualified and competitive in the global maritime market.

Finally, in fourth chapter it is shortly mentioned that some of the technologies will most probably be implemented in educational system and/or maritime industry, such as: block-chain technology, autonomous vessels, cloud based technology, virtual reality, voice-controlled devices, new fuels and 3D printing.
II. MODERN TECHNOLOGIES

In last few years we are witnessing a fast development on all fields of science, all that new technology is affecting shipping industry as well. It is clear that automatisation, digitalization, and cloud computing in everyday situations while on board. Since this fields are rapidly expanding we can expect to see new technologies specially designed for shipping industry same as we saw in the past with ECDIS (Electronic Chart display Information System), GNSS (Global Navigation System) and DGSS (Differential Global Navigation System), ARPA (Automatic Radar Plotting Aid), AMOS (Administration, Management, Operations, and Spares), MSW (Maritime Single Window) LIDAR and SEAGULL e-learning system.

All this digital tools and the ones that are yet to come make it important to implement digital tools in learning processes.

A. Autonomous vessels

Interest in autonomous and remotely controlled vessels is rising due to up-to-date development of technologies such as sensors, networks and self learning software.

Maritime industry can, and will benefit from applications and concepts of autonomous vessels. Autonomous vessel is defined as unmanned vessel which means that there is not a single crewmember onboard. First of all it is important to understand that “autonomy” is very broad term. To understand its future development it must be understood and it is important to distinguish few levels of autonomy. According to the Lloyd’s Register, autonomy is defined and divided into seven levels which can be divided into four groups, as shown on picture υ, for simplicity:

- manned vessel – Vessel manned by crewmembers onboard,
- remote vessel – Vessel manned remotely from shore-based station,
- automated vessel – Vessel manned by pre-programmed algorithm – human can step into process,
- fully autonomous vessel – Vessel which can make decisions by itself without human stepping into process

![Fig. υ. Autonomy according to the Lloyd’s Register [1]](image)

It is matter of time when will transition through earlier mentioned groups start due to constant development of algorithms which are improved by implementing machine learning.

It is expected that the initial application of autonomous vessel will be in coastal liners like bulk carriers, passenger or Ro-Ro vessels. Good example is “Yara Birkeland” shown on picture 2 which is operating across a Norwegian fjord. Why Norwegian fjords? It is mainly because of calm and traffic-free area with very simple route. Example speaks for itself – the time has come. Yara Birkeland’s first zero emission autonomous vessel driven by electricity and is expected to be fully autonomous vessel by 2022.
Fully Autonomous Vessel is ultimate goal for the maritime industry and is predicted to improve maritime safety by eliminating human error which causes 80% of the overall maritime accidents. But before any technology is applied, advantages and challenges must be analysed.

Advantages:
Biggest advantage is removing human error, but there is lot of other advantages such as reducing crew costs, improving safety and efficiency of the vessel while, on the other hand reducing or eliminating environmental impact. One of the proofs of these advantages are results of three year research project by MUNIN (Maritime Unmanned Navigation through Intelligence in Networks) which predicted a saving of over 7 million $ over a 25-year period per one autonomous vessel which includes crew member salaries, fuel consumption and crew supplies.

Challenges:
Biggest challenge is the adaptation of education due to implementation of modern technologies and solutions. Modern problems require modern education. Although there is a lot of advantages by means of saving money by reducing crew member and fuel cost, the initial investment costs are high. It is not for the vessel itself, but also for the shore based control centres for supervising the whole process [3].

B. Digitalisation
One problem concerning education of seafarers is continuous learning process as they advance in their careers. Companies implement new technologies on board and crew needs to be able to learn how it works and get familiar with it.

IBM and MAERSK are working on a block chain-enabled shipping solution designed to promote more efficient and secure global trade called TradeLens.

TradeLens is bringing together various parties to support information sharing and transparency, and spur industry-wide innovation. As part of the TradeLens early adopter program, IBM and Maersk also announced that 94 organizations are actively involved or have agreed to participate on the TradeLens platform built on open standards [4].

Because let’s face it, the cost, size and complexity of global supply chains and the world’s trading ecosystems just keeps growing, and as an industry we have made a habit of making a complex business even more complicated by applying solutions of the past instead of embracing the opportunities digitization can provide us all today. Current problems include:

- Inconsistent data and inequitable sharing of information across supply chains,
- Continued “blind spots” across organizations and geographic boundaries,
- Complex, cumbersome and often expensive peer-to-peer messaging,
- Too many manual, time-consuming processes that increase costs and delay cargoes,
- Inefficient clearance processes which can open the door to fraud.
TradeLens goes to the core of these industry-wide issues by empowering each and every actor in global supply chains to become part of the solution. And here’s what’s at stake when we finally start getting it right:

- Improved efficiency means lower costs,
- Improved effectiveness means more on-time cargo,
- Improved data security means lowered risk,
- Increased market opportunity means top line growth for all.

According to the World Economic Forum, by reducing barriers within the international supply chain, global trade could increase by nearly 15%, boosting economies and creating jobs around the globe [5].

E-learning is a fast and efficient way to improve awareness and knowledge. Good example of e-learning platform is Seagull. They offer a large library of e-learning modules to get the crew required knowledge for their ranks/positions. Each e-learning module is an individual training session with a final assessment at the end. By offering training content both online and offline, their modules are always available at the click of a button [6].

### III. Education

#### A. Current state of education

During the last several years, maritime education in Croatia had seen some changes in the programmes of teaching, practice and student’s structure [7]. Croatia has a very long maritime tradition and seafaring is stated as one of the most prominent professions to be involved in. In relation to that, numbers of institutions (public and private) offers numerous different types of studies in the maritime field. Some of them, mostly private ones, are specialised for seafarers to whom they offer particular types of training for their relevant position on board as well as training and education for special type of vessels. Moreover, some of the private educational institutions offers employment after the seafarer has finished enlisted courses. On the other hand, there are public educational institutions where students acquire adequate knowledge throughout levels of education for their type of studies.

The thing that got the most attention among the student’s population is practice. Most of the universities offer some kind of practice to their students during their years of education, either on the bachelor degree or master degree level. This type of knowledge and experience has been involved in the educational systems for many years but since the shipping and maritime industry changes according with more and more advanced technologies, knowledge and time, the educational institutions spanned more attention to it.

The ever-changing and unstable market of maritime and shipping industry is intertwined with employment rate and job market where students have to have specialised knowledge as well as experience to be more desirable to the employer weather it is a shipping company, maritime agency, transport organization or some kind of other niche of maritime industry. Today’s conditions in job market impose distinguished differences between competitors for one type of job. To perceptively select the career path, maritime educational system as well as mentors and teachers have a unique responsibility to thoroughly present to maritime students various maritime transportation branches and vessel types operated on the markets [8].

Current maritime studies offer variation of knowledge introduced through their curriculum for several maritime studies programme. Maritime studies combine liberal arts and highly professional courses, which makes it largely interdisciplinary form of education. Unlike other universities studies, a maritime study needs to satisfy very specific requirements of international convention and standards. [8] Most of them come from the criteria introduced from the STCW (International Convention on Standards of Training, Certification and Watchkeeping for seafarers as well as IMO regulations, although STCW convention does not prevents the educational institutions from improvements towards new and optimised system of education [9]. Additionally, most of the educational institutions have implemented modernised
simulator and e-learning equipment as well as other tools with respect to traditional educational program (book-by-book). Engaging new tools into educational system improves the knowledge and experience of the student which gives him more opportunity for the future endeavours in the maritime industry. For example: student from the nautical studies will have a better understanding of the situation that might happen someday on the vessel if he’s somehow experienced with it using the simulator equipment. On the other hand, student from the maritime management will have a better view on the maritime industry and shipping industry as a whole, if he’s engaged in the practice during his academy years.

B. Improved educational programme

The quality of maritime education system can be considered as one of the most important pillars for safe, efficient and prosperous maritime industry as well as shipping. Particularly vital is the maritime education at the university level that ensures student cadets and other students from maritime universities top qualification and knowledge in accordance with the STCW convention. Generally, the quality of education of the individuals is correlated to the employability and promotion opportunities. In Croatia, maritime education system is well established with a long tradition of education at the university level for students from maritime universities [υτ].

Considering the growing modern technological achievements that are undoubtedly improving maritime industry, maritime universities are obliged to implement technological advances into their curriculum. Shipping industry have seen abundances of improvements regarding sophistication of the electronics, programmes, modules, shore-based operations, management of the vessel as well as information technologies. If that is put in the perspective of the education, it is clear that a today’s student is required to have special types of knowledge.

The use of newly digital environment for the education of the students is inevitable which implies that there should be a constant process of upgrading tools for e-learning as well as new programmes, studies, practice and technologies, but also a strategy to develop new ones which will be integrated into educational system.

From the authors’ perspective, there should be a strategy to upgrade the current study programmes at the universities or even introduce new ones. New study programs should be well optimised for the upcoming technological achievements and they should also embrace existing ones which will result in the cheaper transition period. Furthermore, there will probably be a need for a combined programme of the information technologies and naval studies which will benefit future structure of the maritime and shipping industry. The student in the future will be given a whole new set of skills. The knowledge of leadership and human resources management as well as activities of organizing and distributing jobs on board, experienced seafarers mostly acquire through working experience and by attending tailor made courses. However, given the modernization of the industry, the improvement in safety and efficiency of working processes on board, the need for systematic approach to this issue and the establishment of educational and training programmes on these topics have been imposed over time [10]. The next thing that can add to the quality of the students’ education is that the maritime universities should invite guest lecturers. Both students and universities will benefit from the guest lecturers because they will gain experience from the persons directly involved in the industry.

C. Implementation of modern studies

The degree of autonomy in the maritime industry grows every day and with thorough verification of all aspects that have to change with it, it will continue to grow.

Automation will require a change in the design and operation of navigational equipment, communication and ship propulsion system and the way of handling that new equipment. With that said, it is obvious that automation will advance in all parts of the ship, so investments would have to be made in equipment for educating deck officers as well as the engine officers.
This will require that the faculties have to upgrade and redesign their system of education, also they have to make changes and investments in modern technology and enable their students, future seafarers, to prepare adequately for the upcoming changes in the maritime industry and master the knowledge of automation.

Secondly, psychology will need to be more prominent and become one of the pillars of the education of the future seaman. By increasing the autonomy of ships, the number of crew on board is reduced and the scope of jobs that the seaman performs is bigger and more complex and therefore the level of stress increases.

Psychology, both in scientific research and in seafaring education, will be of great help. Furthermore, assuming that in the future there will be fully automated ships, without any crew, this will mean that access to psychology in education of a seaman will need to be changed.

The task of the psychologist will be to keep the so-called “boat feeling” at the Shore control centre (SCC) employees. Since managing ships from the SCCs will bring the risk of a lesser sense of responsibility, seafarers will be able to keep this feeling through different psychological exercises [11].

IV. VISION OF FUTURE

A. Block-chain technology

Within the maritime industry block-chain has already made the transaction process decentralized and eventually easy to track. Decentralizing the process of banking removes middlemen, thus reducing the cost of transactions allowing parties to save both time and money. There is no need of inputting paper booking information and Bill of Lading. Transaction parties can now be directly connected and proceed in real-time exchanges of supply chain documents and transactions, while Certificate of Origin and customs clearance information can be shared securely. Maersk and IBM have already launched block-chain-based trade platforms, while other organizations are following [12].

B. Autonomous ships

Automation has the potential to increase safety through a separate way. Supporters of autonomous ships mostly focus on the signs that this trend shows to reduce the risk of human error on board, which has been the main cause of accidents at sea. Indeed, supposing that no personnel will be onboard no more human errors would occur, no one would get injured. Studies indicate that sailor-less ships would be managed from land-based facilities focusing mostly on specific tasks rather than entire jobs [12].

C. Cloud-based technology

Cloud technology not only helps accessing data easily regardless of time or location, as well as reduces data silos. According to a study by the International Data Group, 69% of businesses are already using cloud technology and 18% say they plan to implement cloud-computing solutions at some point. In particular, this ground-breaking technology is an asset for shipping industry as well as it offers [12]:

- better communication between staff at land and sea,
- cost savings,
- remote access to corporate data,
- data loss prevention.

D. Virtual Reality (VR)

The strongest demand for AR and VR technology comes from creative industries. The impact of virtual reality is increasing exponentially in maritime, mainly in the field of engineering, training, and inspection because it can offer major improvement.

Cost-effective software and hardware solutions for Virtual Reality have already helped maritime industry to adapt its options and bring them to beneficial use. Specifically, in May 2017, Winterthur Gas & Diesel installed its W-Xpert Full Mission Simulator for training complete engine room crews [12].
E. Voice-controlled devices

Voice implementation has already made its appearance in aviation and truck fleet inspection, where clipboard inspections processes have been turned into full voice guided inspection processes. New focus areas for voice implementation are the automotive, vessel and cargo inspection, with the scope to convert into voice all defined inspection process steps, allowing real time inspection and hands-free documentation [12].

F. New fuel

Digitalization and de-carbonization are watch words for the coming decade. Today shipping plays an integral part of the global economy and moves more than 80 per cent of world trade by volume. Not only does shipping move the majority share of world trade, it does so while emitting the least amount of greenhouse gases per transported unit. To reduce these emissions, it is needed to move towards alternative fuels. Depending on fuel type, greenhouse gas emissions, NOx, SOx and local particle emissions can be significantly reduced – if we want [13].

G. 3D printing

The next potential big new thing in shipping and some other industries is additive manufacturing, or 3D printing. Not only can additive manufacturing result in new designs for more efficient machinery components, it could also allow spare parts to be produced locally in various ports around the world. This would improve responsiveness to market demands, shorten the time for repairs and contribute to more efficient ship operations. The technology is already being used for rapid prototyping, but it is now gradually being integrated into existing manufacturing infrastructure, for example in the automotive and aircraft-manufacturing industries [13].

V. Conclusion

Technological and scientific knowledge should be intertwined to benefit the future of maritime industry. Maritime industry is one of the broadest economical branches and all new technological achievements are, in one way or the other, implemented in it. Those achievements should also be implemented in the educational system before they are put in use in the industry. Universities ought to be faster in the process of adjustment of modern technologies in their curriculum and practice in order to prepare future students for the job market in the maritime industry. In that way there is a possibility to avoid technology surpassing our knowledge.

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Development of Qualification Standard and Study Program of Logistics and Management in Maritime Transport

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ABSTRACT
For a knowledge-based society and economy, it is important to ensure the process of developing, applying and disseminating knowledge in the cycle of creating new values. For the development, application and dissemination of knowledge, an efficient education system is needed at all levels. The education system needs to address the need for new knowledge, to provide support for employers in developing their own competitiveness and to deliver results in the development and application of knowledge in the economy.

The paper aims to describe the methodological procedure based on HKO principles, for the development of qualification standard and study program in area of Maritime Logistics and Management. Croatian Qualification Framework is a reform instrument, adopted by Croatian government in 2013, which regulates the system of qualifications in the Republic of Croatia. It aims to increase the transparency and quality of the entire educational system, to establish a link between educational programs and labor market and to facilitate the mobility of the European Higher Education Area and the European labor market.

The research was a part of KIKLOP project - Development of Qualification and Innovative Methods of Competence Acquisition in Logistics and Maritime Transport, financed by European Social Fund (φτυω-φτυϊ). The real needs of the labor market in the area of maritime transport and logistics have been studied, and key occupations and the necessary competences to perform key tasks within these professions have been identified. Based on the trends that influence the future development of transport market, the needs of labor market and the development of occupational standards, it is possible to develop the qualification standards that define the SMART learning outcomes that need to be included in the specific education program. In this paper, the improvement of undergraduate study program of Logistics and Management in Maritime Transport will be researched.

KEYWORDS: Croatian qualification framework, qualification standard, study program & logistics and management in maritime transport

I. INTRODUCTION
Although the Republic of Croatia adapted its higher education system in 2005 according to the principles of the Bologna Declaration, a number of weaknesses have been observed. When introducing new study programs, some output parameters such as learning outcomes of students were not fully defined. With rare exceptions, the study programs were devised within the framework of higher education without specific consultation with other important stakeholders such as employers, relevant national authorities and others. The result is, as pointed out by the Ministry of Science, Education and Sports [1], a notable unevenness in the quality of various study programs, problems in their acceptance by the labor market as well as in their general contribution to society.

The Republic of Croatia established the legal framework of quality assurance in higher education by passing the Law of Croatian Qualification Framework [2], which defined the main tools for the equalization of study programs quality. Croatian Qualification Framework (HKO) has been established as a key reform instrument governing the qualification system, with the advancement of educational programs that comply with the standards of qualifications and their components - learning outcomes, with a goal of raising the quality of education and its alignment with the needs of the labor market and lifelong learning [3]. Study programs must ensure the acquisition of learning outcomes, with an effective way of checking these outcomes. A part of higher education institutions has not yet shifted from classical "knowledge transfer" to the development of competences, and only evaluates the contents which students memorized instead of evaluating the acquired knowledge and skills.
Furthermore, the HKO is linked to the European Qualifications Framework (EQF) and the Qualifications Framework of the European Higher Education Area (QF-EHEA). This facilitates the mobility of citizens in terms of learning at European educational space and the mobility and competitiveness of Croatian workers in the European labor market [4]. Linking and comparing with other education systems in Europe will contribute to ensuring the quality of the Croatian education system and recognizing Croatian qualifications in Europe and globally.

Maritime studies present a complex multi-disciplinary scientific field based on activities with various technological, economical, and legal characteristics. Croatian higher education and research institutions in the broad field of maritime affairs have to continually adjust their educational programs that are related to the needs of the domestic and international labor market, and at the same time be recognizable within the European Higher Education Area and comply with all the requirements of the Ministry of Science, Education and Sports, Ministry of Maritime Affairs, Transport and Infrastructure, the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers [5], etc.

In accordance with the principles of HKO, the Faculty of Maritime studies has implemented the KIKLOP project - Development of Qualifications and Innovative Methods of Competence Acquisition in Logistics and Maritime Transport, financed by the European Social Fund [6]. The real needs of the labor market in the area of maritime transport and logistics have been studied, and key occupations and the necessary competences to perform key tasks within these professions have been identified. Based on the trends that influence the future development of transport market, the needs of labor market and the development of occupational standards, it was possible to develop qualification standards that define SMART learning outcomes that need to be included in specific education programs.

II. CROATIAN QUALIFICATION FRAMEWORK METHODOLOGY

Educational programs that aspire to be accredited under the principles of HKO must be based on qualification standards, which is at the same time a quality assurance mechanism, and a guarantee that the qualification holder has certain predetermined and relevant knowledge and skills.

The process of adapting the education system to the needs of the labor market can be divided in several development phases [7]:

- **Phase 1** - an assessment of the future needs for knowledge and skills that are based on key national strategic documents, the structure of the labor market and the clear recognition of the required skills and knowledge for individual occupations and the assessment of future needs for knowledge and skills.
- **Phase 2** – the elaboration of occupational standards for selected professions, in accordance with the given HKO methodology.
- **Phase 3** – the creation of competence matrices through occupations that are covered by an educational program.
- **Phase 4** – the elaboration of qualification standards that define exactly those learning outcomes on which the future education programs need to be defined.

A. The methodology for development of Occupation Standards, Competences and Matrix of competences

Creating the standards for specific occupations in maritime transport and logistics sector was based on the analysis of current and future labor market needs in the Transport and Logistics sector. In accordance with the relevant strategic documents, sector profile and analytical indicators, the demand for occupations was determined for a minimum period of 5 years. The planned methodology for the analysis of sector background included trend analysis and assessment of the sector growth. It also included the trends analysis of key occupations within maritime activities, the analysis of knowledge and skills needed for a particular occupation and plan to adapt qualification standards and training programs [8].

A special emphasis in the analysis of market needs was on the need for occupational standards that are projected to appear and exist in the future.

The methodology for the development of occupational standards and competence matrix [9] is shown in Fig. 1.
The first step in the development of occupational standards is the analysis of the existing national databases in order to identify the existing occupations. In cooperation with employers and project partners, new potential occupations were recognized at the labor market. In the development of occupational standards, the main task was to determine the key job activities and identify the knowledge and skills necessary to perform them. Knowledge and skills combine competences that the employee must acquire through educational system or through work experience [υτ].

By analyzing the working processes and the key activities performed in the workplace, the existing and new competences and occupational standards have been identified. Based on the competences recognized through questionnaire and the occupational standards, qualifications standards and educational programs can be (re)developed. The questionnaire contained questions on key job activities in the workplace and required knowledge and skills, or competences. Moreover, besides the questionnaires, there other methodological tools have been used, such as interviews, focus groups, workshops, etc.

By grouping the competences of all developed occupational standards, it was possible to develop the matrix of competences - a tool that creates a set of competences from several occupations covered by each qualification and study program (curriculum). This is the point where it was possible to clearly determine whether the competence gap exists in relation with the learning outcomes of individual curriculum. If there is a gap or incompatibility, it is important to find a solution how to change, improve and (re)develop the existing study program.

B. The methodology for development of Learning outcomes, Qualification standards and Curriculum improvements

The reality of today’s maritime sector is the narrow specialization of formerly integrated activities. Higher specialization leads to higher requirements in terms of job quality, which is linked to higher market demands and increased competition among companies involved in sectoral activities. For example, changes in seafaring, especially liner shipping, the development of new technologies in the transport process, the development of highly sophisticated technical management systems, the specialization of ships and sea transport etc. changes the way of organizing and managing the sectoral activities. The specialization of the former integrated maritime activities leads to understanding the demand for occupations [11]. Accordingly, the existing occupations are aimed at very narrow specialization created by the market structural changes in the maritime system both within the Republic of Croatia and in the European Union. Creating a qualification standard based on a chosen one or two highly specialized professions will not result in determining the real needs for higher education services in maritime education.
The development of qualification standards and study programs is based on previously developed standards of occupations connected with the study program, the conclusions of the analysis of the profile of the Maritime Transport and Logistics subsector, the matrix of competences as a tool that encompassed different skills and competences from selected occupations associated with the study program. The development of the methodology of developing the qualification standard and the improvement of the curriculum is presented in Fig. 2.

![Diagram](image-url)

**Fig. 2. Methodology for the elaboration of the standard of qualifications. Source: Authors.**

Competence matrices for similar occupations were defined based on the analysis of the complexity of individual competences; factual and theoretical knowledge; cognitive, psychomotor and social skills; the associated autonomy and responsibility that a person must acquire through learning and prove in the process of learning. Based on that, measurable indicators of learning outcomes (or level of learning outcomes) were defined. Learning outcomes were structured according to the SMART principle: specific, measurable, agreed, purposeful and timely.

Developed qualification standards for employment in the maritime sector mark the content and the structure of a certain qualification, including all the information necessary to determine the qualification level, qualification volume and qualification profile, as well as the data required for quality assurance and improvement of qualification standards. With the aforementioned activities, as well as with the analysis of existing study programs, recommendations were provided for the improvement of existing undergraduate university studies at University of Rijeka, Faculty of Maritime Studies - Logistics and Management in Maritime Transport.

### III. DATA COLLECTION, MODEL FORMULATION AND RESULTS

#### A. The identification of the Maritime System and its specifics

After the independence of Croatia and the transition to market economy, there have been inevitable changes that followed worldwide maritime trends. At the level of the Croatian maritime cluster, activities that are related to maritime traffic, maritime transport, transport logistics activities, and finally activities related to the maritime offshore industry can be extracted. The basic cluster group in the maritime sector includes all activities that are closely related to maritime transport. Activities can be divided in several groups: maritime safety, ports and terminals, ship management, sea freight shipping (liners, trumps, tankers, off-shore), marine passenger shipping (liners, tourists), shipping agencies and brokerage, booking of ships and cargo (ship - brokering), control activities, cargo surveying, ship supply services, maintenance and repair of marine equipment, marine insurance and public administration.

It should be noted that the result of a narrow specialization within the Croatian shipping business in recent years has resulted in the establishment of many small companies (SMEs) that are trying to establish...
their market position by doing business with large shipping companies operating on the global market [11]. Higher specialization leads to higher demands in terms of business quality that is associated with growing demands of the market and stronger competition among companies involved in sectoral activities. Besides that, the foreign shipping companies and other companies have founded firms in Croatia which are 100% owned by them (e.g., shipping agencies, ship-management agencies, etc.).

This leads to a conclusion that changes raised from the process of globalization of the maritime sector have contributed to the changes in the structure of local employers and small/medium company development that is considerably more flexible and more adaptable to business dynamics that follow rapid adjustments of shipping companies on the global transport market.

B. Identification and development of Standards of Occupations in the sub-Sector of Maritime Transport and Logistics

According to the market change, through preliminary study conducted within the project, 59 occupations have been identified in the sector. Since this was a much larger number than needed by the project, it was necessary to reduce the number and to narrow the selection to about 20 occupations that would be developed further. Based on the mentioned criteria, competences for 23 occupations have been identified.

Research results were collected through desktop analysis, focus groups, workshops and online questionnaires circulated among stakeholders, employers, alumni, etc. In the first part of the questionnaire, the description of key tasks and specific knowledge and skills required for a particular occupation and workplace were identified. The second part of the questionnaire identified general competences, generic skills, psychomotor skills and workplace characteristics.

Regarding the further development of curriculum of undergraduate study of Logistics and Management in Maritime transport 4 occupations were selected as relevant:

1. Logistics Manager
2. Warehouse Operation Manager
3. Ship Agent
4. Shipbroker

The surveys have been sent to 359 e-mail addresses of relevant employers employing 23 selected occupations at project level. Of the total 359 surveyed, 132 respondents (around 36%) filled in the questionnaire with valid data. For occupations mentioned above (Logistics Manager, Warehouse Operation Manager, Ship Agent and Shipbroker), the total of 56 questionnaires were filled with valid data.

By the identification of key tasks for each individual occupation through questionnaire, focus groups, workshops, etc., a series of competences have emerged. For each occupation, 6-7 key tasks have been determined, out of which competences have been derived. Students who will complete the undergraduate study Logistics and Management in Maritime Transport should acquire 170 skill competences, 62 general competences and 34 aggregate competences [11].

C. Development of the Matrix of Competences

By grouping competences from the occupational standards, it is possible to obtain a matrix of competences - a tool that creates a set of competences from several occupations, covered by a particular qualification and study program.

Table 1 shows the part of matrix of competences for Bachelor of Logistics and Management in Maritime Transport, a qualification that is supported through the undergraduate study program Logistics and Management in Maritime Transport. The study program should educate students for the selected four occupations.
TABLE I. MATRIX OF COMPETENCES FOR BACHELOR OF LOGISTICS AND MANAGEMENT IN MARITIME TRANSPORT

<table>
<thead>
<tr>
<th>OCCUPATION</th>
<th>COMPETENCES</th>
<th>AGGREGATE COMPETENCES</th>
</tr>
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| Logistics Manager     | – Knowledge of transport and logistics processes and methods for solving logistics operational problems  
                         – Demand management: demand forecasting, demand-driven distribution organization strategies, knowledge of the organization of the return of goods (return logistics)  
                         – Methods of organizing and coordinating the participants in the transport and logistics process  
                         – Logistic Processes, Logistics Techniques, Organization of Logistics Processes, Supply Chain Management Techniques, etc.                                                                 | Business logistics    |
| Maritime Agent        | – Principles and methods of organization of maritime, land and air transport  
                         – Specific features of the supply of ships (food, water, fuel, lubricating oils, spare parts, ...), etc.                                                                                               | Technical logistics   |
| Maritime Agent        | – Organization of the internal transport and storage process at the technical, documentation and information level                                                                                           | Information and Communication Technologies |
| Logistics Manager     | – Application of forecasting and prediction methods using specialized software tools  
                         – Demand management: demand forecasting, demand-driven distribution organization strategies, knowledge of the organization of the return of goods (return logistics)  
                         – Methods of resource planning and allocation, vehicle routing and sequencing of transport operations, using specialized software tools  
                         – Ability to solve logistics operational problems  
                         – Understanding traffic-technical characteristics and limitations of transport infrastructure, etc.                                                                 | Information and Communication Technologies |
| Warehouse manager     | – Types, features and functions of distribution centers  
                         – Technology of delivery of goods to customers  
                         – Methods of solving logistics problems of matching and distribution of goods in the warehouse, etc.                                                                                                  | Information and Communication Technologies |
| Maritime agent        | – Working with port information platforms (e.g., Port Community System and Single Window System)                                                                                                           | Information and Communication Technologies |
| Maritime Shipbroker    | – Demand for shipping space and freight forwarding                                                                                                                                                           | Information and Communication Technologies |
| Logistics Manager     | – Knowledge of storage, retrieval and data analysis technologies using databases and data warehouses  
                         – Use of information systems to support planning, shipping, and monitoring of goods  
                         – Types and application of information systems in logistics  
                         – Methods of resource planning and allocation, vehicle routing and sequencing of transport operations, using specialized software tools, etc.                                              | Information and Communication Technologies |
| Warehouse manager     | – Methods for evaluating performance and performance measurement  
                         – Use of information systems for monitoring the movement and delivery of goods  
                         – Use of information systems for monitoring the status of goods, warehouse conditions and process flows  
                         – Use of warehouse optimization information systems, etc.                                                                                                                                            | Information and Communication Technologies |

Source: authors

It was clearly possible to determine whether or not there is a competence mismatch or a mismatch of the required competences with the learning outcomes of individual curricula. If there is a gap, it is important to find a solution through changing and/or modernizing existing regular programs or develop new study program in the appropriate HKO sector.
D. Development of the Matrix of Learning outcomes and Qualification Standard

Learning outcomes for developed occupational standards or the complexity of certain competences define the factual and theoretical knowledge and cognitive, psychomotor and social skills, and the corresponding autonomy and responsibility that a person must acquire and prove in the learning process. Learning outcome matrices encompass common learning outcomes and individual learning outcomes for related professions that will be covered by each qualification. Matrix of learning outcomes for Logistics and Management need to be derived from matrix of competences.

Developed qualification standards mark the content and structure of a certain qualification, including all the information necessary to determine the qualification level, qualification volume and qualification profile, as well as the data required for quality assurance and improvement of qualification standards [12].

The proposal for the minimum volume of the qualification is expressed with 180 ECTS points, according to level 6 of the HKO. The number of points awarded to a qualification reflects the time that an average learner needs to obtain the learning outcomes contained in the proposed qualification standard. The allocation of points to the learning outcome assemblies and, consequently, the qualification standard is in line with Article 7 of the HKO Act, in which the minimum volume is prescribed. The proposed qualifications contain learning outcomes as the smallest comprehensive set of related learning outcomes of the same level, volume, and profile. In the learning outcomes it was attempted to clearly state “What the student must know, understand or be able to do as a result of this learning experience?” The learning outcomes merge into a set that can clearly identify the learning achievement for which the student will receive ECTS points at the appropriate level.

All individual learning outcomes are linked to the idea of qualification, i.e. with the competences that the individual is expected to have after obtaining the appropriate qualification. For this reason, the overall competences of qualifications are hierarchically organized into sets. Several individual learning outcomes are contributing to certain qualification competences. One specific set of learning outcomes contributes to a greater number of competences of a particular qualification. For the qualification Bachelor of Logistics and Management in Maritime Transport, the following set of learning outcomes applies: logistics, transport management, brokerage, port management, ship agencies in maritime transport, information communication technology in logistics, quantitative methods in logistics, legal profession regulations, English language and BSc thesis.

As discussed above, creating a qualification standard based on a chosen only one or two highly specialized professions will not result in fulfilling the real needs for higher education services in maritime education. Accordingly, the creation of highly educated personnel, especially in propulsive innovation activities, must be well thought out and the system must lead to the creation of personnel that will be able to independently adapt to change in a very dynamic market in the long run.

After establishing the standards of occupation and learning outcomes sets and recognized needs of the labor market and the development of qualification standards, it is possible to connect the supply of education with demand for education - the needs of the labor market. With the aforementioned activities, as well as with the analysis of existing study programs, recommendations were provided for the improvement of existing undergraduate university studies at University of Rijeka, Faculty of Maritime Studies; Logistics and Management in Maritime Transport.

E. Improvement of the Undergraduate study program Logistics and Management in Maritime Transport

In terms of the study program Logistics and Management in Maritime Transport, it should be noted that some new occupations and competences have been identified in the framework of occupational standards that are not covered by this program. Once requirements in terms of the needed competence recognized by the market were established, and after the analysis of the current study program, it can be concluded that for some of them there are no appropriate basis in terms of knowledge and skills in the
existing programs. In this context, it was necessary to consider the need for adaptation of the existing courses and teaching content and, where necessary, to introduce new content and courses.

This fact has been pointed out by alumni students who are employed in the maritime sector, in different working places and occupations by different employers. For instance, some competence for occupations such as Ship Agent or Shipbroker, were not recognized in the existing curriculum. Therefore, it was necessary, to develop new learning outcomes at the study program level, and at the Course level as well in accordance with the developed matrix of competences for occupational standards.

In the process of adapting to the labor market needs, certain shortcomings of the existing study program have been observed that influence the development of competences. Learning outcomes from individual courses are applicable to graduate studies, while some courses from graduate level are more applicable at the undergraduate level, which requires the transfer of courses and the new calculation of ECTS credits.

By comparing the acquired qualification standard and the existing study program, the need for introducing new or replacing existing courses is evident. For example, the introduction of a new subject Basic Logistics or Sustainable Logistics into the study program. By analyzing the new proposed and existing study program, bearing in mind the competences and outcomes that students should acquire at the end of the undergraduate study, it was necessary to increase and/or reduce the number of ECTS points to achieve individual learning outcomes for some Courses. It also required the change of the implementation plans or the teaching program.

In accordance with the stated changes to the study program, the improvement of the existing study program, bearing in mind the stated reasons, will be achieved by:

- introducing new subjects that have not been included in the undergraduate study until now
- redistribution of the number of ECTS and the number of teaching hours between subjects with updating of teaching contents,
- changing the status of the course (obligatory or elective Course),
- connecting the object with a partial change of teaching contents
- dividing one course into two without changing teaching content
- changing the elective subjects, or ECTS points of elective subjects

The content of the Logistics and Management in Maritime and Transportation Studies is adapted to the demands of the market for the training of personnel who are able to lead the entire transport process from the point of departure to the point of destination, using modern economic and technological knowledge. The study finds application in all branches of the transport and at the same time forms the basis for the successful operation and development of maritime and transport companies and the relevant social and state structures. Upon completion of the study, students are able to work in maritime, transport and business companies that are responsible for the management of transport and logistics structures.

IV. Conclusion

Changes in the undergraduate study of Logistics and Management in Maritime Transport are the result of a complex process of adapting the education system to the needs of the labor market, conducted within the project Development of Qualifications and Innovative Methods of Acquisition Competences in Logistics and Maritime Transport - KIKLOP, HR.3.1.15-0029, 0029 / University of Rijeka, Faculty of Maritime Studies Rijeka / HKO II financed from the European Social Fund (ESF) - Operational Program "Human Resources Development" 2007-2013.

Before finalizing the necessary changes to the existing study program, in order to ensure a functional education system related to labor market requirements, the three significant phases of adapting the study to the needs of the labor market were completed:
1. An assessment of the future needs for knowledge and skills based on key national strategic documents, the labor market structure and in clear recognition of the required and assessment of future skills and knowledge for particular relevant occupations in the field of maritime transport and transport logistics within the scope of transport and transport technology. According to the Regulations on the Register of the Croatian Classification Framework this area belongs to the sector XI. Transport and Logistics.

2. Creation of occupational standards for selected occupations Logistics Manager, Warehouse Operation Manager, Ship Agent and Shipbroker. The main task, with the help of employers, in defining the standards of occupation was the identification of key tasks and the identification of knowledge and skills necessary for their performance. Knowledge and skills combine the competence that an employee must acquire through the education process or through work experience.

3. Development of qualification standards - Bachelor of Logistics and management in Maritime Transport precisely defines those learning outcomes on which a future educational program should be defined with the aim of preparing students well for carrying out tasks in a wide domain of logistics and management in maritime transport.

In the process of adapting to the labor market needs, certain shortcomings of the existing study program have been observed that influence the development of competences and to overcome the necessary learning outcomes required of students. The main goals of (re)development of study program Logistics and Management in Maritime Transport were achieved by introducing new subjects that have not been included in the undergraduate study until now, the redistribution of the number of ECTS and the number of teaching hours between subjects with updating of teaching contents, changing the status of the course (obligatory or elective Course), connecting the object with a partial change of teaching contents, dividing one Course into two without changing teaching content, changing the elective subjects or ECTS points of elective subjects, etc.

The content of the study program Logistics and Management in Maritime Transport was adapted to the demands of the market for the education of personnel who are able to lead the entire transport process from the point of departure to the point of destination using modern economic and technological knowledge. The study finds application in all branches of the transport and economy sector and at the same time forms the basis for the successful operation and development of maritime and transport companies and the relevant social and state structures. Upon the completion of the study, students are able to work in maritime, transport and business companies that are responsible for the management of transport and logistics structures.

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TRA VISIONS Success Stories on How to Inspire Young and Senior Transport Researchers to Excel Further

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**ABSTRACT**

TRA VISIONS is a series of EU funded projects that aim to showcase European excellence and to increase the competitive advantage of the European Transport Industry. The innovative concepts and solutions are nurtured through a European Wide competition for young as well as senior researchers in the sectors of Road, Rail, Waterborne, Airborne and Cross modal transport. The main objective is to promote out of the box concepts and ideas for the future of European transport and develop these ideas within an environment where purpose driven innovation is cultivated in a risk-free environment. The paper offers an overview on the results of the young researcher competitions, an integral part of the TRA VISIONS activities in the past 8 years, and demonstrates how the new generation of Transport Engineers, with the support of the European Commission, have inspired the industry in adopting visionary concepts for solutions to future transport problems.

**KEYWORDS:** young researchers competition, visionary concepts, future of EU transport, innovative solutions & European excellence.

**I. INTRODUCTION**

The TRA VISIONS competitions are organized every two years to run in parallel with the Transport Research Arena conference (TRA), one of the largest European Transport conferences organized by the European Commission. TRA VISIONS traditionally includes two different competitions aimed at reaching different goals and targeting different participants. The Young researcher competition aims to target undergraduate students and early career stage researchers in the transport sector, to stimulate their minds and give them the chance to interact with a strong transport research community and provide them with podium to show off their ideas. The Senior researcher competition on the other hand is aimed towards the established senior researchers and has the goal to acknowledge the excellence of the existing research and innovation potential in the field of transport in the EU. Although the two competitions have separate evaluation procedures and different rules, both have a common goal which is a creation of a scientific community made of young and senior researchers in the field of transport. The interaction between different generations of researchers and different transport mode research fields allows for the achievement of the overall objective of the TRA VISIONS competitions, the development and deployment of innovative and cross-cutting transport solutions.

In particular, the TRA VISIONS Young researcher competition targets students at universities and technical institutes pursuing bachelor and higher degrees as well as PhDs. Initially, participants are invited to submit an abstract under one of the TRA conference Topics (Call for Ideas). This is the Registration period where all the participants are invited to register their ideas and submit a Title and a short abstract of their ideas. The participants then usually have a 3-month period to further develop their proposals into a final project following a very clear template (Submission of Ideas). This is normally followed by an evaluation period, during which a judging panel determines the three top ideas per mode (road, rail, waterborne, airborne and cross modality). The winner certificates and the cash prizes are awarded at the TRA conference during a prestigious award ceremony. The TRA VISIONS consortium works closely with the organisers of the TRA conference in order to ensure that the competitions have maximum exposure and impact during the conference and beyond. To ensure the active and large participation of students and early stage researchers an extensive and well planned “promotion phase” is carried out.
In order to overcome current as well as future transport related challenges and achieve economic growth even under adverse financial situations, Europe will need cutting edge, state of the art, innovative ideas. Within the TRA VISIONS framework a number of innovative ideas were proposed by students from around Europe since 2014. Many of those ideas have already inspired the research community to propose innovative solutions and the industry to pursue them further in practice. This paper gives an overview of some exemplar ideas stressing the impact that TRA VISIONS have on EU transport industry and hence the importance of such initiatives for the future. It demonstrates that focusing on initiatives such as TRA VISIONS is vital for the future competitiveness of the European Transport industry and the EU economy as a whole.

II. IMPACT OF TRA VISIONS IDEAS ON INDUSTRY AND FORWARD THINKING

In order to assess whether the industry has been influenced in any way by TRA VISIONS competitions, and encouraged to undertake innovative projects or similar concepts, a thorough impact assessment study was conducted. The study identified many concepts and products that have already appeared in the transport industry, which are very similar to the original visionary ideas that were generated through the academic TRA VISIONS 2014 and 2016 Young researcher competitions. Several ideas from TRA VISIONS 2014 and 2016 are presented below as the case studies in the transport modes of Road, Rail and Waterborne. The TRA VISIONS 2018 competition closed less than one year ago and thus it’s still too soon to see if the ideas presented in that competition were adopted by the industry.

III. WATERBORNE CASE STUDIES

A. Waterborne Case Study 1

During TRA VISIONS 2014, a novel idea was titled "Floating Power Generation Plant" (FPGP) [1]. This idea was for an installation that would load Liquid Natural Gas (LNG) from shuttle tankers, vaporize it, and use the fuel to generate electric power. The generated electricity would then be transmitted ashore to the land based establishments. The platform will have the capability of moving around as required from one terminal to another as the supply and demand chains fluctuate.

![Fig. 1. (a) TRA VISIONS 2014 computer model of the FPGP; (b) Pictorial Representation of the FPGP concept](image)

This concept eliminates the requirement for shore-based LNG storage tanks, re-gasification equipment and power generation machinery, hence allowing the consumer to make savings in construction time and costs. The FPGP could also operate as an emergency source of power.

In November 2016, a company 'Modec' announced their development of a power plant ship that uses liquefied natural gas as the fuel for electricity generation (www.modec.com) [2], [3]. Moored to a pier or anchored offshore, the vessels will receive LNG from tankers. They will gasify the fuel on board to generate electricity for transmission to the onshore grid via undersea cable.
Wison Offshore & Marine has announced in January 2017 that they developed a range of products with integrated functions of LNG loading and storage facilities, regasification and power generation.

The similarities of the two aforementioned commercial projects with the idea of the students are obvious.

B. Waterborne Case Study 2

The European offshore wind industry is expanding. Many TRA VISIONS concepts involving a mothership for accessing the offshore wind farms have been developed, one of them is presented in the following figure [4]. These concepts aim to cover the increased needs of the expanding far offshore wind turbine farms by overcoming operational problems due to the harsh environment, supplying the required number of technicians, provide comfort and safe stay onboard and meet the required maintenance schedule and repair of equipment. One solution suggested would be a purpose built 100m vessel fitted with a diesel-electric propulsion unit, capable to accommodate up to 120 wind farm technicians, vessel crew and a number of wind farm support vessels (WFSV).

In January 2016, Damen Shipyards Group, The Netherlands, signed a commercial contract to deliver the first Service Operations Vessel (SOV) for Bibby Marine Services Limited [Source: http://www.damen.com] [5]. This was the first purpose-built vessel for the transfer and accommodation of offshore personnel aiming to maximize working time and staff retention.
The vessel has the interior spaces grouped together into similar task areas and her accommodation has been placed midships for additional comfort – the location reducing vertical acceleration by as much as 15%. The design includes a diesel-electric main propulsion system.

Despite the differences, the commercial vessel described above has many similarities and mission characteristics with the idea presented by the students.

C. Waterborne Case Study 3

During TRA VISIONS 2014 a small crew tender vessel for service and maintenance of the offshore wind parks was presented [6]. The main idea was the design of a crew boat with optimum seakeeping and specific characteristics for the intended operations. The design involves a SWATH vessel with large cross-deck area for easy access to the offshore wind platform and storage of equipment, spare parts and tools, able to operate in up to 2.5m significant wave height. The vessel has a hybrid battery-diesel propulsion system and is presented in Figure 5.

Since then, SWATH support vessels have appeared in Europe e.g. see Figure 5 (a). The carbon fibre SWATH of Danish Yachts A/S, Denmark, which is able to operate and transfer crews in up to 2.5m significant wave height has many similarities to the one designed by the students as part of TRA VISIONS 2014 competition. Similar SWATH was also delivered later (2015) by CTruk, UK, Figure 5 (b). The vessels of the above Figure were published on OffshoreWind.biz website in August 2014 and March 2015 [7], [8].
IV. Rail Case Studies

A. Rail Case Study 1

The winner of the 2014 edition of the TRA VISIONS young researcher competition was awarded for research exploring development of an innovative self-pre-stressed concrete (SPC), addressing the major shortcomings of the materials applied in rail infrastructure e.g. a need for high strength, high resistance to dynamic loads and fatigue as well as durability in harsh environments [8].

This novel material, termed SPC, was based on a particular fibre reinforced cementitious matrix demonstrating excellent performance when compared with traditional fibre reinforced concrete matrices. The innovative aspect of this material is related to its ability to neutralise the matrix expansion due to its chemical activation properties, using the restrain action of the fibre reinforcement. This, in turn, acts as a bond at the interface putting the fibres under tension while the matrix is under compressive loads, protecting the latter against cracking (TRA VISIONS, 2014a).

This has resulted in a material that has advantageous characteristics when compared with traditional concrete used in rail infrastructure construction in general and, in particular rail. Specifically, SPC provides:

- Improved tensile or flexural strength;
- Cost reduction due to the use of concrete with lower strength requirements as well as smaller quantities of steel reinforcement;
- Significantly improved durability and mechanical performance (e.g. post-cracking behaviour).

Since the initial publication of this work at TRA VISIONS 2014 in Paris, where the original idea was awarded with the TRA Visions Award 2014, the research has continued and has resulted in the patent-protected [10] HERACLEX® technology.
Furthermore, a spin-off company, INNOVAcrete s.r.l. (http://www.innovacrete.it/en/) [11] has now been set up by the Università Politecnica delle Marche (Italy) to exploit this technology.

B. Rail Case Study 2 (cross-modal)

The TRA VISIONS competition encourages not only established research projects but also the submission of ideas by students. One such submission in the 2014 edition was related to exploring better customer satisfaction and efficiency by providing mobility as a service [12]. The idea revolved around the following key aspects:

- improved mobility and efficiency by using a more service-oriented approach;
- assessment of combining deregulation and liberalisation with policy;
- assessment of country-specific situations e.g. Finland;
- proposal of innovative measures covering governance and operational aspects.

The student, from Aalto University in Finland, proposed exploring the radical revision of how mobility is being provided in urban areas given the current and future environmental and political (e.g. budget restrictions) framework. The idea highlighted the need to integrate multiple stakeholders, operations and modes into a single mobility service provision portal acting as interface with the passengers. To do so, intelligent transport systems (ITS) would play a crucial role. To do so, the case of Helsinki was examined as well as an outlook of the situation in countries such as Sweden, Germany and the UK. As a result, it was proposed that the Helsinki regional transport authority (HSL) transformed into an entity providing public transport services as part of the service supply of a new mobility integrator. The idea was expanded resulting in a Master’s degree thesis [13].
This idea, in turn, has formed the basis of a pioneering programme in 2015 run by the Finland’s Ministry of Transport and Communications and the Finnish Funding Agency for Innovation (Tekes) and coordinated by the student herself (now project director) aiming to realise the concept of Mobility as a Service (MaaS). Since then, the whole concept of MaaS has captured the imagination of countless start-ups and established Finland as one of the leading countries in the world pursuing the implementation of such concept. The plan described in Ms. Sonja Heikkilä’s thesis and outlined at TRA VISIONS has formed the basis of what is thought to be the world’s first MaaS service implemented in Helsinki. Sonja Heikkilä was named one of the world’s 100 global thinkers by Foreign Policy Magazine.

V. ROAD CASE STUDIES

A. Road Case Study 1

Tire inflation pressure of a road vehicle has a critical impact on the rolling resistance and its influence on vehicle fuel economy and CO2 emissions is huge due to the low attention paid by drivers to tire maintenance. Safety, comfort and tire life are also negatively affected by incorrect tire inflation. Simulations show that maintaining the tire pressure to the nominal value would reduce fuel consumption up to 2%, taking into account that most of the circulating passenger vehicles present tires under-inflated at 75% of the nominal value. Further advantages can be obtained varying pressure according to the vehicle working conditions [15], [16], [17].

In the TRA VISIONS 2016 competition, a team from Politecnico di Torino addressed this issue by presenting a novel on-board electro-pneumatic system for the automatic control of tire inflation pressure (ATPC system) on passenger vehicles and won the third prize [18] (Road mode, Research Area RA1: Decarbonisation, Sustainability and Energy Efficiency).

The design focused on the reduced impact that the product should have had on the standard production process of vehicle subsystems and assembly. A highly fail-safe layout was produced which allows to isolate the tire when the system is not actuated and to limit in any case the minimum in-tire pressure through very simple and robust mechanical actions. The system was built as a prototype and tested on a static test bench. System control logics were developed on the experimental data.
Some pressure management strategies were proposed aiming to reduce the rolling resistance: simulations showed that adapting inflation pressure to current vehicle mass would produce fuel benefits up to 1.6% on NEDC and 2.4% in highway driving, while varying pressure during tire warm-up would reduce CO₂ emissions by 0.53 gCO₂/km (-0.38%) on a cold-start NEDC.

The effects on vehicle dynamics were also studied, considering a variation of the tire pressure within a narrow range of 0.8 bar around the reference value of 2.2 bar. The results of simulated and on-track braking manoeuvres showed that the braking distance varies within a range of about 4-4.5% with respect to the result of reference pressure; specific trends depend on tire characteristics. The ramp steer simulations showed a decrease of the vehicle understeering gradient with increasing tire pressure.

A first-attempt evaluation of the possible manufacturing cost was discussed together with a rough estimation of the economic advantage which can be obtained per-year on a passenger vehicle: the predicted cost is about 500-600 €/vehicle, half of which would be paid back to the customers in terms of fuel economy over the vehicle life. Additional benefits and customer value would come from safety improvements. The novelty of the product is both in the field of application and in its aim. Up to recent days, similar systems have been considered as a technology not suitable for passenger road vehicles. Most of the known applications are intended for military vehicles, earth-moving machinery, all-terrain vehicles, tractors, heavy-duty commercial vehicles, buses and off-road passenger vehicles, where the main aim would be to improve traction on soft soils and restore an optimal pressure on solid soils in order to reduce fuel consumption and tires wear. On the contrary the solution developed by Politecnico di Torino is intended for passenger vehicles and has the aim to produce a relevant improvement on real-world fuel economy of cars and, as a consequence, a significant reduction of CO₂ emissions.

This idea had an industrial follow-up. Indeed, after the competition, the winning team was contacted by IVECO and received a grant to study and develop the system for the application to light-duty and heavy-duty commercial vehicles. Furthermore, the team is working on two control algorithms to estimate the vehicle mass and its distribution on the tires and to evaluate the inflation pressure to maintain the original dynamic behaviour of the vehicle while vehicle mass increases. Patents are pending.
B. Road Case Study 2

There is no way for a shipping/delivery company to offer a reliable, flexible and real-time service maintaining at the low costs. In TRA VISIONS 2016 a team from Politecnico di Torino thought about developing a web application named Handy to share deliveries [19]. The idea was presented during the competition with the aim to create a “public space” where drivers and senders can meet through the internet and arrange shipments. In this way the costs could remain low and the deliveries could be in real-time and in a more flexible way. This idea of a peer to peer delivery business allows travellers worldwide and drivers in a specific city to generate some extra income by carrying things for other people while they travel or drive. Similar businesses were developed and are on the market at the moment. For example through Zaagel travellers can earn money by purchasing specific items like iPhones for people in Egypt. Some sites like Piggybee offer non-monetary “rewards” for delivery, like a ride from the airport. Friendshippr provides delivery services only between people who are in your circle of friends (using Facebook), ensuring a higher level of trust, but also significantly limiting the likelihood you will find a match for your delivery needs/offer. In the United States, Citizen Shipper focuses on the driving delivery market. Citizen Shipper is the most established of the companies in this space, and offers a variety of services including pet transport, apartment moving, and vehicle shipping. They also verify drivers to help ensure confidence in the service and have a price estimator. Handy is different from these services and represents an improvement since it is a structured service for urban deliveries with fixed fares decided by the Handy team and the possibility to have drop-off points. The team has joined the Microsoft BizSpark programme for innovative Start-ups and is developing the product under the supervision of I3P business incubator of Politecnico di Torino.

C. Road Case Study 3

Many older bridges and tunnels were constructed in a period in which trucks and other large vehicles were smaller. Bridge and tunnel strike (BrTS) damages can result in injuries, fatalities and train derailments. At first glance, it may seem like the problem is easy to solve; however, no matter how well planned the road system is, driver error is an ever-present risk. Vehicle heights are continually increasing, and bridge heights built for low traffic areas are often therefore inadequate today. The problem of BrTS is an ongoing nuisance for governments and policy-makers. One of the earliest systems designed to deal with the problem dates to 1906, and was patented by the American engineer James H. Donaldson. The Bridge Guard Whip, which was invented to warn drivers that the train is about to pass into a tunnel or under a bridge. The guards consisted of a number of strips of flexible material attached to a wire stretched across the track which strikes the top of the trains, warning them to stop. Over the years, this type of sacrificial system has evolved into the common BrTS prevention tools still with us today. Most BrTS technology that currently exists on the market is targeted towards preventing BrTS from occurring in the first place. Very few systems are designed to mitigate BrTS impact, as bridge owners are interested.
in protecting the structure and limiting any risk of structural instability. Under the prevention heading, there are three basic BrTS protection schemes: Passive, sacrificial and active systems. BrTS still occur with high frequency, and BrTS prevention systems (passive, sacrificial and active) available on the market are often too expensive to encourage wide implementation. Passive systems may be a ‘quick fix’ and cost effective, but these passive systems are not sufficiently effective as scrape marks are evident on the underside of bridges in the UK. Bridge-owners aim to minimise the occurrences of BrTS and as a consequence, to minimise inspection, maintenance and repair costs. The need to develop an affordable yet reliable solution is crucial to prevent future strikes posing risks to public civil infrastructure [02], [21], [22].

In TRA VISIONS 2016 a team from University of Cambridge proposed a novel framework to detect over-height vehicles and warn drivers of approaching low bridge [23]. The processes are depicted as rectangular shapes, and the inputs and outputs as ellipsoidal shapes. The green represents methods taken from the literature and orange represents novel contributions. The combination of green and orange represents processes that have been taken from the literature and adjusted for the purpose of this research.

![Proposed novel framework to detect OHVs for warning drivers of approaching low structure](image)

By using a single camera, the objective of the study was to develop an over-height detection algorithm that uses computer vision and image processing techniques to differentiate objects in the scene to avoid false detections. The overall framework proposes three parameters that must be manually set by the user in the scene: threshold limit, region of interest (ROI) and dynamic trip wire (DTW). Any object above the threshold limit is considered to be over-height and any object under this threshold limit is acceptable. The ROI is set above the threshold limit and focuses on the region that is over-height. The DTW is used to trigger the image processing when an OHV enters into the ROI. The algorithm is in standby mode until the DTW has been activated. Once the wire has been tripped, the prototype will begin the image processing and convert the video sequence into image frames. Background subtraction is applied to the images and subtracts the foreground images. The foreground image then takes two paths for image processing. The first step is to perform the pixel intensity differentiation. The algorithm will estimate...
the probability of observing pixel intensity values for each pixel. This process will help to detect the object(s) in the scene. The second process is to determine how fast the object is moving through the ROI. Both outputs will go through various constraints set in the code (object reasoning) to determine if the object is over-height or false detection. If the system detects an OHV, a warning is issued to the driver; otherwise, the system goes back into stand-by mode until an OHV enters the ROI again. In the event of a strike, the bridge management system will classify the frequency of the vehicle impedance and determine whether the strike is minor, moderate or severe. The camera is mounted at the same height as the bridge structure and projected perpendicularly to the direction of traffic, as shown in the following figure.

![Diagram](image)

Fig. 12. Functional scheme of over-height vehicle detection with single camera

This represents a great improvement of the already existing systems, such as IRD (International Road Dynamics Inc.’s) and Trigg Industries’s Overheight Vehicle Detection System that reduces collisions between motorists and overhead structures and rely on multiple component systems. The systems detect over-height vehicles moving toward obstacles such as bridges, tunnels and other overhead structures and individually warn drivers. An audible alarm and/or sign is activated when an over-height vehicle is detected by the system.

VI. CONCLUSIONS

TRA VISIONS, by organising bi annual young researcher competition, has achieved the development and wider dissemination of a wealth of innovative ideas, essential for the competitiveness of the European Transport industry and also necessary for solving current and future challenges related to energy, transport, climate change and others. TRA VISIONS competitions are run by a consortium coordinated by WEGEMT, an association of more than 40 European universities in the maritime field. The consortium includes partners from academia, industry and European associations in the Netherlands, the United Kingdom, Belgium, Italy, Germany, Greece, Finland and Sweden. The TRA VISIONS competitions are funded by European Commission through the H2020 Research and Innovation Programme.

Following all the latest technological advancements as well as the new concepts and products in the Transport industry, one can find many similarities between the ideas developed under TRA VISIONS series and what is now coming to the market. There may be some other cases of the TRA VISIONS concepts that have been considered for realization. Some of those concepts are still in the conceptual and may be confidentiality issues preventing their publication.

In brief, looking back at the achievements of TRA VISIONS and assessing its impact on industry, it can be argued that the TRA VISIONS process of cyclically inviting young and senior researchers to participate in an academic competition aiming to develop new transport related concepts and ideas for the future, has succeeded in inspiring the European Transport industry with fresh out-of-the-box novel ideas that are now being developed as new products essential for the future of the European Transport industry.
It also clearly demonstrates that the ideas generated through the TRA VISIONS process reflected the future needs of the European Transport industry. Many of the TRA VISIONS ideas have started to appear on the market and many more are likely to follow. Moreover, there are many new concepts that are now under development that seem to have considered many of the concepts and proposed technologies that first appeared in TRA VISIONS. With proven success stories presented above and perceived excellent future for the TRA VISIONS competitions, we invite all researchers across Europe to take part with their own brilliant ideas in the TRA VISIONS 2020 Competitions, that will take place in Helsinki, Finland, 27-30 April 2019.

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Autonomous Vessels - A Ship Master’s Status Now and In the Future

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ABSTRACT
The job description of ship commander is remarkably wide. He/she is responsible for safety of people onboard and safe operation of valuable vessel and cargo. The ship master must operate according to the advantage of both ship owner and the charterer.

Various international and national laws control the shipping nowadays. Technological development at the moment seems to change shipping in the direction of unmanned vessels which means that shipping legislation must therefore also reform.

The ship master’s demanding role has changed within time and will vary in the future. The aim of this article is to examine the ship master’s role today and how is his/her status going to chance if technological development and regulations will allow unmanned vessels to become reality in marine traffic. The second purpose of this article is to describe master’s role in the present situation in legal and contractual context and to make a study of different changes in the future when controlling of the vessel can be done from ashore.

KEYWORDS: ship master, unmanned vessels & law

I. INTRODUCTION
Ship master’s job description is nowadays remarkably wide. He / She is responsible for safety of the people, valuable ship and cargo and he / she has to act as presentative of shipowner and charterer taking care of their interests. Ship master’s role and position has been unique compared to other positions of the one working in the management tasks on shore side. The master monitors global operations and interests of many stakeholders in a limited working environment, from a vessel. When a ship is operating in international areas, the master acts under different national legislations and takes into account valid laws in the different sea areas and regulations of the local authorities in the port areas. [1]

The ship master’s role has been relatively independent but future vision seems to be that some vessels would operate with reduced crews and in some vessels, there wouldn’t be any people onboard so that ships would operate unmanned. How does the ship commander’s role change in the future, if the job is done from ashore?

II. HISTORY
The oldest known legal texts in the world mention the master of the vessel. For example, Babylonian laws of Hammurabi abr. 2000 B.C includes statutes concerning ship master’s liabilities.

Trade and seafaring were managed from the times of the antiquity even to the 1700’s so that with the vessel there were ship’s owner (patronus senior de la nau), the owner of the cargo/merchant (mercatores), sailor responsible for the navigation of the vessel (naucerus) and the crew (marinarii). The highest authority or power was used by “the ship council” at that time.

The ship master’s legal position has changed considerably in the history; at the beginning he was a leader who was responsible for the navigation of the vessel. Then in addition, he became also the representative of the cargo owner as the merchants did not travel any more with the money and the commodities. His power with respect to the crew enlarged during the times and he was not bound to the decisions of the ship council anymore. The leader of the vessel was then called as “senyor de la nau”. [2] During the times when the communicational equipment were limited, the captain of the vessel had to make contracts on the behalf of the ship owner and the owners of the property on board the vessel, in other words, he had to make all decisions without possibility to consult the ship owner or owner of the cargo.
The sizes of vessels have increased significantly during the history of seafaring and at the same time value of the ship and carried cargo, which the Master is responsible for, have been exploded. [1]

III. SHIP MASTER’S ROLE TODAY

Nowadays, the master of the vessel is working as an employee and representative hired by the ship owner or ship management company and he/she has the highest authority on board. The master is responsible for the seaworthiness of the vessel, safety of the human lives, safe carriage of the cargo to its destination and also protecting the marine environment. [1]

The role of the ship master is described in the book of Maritime Law by Christopher Hill like this:

“The master of a ship is a man of many parts. He needs to be part accountant, part lawyer and more than part seaman/navigator. Above all, perhaps he needs to command the respect of his fellow men. He needs to have more than a fair measure of self-confidence and an ability to make a cool and traditional judgement, sometimes at very short notice, in times of crisis. He is a servant in law, an agent both for his principal, the ship owner, and to some extent the owner of the goods he is carrying. If his ship is under charter and the charterparty so stipulates, he must obey the instruction of the charterer in respect of the employment of the vessel. He is also a commander of men, his crew, and he occupies a position of special trust, fiduciary relationship with his owners. He is absolutely responsible for the safety of his ship and remains in command regardless of whether or not his ship is in charge of a pilot at any given time.” [3]

The ship master is in unique position in many ways when taking care of his/her duties. However, his/her status has narrowed during the times due to changes of shipping environment. Nonetheless, the highest decision-making power belongs to ship master on the vessel. In the critical situations, the master acts and makes his/her decisions ultimately according to his/her own best considerations. The sphere of responsibility of the highest authority onboard is determined among the others in the maritime laws. [1]

The master of the vessel is taking care of both the vessel’s seaworthiness and cargoworthiness. When acting as a representative of the charterer, he/she ensures that loading of cargo and discharging are performed in time and the sea voyage is conducted on schedule taking all economical aspects into account.

Primarily the master must make sure that ship observes both national and international laws and ship owner’s instructions and guidance. Depending of the error or mistake, the master can be personally liable for his/her acts in connection to ship operation [4]. The master must rely on that all crewmembers are competent, and they do their share of ship’s seaworthiness. In practice, the ship master can’t check that the vessel is actually seaworthy, but he/she must rely on the crew’s efforts to prepare the vessel for the next voyage. The question is that, when crew sizes are diminishing, is the smaller number of crewmembers able to take care of vessel’s seaworthiness like they should?

IV. CHANGING SHIPPING ENVIRONMENT

A new technology and increasing level of automation is changing the nature of work in shipping, like it has changed the shipping environment earlier in history. The modern technology and means of communications have made a quick flow of information possible between a vessel and ship management company and with the other parties ashore. The ship master is able to report and inform the ship management and charterer about ship operations more and more effectively. Correspondingly, ship management and charterer can give new instructions to the vessel in no time, which means that the captain of the vessel doesn’t have to make all decisions concerning the vessel’s operation by himself but only those decisions which need immediate measures.

The need for increasing technology and intelligent solutions are often explained by improvement of safety, economic benefits, operational efficiency and reducing labour expenses. However, these changes will cause need for new skills for personnel and new working routines on board and ashore.

There is a several factors which can enable or delay the development of highly autonomous vessels. Obstacles for progress of new technology and automation are at the moment for instance, regulation and
governance, lack of economic advantages, cost of development and physical infrastructure. On the other hand, the factors that can enable the development are economic benefits, international regulation and governmental support. [5]

In the future, the demand for employees in certain positions may decline, for example low- or middle-skilled jobs. In addition, new requirements for workers with various qualifications may increase. The World Maritime University (WMU) has published a report "Transport 2040 - Automation Technology Employment – The future work" together with International Transport Worker’s Federation (ITF) in 2018. In this report, it is estimated that highly automated ships would decrease the growth rate in the demand of seafarers globally and then the possible reduction of mariners would be 22 per cent by 2040. However, demand for new types of workers, like operators who work remotely, different types of maintenance crews and mobility-as-a service providers will increase [5].

A. Automation in shipping

The global trade is strived to be more and more effective. Approximately 62.7 trillion tonne-miles of freight are carried around the world nowadays. New technology and automation are developed at the same time with the growing trade to improve the international logistics and to receive economic advantages. Nonetheless, the differences in the development stage of countries and their relative advantages have an effect on utilization of new technologies. Yet, the countries and regions are not at the same stage of preparedness to implement new innovations or automation because developmental priorities are elsewhere. [5]

The implementation of new technologies in maritime transport have a tendency to occur at relatively slow steps. International agreements and regulations regarding autonomous vessels set challenges to international maritime transport though regionally or nationally the legal barriers and adoption of intelligent solutions are easier to combine. According to WMU’s report, autonomous ships under human command are likely to reach 11 to 17 per cent by 2040 and these ships would operate in national specialized trades and following regional jurisdictions [5].

The International Maritime Organization’s (IMO’s) senior technical body, the Maritime Safety Committee (MSC) has endorsed a framework for a regulatory scoping exercises, “Maritime Autonomous Surface Ship (MASS)”, which purpose is IMO rules to permit MASS operations. MASS is “defined as a ship which, to a varying degree, can operate independently of human interaction”. The categories of autonomy in the regulatory exercise are defined as follows:

- Ship is using automated processes and decision making is supported. The ship crews are working on board controlling systems and functions which are taking place with the ship. Certain operations on the vessel may be automated.
- Ship with seafarers on board but ship is remotely controlled and operated from another location.
- Ship is sailing without seafarers on board and controlled remotely from another location.
- Ship is operating fully autonomously with the operating system, which make decisions and does actions by itself.

MSC’s scoping exercise for MASS includes the list of IMO’s instruments, such as, SOLAS, COLREG, Load Lines, STCW, STCW-F, SAR, Tonnage Convention and special trade passenger ship instruments, which need to be updated to allow autonomous shipping. [6]

V. ROLE OF THE SHIP MASTER IN THE FUTURE

The ship master’s responsibilities and obligations are regulated in many international regulations and national laws. The role of ship crew does not play so remarkable role compared to the master in respect of the legal matters and therefore from that perspective, the future of automated vessel doesn’t seem to be so complicated.
Shipping infrastructure and control of the logistics is developing in the direction of centralized and interconnected operation centres, like fleet operation and maritime vessel traffic service centres [5]. The future vision is that autonomous vessels could be operated from shore-based control centres (Shore Control Centre, SCC), so that an operator could be responsible for operation of several vessels at the same time. At the normal conditions, vessel would operate and solve situations autonomously, but in the event of abnormal or in an emergency the SCC operator would take the full control of the vessel and command the vessel from shore-based ship command bridge.

Ship’s maintenance work will be timed and offered flexibly using specialized staffs, which are placed in certain service hubs. Service staff will conduct the maintenance jobs either remotely or shifted to ports where technical servicing is required [ω].

There is a numerous interesting question related to future unmanned vessels and the ship operators’ responsibilities and obligations. If shore-based control centre belongs to a third party and the ship operations have been subcontracted then the right to act on behalf of the ship-owner would have to transfer to a designated party [ϊ].

Ensuring the seaworthiness of the ship has been one of important task of the ship master’s responsibilities. Before the sea voyage the master must ensure that the vessel is seaworthy, which a can be defined as Christopher Hill’s does it in his book; “a fitness of the ship to withstand the expected hazards of the contemplated voyage laden with cargo” [3]. How the seaworthiness of the vessel is ensured in the future, before departure as now?

The master has to look after charterers interests and ensure that, both cargo operations and the sea voyage are conducted without delay. In the future, monitoring of cargo handling has to be arranged differently, for example with help of information technology and by using a local presentative or agent, so that the task the ship master used to do before, would be transferred to someone who is in turn responsible directly to the shipowner.

How will the liabilities be solved in the future, for example, if ship collides due to programming error and SCC operator is not alarmed in time? Currently, the General Law of Torts defines that, the master is liable to compensate any loss for his/her service, if it can be proved that the cause was fault or negligence [7]. In the United States, accordingly the Public Vessel Act, liability is based on fault, but the negligence has to be exposed before liability is levied. Who is the fault and the cause of accident in this example case?

VI. CONCLUSIONS

It seems that the ship master’s tasks and routines will change at the same time with new technology and digitalization. However, as long as the Master stays on board in his/her vessel, the legal responsibilities and obligations are not expected to change so dramatically. When some ships are going to operate unmanned in the future, numerous ship managerial and operational responsibilities have to transfer to several designated persons a shore. In other words, the ship owner’s role changes also because the owner has to arrange tasks, which used to belong to ship master before. The owner has to make contracts with several representatives or agents instead of one employee.

The role of the person who monitors ships safe navigation will be more similar to Vessel Traffic Service (VTS) operator’s tasks.

The future of unmanned vessels will strongly influence on commercial operations and maritime legislation. The fundamental features in shipping are changing when unmanned ships are taking place – the role of the shipmaster and crew on board a ship - a whole range of laws and regulation across the whole range of maritime law will be affected [8].

The role of a remote-operator of an unmanned ship is comparable to master onboard – they both assume real-time command of the movement and navigation of the relevant ship. By contrast, a pre-
programmer of an autonomous unmanned ship has a unique and unequalled role in the traditional maritime domain. The last human input into the ship’s navigational operation can be theoretically the pre-programmer but differing from a master, the real time decision making influence is not exercised [8].

It is interesting to see, how are responsibilities and roles divided between different parties when there is anybody onboard?

REFERENCES


Examples of Miscommunication in Maritime English

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ABSTRACT

There are many examples of bad communication in maritime discourse or maritime communication. Starting from the level of phonology to the level of pragmatics, there is no doubt that miscommunication happens on a daily life in seafaring.

Therefore, the aim of this paper is to search for examples of bad communication among seafarers or ambiguous situations that might lead to accident or error known as human error. It will be argued that although we try to standardize Maritime English language by means of norms (phonology, morphology, syntax), a context or extralinguistic setting brings new meanings and communicative situations.

However, knowing that seafarers work in multilingual settings, one of the aims set forward in this paper is to bring these ambiguous situations to a minimum. This undertaking is inspired by author’s work in the classroom with students and personal communication with seafarers.

KEYWORDS: maritime discourse, miscommunication, English language & seafarers

I. INTRODUCTION

Miscommunication has been for a long time an issue in a maritime communication. In Maritime English defined as a part of English for Specific Purposes (ESP) there have been many attempts to establish one standardized language or a code that will be a common means of communication at sea. The reason for this lies in numerous ship accidents that occurred due to human factor, and among many is bad communication, misunderstanding or lack of communication. The author of this paper herself did a research in domain of examples of bad VHF communication by analysing VHF transcripts. It was established that non-compliance with the SMCP phrases led to serious accidents at sea. The non-compliance was manifested either through the use of idiom other than English (Mandarin), the use of too conversational style [1].

- What are your intentions?
- Well, I am coming around.

(Allison of the ship Cosco Busan)

The greatest obstacle in a research of such language on a pragmatic level is the lack of the authentic language material. Therefore, the examples shown here will be based on author’s personal observations and research gained in the course of teaching Maritime English to students of Nautical Department at Maritime Faculty Kotor.

II. MARITIME ENGLISH AS PART OF ESP

According to the classification as given by Hutchinson and Waters [2], there are three recognizable languages for specific purposes: EST - English for Science and Technology, EBE - English for Business and Economy, and finally ESS - English for Social Sciences. Although it was not categorized as separated branch, ESP - English for Specific Purposes, such as English for Economy, English for Accounting, English for Engineering, at the time, Maritime English was thought to be a kind of technical English (English for Technicians). It was mainly identified as a glossary or a bunch of specific maritime words. The focus was on speaking and pronunciation of technical words [3]. However, there is no doubt that Maritime English is not a pure register or glossary and that is heavily dependent on a context.
III. Misunderstanding at Level of Phonology

Introduction of the SMCP phrases in 2001 was aimed at establishing rules at all linguistic levels for the sake of avoiding miscommunication among members of multilingual crew on board ship. Introduction of the SMCP phrases in English was a big undertaking and challenge as dominance of English was reluctantly adopted by strong maritime nations such as Russian, Chinese. Thus, according to the SMCP (2001) the nautical alphabet taken from the military discourse and also used in the International Code of Signals should be used (Alpha, Bravo, Charlie, Delta, etc). There is no doubt that this rule should mitigate previous differences that existed in pronunciation of ship names, or flags that the ship flew. For example, if the name of the ship was m/v Bella, depending on the seafarers’ knowledge competence, level of English and nationality, “B” would be pronounced as Boston, Boy, etc. Letter “A” used to be spelled as Alexander, Alexandria or Anna. Thus, there were variations which had to be overcome due to already existing problems prescribed to movement of ship, sound of engine, noise of vhf devices and other distracting sounds that significantly aggravate good communication.

In addition, differences on phonological level are inherent due to differences in phonologic systems of different nations. For example, Italians hardly pronounce “h” as in “hotel” “Harmonia”, hospital and it would sound like “/otel/” “/armonia/”, “/opital/”. Similar case is with French language. This is of particular importance when it comes to pronunciation of the word “help”, particularly in an emergency situation when somebody on board needs help. Therefore, having in mind that creation of the SMCP phrases that gathered a great number of professionals in the maritime field and linguists, it comes as no wonder that they suggested the use of certain words instead of other choices. It is interesting to note that the verb “to help” is applied in the SMCP sentences only two times and the noun assistance is used instead [4]. Thus a word assistance is to be used instead of help and the word require is to be used instead of the word need as in “MV requires assistance”.

IV. Morphology Level

Morphology level is tightly related to the context and connected to a level of semantics. Although, according to the SMCP, ambiguity should be avoided, many words in Maritime English are ambiguous. In order to be interpreted correctly, the context or background must be known. Such is the case with the words port, list or draft. Let us first illustrate a few examples with the noun port:

1. My ship has a list to port (side)
2. My ship has a list to port. (port = harbour)
3. My ship has many ports (Port= opening)

Not less interesting is the word list.

1. We have a bad list to starboard side. (list =inclination)
2. Do you have a list? (Do you have a document?)

The following examples illustrate possible problem with the word draught /draːft/. The first meaning of the word is a distance from the bottom to waterline (draft of the ship) whereas the latter means flow of air. Let us look at the scenario:

1. What is your draft, sir?
2. There is no draft today sir. It is calm and no wind.

Miscommunication problem as illustrated in the second example is related to bad knowledge of the word draught or draft in the maritime context. Every seafarers should know that it refers to the depth of the ship from the waterline to the bottom, making it fit to withstand in water and flow.
V. SYNTAX LEVEL

On the level of syntax, message markers as set forward in the SMCP 2001 are used to signal which kind of message is going to be transmitted. Message markers are question, answer, request, intention, instruction, information and warning. In a linguistic sense, they are performative verbs needed to know which kind of message is going to be transmitted. It is of particular importance in a maritime setting. There is no doubt that ESP analysis in maritime setting must take care of needs analysis and has many similarities with other forms of military discourse (army, police, air forces) and similar specialist discourse fields [5].

Besides message markers being in their nature performative verbs, sentences in the SMCP 2001 are short and made of subject, verb, object pattern.

Example:

QUESTION: Do you carry any dangerous goods?

ANSWER: No, I do not carry any dangerous goods.

The use of message markers in the above examples is a trait of military discourse where communication is repetitive or redundant and as such precise. In a maritime context, little has to be predicted or supposed, therefore, paralinguistic features of communication such as a tone or intonation should be taken to minimum. In the following example:

“I am adrift”

participants in conversation do not see each other (Ship to ship or ship to shore communication) so it is hard to conclude if the message sender intends to convey a pure information (that is not of big relevance for other shipping), or the sender wishes to warn other ships in vicinity to keep clear of the fairway and other shipping.

Finally, the statement “I am adrift” may mean that the ship broadcasting the message requires assistance, such as a tug assistance. Therefore, depending on a specific context, the message has three different meanings.

VI. LEVEL OF PRAGMATICS

Many humorous situations are told and registered in maritime blogs and forums by seafarers as they are best familiar with the examples of bad communication at sea. Examples are hard to find and collect as a language material for linguistic analysis. The following example comes from the site of the Nautical Institute and took place in the Malacca Strait. Although it left its participants in laughter, it has a serious message.

Situation

Communication Blunder
Report No. 200204

Ship A - "Vessel on my port bow, this is the vessel on your starboard bow, with a CPA\(^1\) of 0.15 miles, come in please".

Ship B - "Yes, what is your position"?

Ship A - "Second Mate".


\(^1\) CPA- closest point of approach
Instead of stating the name of the ship, the deck officer states his rank on board. There are many similar examples and although they might be humorous, they might easily lead to ship accident.

Interesting and well known example of bad communication on board ship that almost each seafarers is acquainted with at the beginning of Maritime English course is with German coastguard member left on the bridge alone. After having received message:

*MAYDAY MAYDAY, WE ARE SINKING*, his answer is

*WHAT ARE YOU THINKING ABOUT?*

(Source: https://www.youtube.com/watch?list=RDyR0lWICH3rY&v=yR0lWICH3rY)

**Fig. 1. Participants in communication**

As mentioned at the Introduction of the paper, the VHF materials are rare to be found as a source of linguistic research. However, VHF communications are parts of accident reports and evidence that language barriers and miscommunication directly leads to ship accident.

The following segment was analysed in [1] and the focus was on the too informal conversation that contributed to accident.

Segment of the VHF Communication between the Portuguese Ships and MV Royal Majesty

(1) 2042 fishing vessel (f/v) Sao Marcos [in English language]: “Fishing vessel, fishing vessel call cruise boat.”

(2) 2043 f/v Rachel E [in Portuguese]: “Are you there Toluis [nickname Tony Sao Marcos]?”

(3) f/v Sao Marcos [in Portuguese]: “Yeah, who is this?”

(4) f/v Rachel E [in Portuguese]: “It’s Antonio Pimental. Hey, that guy is bad where he is.”

(5) Don’t you think that guy is wrong in that area.”

(6) f/v Sao Marcos [in Portuguese]: “I just tried to call him. He didn’t answer back. He is wrong.”

(7) f/v Rachel E [in Portuguese]: “I’ve been watching him for the last half hour. He was a big contact on my radar. I picked him up 8 miles away.”

(9) [unknown source] [in English language]: “Channel 16 is a distress channel and this is international, please change your channel, please change your channel.”

(10) [unknown source] [in English language]: “Calling the cruise boat in position 41 02N, 69 24W. Over.”

Some of the words used differ from standards set forward in the SMCP phrases. For example, as regards the use of verbs, these are “pick up”, the phrase “this guy is bad”, “he is wrong”, “Yeah, who is it?”, etc. Apart from the fact that communication is carried in two languages, a non-compliance with standard SMCP is obvious.

**VII. Conclusion**

The paper considers miscommunication in maritime setting on different language levels. Although maritime communication tends to be standardized by imposing sublanguages such as the SMCP, errors in the form or bad communication or miscommunication still occur. In practice, the SMCP phrases have not evenly rooted among different and multinational representatives of vast seafaring community, especially for the fact that English language which is undoubtedly language of sea communication, has a socio-political connotation as well. Dominance of powerful English nation in “maritime empire” since the end of 18th century which [6] is implemented through English language. Reluctance to use English in
communication can be interpreted either as language incompetence or as resistance toward English language.

Differences in communication exist on all language levels, still they are most visible on the level of syntax and pragmatics, the use of language in a particular context. Differences existing on the level of phonology are in a way uniformed and treated through the nautical alphabet and rules for spelling numbers (bearing, latitude longitude). However, as stated in the paper, the oral VHF communications show the serious involvement of non-communication in maritime accidents, but the greatest problem lies in poor availability of such material. Mainly, reports available on the Internet are of a narrative nature and original VHF transcripts are difficult to collect for the sake of pure language analysis.

For the sake of future analysis of language material, a more transparent VHF transcripts or personal blogs written by ship masters and other crew would be a great contribution to studying “deviations” in Maritime English.

REFERENCES
General English Creativity vs. Maritime English Restrictedness

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ABSTRACT

Under the linguistic creativity it is primarily implied the ability of any natural language to create from a limited resource of linguistic units an unlimited number of linguistic units at all levels - the phonetic, phonological, morphological, lexical, syntactic and semantic level. Consequently, limitation of linguistic units accompanied by linguistic unlimited creativity allows the language functionality, respectively the language ability to respond to all challenges of civilization, man and society. With its creativity a language transcends all boundaries and is ready to respond to any new accomplishment or invention of the modern age.

Although English has already been recognized as an international language both on land and at sea, it is necessary to be followed by clear rules in order to reduce the possibility of ambiguity and vagueness while sending and receiving maritime messages. In contrast to the everyday communication, i.e. the conversation in which one statement performs a lot of different functions depending on the context, maritime English is precise and far more limited than general English. This linguistic limitation, respectively adjustedness is the key presumption for effective communication in the maritime profession.

KEYWORDS: linguistic creativity, communication, standardization, safety and security

I. INTRODUCTION

The aim of this paper is to point out the role of English for specific purposes and its importance for the development of modern society. For successful transmission of messages and communication in the maritime affairs until nowadays have appeared several variants of maritime English, in linguistics known as restricted languages. British linguist J.R. Firth introduced this term as a label for a strictly reduced linguistic system that is used for a particular activity. This language is so contextually closed, that only a little linguistic variation is allowed. Such "languages" can be found not only in specialized but also in everyday contexts. These particularities are the most obvious on the lexical level. This level is also under the greatest influence of the non-linguistic factors. However, we cannot make artificial borders between Maritime and General English. These two registers intertwine. Seemingly opposite, these two aspects are mutually compatible and inclusive – it can be said to include, respectively imply themselves. Like a ship that is supposed to be 'trimmed at even keel', so as the linguistic balance at its balance scoops on one side has the creativity, and on the other adjustedness, respectively limitation.

During navigation there are many risks which affect safety of crew, cargo and ship, so there is a constant imperative that everybody on board a ship works as a team. Seafarers are submitted to permanent knowledge and skill check, whether the reason more sophisticated navigational equipment or environmental protection.

II. MARITIME ENGLISH REGISTER

Maritime English is a specific register. Therefore, it requires a specific treatment. The sophisticated system of the maritime English makes it a plain instrument of communication. The opposite “tides” govern the system: creative and economical tendency. The creative side of the maritime language is evident in the forming of new words and meanings, combining of existing units, various metaphors, etc. Thus, limitation of linguistic units accompanied by linguistic unlimited creativity allows linguistic functionality, respectively the ability of language to respond to all challenges of civilization, man and society. With its creativity language transcends all boundaries and is ready to respond to any new accomplishment or invention of the modern age. Maritime English is a restricted language which is characterized by a great many specific features on all levels. As far as restricted aspect of Maritime English is concerned, Standard Marine Communicative Phrases are used in both ship-to-ship and
ship-to-shore communication. The SMCP builds on a basic knowledge of the English language. The Standard Marine Communication Phrases (SMCP) has been compiled:

- to assist in the greater safety of navigation and of the conduct of the ship,
- to standardize the language used in communication for navigation at sea, and
- to assist maritime training institutions in meeting the objectives mentioned above

It was drafted on purpose in a simplified version of Maritime English to reduce grammatical, lexical and idiomatic varieties to a tolerable minimum, using standardized structures for the sake of its function aspects, i.e. diminishing misunderstanding in safety related verbal communications, thereby endeavoring to reflect present Maritime English language usage on board vessels and in ship-to-shore/ship-to-ship communications. This means, in phrases offered for use in emergency and other situations developing under considerable pressure of time or psychological stress as well as in navigational warnings, a block language was applied which sparingly uses, or frequently omits, the function words the, a/an, is/are as done in seafaring practice. Users, however, may be flexible in this respect. Further communicative features may be summarized as follows:

- avoiding synonyms
- avoiding contracted forms
- providing fully worded answers to "yes/no"-questions and basic alternative answers to sentence questions
- providing one phrase for one event, and
- structuring the corresponding phrases after the principle: identical invariable plus variable.

Since the maritime language is further subdivided into registers and subregisters, we can make a distinction between maritime language and maritime languages. The complexity of the nautical register makes learning, that is acquisition very difficult. One should firstly learn maritime terms in his own mother tongue and then move onto the maritime English world.

III. Needs Analysis

At maritime schools and faculties, it is one of the vocational subjects, determined by the students’ needs and usage, of the future seafarers, for whom it will be a common language of communication in their profession with other seafarers of the world (Seaspeak), as well as in aviation (Airspeak). The needs and profile of our seafarers who are now sailing around the world have changed as well as the overall structure of the maritime industry. When it comes to teaching English, the easiest way is to stick to the old-fashioned methods because they are “most effective” for teachers who feel secure in familiar territory and do not want to change anything in their work with future seafarers. Maybe their classes are under control and predictable but a completely different atmosphere prevails on the open sea, i.e. aboard. There are people, without their families, left to the sea and to their knowledge of "the trade". They go to work every morning without abandoning the ship. Any error is paid dearly – from technical to language ones. In methodology can be distinguished two types of errors in foreign language learning: mistake and error. This distinction can be also applied to errors in maritime communication depending on the weight and consequences of failures. The consequence is too mild word for what can follow an error or a mistake in the communication between ship-to-ship, ship-to-shore or the navigational bridge - engine room. Material loss is not worth mentioning in comparison to a human life. Multinationality of ship’s crews requires one common internationally recognized language, which is followed by certain rules of communication. English became the world, and thus the maritime language number one, not because of its linguistic qualities, but of the economic and military superiority of the United Kingdom. The race for that position was long lost for Spanish and Italian even for German language.

As it has already been mentioned, maritime English should be precise, and it can never be overdone in emphasizing of the accuracy in the register of maritime profession. Thus, the limitation of maritime English is just as important, if not, even more important characteristic of professional language – precisely that adjustedness, respectively standardization is essential for communication between
ship-to-ship and ship-to-shore. It can even be concluded that safety of lives at sea primarily depends on that limitation, respectively standardization. In other words, successful communication in the field of maritime transport is impossible without the use of standardized marine communication phrases, which were introduced by the IMO organization in 2001. Communication in maritime and air transport is unthinkable without standardization of these registers.

In achieving its primary task - and that is communication in such a complex phenomenon as the society is - no language, regardless of its standardization, is homogeneous. It is not realized as a single entity, but with non-linguistic influences it is stratified into linguistic layers, which are difficult to separate - as the transitions are continuous. Therefore, all speech variations are the layers of a unique system - language. That the language is not homogeneous and that is very creative, the proof lies in every individual who in his speaking knowledge has a number of speech variations that are often used unconsciously, depending on non-linguistic impacts, i.e. situation. There is a sociolinguistic term for this substitution of speech variations - code switching. There are several classifications of language layers. We can meet terms such as style, variant, type, dialect, sociol ect, idiolect. Functional layers occur by functional stratification, respectively speech variations characterized by specific choice of linguistic resources, their frequency, and they are determined by situation as non-linguistic category. The situation in which the language is realized, includes the function, the type and the domain of activity, place and time, the theme and participants in communication.

The peculiarity of professional language is its vocabulary. In addition to the terminology, it contains parts of the general lexicon. Vocabulary is the most powerful communicative barrier for a layman, who recognizes professional language by a large number of unknown words.

It is important to emphasize that the lexicon of general and professional language has been mutually enriching, because there is a mutual interference between general and professional language.

IV. CONCLUSION

Nowadays in maritime affairs of the world English is widely accepted as a means of communication, and is exclusively used in most of the world’s ports and countries. Only in Latin American countries Spanish is used in maritime and, partially, Portuguese. English for seafarers is an instrument of communication which they use not only for the performance of professional activities, but also in everyday contacts. It has a long-term goal for its users. Among other maritime languages (Spanish, Italian, French and Russian), it is a means of international communication at sea, considering the spread of its use. It has developed on a large scale, as an instrument of communication - from everyday communication, written and oral information, documentation, to scientific presentations.

Unlike English, our maritime language has no role in the global maritime communication. Its function is limited to local area use. Due to its specific development, our maritime language is the subject of study both linguists and maritime experts. The characteristic of our maritime language is borrowing from other languages (in earlier centuries, especially from Italian, and more recently from maritime English) and fighting for local expressions. In addition to that, present language of our seafarers is based on lexical heritage of the whole our Adriatic coast, which gives it a diversity, semantic and stylistic abundance and flexibility of use. This is contributed by numerous maritime school, where unjustifiably little attention is paid to our maritime language. Each seafarer requires a good knowledge of the mother tongue, as well as the knowledge of other vocational subjects.

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Maritime and other discourse communities
- The example of Charter Parties -

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ABSTRACT

In the maritime industry of today, English is the leading means of communication. Similar to the way that the shipping industry is a multidisciplinary and interdisciplinary scientific and professional field, maritime English also comprises numerous registers and sub-registers which are subject to changes and overlapping due to the growth and tendencies of modern shipping. Furthermore, due to the huge economic impact of the industry, it often intersects with other discourse communities and their English for specific purposes. Through the linguistic research conducted over the BIMCO charter parties as the most frequently used and recommended forms of the kind in recent decades, our intention was to present the specifics of maritime English terminology and phraseology united with legalese over a mutual communication purpose. Also, we hope that the paper will clear the way for further research on ESP and discourse analysis of both maritime, legal and compound genres in general.

KEYWORDS: ESP, charter party (CP), lexis & discourse community

I. INTRODUCTION

The English language of today is the koine of the modern world [1], just as Latin used to be the koine of the Roman Empire. In the maritime industry, English is the leading means of communication of all the states and navies of the world, particularly after the formation of the International Maritime Organization (IMO), with its headquarters in London, after World War II. Similar to the way that the shipping industry is a multidisciplinary and interdisciplinary scientific and professional field, comprising a vast area of human activities, maritime English also represents a type of language, the registers of which comprise narrower scientific disciplines and professional settings, such as navigation, marine engineering, marine telecommunications, shipbuilding, maritime law, maritime insurance, maritime economics, maritime ecology, maritime medicine, oceanography and many others [2] [3] [4]. Therefore maritime English is not homogenous, but encloses numerous registers and sub-registers which are subject to changes and overlapping due to the growth and tendencies of modern shipping. In addition to conventions, documents, reports, other standardised forms of official communication and maritime journalism, English is a general, and often the only, instrument of communication among seafarers of various origins and cultures. It poses an even more challenging language learning task for non-native English speakers, if we consider maritime English as a part of English as a foreign language (EFL).

II. CORPUS

A. Charter party

The focus of our research was charter parties, named from the late-Middle English term derived from the French charte partie, which is itself from the medieval Latin charta partita – “divided charter”, meaning one written in duplicate on a single sheet, then divided in such a way that the two parts could be fitted together again as proof of their authenticity.

A charter party (CP) is a written contract signed by the shipowner and the charterer for the hire of a ship, partly or in full, for a certain time period or voyage. Thus the two most standardised types of CPs are the Time Charter Party and the Voyage Charter Party. The standard CP forms are issued by renowned maritime institutions. In recent times, the most recognised institution one is the Baltic and International Maritime Council (BIMCO), established in 1905, which examined the majority of the existing charter parties and has given and still regularly provides its recommendations for the CP forms most used in modern-day shipping. Therefore we decided that the focus of our linguistic investigation would be a corpus comprised of the most used charter parties recommended by the International Maritime Council (BIMCO). For practical reasons, the paper does not comprise the full corpus analysed, but sample and working forms can be found through the official BIMCO web site www.bimco.org. In addition,
we took into account some CPs from practice (4 and 5) which are not fully presented for confidentiality reasons, but were included in the process of our examination. The corpus list is given at the end of the paper.

Given that all the forms have a similar layout, with a variation of clauses, our detailed analysis was based on the charter party called the General Charter Party, As Revised 1922, 1976 and 1994 with the code name “GENCON”, in comparison with both draft and versions from practice, including combinations of clauses and appendices depending on the type of hire and the trade they regulate. In addition to having clauses deleted, added or amended, or even the entire forms replaced, charter parties often include supplements or annexes – the so-called rider clauses or riders.

B. Charter parties as a genre
In our dilemma about whether to view the specified text as an individual genre or, for example, a sub-genre of some other type, such as contracts in general or, in our case, legal documents, we were led by views of some other authors [5] [6] but also trying to find our own evidence for it.

Taking into consideration different understandings of the term genre, we have followed Pauline Robinson [7] who perceives genre as a type of text above a discipline or domain. CPs combine the discourse specifics of two professional settings, thus they go beyond both legal and maritime textual documents. Furthermore, the macrostructure of these texts makes their structure standardised and different from any other type of maritime or legal document. Also, according to Swales and many other authors, it is not only the structure that makes a genre, but also the role it plays in a given community. This role is tightly related to the style, structure, content and audience it is meant for. In the specific case of CPs, the content reflects the interests of the maritime community, thus it is strictly related to its English for Specific Purposes (ESP), primarily in terms of its lexis. On the other hand, the communicative purpose, i.e. mutual relations, are legally regulated and realised through a legal written medium.

III. METHODOLOGY
As known in the research processes of ESPs, the methodology is usually imposed by the specific area and type of the material analysed, often combining different approaches. Considering that the corpus is interesting and abundant for analysis, especially challenging for combining two discourse communities and their very specific and different ESPs, we have been trying to be as specific and focused as possible in our approach. Considering the fact that our primary interest has been maritime English, our starting point in examining the given corpus was that it is reflected mainly in the lexical view of the text, while the syntactic and textual organization is more related to a legal kind of document and genre type.

Namely, although the text is also abundant with legal specific terminology and phraseology, such as archaisms and complex prepositional phrases, English for Legal Purposes here is mostly reflected in long and complex sentences, too extensive for general English, including sentence discontinuity and frequent repetitions for the purpose of clarity, preciseness and all-inclusiveness. Considering the situational context, the primary register is still the one used by the maritime discourse community. The focus of our interest will therefore be the specifics of English for Maritime Purposes (EMS) reflected in maritime terminology and phraseology, sharing its communicative purposes with English for Legal Purposes (ELP) on the example of charter parties.

For these reasons, our in-depth examination went to maritime terminology and phraseology applied within this interesting communicative purpose. We therefore chose the lexical approach, the term being coined in 1993 by Michael Lewis [8] [9]. Since then, many linguists have devoted their attention to specific vocabulary, the study of its development and its acquisition. From the beginning phase of ESP known as register analysis [10] [11] [12] to the most modern movements within ESP known as using English as a medium of instruction (EMI) and Content and Language Integrated Learning (CLIL), even the development of computer programmes for the purpose, vocabulary has remained a core of language teaching ([9] [13] [14] [15]. In that sense, the starting point in every foreign language teaching/learning retains on the Lewis’ statement that “Language consists of grammaticalized lexis, not lexicalized grammar [8].
According to the above mentioned authors and many others, we could generally summarize the lexical approach as a method which concentrates on developing learners’ proficiency with specific lexis i.e. lexical items or words and word combinations. In modern times, it overcomes the traditional dichotomy between grammar and vocabulary. A modern lexical approach does not perceive lexis as single words but also as the word combinations stored in our mental lexicons [9] [13].

IV. ENGLISH FOR SPECIFIC PURPOSES

ESP has been considered as a distinct activity within the English Language Teaching (ELT) and as a part of applied linguistic research. In the attempt to define the English language for specific purposes, linguists generally agree that its purpose is to meet the specific language needs of the one who studies it [16] [17] [18], and which is related to the area that persons deals with and which makes it different from the general English language.

ESP as a linguistic movement is often criticized for lacking theoretical foundation [12] [19]. The reason for it, being its advantage and main feature at the same time, is that it retains its emphasis on the practical results, which primarily focuses the procedures and course designs focused on meeting the specific needs of its learners. In the attempt to determine a possible classification of ESP, we come to an interesting remark by Diane Belcher [20] that there is simply as many types of ESPs as there are or will be special needs for language learning.

There is rarely a profession that does not require some form of professional language training, either being for academic purposes (as English for Academic purposes – EAP) or for occupational purposes only (English for Occupational or Vocational Purposes – EOP or EVP) [11] [12] [21] [22].

V. ENGLISH FOR MARITIME PURPOSES

Speaking of maritime English, it can also be seen in both lights. Namely, considering numerous Universities and Academies in charge of the education and training of students and seafarers, and given the fact that English is the official language of maritime industry, there is no doubt that English for (Academic) Maritime Purposes (EAMP) is a very contemporary and noteworthy branch of ESP today. Also, shipboard crews include positions that do not require higher education or academic courses for certificates of competency (e.g. ratings’ positions), thus we can also talk about Maritime English for Occupational Purposes, also mentioned as Vocational or Professional English. Generally, the professional English language competence is the basic tools of communication for any position on board a vessel, and includes at least some mandatory trainings and certificates. The complexity of maritime English is one more evidence of its significant and challenging position within contemporary ESPs.

VI. MARITIME LEXIS

Similar to other “specific” (English) languages, the shipping industry is extremely demanding in terms of familiarisation with the given professional setting and terminology. Thus, CPs offer a series of specific lexemes from shipping in general, shipbuilding, ship stability, stowage and sea transportation, international maritime trade and transportation, insurance, (international) maritime law and other relevant fields and activities related to maritime affairs. In addition to specifically maritime registers, we also come across a long list of general English words with specific meaning and interpretation in the given genre context. Also, the fact that the official maritime language is English makes the interpretation of the texts ever more demanding for non-native English speakers. The restrictions of other languages in

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1 Here we will refer to Hutchinson and Waters [21] where ESP is classified according to professional areas, which can be further classified as Academic or Occupational. Dudley-Evans and St. John [12], on the other hand, consider English for Vocational Purposes (EVP) and English for Professional Purposes (EPP) as subordinate classes of English for Occupational Purposes (EOP).
TABLE I. MARITIME TERMS IN CPs CLASSIFIED BY THE RELATED AREAS

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ship, ship characteristics and stability</td>
<td>GT/NT (gross tonnage, net tonnage, summer loadline, deadweight capacity, afloat, ship, vessel, trim, seaworthiness, portside, starboardside, aboard, berth, etc.</td>
</tr>
<tr>
<td>Persons engaged on board or related to cargo shipping</td>
<td>Shipowner, Charterer, Master, agent, Manager, Shipper, Receiver, Consignee, Stevedore, Mariner, Pilot, Crew, craneman, winchman, Chief Engineer, etc.</td>
</tr>
<tr>
<td>Cargo and cargo handling</td>
<td>deck cargo, dunnage, laytime, stowage, cargo handling gear, loading/discharging, cargo winches, demurrage, tally, trim, lash, etc.</td>
</tr>
<tr>
<td>Forms and documents</td>
<td>Charter Party, Bill of Lading, Claim, Notice of Readiness, Contract of Carriage, Time sheet, etc.</td>
</tr>
<tr>
<td>Shipping industry, including financial and banking terms</td>
<td>freight, hire, deadfreight, lumpsum freight, shipment, delivery, goods, business, cargo, prepaid, payable, freight tax, brokerage commission, rate of exchange, etc.</td>
</tr>
<tr>
<td>Maritime law and insurance</td>
<td>average, insurance, indemnity, claim, policy, adjustment, lien, etc.</td>
</tr>
<tr>
<td>Other maritime terms</td>
<td>ashore, manning, berth, loading port, discharging port, sealing, tank, dispatch, etc.</td>
</tr>
</tbody>
</table>

terms of the maritime registers impose the use of many Anglicism. Furthermore, even when there are certain technical words in the local language, seafarers, for practical reasons, often use the English terms or adjusted terms derived from them. Some of those terms in time become standard in local languages, whereas some remain unofficial or colloquial. The examples from the corpus would be terms such as Charter Party, Charterer, Shipper and similar, sometimes transcribed into the local language (for example, in Montenegrin: Čarter Parti, Čarterer, Šiper and similar).

A. Technical vocabulary

The specifics of English maritime lexis are technical words and phrases, the word composition and use of general lexis. For the purpose of easier overview, we can make a general table of terms’ examples from the corpus, classified by the related areas (Table I):

It is worth mentioning here the limitations of this effort, considering the interrelations of the areas and their registers – i.e. the terminology and areas often overlap.

Since the lexical units of maritime English in the given corpus are difficult to fully present or classify, we can conditionally divide them into two large groups: lexical units specific to the maritime register (e.g. portside, starboardside, seaworthiness, trim, berth, afloat, demurrage, aboard, ashore etc.) and lexical units from general English which have a specific meaning in maritime contexts (such as receiver, average, hire, adjustment etc.). The latter group would also include general English words belonging to the register that form maritime collocations, e.g. under way, laydays, laytime, clear day, weather working days etc. Here again we also need to mention that languages differ in terms of registers, which makes it even more challenging if we need to translate certain maritime (English) terms into some other language. This would create an additional group of terms and phrases that have a specific form in English, but not in the language that they are translated into, where those terms need to be translated with a general term or terms (even a clause), in order to define it as precisely as possible. For example: starboardside and portside in many languages would need to be translated descriptively as the right side of the ship and the left side of the ship.

Specific interpretations and definitions of terms and phrases

As we have already mentioned, CPs contain many terms and phrases that the majority of people would not be familiar with, and which are sometimes even difficult to understand within the discourse community itself. Therefore, these forms are often accompanied by official definitions and explanations of terms and clauses. For that purpose, maritime institutions, such as BIMCO, publish certain rules called Interpretation Rules. In addition, the same purpose is achieved by various notes, manuals, guides and similar serving both the creators and readers of the texts. They can define some general and simple terms, such as port, as well as those unlikely to be known to laymen, such as laytime, demurrage, vessel being in free pratique and New Jason Clause.

The same thing can be found within the CP itself. The definitions and interpretations of single words or phrases reflect the intertwining of the legal style with the maritime discourse, in terms of the “wide” and comprehensive defining of maritime lexis, phrases or expressions, e.g.:
“PORT” shall mean an area, within which vessels load and discharge cargo whether at berths, anchorages, buoys, or the like, and shall also include the usual places where vessels wait for their turn or are ordered or obliged to wait for their turn no matter the distance from that area. If the word “PORT” is not used, but the port is (or is to be) identified by its name, this definition shall still apply.

“VESSEL BEING IN FREE PRATIQUE” and/or “HAVING BEEN ENTERED AT THE CUSTOM HOUSE” shall mean that the completion of these formalities shall not be a condition precedent to tendering notice of readiness, but any time lost by reason of delay in the vessel’s completion of either of these formalities shall not count as laytime or time on demurrage.

“ON DEMURRAGE” The laytime has expired. Unless the charter party expressly provides to the contrary the time on demurrage will not be subject to the laytime exceptions. “Per Working Hatch Per Day or Per Workable Hatch Per Day” – Laytime is to be calculated by dividing the quantity of cargo in the hold with the largest quantity by the result of multiplying the agreed daily rate per working or workable hatch by the number of hatches serving that hold. Thus Laytime = Largest Quantity in One Hold = Days Daily rate per hatch x Number of hatches serving that hold. A hatch that is capable of being worked by two gangs simultaneously shall be counted as two hatches.

The fact that some words from general English are given a completely new meaning within the maritime setting imposes even hire requirements in terms of familiarisation with the vocation and with vocational (maritime) English, especially in the learning/teaching of EFL.

B. Acronyms and abbreviations

The use of acronyms and abbreviations is one of the main lexical features within the maritime discourse community, including CPs. They are usually created by the first letters of compounds or phrases, with or without a slash, e.g. CP or C/P, NOR, or by codified names, i.e. abbreviating or connecting several words into one (MARPOL, GENCON). They can be pronounced in the shortened form (SOLAS, BIMCO) or in full (Abt., B/L). A large number of abbreviations and acronyms are widely accepted as such and are official in maritime communication (DWT, B/L), while there are those that are abbreviated for practical reasons and for fitting within the text or text box (e.g. load., disch. and cl.). Some of the examples from the corpus are given in the table below (Table II).

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>DWT</td>
<td>Deadweight (capacity)</td>
</tr>
<tr>
<td>GT/NT</td>
<td>Gross Tonnage/Net Tonnage</td>
</tr>
<tr>
<td>Cl.</td>
<td>Clause</td>
</tr>
<tr>
<td>Abt.</td>
<td>About</td>
</tr>
<tr>
<td>C/P</td>
<td>Charter Party</td>
</tr>
<tr>
<td>B/L</td>
<td>Bill of Lading</td>
</tr>
<tr>
<td>Load./Disch.</td>
<td>Loading/Discharging</td>
</tr>
<tr>
<td>NOR</td>
<td>Notice of Readiness</td>
</tr>
<tr>
<td>BIMCO</td>
<td>Baltic International Maritime Council</td>
</tr>
<tr>
<td>m/v or MV</td>
<td>Motor vessel</td>
</tr>
<tr>
<td>MT or PMT</td>
<td>Metric ton, per metric ton</td>
</tr>
<tr>
<td>LMAA</td>
<td>London Maritime Arbitrators Association</td>
</tr>
<tr>
<td>CSO</td>
<td>Company Security Officer</td>
</tr>
<tr>
<td>bhp</td>
<td>Break horse power</td>
</tr>
<tr>
<td>MARPOL</td>
<td>International Convention for the Prevention of Pollution from Ships</td>
</tr>
<tr>
<td>SOLAS</td>
<td>Safety of Life at Sea</td>
</tr>
<tr>
<td>MTSA</td>
<td>Maritime Transport Security act</td>
</tr>
<tr>
<td>N/A</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>WIBON</td>
<td>“whether in berth or not”</td>
</tr>
<tr>
<td>IMO</td>
<td>International Maritime Organization</td>
</tr>
<tr>
<td>FIO</td>
<td>Free in and out</td>
</tr>
</tbody>
</table>
We can also notice that the use of abbreviations in the corpus analysed is less frequent than in regular maritime documents and communication. The main reason is the difference in legal formality i.e. regular maritime correspondence and communication tends to be as practical and concise as possible, while legal documents require additional precision and formality.

C. Nouns, noun phrases and nominalisation

Considering that the given texts are of a legal nature, its sentences are of a stronger nominal character compared to everyday language. Similar to other maritime texts, we find here an abundance of nouns generated in various ways: by conversion, affixation (adding suffixes or prefixes) and composition.

Conversion

Examples of conversion would be nouns, such as: ship, load and man converted into verbs to express a type of movement, state or activity, such as in:

...expected ready to load...

...and to secure that she is properly manned....

...which the Charterers bind themselves to ship....

Nouns can also be converted into an adjective, creating a collocation, or into a noun phrase with another noun, such as in the case of port (Port Authorities, port facilities, port workers). The noun shipping (shipping agency, shipping company, shipping expenses, etc.) acts in a similar way.

Affixation

In this case, the nouns are derived mainly from verbs, mostly by adding suffixes, such as:

-age (stowage, salvage, towage), -ion (allocation, distribution, navigation, cancellation, recommendation), -ness (readiness, seaworthiness), -ment (shipment, fulfilment, requirement), -ance (compliance, performance), -ing (loading, discharging, tallying, shipping, failing) and -y (delivery). We also have suffixes, such as -er, -or or -eer, added to verbs or nouns to mark a job title or role aboard ship or ashore and related to ship operations, e.g. receiver, Charterer, shipper, broker and engineer.

ComposiƟon

One of the most productive ways of creaƟng words and noun phrases is composition. Considering the somewhat restricƟve use of arƟcles in mariƟme English, due to pracƟcal tendencies to provide as short and concise expressions as possible, it might be more convenient to talk about compound nouns than noun phrases. CPs are abundant in these, sometimes written with a dash, sometimes as a unique word, for example: loadline or load line, drydocking or dry-docking, summerline, unseaworthiness, prepaid, breakdown, craneman and winchman.

In common with the English language’s tendency to create nominal compounds, the frequency of compound nouns and noun phrases, especially those with a noun in an attributive position, is obvious in official documents, such as the corpus analysed, e.g. summer load line, sufficient motive power, vessel’s cargo handling gear, Stevedor’s written acknowledgment, running days, and demurrage rate, among many others.

One of the most frequent and dynamic form of compound nouns is the one where both the noun modifiers and the head noun are represented by nouns (Nm+Nh, or NmNh, as recommended lately). They can be further classified according to the function of the modifier (Nm). Since compound nouns are made by contraƟng wider expressions, modifiers usually replace relative structures, pointing to the purpose or specific meaning of the main noun, e.g.

salvage ship – a ship for salvage

cargo liner – a liner for carrying cargo, a liner which carries cargo.
They can also replace various prepositional syntagms where modifiers determine place or time, e.g.:

- port facilities – facilities of the port (or in the port)
- deck cargo – cargo on the deck
- summer loadline – loadline in the summer

or a partitive relationship, such as:

- discharging port – port of discharge.

In the analysed corpus, noun compounds are very frequent in titling the professional engagement or activities of individuals, employing verbs such as: to work, to employ, to engage, wherein modifiers mark the domain and field of engagement, e.g.:

- Deck Officer – an officer engaged on the deck
- Engine Officer – an officer engaged in the engine room department
- loading port agent – an agent engaged in or for the loading port.

Maritime English is also abundant in multiple-noun compounds, usually reflecting the relationship of purpose or a partitive one, e.g.:

- cargo handling equipment – the equipment for the handling of cargo
- engine room department – the department of the engine room.

Since the noun ship is female in English, using the pronoun she, this personification results in very frequent use of the Saxon genitive [1]: Vessel’s name, Vessel’s Master, Vessel’s Crew, Vessel’s cargo handling gear, etc., and is also frequently used in determining the functions and obligations of contractual parties: Owner’s obligations, Owner’s indemnity, Owner’s colours, Charterer’s account, Charterer’s risk, Charterer’s consent, Agent’s commission, Master’s responsibility, etc. These examples are even more related to legal discourse specifics, considering that they are used in such a form, and not in pronouns, in order to be detailed and avoid any misinterpretation or ambiguity.

This leads us to another difference between the two discourses. While we can see examples of contracting expressions into (maritime) compound nouns where modifiers often replace syntagms or even clauses, in legal forms we have unusually formal and complex expressions such as:

- ...on the part of the Owners... instead of the possible ...by the Owners..., or:
- ...in the manner stated... instead of the possible ...as stated....

D. Collocations

Collocations or word pairs or doublets are standard legal phrases comprised of two or more words. Such phrases can combine terms of similar or synonymous meaning, such as legal and valid and wear and tear. In addition, maritime discourse is also abundant with specific standardised word pairs, such as full and complete (cargo), get and lie (always afloat), loading and discharging and cranemen/winchmen.

E. Proper nouns and capitalization

Due to the formality of the text type, the attention is given also to the layout of its textual elements, including the graphological means used for the purpose of emphasizing certain text points. In addition to general proper nouns such as names of institutions and organizations, e.g.: United Nations, Government, Security Council, European Community etc., as well as the official titles of regulations, conventions and procedures, such as: York-Antwerp Rules, Shortened Arbitration Procedure, Arbitration Act,
etc., capital letters are also used for the emphasis of key words, actors or points of the CP as an agreement, as presented within the following examples of proper and capitalized nouns:

- titles and names of clauses: Time/Voyage Charter Party, Both-to-Blame Collision Clause, Taxes and Dues Clause, Law and Arbitration;
- names of contractual parties and titles: Shipowner, Charterer, Master, Manager, Shipper, Receiver, Mariner, Pilot, Chief Engineer, Broker;
- documents: Charter Party, Bill of Lading, Notice of Readiness, Contract of Carriage;
- and the key words of the CP: Vessel, War Risks, General Average.

Here we also need to mention two related phenomena, again, in the function of legal preciseness and avoidance of any possible ambiguity. In the typically (too) long sentences of legal discourse, we easily detect the abundance of repetition, e.g.:

> If at any time before the Vessel commences loading, it appears that, in the reasonable judgment of the Master and/or the Owners, performance of the Contract of Carriage, or any part of it, may expose, or is likely to expose, the Vessel, her cargo, crew or other persons on board the Vessel to War Risks, the Owners may give notice to the Charterers cancelling this Contract of Carriage, or may refuse to perform such part of it as may expose, or may be likely to expose, the Vessel, her cargo, crew or other persons on board the Vessel to War Risks; provided always that if this Contract of Carriage provides that loading or discharging is to take place within a range of port, and at the port or ports nominated by the Charterers of the Vessel, her cargo, crew or other persons aboard the Vessel may be exposed, or may be likely to be exposed, to War Risks, the Owners shall first require the Charterers to nominate any other safe port which lies within the range for loading or discharging, and may only cancel this within the range for loading or discharging, and may only cancel this Contract of Carriage if the Charterers shall not have nominated such safe port or ports within 48 hours of receipt of notice of such requirement.

In the underlined structures we find the illustration of another specific feature of legalese arising from its detail and all-inclusiveness – reiteration. In addition to entire clauses being repeated within the same sentence, we see that the noun phrase Contract of Carriage is repeated as many as four times, as well as her cargo, crew and other persons on board, Vessel, Master, Charterers, etc.

Therewith, the avoidance of pronouns is also evident, as we have already seen it, again, due to the tendency of the legal community to avoid and exclude any possible unclear points or misunderstandings, often to the detriment of the beauty of the language.

F. Positive and negative words

Although English tradition recommends positive words and phrases for the purpose of creating a positive cooperative atmosphere, their use in legal documents is limited due to the emphasis on the legal validity of the document. Still, in CPs they also have the function of creating a positive atmosphere and of stimulating a positive reaction from the parties to the contract. Such words and structures are: ready to load, safety get and lie afloat, full and complete cargo, due diligence, properly manned, readiness, free use of, seaworthiness, etc.

On the other hand, an even more important role in CPs, as well as in other legal texts, is played by negative words and phrases in the sense of anticipating possible problems and limitations that can arise during its realisation, e.g. loss or damage, unseaworthiness, not ready, cancelling, delay, neglect, negligence, prohibit, collision, disaster, danger, accident, sacrifices, rebellion, warlike operations and mines.

G. Binomial and multinomial expressions

Binomial and multinomial expressions would be a category somewhat broader than collocations since they are comprised of two or more words or phrases from the same grammatical category with the same semantic relations and connected by syntactical means, such as “and” or “or”. Some typical shorter ones here would be: loading and discharging, law and arbitration, get and lie, loss or damage; loss, damage or delay, owners or their manager; manned, equipped and supplied; neglect or default, on
board or ashore, to tow and/or assist vessels, life and/or property, earned and non-returnable, lost or not-lost, to sign or endorse; loaded, stowed and trimmed, tallied, lashed and/or secured; risk, liability and expense, provide and lay, Sundays and holidays and many others used, again, for the purpose of detail and thoroughness.

VII. CONCLUSION

In analysing the most common and recommended types of charter parties nowadays, we focused on the lexical approach in order to present the specifics of maritime lexical items used within a legal linguistic medium for achieving a unique communication intention.

For practical reasons, our detailed lexical analysis was focused on the UNIFORM GENERAL CHARTER under the codified name of “GENCON”, with consideration of other relevant CPs, both sample and forms from practice, which together can be perceived as a genre per se shared by two distinctive discourse communities, maritime and legal. The specifics of maritime vocabulary found within the analysed corpus and presented regard mainly the specific technical terms, nouns and noun phrases, collocations, binomial and multinomial expressions etc. Also, we tried to show the influence of the legal discourse community and legal textual context on the selection and use of maritime lexis in this kind of genre, e.g. specific definitions of some general maritime terms, reiteration, more capital letters, more complex phrases etc.

In our intention to be as specific as possible, we tried to shed some light on only one aspect of possible analysis related to (maritime) ESP and specifics of a discourse community using the lexical approach to primarily maritime vocabulary. At the same time, we hope that our modest contribution clears the way for some further research in specific discourses and specific genres, as well as in English for Specific Purposes and as a lingua franca.

CORPUS LIST
1) RECOMMENDED, THE BALTIC AND INTERNATIONAL MARITIME COUNCIL UNIFORM GENERAL CHARTER (AS REVISED 1922, 1976 and 1994), (To be used for special trades for which no specially approved form is in force), CODE NAME: GENCON (sample copy)

2) BIMCO TIME CHARTER PARTY FOR OFFSHORE SERVICE VESSELS, CODE NAME: SUPPLYTIME 2005 (sample copy)

3) HYDROCHARTER Voyage charter Party. Recommended by The Baltic and International Maritime Council (BIMCO), Copenhagen. Issued 1st January 1923. Last amended July 1997 (sample copy)

4) RECOMMENDED, THE BALTIC AND INTERNATIONAL MARITIME COUNCIL UNIFORM GENERAL CHARTER (AS REVISED 1922 and 1976), INCLUDING “F.I.O.” ALTERNATIVE, ETC., (To be used for trades for which no approved form is in force), CODE NAME: G E N C O N (M/V Glyfada)

5) BIMCO TIME CHARTER PARTY FOR OFFSHORE SERVICE VESSELS, CODE NAME: SUPPLYTIME 2005 (Mamola Challenger Shipping)

REFERENCES


A Quantitative Study into Perceptions and Attitudes of Corporate Social Responsibility and Sustainability Developments in International Shipping

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ABSTRACT
In recent decades, the international community has demonstrated a growing concern and tendency to halt adverse environmental impacts generated by business activities. Among a plethora of regulatory initiatives and collaborations, the United Nations recent remarkable development toward this direction. The International Maritime Organization (IMO), as the United Nations specialized Agency to deal with safety at sea and protection of the marine environment, has been, actively, engaged and harmonized its strategy with global sustainability mandates. Similarly, a great deal of research and motivation has been placed on corporate social responsibility (CSR), as a business operating model that goes beyond regulatory compliance and integrates sustainability challenges. In view of the limited amount of related research, the purpose of this paper is to investigate and provide a better understanding against perceptions and attitudes of CSR and sustainability insights and practices into the maritime industry. Research data collected via a questionnaire survey conducted in shipping companies, based on countries worldwide and managing tankers and/or dry bulk carrier ships. Chi-square test of independence and Spearman’s correlation coefficient measures are employed to test the statistical significance and strength of association between selected variables, verifying, thus, our formulated hypotheses. Findings show that shipping companies perceive CSR as a voluntary and beyond regulatory compliance businesses approach that, further, shares sustainability aspects (social, economic, environmental). Moreover, shipping companies have been, increasingly, integrating into their safety management system (SMS) provisions of CSR and sustainability principles, while, at the same time, seek to remain compliant with statutory maritime legislation. However, certification against an official CSR Standard and, subsequent, adoption of standardized CSR measurement and reporting methods, has not yet been the case in shipping.

KEYWORDS: corporate social responsibility, sustainable shipping, safety management systems & tanker/dry bulk maritime sector

I. INTRODUCTION
Corporate Social Responsibility refers to a concept that has been, gradually, extended and applied to a wide spectrum of business activities. Although difficult to be precisely defined, however, it can be assumed that CSR concept derives from the expectations a society has from enterprises. And such expectations go beyond the mere fulfillment of company’s financial obligations towards employees [36]. An underlying idea here is that, either intentionally or unintentionally, business operations generate impacts that affect the economic, social and environmental system in which they function. In the era of climate change and environmental challenges, companies are closely scrutinized for their business decisions and the impact they bring to society. Therefore, stakeholders, namely, those who, directly or indirectly, are affected by organizations’ activities, foresee firms as entities that have a societal role to fulfill, along with their profit making pursuit [4]. With regards to sustainable development, the term was first introduced by ‘Our Common Future’ report, published by the United Nations World Commission on Environment and Development (WCED), in 1987. Such report, along with a complete diagnosis of the environmental situation and imminent climate change challenges, introduced one of the most, commonly, used definition of sustainable development, which is: “the development that meets the needs of current generations without compromising the ability of future generations to meet their own needs” [40].

The shipping industry has been significantly impacted from worldwide CSR and sustainability developments. Presently, the International Maritime Organization has welcomed latest United Nations 2030 Agenda on Sustainable Development and associated Sustainable Development Goals. As a result, in an
attempt to cope with current United Nations sustainability mandates, the International Maritime Organization has already published its Strategic Directions (SD) and High level Action Plan (HLAP), for the 2016-2017 period [19]. Such initiative refers to a remarkable sustainability undertaking throughout IMO’s long history, which, furthermore, has explicitly recognized corporate social responsibility, as a mean to achieve sustainable development. In that respect, it is of great significance the Organization’s statement, made during World Maritime Day symposium, on 26 September 2013, that a sustainable maritime transportation system “should be achieved, inter alia, by anchoring the vision of sustainable development into “Corporate Social Responsibility” (CSR) related activities” [18]. However, with the exception of a few shipping segments (i.e. container, cruise/passenger maritime sector) there is not much available research to light CSR and sustainability understanding and practices in the remaining maritime segments (i.e. dry and tanker) [23].

Through an empirical investigation conducted in the dry bulk and tanker shipping companies, this study investigates contemporary perceptions and attitudes borne by CSR and sustainable development implementation.

II. BACKGROUND

The adequacy of natural resources to meet society’s standing needs refers a deeply intellectual and practical issue that has, regularly, been the subject of analysis and research of several sciences and disciplines (i.e. economics, environmental, physics, engineering etc.) [9]. Scarcity of world’s natural resources and undesirable environmental impacts generated by the increasing use of land, air and sea, threaten our society’s prosperity and have quite frequently been recognized as causing factors of conflicts around the globe [13]. The predominant role of the oceans, as a vital source of life and economic development, has given rise to establishment of an institutional and legal framework, founded and exercised at international, regional, national and local level. The United Nations Convention on the Law of the Sea (UNCLOS) and the establishment of the International maritime Organization are some of the most vigorous ventures and sources of ocean governance in an attempt to oversee and ensure the sustainable use of the sea [32].

The theoretical framework for sustainable development initially came up, as a notion, between 1972 and 1992. The United Nations Conference on the Human Environment, at Stockholm, in 1972, was the first dedicated international meeting with a focus on worldwide sustainability challenges [40]. Since then, increasing environmental concerns and the necessity to balance environmental and social implications with economic pursuits have triggered a series of international conferences and global sustainability initiatives [38]. However, the 2030 Agenda for Sustainable Development, incorporated 17 Goals and 169 associated targets, adopted on September 2015, at United Nations Headquarters, represents UN’s latest distinguished resolution. With that movement, United Nations entered a new era and shared a new vision for sustainable development that will lead the world for the next 15 years [35]. It is worth commenting at this point that a notable feature of the 2030 Agenda was the identification and disclosure of sustainable development under its three dimensions: economic, social and environmental (known also as the triple bottom line approach) [41].

Likewise sustainability trends, the concept of corporate social responsibility has become increasingly important in the business arena. Although there is not an agreed definition, however, CSR is mostly defined as “a concept whereby companies integrate social and environmental concerns in their business operations and in their interaction with their stakeholders on a voluntary basis” [4]. However, CSR does not refer to a newly born idea and its origins are traced back in the ‘social contract theory’. The concept of ‘social contract’ was born centuries ago and, in its earliest version, had stressed the rights and responsibilities of the state to its citizens and vice versa. In line with social contract theory, the ‘Iron law of Responsibility’ assumes that the power gained by private enterprises bears moral obligations to society [10]. In another perspective, it has been argued that CSR has its roots to stakeholder theory and, as such, encompasses business pursuits to manage relationships and risks generated by their interaction with stakeholders [1]. In our era, growing environmental concerns and the need to consider business
impacts in an integrated manner (namely, from a social, economic and environmental angle) have transformed CSR thinking to a more managerial tool that embraces sustainability challenges [5].

The internationality and efficiency of shipping, as a mean of carrying 90% of internationally traded throughput, has been well recognized [16]. However, shipping has, at all times, been considered a risky business with a lot of perils to be originated by seaborne transport of goods. Dealing with risks has always been a routine for maritime professionals and, as a matter of fact, either directly or indirectly, maritime personnel has continuously been conversed with themes such as, health, safety and environmental protection, stakeholder management, seamen labor rights, energy efficiency and emissions reduction. Moreover, the management of ships requires several cross-border maritime activities and transactions to be taking place on a daily basis among multinational entities and stakeholders [8]. However, it is reasonable to assume that verifying ships’ seaworthiness and preserving the marine environment is not a matter to be left to the discretion of a sole entity, namely the ship-owners. Certainly, those have been tasked with the technical management of ships have assumed the primal responsibility to ensure the seaworthiness of their vessels. Though, the complicated and multilateral nature of the shipping business generates difficulties and contrasting interests among entities, in their attempt to offset commercial pursuits with regulatory requirements [34].

Concerns and complexity of maritime business, as indicatively discussed above, have been framed and constitute part of the scope of the ocean governance system. Currently, perhaps more intensively than ever before, there is an obvious growing trend to establish a sustainable and socially responsible shipping industry. In the light of the United Nations 2030 Agenda, the maritime community has transformed its approach to sustainability, which, unambiguously, is now seen as an integrated notion (economic, social and environmental) that needs to be enclosed in a CSR framework [18]. In the light of such progresses, maritime companies have been renovating and adjusting their strategies focusing on major areas of risk such as: energy efficiency, emissions reduction, stakeholder engagement, positive impact in local communities, navigational safety, labor and human rights, health and safety in their operations, technology upgrading and sustainability disclosures. An indicative example of that trend is the container and cruise shipping industry where it has been witnessed a profound motivation and adoption of sustainability and CSR initiatives [23]. However, despite the rising tendency to establish a standardized framework, there is not much available research to light CSR and sustainability perceptions and practices in international shipping, which are, mainly, seen as a voluntary undertaking, associated with maritime safety, environmental and quality management matters [20].

The aim of this paper is to investigate and portray perceptions and practices associated with CSR and sustainability encounters, as experienced by shipping companies operating in the dry and tanker shipping sector. Assessing theoretical and practical implementation matters will provide us with a better understanding of CSR and sustainability notions in shipping. Likewise, study results will facilitate the identification of shipping industry’s awareness and practical approach to CSR and sustainability, in an effort to comply with latest regulatory developments and achieve a more sustainable business performance.

A. Awareness and attitude

Analysing further the concept of iron law of responsibility, it has been concluded that corporate social responsibility, although not easily approachable due to its several aspects, though, can be interpreted as the company’s culture and willingness to consider and act beyond the narrow and established financial, technical and regulatory requirements [10]. According to Aras and Crowther (2008), CSR is perceived as a voluntary business tool that goes beyond mere compliance with mandatory regulations and integrates sustainability within organization. In that sense, CSR incorporates also an ethical dimension, which reflects social norms, cultural and society’s expectations. Such area of concern lies beyond regulatory control and is a matter of every firm to operate responsibly and minimize risks to its stakeholders [25]. Equivalent to this stance has also been the declaration of European Commission (EC), which suggests that a socially responsible firm should go beyond mere compliance with applicable legislation and deal with social, environmental, ethical, human rights and stakeholder challenges, in an integrated manner and at strategic level [11]. In line with EC approach, Lombardo (2009) supports that a CSR initiative
expands beyond firm’s statutory obligation and relates to a voluntary action that, proactively, seeks to internalize negative impacts and, in the long-term, reduce business risks (i.e. environmental pollution, conflicts with stakeholders etc.). What can be inferred at this point is that sustainability elements (i.e. several social, environmental and economic aspects) are embedded and form part of CSR managerial approach [22].

Elkington (2013), in 1994, was the first who addressed the three elements of sustainability in one term, namely, the: ‘triple bottom line’ [12]. Nowadays, such approach to sustainable development is more topical than ever, since it encompasses the expectations of modern era to cope with sustainability in an integrated manner [2]. Consistent with this approach to sustainability, United nations 2030 Agenda stressed the need to consider sustainable development as an integrated element (social, environmental and economic) and, furthermore, embrace such initiative under a CSR business framework [39]. According to a study on CSR implementation, carried out in the Baltic Sea maritime sector, CSR has not been merely recognized as a mean to deal with minimum maritime health, safety and environmental regulation. Contrary, CSR engagement was perceived as a mean to contribute to the overall company’s social, environmental and economic performance, advance the quality of provided services, enhance company’s reputation and offer, thus, a competitive advantage [20]. Correspondingly, the beyond compliance approach to sustainability has been also encompassed in another IMO’s statement, made at World Maritime Day symposium, September 2013, that “optimally, a safety culture should go beyond mere regulatory compliance and deliver added value for the System through the promotion of safety culture aims” [18]. As it can be deduced so far, such readings have paved the way forward to a more integrated manipulation of CSR and sustainability in shipping. In such a new scheme, CSR has been recognized as a voluntary and beyond regulatory compliance concept which, furthermore, intersects and integrates current sustainable development mandates (as has been formulated under the triple bottom line approach) [39]. It is, therefore, hypothesized that:

\[ H_5: \text{Companies that perceive sustainable development under its three dimensions are more likely to understand CSR as the conduct of operations in a manner that goes beyond mere regulatory compliance and integrates social, economic and environmental concerns into business operations.} \]

B. Practices, Measurement and Disclosure

In broad terms, and depending on the industry’s applicable local and/or international legislation, it is the duty of every employer to establish a safety management system and define all resources and organizational arrangements necessary for managing health, safety and environmental risks at the workplace [15]. There are various legal frameworks (at regional, national and international level) that dictate the establishment of a safety management system. For example, the Health & Safety at Work Act 1974 (HSWA), sets the basis for health and safety law and employers and employees duties in United Kingdom [17]. Likewise, in shipping, the introduction of the International Safety management (ISM) Code, by IMO, in 1998, aimed at setting the legal framework for the establishment of a safety management system that considers all applicable regulatory requirements and prescribes specific procedures to minimize risks [28]. Treating CSR as a business model, it arises that ensuring a risk free workplace constitutes an integral component of business CSR strategy [7]. Moreover, as previously discussed, CSR is regarded a voluntary and beyond compliance undertaking that integrates several health, safety, social and environmental concerns into company’s strategy and decision making process [29]. With regards to quality, Frolova and Lapina (2014) supports that CSR correlates to quality management approach. In that sense, a quality management system forms the basis to create and diffuse CSR and sustainability at all levels of the organization [14]. Indeed, bearing in mind the issue of quality within an organization, which in broad terms extends beyond compliance with minimum statutory requirements, we could assume that the concepts of CSR and quality have plenty crossings [6]. In such perspective, implementing a CSR strategy is expected to improve the service quality to customers and well-being of employees within the organization and society, through the reduction of workplace risk and negative impacts (economic, social and environmental), fulfilling, thus, indirectly, sustainability objectives [29].
In an attempt to frame CSR within the maritime context, it could be alleged that, traditionally, CSR notion has been treated synonymously to ‘quality shipping’. In that sense, the quality notion reflected the attempt of ship owners to manage their ships in compliance with applicable, national, regional and international health, safety and environmental protection rules, maintaining, thus, profitability of their business [23]. As per Donaldson (1994) the issue of quality in shipping encompassed ship owners’ effort to eliminate substandard vessels. However, globalization trends, stricter regulation, increasing efforts for more transparency and control on labour rights, easier flow of information, growing stakeholders’ pressure on sustainability, maintenance of good customer relations and the vulnerable to accidents image of shipping have made maritime companies to transform their perceptions towards ‘quality’ [23]. It is therefore expected that, although the management of ships has been, habitually, referred to an activity mostly governed by typical maritime statutory legislation, though, worldwide regulatory and business developments have affected the structure of traditional safety management systems that govern shipping operations. Further to that, it is believed that engagement with CSR and sustainability developments has influenced the traditional approach to SMSs and has urged shipping companies to integrate relevant principles/standards into their SMS requirements and structure [20]. In the outcome of such argumentation, the following hypotheses are formulated:

**H1 (a):** Companies that engage CSR principles are more likely to have incorporated in their SMS the provisions of a CSR Standard.

**H1 (b):** Companies that engage CSR principles are more likely to have incorporated in their SMS the provisions of sustainability Standard.

### III. RESEARCH METHODOLOGY: SAMPLING, DATA COLLECTION AND ANALYSIS METHODS

In line with our research aim, this study has adopted a deductive method of reasoning and has been conducted by employing a quantitative research approach. Consistent with adopted methodology, our research commences by reviewing the literature and analysing theories related to our topic. Next, specific hypotheses are developed and variables identified [21]. Quantitative data has been collected using a self-administered questionnaire survey. As such, an electronic questionnaire was sent via email to 50 shipping companies, based in 14 different countries. Survey participants work in various departments such as, operations, QHSE, technical, HR, management and accounting and, in that sense, they are considered to be adequately aware and experienced to express their organization’s perceptions and attitude toward CSR and sustainability. Participating companies were identified as those having assumed the technical management of dry bulk carriers and/or tanker vessels. The management of other ship types (i.e. containerships) was also permissible, however, it was obligatory that, along with other ship types, they should manage dry bulk carriers and/or tanker vessels. All variables (independent and dependent) were presented as statements and respondents were asked to indicate their level of agreement on a five point Likert (Strongly Agree to Strongly Disagree) and Yes/I am not sure/No, scale of choices. Moreover, descriptive statistics are employed to discuss demographics and provide some general inferences of our collected data [27].

The nature of selected variables and collected data has determined the test selection to verify our hypotheses. In particular, hypothesis 1 (H1) is tested using Spearman’s correlation measure. Such selection is done on the basis that both dependent and independent variables are categorical, measured on an ordinal scale. The *p-value* obtained by the observed correlation Rs value and the sample size, determine whether a statistically significant relationship between variables exists. A *p-value* which is less than $\alpha=0.05$ (level of significance) suggests a statistically significant relationship between variables and implies rejection of null hypothesis. Moreover, *Spearman’s correlation coefficient* (Rs) is used to determine the strength of such association. Coefficient Rs ranges between -1 (perfect negative correlation) to 1 (perfect positive correlation). A value close to 0 implies no relationship between variables [33]. With regards to hypotheses 2(a) and 2(b), *chi-square test of independence* is employed to examine whether a statistically significant relationship between variables exists. Selection of this test was based on the assumption that variables are categorical, measured on a nominal and ordinal scale. On a conceptual
basis, the null hypothesis is rejected, when the \( p\)-value is less than \( \alpha = 0.05 \) (significance level). Suitably to the data type, *contingency coefficient* (C) measure is further used to determine the strength of such association. *Contingency coefficient* (C) value ranges between -1 to 1. Values close to -1 indicate a strong negative association, while values close to 1 show a perfect positive association. 0 values imply that there is no association between variables [24]. The Statistical Package for Social Sciences (SPSS) version 25 for windows was used for conducting our statistical analysis.

Table I. below summarizes our research hypotheses and corresponding variables incorporated in our survey and data analysis.

<table>
<thead>
<tr>
<th>Alternative Hypothesis</th>
<th>Independent Variable</th>
<th>Dependent Variable</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>( H_0: ) Companies that perceive sustainable development under its three dimensions are more likely to understand CSR as the conduct of operations in a manner that goes beyond mere regulatory compliance and integrates social, economic and environmental concerns into business operations.</td>
<td>Companies understanding of sustainable development under its three dimensions (economic, social and environmental). (Ordinal)</td>
<td>Companies’ perception of CSR as the conduct of operations in a manner that goes beyond mere regulatory compliance and integrates social, economic and environmental concerns into business operations. (Ordinal)</td>
<td>Spearman’s correlation coefficient</td>
</tr>
<tr>
<td>( H_{a1}: ) Companies that engage CSR principles are more likely to have largely incorporated into their SMS the provisions of a CSR Standard.</td>
<td>Engagement of CSR principles by companies. (Nominal)</td>
<td>Level of importance into SMS formulation of the provisions of a CSR Standard. (Ordinal)</td>
<td>Chi-square test of independence</td>
</tr>
<tr>
<td>( H_{a2}: ) Companies that engage CSR principles are more likely to have largely incorporated into their SMS the provisions of a sustainability Standard.</td>
<td>Engagement of CSR principles by companies. (Nominal)</td>
<td>Level of importance into SMS formulation of the provisions of sustainability Standard. (Ordinal)</td>
<td>Chi-square test of independence</td>
</tr>
</tbody>
</table>

IV. RESULTS

A. Descriptive Statistics

A descriptive statistics analysis has been done with the objective to present an overview of demographics, and companies’ perceptions and practices from CSR and sustainability engagement. The nature of collected data, which are categorical, measured on a nominal and ordinal scale implies that our selected variables will be described by their frequency distribution.

Demographics

Participating companies, having assumed the technical management of ships, are based in 14 different countries around the globe. The majority of them are based in Norway (22%) and Greece (20%), while 10% are based in Italy, Turkey, Monaco, Sweden and Belgium. Such a variety diversifies study results and, thus, does not limit our survey scope and findings to the context of a single country. Out of the total 50 respondents, 76% are males with the remaining 24% being females. The biggest participants group (34%) belonged to the 41 to 50 years old age group. The majority of the respondents (64%) are employed in the QHSE department, while 4% are employed in the technical and accounting/management departments. With regards to company’s size, 52% manage a fleet that ranges between 1 to 40 ships, while 48% manage more than 41 ships. The majority of companies (58%) employed (both at the office and ashore personnel) more than 251 persons, while 8% answered that their employees’ number ranges between 1 to 50 persons. The highest companies’ rate (48%) represents ship owning companies performing exclusive technical management services to a sole ship owner. Moreover, 74% answered that they manage tankers and/or gas carrier vessels and dry bulk vessels, while 4% manage
passenger/cruise ships, additionally to their dry and tanker managed fleet. Reviewing demographical data, it can be assumed that there is a diversification of our sample population, in terms of companies’ size, management ‘style’ and types of managed ships. Furthermore, the fact that participants are mostly occupied in the QHSE department, demonstrates a good awareness level and participants’ involvement related to CSR matters within their organization.

**Awareness and attitude**

Most of the participants (94%) answered that they were personally aware of CSR theme, while 6% of the participants replied that they were not aware. Moreover, 82% of the companies have adopted CSR policy/principles into their ship management policy. Such a fact seems to be consistent with our literature review conclusions, which implies that CSR refers to an expanding concept that has been, steadily, reflected into shipping companies’ policy and operating practices [30]. Interestingly, 70% consider the establishment of a sustainability policy/programme to be part of company’s CSR policy/program. Such evidence is aligned with IMO’s standpoint, namely, that sustainability initiatives should form part and embraced into a wider CSR philosophy [18]. However, it is worth commenting at this point that CSR awareness and adoption of its principles is a questionable issue. CSR awareness is an element that bears a lot of subjectivity, since it does not offer us any qualitative information about how practically (i.e. through which procedures, policies, operating practices) CSR is captured and implemented throughout shipping operations (as this is out of the scope of this study).

Literature review deductions are also consistent empirical findings, which show that 96% of companies understand CSR as the conduct of business operations in a manner that goes beyond mere compliance with statutory health, safety and environmental regulations (i.e. ISM, ISPS, SOLAS, MARPOL, MLC etc.) and integrates social, economic, environmental, ethical, human rights and consumer concerns into business operations and management strategy [4]. Such result is consistent with perceptions that treat CSR as a voluntary approach that goes beyond what minimum law requires [31]. Another important feature derives from the fact that although the majority of the companies have incorporated CSR principles (82%), however, only 2% found to have been officially certified against a CSR Standard (i.e. ISO26000, SA8000 etc.). Such companies’ stance is, potentially, attributed to the plethora of maritime regulations that, traditionally, have been governing several social, health, safety and environmental aspects of shipping operations [3]. In line with this attitude, is also Yuen and Lim (2016) study, which identifies existing maritime regulatory regime as adequate to address industry’s social and environmental issues. Such considerations have, potentially, deterred certification against an official CSR Standard (i.e. ISO26000), which could be viewed as pleonasm by shipping companies [3]. Consistent with our literature review conclusions is the fact that 82% perceives sustainable development as the conduct of business in a way that company’s economic, social and environmental impacts are considered and eliminated. This result is highly representative and in line with the current regulatory regime, which considers sustainability in an integrated manner (triple bottom line approach to sustainability) [2].

**Practices, Measurement and Disclosure**

98% of the responding companies considered the provisions of maritime statutory legislation to be very important to the formulation of their safety management system. Such a finding was expected since the shipping industry has, traditionally, been more familiar with statutory maritime regulations, than with CSR and sustainability requirements of non-maritime related conventions. However, interestingly, 74% consider CSR and sustainability principles to be also very important to the formulation of their company’s SMS. Considering such attitude, and contrasting it with our literature review assumptions, it is further assumed that CSR and sustainability concepts have been drastically expanding to the shipping industry and have urged shipping companies to incorporate relevant principles/standards into their SMSs formulation [20].

The preferred type of performance reporting was found to be an integrated health, safety and environmental report (72%). It is worth mentioning that only 16% use a standalone CSR/sustainability performance reporting type, which is considered to be a low rate of preference, comparing to the fact that 82% have adopted CSR policy/principles. In conjunction with this, only 18% communicates their
performance measurement report externally (i.e. industry / press). Such findings confirm that the use of dedicated CSR/sustainability reporting still remains at an early stage. Additionally, the conventional approach to performance measurement and reporting (namely the integrated health, safety & environmental report) is, mainly, destined for internal communication (i.e. top management, company’s employees etc.). Such findings come to affirm Lund-Thomsen, Poulsen and Ackrill (2016) standpoint, namely, that devoted CSR measurement and reporting tools in shipping, although growing, however, are not yet at an advanced stage as it has been the case in other industries (i.e. aviation, auto sectors etc.).

B. Hypotheses Testing Results

Hypothesis 1 Testing results

Further to above mentioned alternative hypothesis $H_\nu$, the null hypothesis has been formulated as follows:

$H_\nu$: Companies that perceive sustainable development under its three dimensions are not likely to understand CSR as the conduct of operations in a manner that goes beyond mere regulatory compliance and integrates social, economic and environmental concerns into business operations.

According to the Spearman’s correlation measure, the $p$-value is 0.000, which shows a statistically significant relationship between variables. As such, at the level of significance $a=0.05$, companies’ understanding of sustainable development under its three dimensions, is significantly related with their perception of CSR as the conduct of operations in a manner that goes beyond mere regulatory compliance and integrates social, economic and environmental concerns into business operations. Therefore, the null hypothesis is rejected.

Moreover, from the application of correlation coefficient ($R_s$) measure, estimated $R_s$ value is 0.526. Such result implies that there is a positive association between variables. Therefore, further increasing companies’ understanding on sustainable development in its three dimensions (independent variable) is expected to raise CSR comprehension as the conduct of operations in a manner that goes beyond mere regulatory compliance and integrates social, economic and environmental concerns into business operations (dependent variable). Furthermore, as implied by applied correlation, obtained results are valid for more than 99% of companies.

Table II. below summarizes the results from the application of Spearman’s correlation measure.

**TABLE II. HYPOTHESIS 1 TESTING RESULTS: APPLICATION OF SPEARMAN’S CORRELATION MEASURE**

<table>
<thead>
<tr>
<th>Null Hypothesis</th>
<th>p-value</th>
<th>Spearman’s correlation coefficient ($R_s$)</th>
<th>$H_\nu$ Rejected ($a=0.05$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$H_\nu$: Companies that perceive sustainable development under its three dimensions are not likely to understand CSR as the conduct of operations in a manner that goes beyond mere regulatory compliance and integrates social, economic and environmental concerns into business operations.</td>
<td>0.000*</td>
<td>0.526**</td>
<td>YES</td>
</tr>
</tbody>
</table>

* $H_\nu$ rejected at significance level $p<0.05$
** $-1 \leq (R_s) \leq 1$, $-1$ = perfect negative relationship, 0= No relationship, 1 = perfect positive relationship

Hypothesis 2(a) Testing results

As per previous formulated alternative hypothesis $H_{2(a)}$, the null hypothesis has been declared as follows:

$H_{0(a)}$: Companies that engage CSR principles are not likely to have largely incorporated into their SMS the provisions of a CSR Standard.

Applying chi-square test of independence, the $p$-value is 0.000. As such, at the level of significance $a=0.05$, companies that engage CSR principles are more likely to have mainly incorporated in their SMS the provisions of a CSR Standard ($X^2(8) = 36.832$, $p$-value = 0.000). As a result, a statistically significant relationship between variables is identified and the null hypothesis is rejected.
From the application of contingency coefficient measure, obtained value is 0.651. This result indicates a positive correlation between variables. Therefore, it is assumed that further increasing CSR engagement into company’s policy (independent variable) is expected to reasonably accelerate the incorporation into company’s SMS of the provisions of a CSR Standard (dependent variable).

Table III. below summarizes the results from the application of chi-square test of independence and Contingency Coefficient measure.

<table>
<thead>
<tr>
<th>Null Hypothesis</th>
<th>p-value</th>
<th>$\chi^2$</th>
<th>Contingency Coefficient (C)</th>
<th>$H_0$ Rejected (a&lt;0.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$H_{0a}$: Companies that engage CSR principles are not likely to have largely incorporated into their SMS the provisions of a CSR Standard.</td>
<td>0.000*</td>
<td>36.832</td>
<td>0.651**</td>
<td>YES</td>
</tr>
<tr>
<td>$H_{0b}$: Companies that engage CSR principles are not likely to have largely incorporated into their SMS the provisions of a sustainability Standard.</td>
<td>0.000*</td>
<td>30.402</td>
<td>0.615**</td>
<td>YES</td>
</tr>
</tbody>
</table>

* $H_0$ rejected at significance level $p<0.05$

** -1≤ (Rs) ≤1, -1= perfect negative relationship, 0= No relationship, 1 = perfect positive relationship

V.Discussion

As indicated by the study results, the perception of CSR as the conduct of business operations in a manner that goes beyond mere regulatory compliance and integrates social, economic, environmental, ethical, human rights and consumer concerns into business operations, is highly diffused in the shipping industry. The various viewpoints that consider CSR either as synonymous to sustainability or as the social division of sustainable development have not been, widely, adopted by shipping companies [26]. According to this study, companies’ understanding suggests that CSR is considered to be a multidimensional subject (health, safety, environmental, labour etc.), which embraces various topics and aspects that extend beyond mere compliance with statutory requirements [10]. Additionally, CSR refers to a concept and decision taken at strategic level. Such study results provide important deductions when reviewed in conjunction with companies’ understanding on sustainability. As per research results, sustainable development has been understood as the conduct of business in a way that company’s economic, social and environmental impacts are considered and, as such, business activities are performed transparently and with the aim to eliminate social and environmental impacts. Such finding leads to the deduction that shipping companies have restructured their knowledge and, thus, recognized sustainability as an integrated challenge [37]. Similarly, evidence from testing hypothesis $H_2$ indicates that shipping companies’ current standpoint on CSR is fully aligned with contemporary understanding on sustainable development (as defined under its triple bottom line approach) [18]. Additionally, the positive relationship between our dependent and independent variables (as indicated by correlation coefficient (Rs) measure, 0.526) denotes that the more companies appreciate sustainability under its three dimensions, the more they comprehend CSR as a voluntary and beyond compliance business model that integrates sustainability challenges.

Shipping operations have been mostly governed and ruled by typical maritime statutory standards and Conventions [20]. According to Yuen and Lim (2016), the non-adoption of CSR by shipping companies is, primarily, attributed to the ample existing regulatory standards, which are considered sufficient to address social, health, safety and environmental matters in the maritime industry. As a matter of fact, the burden of regulations forces maritime companies to devote most their time complying with existing statutory maritime regulations, rather than exceeding them, though, i.e. the adoption of voluntary CSR/sustainability Standards [42]. However, as this study has revealed, CSR and sustainability principles have been raising their ground into operating practices and procedures of shipping companies, through their incorporation into safety management systems. In other words, shipping companies have, progressively, commenced formulating their SMS, based on the provisions of CSR and sustainability Standards.
Similarly, results from testing hypothesis $H_2(a)$ and $H_2(b)$, allow us to confirm that engaging CSR and sustainability principles into an organization’s policy, urges companies to transform their traditional approach to SMS and incorporate into it relevant CSR/sustainability provisions. Furthermore, the positive relationship identified between our dependent and independent variables (as indicated by contingency coefficient ($C$) values $0.651$ and $0.615$) signifies that the more we increase CSR principles engagement within an organization, the more we raise the integration into company’s SMS the provisions of a CSR/sustainability Standard. It is worth commenting at this point that, according to our study, such growing integration into SMS of the provisions of CSR and sustainability Standards has not been, essentially, accompanied by companies’ desire to achieve official certification against an approved industry Standard [3]. Such a stance is, potentially, attributed to the voluntary and beyond compliance perceived character of CSR notion which, along with the adequacy of existing maritime legislation to deal with CSR and sustainability challenges, deters shipping companies to seek certification against an official CSR/Sustainability Standard [42].

VI. IMPLICATIONS AND LIMITATIONS

A. Implications

The main aim of this study was to investigate perceptions and practices associated with the application of CSR and sustainability developments in the shipping industry, and, specifically, in the tanker and dry bulk shipping sector. Further to our research findings, this study advances our insight and enhances our understanding on CSR and sustainability notions in shipping. Accordingly, the first implication relates to the identification of CSR as a beyond regulatory compliance and voluntary initiative that shares several aspects of business operations (i.e. social, environment, health, labor etc.). In terms of sustainability, it has been, without doubt, recognized by shipping companies as an integrated economic, social and environmental approach to ensure business viability. Being aware of such reasoning, practitioners can use this knowledge and consider CSR as a facilitator and vehicle in their attempt to integrate sustainability in their operations. Thus, bearing in mind such interpretations can assist to overcome barriers and practical issues generated by their implementation. Moreover, study findings could constitute a good starting point for researchers and academics to build on such conclusions and investigate further various generated interactions, practical implications and implementation issues.

Policy makers and regulators can employ study findings and formulate effective and practical CSR and sustainability regimes that would assist shipping companies to achieve their objectives. A fundamental idea stems from the recognition of CSR as a strategic, voluntary and beyond compliance approach that integrates sustainability elements. Such a finding, viewed in combination with the fact that shipping companies have not sought official certification against an approved CSR standard, although the vast majority of them have adopted CSR principles into their policy, demonstrates shipping industry’s unfavourable stance towards the formulation of a new mandatory CSR regulatory regime. In support to this view has been also the fact that the vast majority of shipping companies has already incorporated into their SMS the provisions of CSR and sustainability Standards, without having, primarily, been officially certified. Therefore, policy makers and regulators should direct their efforts in advancing companies’ theoretical and practical awareness on sustainable development requirements and CSR implementation and reporting techniques, rather than establishing a new statutory CSR regulatory regime.

Clarifying theoretical and practical dimensions of CSR and sustainability can, positively, facilitate ship managers into their day to day operations and provide them with practical solutions. Bearing in mind research findings, ship managers should, primarily, adopt CSR at strategic level. Sustainability objectives need to be reflected into company’s safety management system and, therefore, a business operating model, founded on CSR principles, has to be, subsequently, developed. Secondly, the non-official certification against a CSR standard should not be seen as a factor that decreases company’s ability to, effectively, deal with sustainability challenges. However, modernization and adoption of alternative integrated CSR measurement and reporting methods refers to an area that shipping companies need to consider and improve, in order to meet latest CSR and sustainability measurement and reporting standards requirements.
B. Limitations and Future Opportunities

There are some limitations associated with this study. Firstly, our research does not take into account opinions of other shipping stakeholders, such as charterers, Flag Administrations, Port States etc. As such, results cannot be generalized and compared with the views of such important industry stakeholders. Therefore, additional research is recommended in order to take into account further entities, with the aim to enrich even further study findings. Secondly, the element of subjectivity that characterizes perceptions, awareness and practices of CSR and sustainability calls for further research and engagement of qualitative information. In that sense, it is encouraged the further investigation of actual companies’ procedures, policies, operating practices, management systems structure etc. so as to ascertain ‘how’, practically, CSR and sustainability is captured and implemented throughout shipping operations. Thirdly, conclusions drawn by this study should be also considered in conjunction with CSR and sustainability standards and practices employed by other industries (i.e. aviation, chemical industry, oil & gas etc.). The objective would be to provide further insights, compare CSR in shipping with other industries, discover gaps and provide solutions that will overcome barriers and facilitate CSR and sustainability implementation in shipping.

To sum up, it can be concluded that our research findings are valid for the sample of companies investigated and reflective of their personnel responses against statements in the questionnaire. The fact that shipping companies are globally based gives us the flexibility not to restrict study results to the context of a single country or market area. However, although findings suggest that shipping companies have, gradually, increased their awareness and implementation of CSR and sustainability into their operations, though, further research is recommended to address identified limitations.

VII. CONCLUSIONS

Our study intended to illuminate shipping companies’ perceptions and practices related to CSR and sustainability implementation. The relatively recent engagement of the shipping industry with such notions, latest growing trends and regulatory developments in that field, and the limited related empirical studies in the dry and tanker sector, justifies our motivation to research this area. Literature review and empirical research showed that CSR and sustainability are, nowadays, highly diffused and reflected into shipping companies’ policies and operating practices. Maritime professionals appear to be well-versed with CSR concept, which is mainly perceived as a voluntary and beyond compliance approach that, furthermore, integrates sustainability elements. On the other hand, sustainable development is also understood as an integrated notion (economic, social and environmental), which intersects and forms part of CSR concept and can be, furthermore, effectively achieved when it is grounded on CSR principles. In terms of CSR and sustainability implementation, shipping companies, although they have progressively integrated such notions into their policy, however, they are not keen of obtaining official certification against an approved CSR/sustainability standard. Such an attitude could be justified by the plethora and adequacy of existing maritime legislation [42]. Nevertheless, as study findings revealed, shipping companies have moved a step forward and incorporated into their safety management systems the provisions of CSR and sustainability standards and guidelines, in their attempt to achieve sustainability. Though, it should not be overlooked companies’ overall approach to the whole issue, which calls for enhanced information, training, education on sustainability and CSR implementation, rather than development and enforcement of a statutory CSR regime. Besides, the employment of dedicated CSR/sustainability measurement and reporting methods is an area that needs to be further developed, as shipping companies prefer to measure and report their overall performance by using and integrated health, safety and environmental report. Further research on this topic is recommended, focusing on best management practices and effective implementation aspects to be promoted, so as to assist the shipping industry achieving its sustainability goals.

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No potential conflict of interest was reported by the authors.

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Contributing to The Development of Organizational Structures in Shipbuilding Enterprises Through the Application of The System Dynamics Modeling

**ABSTRACT**

The paper highlights organizations and organizational structures as well as relevant factors and characteristics. It presents contemporary trends and structures, including team and process structures. In addition, it describes contemporary trends, such as business process reengineering, outsourcing, and networking.

Ultimately, the aim of this paper is to present and describe the organizational structure of the shipbuilder Brodosplit and explore the effects of the choice of structure on business processes and competitiveness in the market. A performance rating is also provided. By applying two basic principles – abstraction and aggregation – we propose a shipbuilding process development model as a contribution to the organizational structure model of shipbuilding enterprises through the application of system dynamics.

**KEYWORDS:** organizational structure, shipbuilder, system dynamics & modeling

**I. INTRODUCTION**

Organizational structure is the backbone of every organization. Shipbuilders are no exception. The aim of this paper is to provide an overview of the types of organizational structures, from the simpler, traditional structures, to the more complex, contemporary systems. The characteristics and inherent advantages and disadvantages of these structures are crucial, so we sought to emphasize that no structure is inherently right or wrong; rather, the choice of structure is dependent on the factors that affect the organization as well as its needs and characteristics. Shipyards have a distinct position on the market. This makes defining their organizational structure subject to a specific combination of factors.

Shipyards are complex systems with numerous employees who generate complex products. Consequently, they require a decentralized organizational structure with multi-level decision-making to avoid the overreliance of the entire organization and its jobs on a single centralized unit, which in that case must shoulder too much responsibility while managing and monitoring even the most minute processes, which is virtually impossible from the point of view of efficiency. However, given shipbuilders’ long lifespans and the complexity of their products, a certain degree of centralization is necessary to enable the harmonization of all activities as well as the development of a common vision and the specific knowledge that is necessary to generate a product that is as technologically complex as a ship, at all organizational level [11].

As a contribution to the organizational structure model of the shipbuilding company through the application of system dynamics [1], we propose a shipbuilding process development model that is based on the following basic principles:

1. abstraction, and
2. aggregation.

The above principles enable us to break down the business-production process into the following dynamic phases and control events [17]:

1. **SHIPBUILDING CAPACITY SUPPLY** in the global maritime market, which requires access to fresh market information concerning the state of supply/demand as well as mandatory tender
documents and information regarding the strength of the competition and the solvency of contracting entities.

2. SUCCESSFUL CONCLUSION OF THE COMPETITION, i.e. the signing of a contract with a contracting entity, which launches the sub-process of preparing the implementation documentation. Furthermore, this includes specifying materials and production materials, concluding contracts with suppliers and subcontractors, establishing delivery deadlines and quantities, collecting receivables and paying off debts, and establishing the subcontracting dynamics.

3. FINALIZATION OF THE IMPLEMENTATION DOCUMENTATION, including the whole technological implementation documentation, which marks the beginning of production of sections and part of the equipment, and this requires compiling appropriate documentation for the reception warehouse.

4. BEGINNING OF SHIP CONSTRUCTION ON THE SLIPWAY, i.e. laying of the keel as the start of the construction of the hull and gradual fitting-out,

5. SHIP LAUNCH, initiating the final fitting-out and requiring access to equipment and control and handover documentation.

6. SHIP HANDOVER, which requires technical documents in the event of refurbishment due to the ship operator’s complaint.

7. WARRANTY PERIOD FOR THE EXPLOITATION OF THE SHIP, ending upon the expiration of the warranty period.

II. CONTEMPORARY TRENDS AND ORGANIZATIONAL STRUCTURES OF SHIPBUILDING ENTERPRISES

A. Team Organization

There are several types of teams, and their division varies. The selected literature [6] divides teams into 4 types: advisory, action, project, and production teams. Advisory teams participate in strategic decision-making. Due to the long-term nature of these decisions, these teams closely co-operate with top management and supply it with necessary information, but do not have contact with any other unit within the organization. Action teams gather members who possess highly specialized knowledge and skills. They cooperate with other organizational units and are in charge of short-term assignments that get repeated under new circumstances. Project teams have already been mentioned above. These teams consist of members belonging to different branches of the organization who have been temporarily assembled to perform a particular task or implement a project. The most prevalent teams are cross-functional teams, whose main feature is that they consist of highly specialized professionals from various organizational units, and may even include clients, suppliers, or external consultants. These are very flexible units, most frequently formed in order to develop a new product or innovation or carry out research. The literature defines production teams as a group of individuals whose task is to achieve shared production goals, with each individual playing a specific role that is accompanied by numerous incentives and sanctions [6]. These teams are dependent on other units, which makes good coordination among all involved parties an imperative. There are two additional types of teams also mentioned. Self-governing teams are independent of the management and are responsible for their own work performance. However, they are restricted by the goals of the organization in which they operate. Virtual teams imply physical displacement and remote networking of their members. They can perform any of the other teams’ functions, but they are no substitute for face-to-face communication.

Creating a functional and efficient team is not a one-off project, especially if it consists of people who have never cooperated with each other. Every team has a lifecycle, meaning that from the moment of its formation, it passes through various phases and stages, and has its own ups and downs [6].

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As shown in Fig. 1, team development has five phases. In the first phases, formation, the manager of the future team selects its members. This is followed by the members getting to know one another, talk and gather information about the team. The team starts working during the adjustment phase. Members are still not well acquainted, the degree of cohesion is low, and conflict of opinions, characters, interests, ideas, and expectations occurs. This is the most precarious stage of team formation, with teams commonly breaking down or failing to progress past this stage. Those who succeed enter the standardization stage. Conflicts start to abate, while trust and cohesion intensifies. Communication has been established and roles divided, which marks the start of the period of successful operation. The next phase is implementation – here the team performs actual work. The degree of cohesion is high, the members are in balance, and this creates synergy. Tasks and goals are accomplished, thus fulfilling the purpose of the team's formation. This is the stage that every team strives to reach, but many never fully succeed. When the task has been completed and goals accomplished, the team enters the dissolution phase. Of course, a team may fail to complete its task, or the dissolution stage may occur much earlier; for example, if the team fails to push beyond the adjustment phase. However, if the task has been successfully completed, this phase is a natural stage in a team's lifecycle; it leaves members with new experiences and good memories. A team’s trajectory in the real world may not be as linear as theoretically presented here. There are various factors that may affect the normal development of a team or cause regression to a previous phase, such as the departure of a member or members, who then need to be replaced, forcing the team to regroup and readjust. Such development may be triggered by intra-organizational changes, changing tasks, or market fluctuations [6].

Every team strives for efficiency; there is no exception. To achieve this, there are certain prerequisites that the team and its leader must fulfill [6]:

1. setting a clear exalted goal,
2. ensuring an effective structure,
3. competent team members,
4. commitment to the creation of a successful environment,
5. creating a climate of cooperation,
6. achieving the standard of excellence,
7. support and acknowledgment,
8. leadership based on the principles of team leadership.
B. Business Process Reengineering and Process Organization

Business Process Reengineering (BPR) is one of the novel approaches to organizational adjustment. The concept is thought to have originated in the 1990s, although it shares some common points with the earlier concept of Total Quality Management (TQM). The word “reengineering” implies a redesign, which in this case has to do with business processes. In other words, BPR primarily focuses on improving business processes, which are viewed as customer-oriented activities rather than sets of business functions. A business process is generally defined as a set of mutually conditioned activities and tasks which serve to turn input into output [1]. Business process reengineering may be generally defined as a fundamental change of thinking and a radical redesign of business processes that aims to dramatically improve key business parameters, such as costs, quality, services, and speed [7]. Although the nature of reengineering may vary depending on the organization in which it is implemented, the consensus of opinion is that it is a process-focused change of the mode of operation aimed at improving business performance. It, therefore, implies a completely different way of looking at the organization and its processes in relation to the perspective taken thus far, which necessarily implies a substantial transformation, or, as the definition states, fundamental and radical changes.

The main features of reengineering are [7]:

- fundamentally changing the way of thinking,
- focusing on processes rather than structures or functions,
- radically changing the approach to problem-solving,
- striving to change and improve business,
- drastic changes,
- a new beginning,
- reinvention and a dynamic and creative approach to business,
- a radical redefining, reorganization, and redesign of business processes,
- the focus on core business processes.

Although reengineering may be informally likened to redesign or restructuring, it is its own separate concept. The difference is the emphasis on processes rather than functions or structures. Secondly, reengineering does not imply downsizing, although it does results in a shallower organization. Its novel feature is the focus on the core business and outsourcing of all other tasks and activities. The desired goal for the organization is to perfect the key activity or activities, or what it actually does [7]. The need to reengineer co-occurs when there is awareness within the organization that a change of the way of thinking and viewpoint is necessary. Naturally, the root of the desire to change is often uncompetitiveness, inefficiency, and poor business performance, or the existence of a market threat that is urging the company to improve internally so as not to lose its status. There is a need to introduce a change that will help the company be more successful in the adaptation to market conditions, adopt a customer-oriented strategy catering to customer wishes, and improve its competitiveness. In addition to what was already mentioned, the utilization of information technologies also needs to be optimized, as it is impossible to operate in the modern world without it.

![Fig. 2. The Phases of Business Process Reengineering [7]](image)

Fig. 2 shows the phases of business processes reengineering. In the first phase, a vision is created and objectives are set, which is necessary if the organization wants to define what it desires to achieve.
through reengineering. If this phase is not executed with precision, the whole process will probably not make sense and will not yield the necessary results. The second phase deals with the desired, quantifiable results, which is best done through benchmarking, or comparison with the best. This is followed by process redesign and institutional transformation. Lastly, the final phase involves monitoring of reengineered processes [7]. The reengineering process must be carried out by certain individuals. There are three core groups in the reengineering process: the supervisory board or CEO council, the reengineering team (work/process reengineering teams) and the process leader (transformational leader). The Supervisory Board plays a key role and is made up of the organization’s top management, whose task is to develop a strategy and monitor its implementation. Reengineering teams are operating units that implement the process. The optimal team size is between 5 and 10 members, and it is desirable to hit a good ratio of internal (employees) and external team members in order to strike a balance between objectivity and organizational know-how. Team members need to possess the know-how regarding the implementation of reengineering as well as be creative, flexible, and dedicated, have a propensity for teamwork, harbor a vision, and share similar qualities. It is therefore desirable that the reengineering team be made up of only the best individuals. The process leader guides the process and coordinates the teams [7]. Organizations that manage to carry out business process reengineering adopt a process-based organizational structure (Fig. 3).

![Process Organization](image)

**Fig. 3.** Process Organization [1]

Process organization is very shallow and has only a few hierarchical levels. The focus is on processes, which serves to emphasize horizontal relationships, while the vertical ones are minimal. This organization is therefore sometimes referred to as the horizontal organization. The top management team is relatively small and processes are managed by process directors (managers). Teams are responsible for process implementation, and their number may vary relative to the complexity of a task. Teams have a substantial amount of freedom in their decision-making, so they are better able to promptly respond to environmental requirements, i.e. customer demands. Customers themselves are the ultimate focus of such organization since its primary goal is customer satisfaction. Consequently, the teams carry out the entire process, starting with suppliers and ending with customers. For these reasons, the teams need to possess substantial knowledge and be highly informed, since they are also responsible for goal achievement. Naturally, the responsibility is accompanied by rewards for achieved results to motivate the teams and promote teamwork [6].
This organizational structure is suitable for medium and large companies operating in changing and uncertain environments since its flexibility enables such organizations to successfully overcome various obstacles. However, it should be noted that, in reality, one would be hard-pressed to find an organization that is entirely process-based; this structure is usually implemented within the framework of some of the more traditional structures, which results in hybrid structures [6].

Reengineering is a radical and exhaustive process that brings changes to all levels of an organization, so its adoption requires courage, determination, and perseverance. However, if done properly, it brings excellent results.

III. DESCRIPTION AND ANALYSIS OF APPLIED AND IMPLEMENTED INTERNAL CORPORATE MANAGEMENT MECHANISMS

Shipyards have a distinct position on the market. This makes defining their organizational structure subject to a specific combination of factors. Shipyards are complex systems with numerous employees who generate complex products. Consequently, they require a decentralized organizational structure with multi-level decision-making to avoid overreliance of the entire organization and its jobs on a single centralized unit, which in that case must shoulder too much responsibility while managing and monitoring even the most minute processes, which is virtually impossible from the point of view of efficiency. However, given shipbuilders’ long lifespans and the complexity of their products, a certain degree of centralization is necessary to enable the harmonization of all activities as well as the development of a common vision and the specific knowledge that is necessary to generate a product that is as technologically complex as a ship, at all organizational level [1].

Operating in the global market requires us to give some consideration to the environment during the analysis. First of all, the sale function should be separated in order to enable participation in the market where the product must be sold first and produced later. The focus is, as usual, on customer demand. Procurement is another important factor since the cost of materials and equipment makes up to 60% of the ship’s value. In addition, partners and subcontractors are inevitable in the process of production, so today more and more shipyards lean towards outsourcing. Competition is a constant source of pressure that urges a shipyard to improve and advance as well as modify its organizational structure in order to achieve greater efficiency and flexibility. Flexibility is very important when it comes to legislative adjustment, which is the process of alignment with the laws of the home country and responding to any legislative changes. Finally, incessant technological progress is another inevitable factor that the company needs to keep in step with in order to maintain competitiveness. This includes adopting new working methods and techniques, as well as building new types of ships, especially specialty vessels that have been gaining traction recently [6].

Shipyards have for many years been structured according to traditional organizational structure models, such as the functional and divisional structure, but contemporary changes and globalization have forced them to opt for the implementation of more flexible structures. Of these, the most prominent are the project and matrix structure, although they are by no means the only ones. More specifically, due to the above-outlined factors and their demand on the organizational structure, a certain degree of centralization is retained, along with some of the features of functional and divisional organizational structures. It is clear that the basis of organizational structure in shipbuilding enterprises is still the functional structure, which is most suitable for large companies that produce uniform products using the same technology in the same location. Project-based organizational structure has become indispensable when it comes to product realization — meaning shipbuilding — where every product is produced under the supervision of a project manager who manages everything aspect of this venture and reports to the shipyard’s administration. This cuts down on the communication lines, grants better control and greater efficiency, and reduces the probability of error and misunderstanding. Such division enables the shipyard to design each ship as a separate project, with top management never losing control over these processes [6]. Such organizational structure is a functional project matrix structure, as shown in Fig. 4.
Brodosplit was found to truly implement a functional project organizational structure. However, it should be emphasized that the structure is quite fluid and may occasionally adopt various forms, depending on market developments and the needs of the shipyard. Additionally, the functional project structure is observable when viewing the organization from the production side, i.e. if only looking at its core business, namely, shipbuilding. When looking at the hierarchy and organization of legal entities operating within Brodosplit, the organizational structure resembles that shown in Fig. 4.

It may be said that the Brodosplit Shipyard has been successfully implementing a functional project matrix organizational structure. A project team is formed during the construction of each ship. The team is led by a project manager, who coordinates all processes and reports to the top management regarding the results. This has generated strong horizontal relationships and achieved a certain degree of decentralization.

Nevertheless, the vertical chain is still dominant across all other shipyard activities, which is a result of the functional organizational management structure, where the management coordinates sectors, sectors coordinate departments, and departments coordinate units. However, it is this matrix arrangement that enables horizontal communication, since it forces departments to cooperate in order to coordinate all shipbuilding-related activities. Each step, from the sale, to the project design, procurement of materials, shipbuilding that involves multiple specialized units, interior design, installation of equipment, and the launch, requires top-notch coordination and planning, which Brodosplit has achieved due to its organizational structure.

The company’s efforts to keep its structure fluid aid its quest for flexibility. More specifically, as each unit has the option of helping any other unit in the pursuit of a better task distribution and there is the option to outsource a unit to another company as a separate business entity, this ensures flexibility to organize the units as needed in order to optimize resource allocation and minimize costs. This is not easily achieved in a company with over 2200 employees, but Brodosplit has so far been successful.

The precarious position of shipbuilding in Croatia and the failure of European shipyards to compete with the Far East, in conjunction with the EU initiatives, have forced Brodosplit to make a strategic turnabout and, in addition to the building of standardized ships, take up the production of more technologically demanding ships, such as polar cruisers, yachts, luxury sailboats, and naval ships, as well as to initiate projects outside the domain of shipbuilding, such as the "Gate of Venice" project or the construction of wind turbines. By keeping an ear to the ground for developments in the global market, they are constantly on the lookout for market niches that provide opportunities for negotiations new business endeavors. Regardless of the less-than-stellar financial indicators, Brodosplit is striving to increase its competitiveness and strengthen its position on the market through restructuring and the application of the appropriate organizational structure.

IV. CONTRIBUTION TO THE SHIPBUILDING PROCESS DEVELOPMENT WITH THE AID OF THE SIMULATION MODEL

System Dynamics Methodology of simulation modelling is very suitable for computer simulation of behavior dynamics for even the most complex organizational systems. The business-production process...
(PPBP), without doubt, belongs to that group of systems. Furthermore, we will observe the PPBP as a whole, in accordance with the System Dynamics Methodology, i.e. as system consisting of nine relevant sub-systems:

1. Planned process of shipbuilding as a whole (CPPIB)
2. Co-operation, i.e. external flexible labor capacities (KEKRK)
3. Internal performers of work tasks, i.e. work units (IIRZ)
4. Procurement of materials, production materials, machinery and devices to be built into the ship (NM)
5. Existing claims and debts (SPD)
6. Giro account balance, i.e. cash inflows and outflows (SNŽR)
7. Total income, income, profit, expenses, penalties, stimulations (UPDT)
8. Investments in basic and permanent circulating capital (IOTOS)
9. Short terms and long terms loans, i.e. shipbuilding financing sub-systems

Between the aforementioned sub-systems representing the highly-aggregated PPBP structure, there is a number of material, energy and information flows. Those are in fact intercommunication flows of basic material, additional material, machinery, devices to be built into the ship, one’s own staff, sub-contracting flexible staff potential, money, documentation, data on the condition and the change of condition of sub-system elements, and the organizational system of the PPBP and its relevant “surroundings” (global maritime market, as well as national and foreign markets pertaining to staff, money, energy, information, material resources etc.).

By applying the two main principles (approximation and aggregation) it is possible to present the business-production process (PPBP) with the following dynamic phases (process phases – SP) and with discrete control events (discrete event – DD):

1. SP: SHIPBUILDING CAPACITY SUPPLY – PBK in the global maritime market, which requires access to fresh market information concerning the state of supply/demand as well as mandatory tender documents and information regarding the strength of the competition and the solvency of contracting entities.
2. D.D.: CONCLUSION OF THE COMPETITION, i.e. the signing of a contract with a contracting entity, which launches the sub-process of preparing the implementation documentation. Furthermore, this includes specifying materials and production materials, concluding contracts with suppliers and subcontractors, establishing delivery deadlines and quantities, collecting receivables and paying off debts, and establishing the subcontracting dynamics.
3. By concluding the compilation of implementation documentation, i.e. the IIDIOP, which also includes concluding of the compilation of the entire technological implementation documentation, the building of sections and parts of equipment out of the slipway begins. The reception warehouse shall be provided with adequate documentation, whose collection is a requirement for the DD PUTTING DOWN THE KEEL – PK.
4. Putting down the keel – PK is a requirement for the SP BEGINNING OF SHIPBUILDING ON THE SLIPWAY – PGBNN, i.e. the beginning of the construction of the ship’s hull and gradually equipping it. In this phase, it is necessary to provide the warehouses with adequate documentation.
5. By completing the shipbuilding on the slipway, the DD process of launching of the ship – PB begins, which is when the SP FINAL EQUIPPING OF THE SHIP – ZOB is initiated. It is necessary to provide adequate equipment, as well as to provide control and handover documentation.
6. Following the phase of equipping the ship – ZOB, the DD SHIP HANDOVER – PPB is carried out, for which commissioning documentation is required due to possible future improvements following a ship owner’s complaint.
7. Following the handover of the ship – PPB, the DD COMERCIAL USE OF THE SHIP IN THE WARRANTY PERIOD – KKBUGR begins, and it ends with the DD warranty period expiry – IGR.
8. Following the expiry of the warranty period – IGR, the SP COMERCIAL USE OF THE SHIP – KKB begins. This phase comprises the agreed time period (from 8 to 10 years) during which the ship
owner is required to fulfil all of their financial obligations (pay their debts) towards the shipyard, i.e. to pay the full price of the ship. The “commodity credit” given by the shipyard to the ship owner defines the agreed time period.

9. DD Speed (rate) of recovery of the shipyard’s claim – BNPB effects the decrease in the SP pertaining to the shipyard’s unpaid claim – SNPOTB, whose final amount or state equals zero, meaning that the entire process of building a new ship is completed.

In order to carry out the phase of ship launching – PB, the following preliminary phases have to be fully completed: PBK - shipbuilding capacity supply, ending with the signing of a shipbuilding agreement – PU, whose previous state was equal to PU=0, while following the signing of the agreement it changes to PU=1. That initiates the beginning of the phase “compilation of implementation documentation and other preparations” – IIDIOP, as well as the specification of materials and production materials, along with the signing of agreements with suppliers and sub-contractors. Subsequently, the building of sections and parts of equipment begins, and so does the provision of the reception warehouse with adequate documentation, whose collection is necessary for the next PBPP phase, i.e. putting down the keel – PK. If the IIDIOP phase is fully completed, it is possible to put down the keel, and the discrete variable PK equals 1 (PK=0 changes to PK=1), which initiates the next PPBP phase i.e. PGBNN – beginning of shipbuilding on the slipway. In order to carry out the launching of the ship – PB, the previous PGBNN phase has to be fully completed. If said condition is met, the variable PB change its value of PB=0 to PB=1, which is how the next PPBP phase of final equipping of the ship – ZOB is initiated.

In the complete model, all discrete variables: PU, PK, PB, PPB, IGR and BNPB, have the initial value of “zero” and the active amount of “one”, which points to intelligent binary control switches that block the next phases of the PPBP process when the value equals “zero”, while if the value equals “one”, they initiate the next PPBP phase.

In other words, the model uses a special and complex logical switch that allows for initial and controll-alogical PPBP management, i.e. a modular-expert computer simulation of managing of the shipbuilding process whose code name is “IKLUPPBP”. It is necessary to point out that all initial SP states (IIDIOP, PGBNN, ZOB, KKBUGR, KK and SNPOTB) or phases equal zero.

A. Example of the system dynamics model – the 5th PPBP phase PB – launching of the ship

It is evident that the characteristic of the PPBP are those of a very complex intelligent management system, which is why a software-modular procedure is used for its realization. The global simulation model of the PPBP is presented with over 250 analogue sub-models, i.e. software modules with a mutually analogue base structural model for every PPBP phase, shown in Fig. 6.
Mathematical-computer model of the 5th PPBP phase

System dynamics simulation model – the 5th PPBP phase:

A PK.K=1

R BRNN.KL=PK.K*NBRNN*SKL3.K

C NBRNN=31712

L PGBNN.K=PGBNN.J+DT*(BRNN.JK-ZPNN.JK)

N PGBNN=0

R ZPNN.KL=DELAY(BRNN.KL,VKPNN)

C VKPNN=30

L SZPNN.K=SZPNN.J+DT*(ZPNN.JK)

N SZPNN=0


C PS3"A"=24421000

C PS3"B"=3291000

A SKL3.K=CLIP(0,1,SZPNN.K,PSPNN)

SKL3= logical (expert) switch which controls the carrying out of the planned shipbuilding process and stops it in due time
All others phases of the shipbuilding process, as well as active participation of all those involved in the shipbuilding production process, are presented through analogue software modules functioning as an “organizational unit” with additional sectors and sub-sectors: claims, debts, giro account, penalties, stimulations, total income, expenses, prices, profit, basic funds, short term and long term loans.

V. CONCLUSION

The aim of structures and processes is to improve business by increasing efficiency and flexibility, as well as employee satisfaction. If the right organizational structure is selected and successfully implemented, as well as if the necessary processes are carried out, the chances of the organization fulfilling its purpose increase significantly, both in case of a business entity and a non-profit organization.

The shipbuilding company Brodosplit does strive to comply with said objective. As factors do not go in its favor, the journey is quite difficult. However, the right steps have been taken in order to adapt to the environment and achieve better results. The implemented organizational structure is in line with the needs of the shipyard and it provides the necessary flexibility. A strong and centralized leadership has been established, but the horizontal links keeping the organization in balance are also very strong. Coordination is really good, and communication between departments has been established. Naturally, there is always room for progress at all levels, but the idea Brodosplit is guided by follows modern trends and organization science ideas, thus creating the prerequisites for future business success.

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How to Manage Risk - ISO Standard 9001:2015?

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ABSTRACT

The ISO 9001 standard is the fundamental standard for quality management systems and is used by over one million organizations around the world, regardless of the size and type of activity they are doing. Seafarer training and training institutions must have one of the quality management systems, usually ISO 9001. Due to this, it is of great importance to introduce this standard and to maintain it. Quality is today one of the most important characteristics of successful business, and by implementing the ISO 9001 standard, a high degree of quality of products and services is achieved. The paper describes the standard ISO 9001:2015, its advantages and disadvantages. An emphasis is put on determining the risks and measures that need to be taken to minimize such risks. The risks are analysed, on few institutions that organizations face, the problems that arise in risk management, and the risks that the company takes with regard to the organization's operations.

KEYWORDS: quality, standard ISO 9001:2015, risks & quality management system

I. INTRODUCTION

 Nowadays, when processes of production, supply and trade can be located miles away, and people involved in processes do not know each other, quality is of utmost importance for business success. A large number of people, in industrialized countries, depend on the quality of the products or services they use. ISO 9001: 2015 [2] sets new standards for quality management, facilitating the implementation of it, and raising quality to higher level, which leads to higher quality of the final product and better business organization. Risks occur in accordance with standard changes and need to be controlled and maintained. The purpose of the research is to give examples of risks that organizations in Croatia encounter and describe how they adjusted their business to certain risks in order to maintain high quality of the product or service.

II. REASONS FOR KEY CHANGES TO STANDARD ISO 9001:20115

Following the publication of standards from 2008, the ISO organization started immediately with its revision. The main goals were: development of a long-term strategic plan, enhancing the compliance of the ISO standard management system, revitalizing new trends in quality management, data analysis from extensive users’ survey. Systematic review of ISO 9001: 2008 was completed in March 2012. It showed that although there is still a high degree of satisfaction with the current version of the standard, changes are necessary. ISO 9001:2015 standard [6] ensures that the requirements are collected and covered for the next 10 years or more and applicable to all types of organizations operating in any sector. The current focus is on effective management process which gives the desired results. The last major revision in 2008 showed that appropriate changes could be maintained in the environment in which the organization operates, and could improve compatibility and alignment with other ISO system management standards.

By 2015, ISO 9001 standard represented a collection of requirements that needed to be completed and all evidences documented. Regarding the previous revision of standards, this started with analyzes and organization arrangements, although ultimately a part of the standard remained unchanged.

III. RISKS IN ISO 9001:2015 STANDARD

During each major revision of ISO standard, a new concept is introduced. It enables implementation of already established quality management system. The term "risk-based thinking" or risk management, which is the basis of ISO 9001:2015, implies risk identification, risk analysis, categorization, control and
risk reassessment. Improvement and advancement is the purpose of risk management. The ISO 9000: 2015 standard defines the risk as an "effect of uncertainty". The word risk is mainly used when there is an unexpected event that is likely to occur. However, the consequences of the risk may be negative and positive. Standards together with risks often have opportunities. The risk concept in the previous standard edition was only implicitly present, e.g. through planning, review and improvement requirements. This revision is explicitly mentioned and embedded in the overall management system [4]. The organization can choose methods and tools that meet its needs.

Organization’s activities involve dealing with certain risks, and entrepreneurs often rely on experience and intuition in risk management, making business more demanding. It is more important to quantify the risks that might disable organization in achieving its desired potential. In order to minimize and maximize the positive outcomes, it is necessary to design systematic and good quality risk management. Due to rapid and frequent changes, the term uncertainty emerges as a phenomenon that has a significant impact because it is difficult to be measured and cannot be shown with the understandable measuring unit. Therefore, the concept of risk is measurable in the form of probability [%]. It is possible to say that the risk represents the unit of uncertainty, and since it can be measured, it is possible to manage the same. The risk contains three essential elements: the perception of whether an adverse event may occur, the likelihood that it will occur and the consequences of the event that may occur. In addition to observing the negative risk, consideration should be given to its opportunities and to exploit the positive effect of its occurrence. Lost opportunities are also considered as a risk. Therefore, in assessing a risky situation, the benefits and disadvantages of a potential outcome are estimated. The risk concept has always been implicit in ISO 9001. This revision makes it more explicit and incorporates it into the overall management system. Reflection based on risk analysis can help in identifying opportunities that can increase the satisfaction of its customers or those offering services. According to new standard, organizations are required to understand the context of internal and external processes. One of the key tasks of the quality management system is to act as a preventative tool. An expert in risk management with over 20 years of experience working with ISO standards, Ph.D. Zdenko Adelsberger notes the lack of relevance, inconsistency and a series of questions regarding risk management within ISO 9001: 2015. He explores how to implement risks and opportunities. An attempt is seen in ISO 9002:2016, ISO 9001: 2015 implementation guidelines. He further states that some facts are “practically unworthy” and concludes with a suspicion that this request will comply only with formal requirements. For a deeper risk management understanding, he proposes the ISO 31000 standard. It is defining the generic risk management process for all areas of application [1].

IV. EXAMPLES OF RISKS IN 9001:2015

A. THE CROATIAN REGISTER OF SHIPPING
The Croatian Register of Shipping is a Croatian independent, non-profit public institution engaged in activities related to the protection of human life and property at sea, prevention of pollution of marine environment and certification of quality management system with the head office in Split. ISO 9001: 2015
standard required investment of human and material resources. It brought quality improvement in organization and all interested parties, long-lasting utility and hence certain risks [9]:

A number of preconditions should be met when ensuring the transparency of work, impartiality and integrity of the Croatian Register of Shipping and its staff. Relationships of owners and all interested parties must be at a high professional level in order to avoid any kind of benefits. There is a need for self-assessment and independent certification within the organization. Clients should not be financially dependent on the organization. Excessive attachment of the Croatian Register of Shipping or staff with interested parties and the possible intimidation or blackmailing of staff by the witnesses seriously leads to distortion of transparency, impartiality and integrity of the organization.

Create an interested and motivated team of technical staff with a low fluctuation rate, oriented to an adequately rewarded career in the Croatian Register of Shipping. In order to avoid the risk that brings potential unwillingness and reluctance of staff to adapt to new business requirements it is also required to provide the resources that are available to meet new services and regulations and to provide some financial stimulus and innovative plans that will affect the efficiency of the staff itself.

When selecting, employing and training, it is necessary to ensure the availability of high-quality candidates to meet certain jobs due to poor demographic trends in society, weak shipbuilding, and shipping industries. This condition is important in order to avoid employing of an inadequate staff that poses a risk to the organization's business. It is also necessary to insist on further training of the staff.

Provide adequate infrastructure and working environment to maintain service compliance, workplace and environmental protection - one of the most important potential risks because it directly affects the image of the organization. It is of utmost importance to ensure that working conditions are as good as possible in order to minimize the accident or injury rate. As a consequence of the risk, there is possibility of lack of safety awareness and environmental protection.

Implement services by its own employees, key research and certification features defined in the Croatian Register of Shipping annual plan. The risk of poorly performed services can lead to a lack of trust among stakeholders. To ensure the effective implementation of the services it is necessary to implement IT sector of the Croatian Register of Shipping, and to enable the upgrading of electronic reporting systems from remote locations.

Introduce efficient new services as a response to stakeholders’ demand. There are frequent changes to international maritime regulations and specific regional environmental requirements. Is necessary to adapt to new requirements and regulations in a simple, fast and efficient manner.

B. Faculty of Maritime Studies in Split
As well as other organizations, Faculty of Maritime Studies in Split has also implemented ISO 9001:2015. All the risks were recognized earlier and certain preventive measures were implemented.

Examples of risks that the faculty faced with:

- economic changes (lower growth, reduced tax revenues, limited quality of existing services)
- innovation non-imposition which results in reduced quality of service compared to others
- loss or misuse of funds (fraud, improper behavior)
- unsuccessful or delayed introduction of new technology
- failure of the supplier or contractor
- incompetence of employees
- project delays.

All risks are defined through the likelihood of the risk incurrence and its seriousness i.e. its direct effect on business and achievement of goals. During the teaching process, the greatest degree of urgency occurs through innovations non-imposition, which directly affects the quality of services compared to competition. The Faculty implements its own teaching process with new technologies, tries to keep up-to-
date teaching to maximize risk assessment. In the case of activity processes in the library there is a certain risk of unauthorized use. However, the level of risk itself is acceptable as the Faculty relocated to new modernly equipped premises and all preconditions required for high quality are satisfied. The lack of new technologies and innovations is defined as the highest risk for IT support. Still, the level of risk itself is low; all rooms are equipped with modern IT equipment. In the case of general and legal affairs and accounting process, there is a high exposure to risk associated with inadequate number of employees, which leads to inefficiency and ineffectiveness. Assessing the total exposure to this risk is high, and in order to reduce the risk it is necessary to recruit new staff. The greatest danger comes from the risk of non-compliance with law and procedures. It is also necessary to identify any occurrence or non-compliance with the legal framework and the like, and to determine causes of the occurrence. Finally, corrective measures should be introduced.

V. CONCLUSION

This paper highlights the importance of quality today. Organizing activities have a mission and aim of serving the needs to the end-users. In this way the best possible services and products are shown in mutual benefit. In order to achieve the optimal level of quality, a large number of organizations have implemented the ISO 9001:2015 standard, which helps organizations to manage quality and business processes systematically. There are a large number of standards and rules that precisely describe risk management, self-management methods, and risk assessment methods. They also show that high quality risk management is a very important discipline that should not be neglected.

Organizations around the world are focused on risk issues that may have a negative impact on business. It is concluded that risk prevention and risk control are the best methods to prevent potential consequences.

One of the examples is the Croatian Register of Shipping. It is independent, non-profit public institution and its activities are related to the protection of human life and property at sea, prevention of pollution of marine environment and certification of quality management system. ISO standard brought improvement in quality, long-lasting utility but also certain risks. Relationships of owners and all interested parties are at high professional level. There is a need for self-assessment and independent certification within the organization. Personnel must be at an impartial level, without own interests, and free of any potential financial interests with clients. Faculty of Maritime Studies in Split has also implemented ISO 9001:2015. The risks such as project delays, misuse of funds, economic changes etc. were recognized earlier and certain preventive measures were implemented to keep the risks at the lowest possible level. The IT support process introduction was of crucial importance for faculty operations.

Risk management brings numerous benefits such as identifying and analyzing market-related risks, facilitating communication of operational risks and the potential consequences of their occurrence, increasing customer’s and investor’s confidence, and better management of suppliers.

REFERENCES
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Impact of the Offshore Market Crisis on the Performance of Croatian Maritime Shipping Companies

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ABSTRACT
The recent global economic crisis started in 2008 as a subprime (high-risk) mortgage market crisis in the USA and developed into a large-scale international economic crisis, affecting banking systems, financial institutions, insurance, funds and stock exchange. The crisis was followed by the Great Recession and the Eurozone crisis, impacting both the service and production sectors. The global crisis was a very complex phenomenon, not only with regard to its scope and scale, but also due to the complexity of global economic relationships. International companies and all companies performing on international markets have been affected by the events, directly or indirectly related to the crisis, which have been occurring on their respective markets. After a brief overview of the causes, scope and consequences of the global economic recession, this paper provides an analysis of the effects of the offshore market crisis on the performance of Croatian maritime shipping companies (in this paper that are Atlantska plovidba d.d., Jadroplov d.d., Lošinjska - Holding d.d., Brodospas d.d.).

KEYWORDS: crisis, offshore market & maritime shipping companies

I. INTRODUCTION
Since the dawn of time, the life of man has been affected by crises – religious, political or economic – to a lesser or to a greater extent. They have always been part of our existence. The economic crisis that broke out in 2008 was the first truly global crisis. A number of causes led to a financial crunch in the United States, followed by a recession that affected most of the service and production sectors all over the world, including North America, South America, Asia, Africa, Europe and Eurozone. As Croatian maritime shipping companies operate across the world, this paper analyzes the extent to which the disturbances in offshore markets contributed to the performance of the Croatian maritime shipping companies.

II. FINANCIAL CRISIS
There are numerous factors that may trigger financial crises in various countries and their dissemination to other parts of the world. The experience of financial crises in Europe, Central America, Asia and Russia in 1990s, and the subsequent analyses, indicate common causes of these financial crises which were pronounced to a greater or lesser extent in each individual situation. The causes may include inadequate government policy on the state financial systems, government policy on influx of foreign capital, or government macro-economic policy. There is always an interrelation of various factors that eventually lead to the emergence and development of a financial crisis.

The most important factors that ultimately result in a crisis include: increased debts and mortgages, exogenous international negative shocks (such as fall in the export prices in the global market or increase in interest rates causing difficulties in debt servicing), exchange risk exposure (currency devaluation threat), volatility of international short-term financing, and infectious global dissemination of crisis, when the latter appears in one country and easily spreads around due to the interrelated trades and finances. Not all disturbances in the financial market should be considered as financial crisis – just the ones hindering the performance of the essential tasks entrusted to financial systems [4].

The recent economic crisis started in 2008 as a subprime (high-risk) mortgage market crisis in the USA and developed into a large-scale international economic crisis, affecting banking systems, financial institutions, insurance business, funds and stock exchange. The crisis was followed by the Great Recession and the Eurozone crisis, impacting both the service and production sectors. The growth rate of the
world GDP declined, real-estate prices fell and various industrial sectors started making huge losses. There were a number of indicators warning that the global economy was threatened by a serious recession. These indicators were very complex, not only regarding the scope and scale, but also pertaining to the complexity of global economic relationships. The crisis spread across the continents. In the European Union, it heavily affected the real economy, which gave rise to adverse feedback effects in financing, real estate value and loan performance. Some of the EU members appeared to be more vulnerable than others. This resulted in differences in their actual standings and exposure to the real-estate “balloon”. The crisis had negative impacts not only on the economic activities but also on potential outputs, i.e. production levels with regard to the full use of available workforce, capital and technology, which had a huge impact on long-term growth and fiscal situation.

The stable values of the economic growth and job creation, which had been experienced in the previous decade, were simply erased. GDP in the EU (and in the Eurozone) declined by 4% in 2009, industrial production fell to the values recorded in 1990s, while 23 million people – or 10% of the active population – lost their jobs. For millions of people the crisis was a great blow that revealed the fundamental weaknesses of all economies [8]. Governments and central banks of the affected countries tried to cope with the crisis and bring the ongoing adverse processes under control. Initially their reactions were mild but, as the crisis continued, the banks and states became very determined: the liquidity of the banking sector was ensured and some banks were taken over. However, the crisis was too serious to be overcome easily, and many arduous and painful measures were taken to bring the situation under control and to mitigate negative effects of the crisis on the real economy.

III. OFFSHORE – DEFINITION AND DEVELOPMENT

Originally, the English term offshore means “moving or located away from the shore”, i.e. outside of national boundaries. In today’s practical economy, the term refers to business activities, including banks, corporations, investments and deposits, which are legitimately transferred to foreign countries in order to avoid national tax laws or to enjoy relaxed regulations, cheaper labor, and the like.

In the terms of business activities, offshoring is similar to outsourcing. It involves the relocation of a business process, or a part of it, from one country to another – manufacturing or supporting processes, such as accounting, call centers, and other services. The offshoring company takes advantage of more favorable operating conditions in a foreign country (cheaper labor and material, lower overheads, loose regulations...), which often results in significant cost savings and stronger competitiveness. Offshore investing refers to investors residing outside of the country in which they are investing. Offshore banking involves the securing financial assets in foreign countries in order to avoid taxes or to make it more difficult for these assets to be threatened by a person or entity in the home nation.

Many countries and territories have become offshore financial centers (OFCs) with favorable regulatory standards that improve the flow of capital and facilitate international business transactions. Offshore companies are able to participate in legal affairs without major assets. Typically the process of registration is quite simple, requiring personal information, bank account and PO box. The trend in growing tax rates is one of the reasons for the development of offshore financial centers across the world, although almost all large home nations provide some sorts of tax benefits [9].

The term OFC initially referred to the financial centers in Caribbean territories (Bahamas, Bermuda, Cayman Islands...), Liberia, Jersey, Guernsey, Isle of Man, and other countries, zones or territories which had no financial infrastructure whatsoever. Multinational banks, corporations and large US banks established their subsidiaries there to carry out financial operations. These offices were not bound by strict regulations and restrictions regarding the financial reserves and requirements on financial transaction operations that were in force in their home countries. On the contrary, offshore centers offered reduced taxes and foreign currency control, unlimited flow of capital and free movement of interest rates [9].
Today, any country or jurisdiction with liberal regulations on financial transaction operations, providing financial services to non-residents, is considered an offshore center. In 1981, an offshore zone was established in New York, USA, enabling American non-residents to perform euro-currency transactions without being subject to strict US regulations. Similar offshore zones providing benefits for non-residents are available in London and Tokyo. Important financial markets include Hong Kong, Singapore, Luxemburg, Panama and Bahrein, which started as offshore oases and developed into main financial centers over time.

Modern offshore areas, or markets, can be divided into several groups [9]:

- Large international markets such as London, Tokyo and New York, which have ensured special financial privileges for their non-residents through business liberalization;
- Centers that do not have the characteristics of large international markets due to the lack of developed financial infrastructure and strong national financial market. These classic financial markets and tax havens include Bahamas, Bermuda, Cayman Islands, Malta, Cyprus, Gibraltar, Puerto Rico, etc.;
- Centers that are not zero tax regimes but have established superior banking and financial infrastructure – like Luxemburg, Hong Kong and Singapore. These small jurisdictions have become important financial markets due to strategic and other advantages.

At the moment, Europe is home to a dozen significant offshore centers, including Cyprus, Dublin, Gibraltar, Guernsey, Isle of Man, Jersey, Liechtenstein, Luxemburg, Madeira and Malta. Individual offshore centers may vary in types of business activities, but all of them offer facilities for operations in the areas of banking, mutual funds, insurance, shipping, mediation and direct investment.

IV. IMPACT OF OFFSHORE MARKET CRISIS ON THE CROATIAN SHIPPING COMPANIES

A number of various world markets have still been recovering from the world crisis that started in the United States in 2008 and spread globally. The 2008 crisis, followed by the global economic recession, has still been felt in many markets. It represents a very complex phenomenon, not only with regard to its scope and scale, but also due to the complexity of global economic relationships. International companies and all companies performing on the international markets have been affected by the events, directly or indirectly related to crisis, which have been occurring on their respective markets. As Croatian maritime shipping companies operate across the world, their business activities have also been influenced by the disturbances in offshore markets. Here is an analysis of the impact of the crisis and recession on the performance of the Croatian maritime shipping companies.

A. Jadroplov d.d.

Jadranska slobodna plovidba, now called Jadroplov, is the shipping company founded in 1947. Initially the company was intended for coastal navigation and trading in the Adriatic Sea. The headquarters was situated in Rijeka, along with the headquarters of other Yugoslav shipping companies. The rapid growth of tonnage and trade in the Adriatic ports was constantly at odds with the socialist concept of centralization of the national merchant fleet but, with time, practical business reasons prevailed. In 1956 Jadroplov headquarters was moved from Rijeka to Split, the city which twenty years earlier used to accommodate eleven shipping companies, including Yugoslav Lloyd, the largest shipping company at that time. Shortly after that, the company was licensed for transportation of passengers and goods in the international trade. After transformation of the state-owned companies in 1993 it became a joint stock company. Its registered business activities include [5]: repair, reconstruction of ships, open and short-sea carriage of passengers, open and short-sea carriage of cargo, road haulage of cargo, transshipment (loading / discharge) of cargo in ports, transshipment (loading / discharge) of cargo at wharfs / quays, warehousing of goods, marine trade services, travel agency and tour-operating activities, other tourist services, other agency business in trading area, renting of own real-estate properties, car renting, renting of other land means of transport, renting of vessels, renting of office machinery and equipment, computers included, consulting on hardware, data processing, data base creation, technique and technology research and experimental development, market analysis and public research, business and man-
agement consulting, technical inspection and analysis, promotion (advertising), secretarial and translating services, education of adults and other training activities, organization of courses and seminars for acquiring certificates of competence and seafaring skills, retail trade, public, warehousing services, brokerage in domestic and international market and other business activities. The total revenue of Jadroplov d.d. from 2008 to 2014 is shown in Figure 1.

Even without an in-depth analysis of the Jadroplov d.d. turnover, it can be noted that the offshore market crisis heavily affected the company’s performance, which remained low until the year 2014. As can be seen in Figure 2, the EBIT of Jadroplov company decreased from 2012 to 2015, which shows that the effects of the global crisis were also felt in 2015. Gross profit of Jadroplov d.d. from 2013 to 2017 is shown in Figure 3.

B. Atlantska plovidba d.d.

Atlantska plovidba d.d. is a shareholding company engaged in international transport of passengers and cargo. The company was founded in Dubrovnik in 1955. Its registered business activities include [1]: deep-sea and coastal transport, internal river and waterway transport, other associated services in maritime and river transport, passenger and tour-operator services, other transport agency services, rental of own real-estates, rental of ships, scientific research and development, accounting and auditing services, tax consultancy, market analysis and public research, business and management consulting, secretarial and translating services, hotels and motels, camps, restaurants and canteens, wholesale and brokerage, retail and repairs of household appliances, import and export of vessels, ship equipment and inventory, technical equipment and spare parts for maintenance, servicing and repairs, import and export of office equipment and stationary and other business activities.
The corporate policy of Atlantska plovidba d.d. is to maintain an independent position in the dry bulk market and to consistently meet the needs and expectations of Croatia’s national and international clients. The total revenue of Atlantska plovidba d.d. from 2008 to 2014 is shown in Figure 4.

Fig. 4. Total revenue of Atlantska plovidba d.d. over the period 2008-2014 (in thousands of Croatian kuna – HRK). Source: authors, according to Atlantska plovidba d.d. annual financial statements, available at [φ]: http://www.atlant.hr/data/υψφχόχόόωτ_φύψ _mala_NE-REVIDIRANI%φτIZVJESTAJ%φτPOSLOVODSTVA%φτI-XII-φτυψ(AP).pdf

As is the case with Jadroplov d.d., it can be noted that the offshore market crisis heavily affected the performance of Atlantska plovidba d.d., which has been in decline since 2008. EBIT of Atlantska plovidba d.d. from 2011 to 2015 is shown in Figure 5. Compared with Jadroplov d.d., Atlantska plovidba d.d. saw a decline in EBIT in 2012 compared to 2011 while in 2013 EBIT was higher than in 2012, followed by new falls in 2014 and 2015. The effects of the crisis can still be felt. Gross profit of Atlantska plovidba from 2013 to 2017 is shown in Figure 6.

Fig. 5. EBIT of Atlantska plovidba d.d. from 2011 to 2015. (in HRK) Source: www.poslovna.hr [10]

Fig. 6. Gross profit of Atlantska plovidba from 2013 to 2017. (in HRK) Source: www.poslovna.hr

As can be seen in Figure 6, gross profit of the company decreased from 2013 to 2014. In the following year, however, the performance improved and gross profit increased, resulting in positive balance in 2017 after many years. For Atlantska plovidba, the year of 2017 was a turning point that indicated the end of the crisis.

C. Lošinjska plovidba – Holding d.d. for sea shipping, shipbuilding and tourism
This company was established in 1958 by merging two sea shipping companies – Obalna plovidba [8] from Rijeka and Lošinjska plovidba from Mali Lošinj. The company operated 38 wooden boats and started opening regular lines across the Mediterranean. The performance of the company steadily grew through acquiring second-hand steel ships of larger tonnage, ordering newbuildings such as M/V Illovik in 1961 and M/V Srakane in 1962, and opening regular runs, particularly between Croatian and North Africa. These ports became the company’s main market because of the size of the vessels and the distribution of Mediterranean runs among the shippers. In addition to the ports of Lybia, Algeria and Turkey, served by 25 vessels, Lošinjska plovidba maintained regular lines to the Near East using five to six ships. This was the time of successful performance of the company’s fleet that comprised 30 liners.
In the early 1990s, following the collapse of the former Yugoslavia and during the Homeland War in Croatia, the company’s performance considerably deteriorated due to the loss of main markets and the complete halt of transit through national ports. In order to survive, the company had to sell old ships and to engage the remaining fleet in tramp trade. The first essential step toward the recovery was the establishment of the feeder service in 1998, with several vessels regularly calling at the ports of Rijeka, Ploče, Bar, Gioia Tauro, Venice, Taranto, Malta and Kopar. The service was closed in 2008 when the company switched to handy and handy max ships (28,000–42,000 DWT) and entered dry bulk markets across the world [6]. Figure 7 presents the performance of Lošinjska plovidba – holding d.d. during the crisis in offshore markets.

EBIT of Lošinjska plovidba-holding d.d. from 2011 to 2015 is shown in Figure 8.

Comparing the company’s performance with Jadroplov d.d. and Atlantska plovidba d.d., a notable difference can be seen in EBIT movement. In 2011, EBIT reached the lowest values, but recovered over the two following years, only to start falling again after 2013. The analysis of the total revenue of Lošinjska plovidba – holding d.d. during the period 2008-2014 indicates that the company suffered the same fate as Atlantska plovidba d.d. and Jadroplov d.d. The global recession and the crisis of offshore markets produced adverse effects on the company’s performance, with a downward trend starting in the year 2009. Gross profit of Lošinjska plovidba - holding d.d. from 2013 to 2017 is shown in Figure 9.

As can be seen in Figure 9, gross profit of the holding decreased from 2013 to 2015, which shows that in 2015 the effects of the crisis were still felt, whereas in 2016 the situation became better and gross profit increased.

D. Brodospas d.d.

Brodospas was founded in 1947, with the task of cleaning Croatian ports, shipyards and waterways from numerous remains of World War II, impeding the safety of navigation along the national shores. In early days, the headquarters of the company was in Rijeka, but in mid-1950s it moved to Split. Numerous logical and sound business, naval and technical activities were developed: underwater activities, diving,
handling sunken and dismantled floating vessels, lifting and transporting heavy goods, calling at the Adriatic ports and then seafaring across the seas of the world. Brodospas then focused on specialized maritime-technical services for drilling platforms at sea as well as on freight transport. In early 1970s, and much more intensely in 1977, Brodospas became involved in offshore activities. The latter is a short term that actually involved exploration and exploitation of oil and gas exploration sites, thus merging and coordinating all offshore maritime and technical activities that generated most of the company’s revenues. Once a state-owned enterprise and now a joint-stock company, Brodospas has a highly experienced and capable marine crew and owns eight specialized vessels, namely Anchor-handling / Tug / Suppliers (AHTS), including the Brodospas Sun, Brodospas Moon, Brodospas Star, Brodospas Storm, Rainbow Brodospas, Ibis Brodospas and two newly built, modern, and robust vessels, the Brodospas Alfa and Brodospas Beta). Services provided by the above vessels and their crews include: transportation / supply of drilling rigs with the required materials; towing platforms, both on long and short lines; positioning and anchoring of platforms, always in line with the highest standards with reference to quality of staff, technology, equipment and safety at sea. At the beginning, the services were provided through the long-term contracts with Zagreb-based INA national oil company, in the area of the Adriatic and Mediterranean. Since 1991, the activities have been extended to the North Sea and the Middle East, and later to West African and other offshore locations. Offshore services provided to many major oil companies such as AGIP, CHEVRON, TEXACO, SHELL, OCCIDENTAL, AMOCO, CONOCO, SAMEDAN, SAIPEM, CROSCO, INA-NAFTAPLIN, EDISON GAS, INAGIP, PETROBEL, MICOPERI, BRITISH GAS, AGIP GAS, LIBYA, AGIP OIL LIBYA, and also across the “spot market” (call services) of the North Sea, provided to BRITISH PETROLEUM, STEWART OFFSHORE, LAMBERT BROTHERS, JACOBS, ROWAN and other companies have always been performed to the partners’ full satisfaction. Brodospas’ performance was confirmed by excellent grades given by NOBLE, DENTON and ASS. Two vessels were engaged by the British Coast Guard and were proclaimed the best ships of the year on several occasions, during their operation in the North Sea. Specialized tug suppliers have the highest class of registry institutes (Bureau Veritas and Croatian Registry of Shipping). Brodospas vessels are equipped with high-capacity fire-fighting equipment as well as with cutting and welding equipment. Furthermore, two new modern vessels for the rig supply, tow and anchor handling, are fitted with the equipment for collecting oil from the sea surface and with the most modern ship management system (via satellite), i.e. the so-called “dynamic positioning” (DP2). EBIT of Brodospas d.d. from 2011 to 2015 is shown in Figure 10.

Figure 10 shows the value of EBIT dramatically falling 2015, compared to the previous year. Clearly the crisis on the offshore market, which was the main source of corporate income, heavily impacted company’s EBIT, operations and performance. Gross profit of Brodospas d.d. from 2013 to 2017 is shown in Figure 11.

As can be seen in Figure 11, gross profit of Brodospas d.d. holding decreased between 2013 and 2015. Apparently, the effects of the 2008 global crisis decreased after that, so that a recovery can be observed in 2016 when the company’s gross profit increased. For Brodospas d.d. the year of 2017 marks the moment when the crisis ended.
When studying the performance of all the above analyzed Croatian shipping companies, it can be noted that the year of 2015 was the time when these companies experienced the effects of the global crisis to the largest extent.

V. CONCLUSION

The recent global economic recession has deeply shaken the world economies and all elements of the economic architecture. There are numerous factors that gave rise to crises in various countries and their dissemination to other parts of the world. Although the governments and central banks of the affected countries have been continuously taking comprehensive and painful measures to deal with the crisis and to bring the ongoing adverse processes under control, the recovery of the economies has been slow and the effects of the financial crisis and global recession are still felt.

As a number of Croatian maritime shipping companies operate around the world, they experienced the same fate as the other players in the offshore markets. This study presented an analysis of four shipping companies – Jadroplov d.d., Atlantska plovidba d.d., Brodospas d.d. and Lošinjska plovidba holding d.d. – and the extent to which the disturbances in offshore markets contributed to their performance. Insights into their annual turnovers from 2008 to 2015, i.e. their revenues and losses, revealed that the offshore market crisis heavily affected their performance. The year of 2017 was the turning point when the crisis and its adverse impacts ended for most of the companies.

REFERENCES


ABSTRACT
Nautical tourism has been rated as the most promising selective type of tourism, which has, over the past decades, dramatically expanded worldwide.

Montenegro has gained a significant position in the marina industry market in the last ten years, primarily due to its geographical position, climatic conditions and natural resources. Nowadays, Montenegro is an attractive destination for the development of nautical tourism which attracts numerous investments. Mostly, modern marinas in Boka Bay have contributed to the growth of nautical tourism in the area of Montenegro.

This paper analyzes the Montenegrin marinas as the centers of nautical tourism. The analysis relies on the benchmarking method and the data used are the result of secondary research.

The aim of the paper is to get the picture of the current state of this sector and the best example from the practice in Montenegro through the comparison of marinas based on significant benchmarking criteria. The selection of the criteria is defined from a functional, spatial and environmental aspect.

KEYWORDS: nautical tourism, benchmarking, marina & Montenegro.

I. INTRODUCTION
Maritime (nautical) tourism, as well as marina industry as its very important segment, experience commercial development in the European economy. Following the trends in the growth of nautical tourism, as a multifunctional activity with an emphasized maritime component [1], there is a need for the research and monitoring of marina industry which represents a new economic phenomenon.

Over the past decades, the average size of vessels in marinas has dramatically increased in length and width. In this regard, the size of the available berths determines the choice of a marina. The busiest berths are those between $30m$ and $40m$ [2]. However, the global trends in the field of nautical tourism show an increase in the number and size of yachts. Figure 1 shows the growth in the number of $90 +$ meters long yachts within the period from 1991 to 2010. From 2000 to 2010 this number almost doubled.

![Growth of the number of 90-metre yachts](image)

The number of marinas and facilities equipped to accommodate larger yachts is very limited. Although the $90 +$ meters long yachts represent a smaller part of the total world fleet, their increase in number will influence the functioning of marinas and require the investments in supporting infrastructure [2].

The vision of a so called „good marina“ or „Marina 2020“ is based on the following principles of contemporary marina business [3]:
- economically and environmentally sustainable marina, with a significant role in the local community (employment, training, economic growth, additional activities),
- good cooperation with tourism organizations and the engagement in the promotion of the destination in order to create loyal marina customers,
- contribution to the local community and the maintenance of the utmost importance,
- work at full capacity,
- the implementation of the environmental laws and standards and the development of corresponding policies,
- a strong environmental protection strategy, membership in significant eco-associations, support and participation in ecological projects,
- cooperation with local and regional enterprises,
- the establishment of business sustainability and the guaranteed provision of the highest possible quality of service to customers.
- cooperation within the sector and the membership/participation in the cluster, if possible.

Europe has approximately 10,000 marinas. Most of them are located in Sweden, Finland, Great Britain, the Netherlands, Germany, France, Spain, Italy and Croatia [4]. The total capital of the European nautical market is estimated at 60 billion euros [5]. There are about 25 million recreational vessels, nearly 25,000 marinas in the world and slightly more than 700 mega yachts in construction. Marinas in the Mediterranean are the largest in size in comparison with the rest of Europe, and the average number of berths per marina is 426, 83 [4]. By 2030, marine industry is expected to duplicate its actual position in maritime industry. The commercial maritime transport, the naval and offshore energy production sectors are expected to grow the most [6].

The Adriatic is becoming an increasingly attractive destination for sailing. Italy has the leading position in the number of marinas - 188, that is, 56.8% of the total number of Adriatic marinas and it has more than 48,000 berths (62.2%). Italy is primarily followed by Croatia with 122 marinas and slightly more than 20,000 berths, then Slovenia with eight marinas and 3,470 berths and Montenegro also with 8 marinas and 3,450 berths [7]. In Montenegro, three more marinas are in the phase of construction: Porto Novi, Luštica Bay and Lazure Marina, which will contribute to the increase of nautical capacities with additional 570 berths.

The paper presents the comparative analysis of the main Montenegrin marinas: Bar Marina, Dukley Marina Budva, Marina Porto Montenegro, and Kotor Marina. Ten years ago there was only one “proper” marina in Montenegro. It was Bar Marina with slightly more than 550 commercial berths. Today, Bar Marina has the largest number of berths - 900, slightly smaller capacity is available in Porto Montenegro - 450, Dukley Marina - 300 and Kotor Marina - 65 berths [8; 9; 10]. The average number of berths in the four Montenegrin marinas is 428, which is in accordance with the rest of Mediterranean. This data indicate a significant development of marina industry in Montenegro in the last decade.

Having in mind all the data presented, two research questions could be raised in this paper:

- What are the comparison criteria for the best marina practices?
- Which Montenegrin marina is the most competitive?

On the basis of the relevant literature [11; 12; 13; 14; 3; 15; 16; 17; 18], as an answer to the first research question, we propose the set of three groups of criteria that best describe marina business: a) spatial criteria, b) functional criteria, and d) environmental criteria. The criteria will be compared in regard to their existence and the level of development in the four Montenegro marinas investigated. In this paper, the benchmarking method is suitable for identifying the best marina business practice [13;
This method will be applied to the relevant groups of criteria in order to find an answer to the second research question.

II. LITERATURE REVIEW

The contribution of marinas to the Montenegrin economy and their rapid development was not accompanied by sufficient scientific research. In the Montenegrin legislation, nautical tourism is defined as “the sailing and stay of nautical tourists on sailing vessels, as well as their stay in nautical tourism ports or marinas and in other harbour facilities for the purpose of holiday and recreation” [20]. Marinas are the objects of nautical tourism and an integral part of maritime economy. They can be defined as “objects of nautical tourism with naturally or artificially protected water surfaces (sea, lakes and rivers) specialized for the provision of connection, supplies, storage service, the maintenance and service of vessels as well as the provision of catering, rental and other services in accordance with the requirements and specific needs of nautical tourists” [21].

In today’s changing competitive environment various organizations are forced to explore and implement a number of innovative philosophies and management techniques. Benchmarking, as one of such techniques, attracts extreme attention due to its efficiency and wide application [22].

Benchmarking is defined as “a continuous and systematic process of comparing products, services, processes and outcomes with other organisations or exemplars, for the purpose of improving outcomes by identifying, adapting and implementing best practice approaches” [23]. Benchmarking can be used in the vast spheres of business from the manufacturing industry to the administration of public services, but also at different levels of business - sectors, business units, enterprises, etc. [24].

Most of the scientific papers refer to the benchmarking of container ports and terminals, from the aspect of efficiency. The comparison of port efficiency with the world best practices helps managers define the strategies to achieve and maintain competitiveness in the maritime market [24; 25; 26; 27]. It is proved that only similar ports could be compared based on benchmarking analysis of port components (criteria, variables, characteristics) [28; 19].

Authors analysed the criteria for the selection of a port using the benchmarking method and concluded that geostrategic location of a port, links with the hinterland and traditional and complementary logistics services are the most relevant for the customers when choosing a port [29]. The geographical position of a marina is of great importance for the development of nautical activities. Linking the marinas on a global scale with roads, railways, airports and the sea should be dynamic and flexible [30]. Montenegro is extremely attractive for nautical sailing because of a favorable geographical position and climatic conditions; it is a well-preserved and unpolluted destination with unexplored sailing areas and the abundance of natural riches and cultural heritage. Some authors measured the attractiveness of the locations of Montenegrin marinas using the multi-criteria method [15]. The results are as follows: Bar - medium attractive destination, Budva - highly attractive destination, Tivat - medium attractive destination and Kotor - highly attractive destination. Considering that the previous analysis was done prior to the construction of the Porto Montenegro marina, the analysis cannot be considered relevant when it comes to this marina.

There are benchmarking studies of cruising ports, as well [31]. It is noted that a specific criterion for the development of a cruising port is the range and quality of port services (technical support and maintenance of vessels, pilotage, security service, customs services, waste water disposal, tourist information, etc.) From the functional perspective, the analysis covered the spectrum of nautical and tourist services offered by the marinas as well as the costs of berths [4; 32; 33; 34]. Nautical tourists have a higher purchasing power and a more subtle taste and therefore, it is necessary to ensure a rich, and at the same time a high-quality nautical offer. A modern marina should provide [32]: basic services (facilities for the harboring of yachts), peripheral services (parking, toilet, radio, electricity, water, post, devices for disposal waste, etc.), base-derived service (shipyard, yacht club, gas station, sailing school, restaurants,
etc.), and complementary services which enrich the offer and distinguish a marina from the competition (supermarkets, shops, ship suppliers, etc.).

Competition between marinas was investigated in literature [4; 33; 32]. Marinas today mainly compete in terms of prices, service programs, security, technical support, etc [4]. The main factors of competitiveness of marinas are: the price of berths, the mooring capacity of berths (dry berths and sea berths), and infrastructure equipment (water supply, electricity supply, repair and maintenance workshops, petrol station, video surveillance, technical support, catering facilities) [33].

A marina is competitive if it has the ability to occupy a new position in the competitive market or at least maintain the existing one; a modern/leading marina will have a competitive offer in comparison with other marinas that focus on similar business goals [32]. The ultimate goal is to achieve a level of profit that at least compensates for the capital invested. The application of benchmarking techniques is proposed in order to increase the competitiveness of marinas and improve the quality of business. It is convenient to start the comparison of the marketing strategy of a marina with the strategies of its competitors, and then proceed with a comparative analysis of organizational, technical and other processes that affect the business result [12].

The benchmarking methodology was applied in marina operations from the aspect of revenue management [17]. The authors point out that marina managers should be more open when it comes to sharing information, and that it would be valuable to develop a model for the implementation of this technique in marina business.

The criteria for the benchmarking analysis of marinas in Croatia were [18]: the exploitation of the capacity of connections at sea and on land, the average price of an occupied berth, the business income of a marina per occupied and available berth, income structure, etc. In order to highlight the importance of clustering for further economic growth and sustainability, in the study of Arc Manche Channel, marinas are compared based on size, location and ownership, development goals, income, services and business units [16].

In environmental context, benchmarking was applied to the following criteria: ecological facilities, operational procedures, landscape approach, educational programs and similar/corresponding issues [13]. The concept of sustainable development in marinas is a significant economic challenge, where capacities, facilities, resources and equipment are aligned with the principles of environmental management to improve the overall quality of services, achieve competitiveness in the marina market and attract investors and customers [35]. All nautical tourism facilities should operate in accordance with ISO standards: ISO 14000 and ISO 9001. Therefore, environmental management is an integral part of a marina business, and this should be a continuous and interactive process that is in line with other marina activities [36]. Some of the organizations that contribute to the standardization of environmental management practices are: Eco-Ports, RINA- Royal Institution of Naval Architects, Clean Marina, ICOMIA - International Council of Marine Industry Associations, EMAS-Eco-Management and Audit Scheme, Gold Anchor Harbor Association, Blue Flag - Foundation for Environmental Education, etc.

Based on comprehensive literature review presented above, we propose the methodology for creating the framework for the benchmarking analysis of Montenegrin marinas, as follows in continuation of the paper.

### III. METHODOLOGY

The choice of the right marina for boat-owners requires the consideration of several criteria presented in Table I [14]. There are three main groups of criteria and 21 sub-criteria, which will be the basis for a comparative analysis of Montenegrin marinas and a benchmarking framework.

Based on the secondary research and the data available on the web sites of marinas [8; 9; 10; 37] and other similar sources, we investigated the level of development of these 21 sub-criteria in the four of eight leading marinas on the Montenegrin coast respectively (see Table I):
• Bar Marina,
• Dukley Marina, Budva,
• Porto Montenegro, Tivat and
• Kotor Marina, as part of the Port of Kotor.

### TABLE I. THE CRITERIA FOR THE SELECTION OF MARINAS

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Sub-criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatial criteria</td>
<td>SC_1 exposure to winds and waves (maritime conditions)</td>
</tr>
<tr>
<td></td>
<td>SC_2 water depth</td>
</tr>
<tr>
<td></td>
<td>SC_3 length of berths</td>
</tr>
<tr>
<td></td>
<td>SC_4 marina system</td>
</tr>
<tr>
<td></td>
<td>SC_5 boating destinations</td>
</tr>
<tr>
<td>Functional criteria</td>
<td>FC_1 parking</td>
</tr>
<tr>
<td></td>
<td>FC_2 electricity, water and WiFi</td>
</tr>
<tr>
<td></td>
<td>FC_3 maintenance and fuel</td>
</tr>
<tr>
<td></td>
<td>FC_4 waterfront facilities</td>
</tr>
<tr>
<td></td>
<td>FC_5 garbage and recycling</td>
</tr>
<tr>
<td></td>
<td>FC_6 opening hours</td>
</tr>
<tr>
<td></td>
<td>FC_7 security and closed-circuit television (CCTV)</td>
</tr>
<tr>
<td></td>
<td>FC_8 experience and knowledge of marina team</td>
</tr>
<tr>
<td></td>
<td>FC_9 emergency response procedures</td>
</tr>
<tr>
<td></td>
<td>FC_10 events and social program</td>
</tr>
<tr>
<td></td>
<td>FC_11 reciprocal berthing arrangements</td>
</tr>
<tr>
<td></td>
<td>FC_12 awards and accreditation</td>
</tr>
<tr>
<td></td>
<td>FC_13 prices</td>
</tr>
<tr>
<td>Environmental criteria</td>
<td>EA_1 ISO standards (QMS, EMS)</td>
</tr>
<tr>
<td></td>
<td>EA_2 Blue Flag</td>
</tr>
<tr>
<td></td>
<td>EA_3 ecological projects</td>
</tr>
</tbody>
</table>

It is important to emphasize that we investigated the marinas of similar characteristics, as explained in literature [11; 12; 13; 14; 3; 15; 16; 17; 18]. The marinas analysed have a commercial character and mostly contain sea berths. They are compared on the basis of relevant and important criteria for customers when choosing a marina. The criteria are grouped into the following three categories:

- Spatial criteria (SC),
- Functional criteria (FC) and
- Environmental criteria (EC).

A leading marina was proposed on the basis of the research data. In the following Tables II, III and IV we presented a comparative analysis of investigated Montenegrin marinas.

### IV. RESULTS

Initially presented is the analysis of the spatial criteria of Montenegrin marinas. Then, we compared remaining functional and environmental criteria, as well.

#### A. Spatial criteria analysis

In Table II, marinas are compared on the basis of six spatial criteria: location convenience (SC_1), water depth (SC_2), length of berths and operational shores (SC_3), the type of marine system (SC_4), and the attractiveness of the destination (SC_5).

When choosing a location for anchoring, every boat owner primarily takes care of maritime conditions. The results of this study shows that Bar Marina and Dukley Marina are partially protected, while Porto Montenegro and Kotor Marina, as marinas in Boka Bay, are naturally protected from the effects of waves and winds, providing maximum safety and protection for the yachts.
TABLE II. COMPARATIVE ANALYSIS OF SPATIAL ASPECTS OF MARINAS [8;9;10;37]

<table>
<thead>
<tr>
<th>CRITERIA</th>
<th>Bar Marina</th>
<th>Dukley Marina</th>
<th>Porto Montenegro</th>
<th>Kotor Marina</th>
</tr>
</thead>
<tbody>
<tr>
<td>SC_1</td>
<td>Partially protected sea</td>
<td>Partially protected sea</td>
<td>Naturally protected from winds and open sea</td>
<td>Naturally protected from winds and open sea</td>
</tr>
<tr>
<td>SC_2</td>
<td>5.5 m</td>
<td>5 m</td>
<td>15 m</td>
<td>13 m</td>
</tr>
<tr>
<td>SC_3</td>
<td>do 35 m</td>
<td>do 70 m</td>
<td>do 250 m</td>
<td>do 25 m</td>
</tr>
</tbody>
</table>
| SC_4     | No information | No information | ”Med” or ”stern to” mooring system for boats | Floating systems (pontoons – type “S”)
| SC_5     | Bar Marina is ideal as a starting port for sailing on picturesque Montenegrin coast | Budva – center of Montenegrin tourism, Old city Budva, Dukley residence | Boka Bay, exclusive superyacht marina and yachting paradise, collection of 290 luxury waterfront residences | Boka Bay, Old city Kotor (UNESCO), rich historical and cultural heritage |

Also, one of the important criteria closely related to the former is the depth of water. The greater the depth of the sea in the aquatorium, the better safety for the boats. Additionally, a greater depth opens the possibility of berthing yachts with a larger draft. Figure 2 shows the marinas analyzed, according to the maximum sea depth in meters. It can be noticed that the Porto Montenegro marina takes the leading position with a maximum depth of 15 m and is followed by Kotor Marina - 13 m, Bar Marina - 5.5 m and slightly less deep Dukley Marina whose depth is up to 5 m.

When it comes to the Montenegrin marinas, the analysis indicated that all marinas have the capacity to berth yachts between 30m and 40m. More precisely, Kotor Marina can receive yachts up to 30 m in length, Bar Marina up to 35 m, Dukley Marina up to 70 m, while Porto Montenegro has the largest berth in the world - 250 m (see Figure 3).

The fact that Porto Montenegro can accommodate the largest yachts in the world, whose length is up to 250 meters, ranks Tivat marina as a world leader. Porto Montenegro has 450 berths for yachts and super yachts, and 127 berths, out of the total number of berths, is intended for super yachts [38].

The operational shore dimension is also a significant spatial parameter. The length of the operational coast of Bar Marina is 3.703 m, Dukley Marina – 4.000 m, and Kotor Marina – 471.7 m. It can be concluded that the length of the operational coasts is relatively adequate to the number of available berths.

The type of marina system has a significant impact on the safety of the vessels and the convenience of access. There are fixed marinas and floating systems with pontoons [14]. On the websites of the marinas
investigated, there is not enough data indicating the type of marina system. Therefore, the recommendation for the future is the increase in the amount of information available. The mooring system for boats in Porto Montenegro is “Med mooring” or “stern to mooring”. For yachts on all jetties, with the exception of Jetty 1, the mooring system consists of two bow mooring lines (ground lines) [9]. Kotor Marina mainly uses the floating system (pontoons type “S”). On the basis of incomplete data, it is not possible to select the leading marina when it comes to the marine system.

Montenegrin marinas are located in attractive locations along the Montenegrin coast. Bar Marina is ideal as a starting port for navigation, as it has a very attractive geographic and geo-economic position. The favorable macro-geographical position of the marina is also indicated by the fact that it is located near the airport and railway, at a distance of 104 Nm from the Strait of Otranto and the relative vicinity of the sea coasts of Greece, Croatia, Albania and Italy [39].

Dukley Marina is located in Budva, in the central part of the Montenegrin coast, along the walls of the Old Town. This marina is the first destination after entering the Adriatic from the Ionian Sea [41]. Also, Budva is recognizable as the cradle of the Montenegrin tourism. Within the marina are Dukley Residences with diverse and high-quality offers.

Porto Montenegro marina has the deepest water and the most beautiful landscape in the Mediterranean. It is located in a naturally protected port offering the maximum safety and protection for the yachts. Three airports (Podgorica, Dubrovnik, and Tivat) are nearby, while the Tivat airport is only seven kilometers away from the marina. The natural advantage of the marina, apart from being located in the protected Bay of Kotor, is that it is halfway between Athens and Venice, close to the innumerable Adriatic islands, and to the Aegean Sea, as well [40]. The crew of Porto Montenegro marina offers marina residents and guests full homeport experience in one of the world’s most spectacular cruising grounds [9].

Kotor Marina is located in the southeast of the Adriatic Sea, at the end of the Boka Bay and in a direct contact with the urban core of the Old Town. Boka is marketing-wise a best recommended nautical destination, since Kotor is under the protection of UNESCO, and Boka Bay is on the list of the most beautiful bays in the world [41]. Although the capacities of Kotor Marina are smaller than the capacities of the previous marinas, Kotor Marina is extremely attractive for sailors, due to the rich history of the city, medieval architecture and the natural beauty of the bay. The additionally confirmed fact is that, since 2017, the share of Kotor Marina is almost 40% in the total yacht traffic in Montenegro.

B. Functional criteria analysis

In Table III, marinas are compared on the basis of thirteen functional criteria: parking (FC_1); electricity, water supply and free internet access (FC_2), maintenance and fuel (FC_3), waterfront facilities (FC_4), garbage and recycling (FC_5), opening hours (FC_6), security and CCTV (FC_7), experience and knowledge of marina team (FC_8), emergency response procedures (FC_9), events and social program (FC_10), reciprocal berthing arrangements (FC_11), awards and accreditation (FC_12) and prices (FC_13).

According to the data collected (Table III), all marinas offer water, electricity and free internet access (Wi-Fi). Modern vessels can have significant requirements for electricity, such as 415V and 32A [14]. Porto Montenegro offers the following electricity options: 16A, 32A, 63A, 125A, 250A, 400A, 600A i 1000V, 230V, 400V [9]; the following options for electrical installations are available in Bar Marina: 16A, 32A, 63A and 230V, 360V [8], while Kotor Marina has two power sources of 150 A and 200 A. Dukley Marina provides 24-hour power supply, however there is no information about the capacities of electrical installations in this marina. All marinas have water supply. The conclusion is that the marinas, especially Porto Montenegro, meet the requirements of modern vessels.
When it comes to the maintenance and repair services, it can be seen that Bar Marina contains a service hangar for yacht service and marine engine service [8]. In Porto Montenegro marina, there are the representative offices of numerous world yacht services (Sunseeker Adriatic Group, S-Nautica, MRM, Navis Yacht Charter, IYC, Lunamar, BWA Yachting, Dominator Ilumen, Azimut Yachts and Burevestnik group)
Marina Kotor owns a service zone, as well. Fuel supply is one of the most important factors that enriches the offer of nautical tourism. The marinas analysed have petrol stations in their area. Bar Marina and Porto Montenegro marina supply vessels with the fuel whose quality corresponds to the standard ISO όφυϋ/φτυτ [ό; ύ]. A significant benefit for the boat owner who choose Porto Montenegro is that the fuel is exempt from tax and customs, and is cheaper up to 45% than in other European countries [9].

The marinas investigated efficiently provide the necessary services 24/7. Also, what is a common feature for all marinas is the availability of parking and waste disposal facilities. Marinas are objects at risk, given that they accommodate the vessels of extremely high value [14]. Therefore, it is necessary to provide a sense of personal safety as well as the protection of the property of nautical tourists, and marina itself. In order to provide this level of security, marinas should have installed video surveillance equipment (CCTV), which is the case in all Montenegrin marinas covered by this research. In addition, the marinas are in contact with corresponding state security departments in case of emergency interventions (police, firefighting department, ambulance, security).

In order to be able to act quickly, it is recommended that marinas have fire extinguishers, hoses and hydrants, alarms, trained emergency personnel as well as organized fire and urgent exercises to test these procedures [14].

An important part of the supply of marinas are the accompanying waterfront facilities. Among the basic requirements of nautical tourists are: toilets, showers and changing rooms. Comparing the four Montenegrin marinas on this basis, it can be concluded that they all have the basic facilities in offer, especially Dukley Marina and Porto Montenegro. Tivat marina next to the main facilities, boasts numerous crew facilities (yachting club, club crew, sports club, nautical equipment stores), catering facilities (Regent hotel and five-star residential objects, international restaurants and bars, pool complexes and beach bar, night club), 60 exclusive retail outlets and fashion boutiques, international schools, galleries and museums) [9]. Bar and Kotor Marinas have a significantly lower offer of facilities, which mainly reaches the basic needs of nautical tourists.

In addition to a convenient location, infrastructure facilities and a wide range of services, it is necessary for a marina to have a trained and experienced team. Bar Marina, led by the managers with the years of experience, professional attitude and high responsiveness, effectively provides 24/7 service to all customers with a special attention to the provision of a safe and pleasant stay in the marina [8]. Kotor Marina can also boast a long tradition. The management of this marina invests in the development of its employees through various trainings, the attendance at the seminars, courses, round tables and other specializations organized by professional educator. Employees regularly respond to the trainings and refer to them in order to transfer the skills and knowledge acquired to other employees and apply the knowledge in business practice.

Dukley Marina promotes on the website the exceptional concierge team that provides a higher and more exclusive level of service [10]. Porto Montenegro, as the youngest of these marinas, cannot boast a long tradition, but is distinguishable as a marina with a multilingual marina team, an excellent concierge team and the team of yachting professionals who understand the needs of the captains and crew. The marina director is a superyacht captain with many years of experience worldwide [9]. Comparative analysis concludes that the Montenegrin marinas recognize the importance and strive to improve the competences of their teams.

Marinas are intended for entertainment and recreation, so nautical tourists require rich cultural and social programs. In that sense, as can be seen in Table III, Porto Montenegro marina takes the lead. This marina is the host of the international fair MYBA and numerous regattas. Additionally, the marina organizes various celebrations (eg. weddings, cocktails), fashion shows, music concerts and international DJs, performances, exhibitions, wine tastings, luxury brand launches, etc. [9]. Other marinas have a significantly lower offer and are mostly active only during the summer months.
The accreditation and awards are an important reflection of the commitment of a marina to quality maintenance and customer service, which ensures the trust of potential users [14]. In the world of marinas, the International Gold Anchor Standard serves as the rating standard. The Gold Anchor Scheme helps boat owners find an appropriate marina with recognizable quality and service standards. Also, through the benchmarking according to measurable criteria, the scheme helps marinas improve their services and work towards higher standards [4]. Only two, out of the four marinas analyzed have this certificate. Bar Marina has three Gold Anchors [8], while Porto Montenegro was awarded the highest rank - five Platinum anchors [9], a number of other awards, as well (See Table III).

Some world companies own multiple marinas and have reciprocal agreements between the marinas, so their customers can use berths in reciprocal marinas at no additional cost [14]. This is still not the case in Montenegro.

Bar Marina, Dukley Marina and Kotor Marina are compared on the basis of their online price lists, while the price list of Porto Montenegro is only available to the interested users [8; 10; 37]. Based on the data presented in Table IV, it can be concluded that Dukley Marina has the higher prices of berths per year compared to Bar and Kotor marinas.

<table>
<thead>
<tr>
<th>Name</th>
<th>LOA (m)</th>
<th>High Season</th>
<th>Low Season</th>
<th>Annual</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Daily</td>
<td>Monthly</td>
<td>Daily</td>
</tr>
<tr>
<td>Kotor Marina</td>
<td>6 - 25</td>
<td>20 - 85€</td>
<td>408 - 1.704 €</td>
<td>17 - 85 €</td>
</tr>
</tbody>
</table>

The data presented indicates that the prices of marinas that provide a narrow range of services are lower than the prices of a modern, well-equipped marina.

C. Environmental criteria analysis

In Table V, marinas are compared on the basis of three environmental criteria: ISO standards - Quality Management System and Environmental Management System (EC_υ), Blue Flag or other similar organization (EC_φ) and ecological projects (EC_χ).

A comparative analysis of environmental aspects of the Montenegrin marinas shows that marinas apply ISO standards in their business (see Table V). Bar Marina is the first marina in Montenegro, which has implemented several certificates since 2017: ISO 9001: 2015 and ISO 14001: 2015. The certification was awarded by TÜVRheinland, a prestigious certification authority, and the certificates are valid until 2020 [8]. Also, Kotor Marina has recently applied the same ISO standards, while Porto Montenegro has applied ISO 9001:2008 and ISO 14001:2008 [9]. Dukley Marina provides no information on the application of the standards of this type.

<table>
<thead>
<tr>
<th>CRITERIA</th>
<th>Bar Marina</th>
<th>Dukley Marina</th>
<th>Porto Montenegro</th>
<th>Kotor Marina</th>
</tr>
</thead>
<tbody>
<tr>
<td>EC_2</td>
<td>Blue Flag (2017)</td>
<td>Blue Flag (NO)</td>
<td>Blue Flag (NO)</td>
<td>Blue Flag (NO)</td>
</tr>
<tr>
<td>EC_3</td>
<td>SUST MARINA</td>
<td>Ecological action of sea bottom cleaning</td>
<td>Global ecological project “Seabin”</td>
<td>Project „Business facility – passenger terminal and border crossing”</td>
</tr>
</tbody>
</table>

Out of the four marinas analysed, only Bar Marina has an exclusive recognition - Blue Flag since 2017 [8]. The world’s leading marinas participate in the international Clean Marinas program, which could be a challenge for the Montenegrin marinas in the future.
The participation of the marinas in various ecological projects would greatly contribute to the promotion of sustainable tourism. In Table V it can be seen that the four marinas are active in this field. Bar Marina promotes the participation in the international project “Implementation and Promotion of the Sustainable Development Concept at AD Marina Bar” - SUST MARINA, from 2014 - 2018. The goals of this project were obtaining the aforementioned certificates and the recognition and application of modern technologies in business [8]. Porto Montenegro marina is a part of a global ecological project known as “Seabin” - a new, revolutionary technological method which protects marine biodiversity and maintains the eco standards of sea water through advanced disposal of floating waste, fuels and chemicals in the sea. Kotor Marina is active when it comes to projects on environmental protection, the marina has been a leader in a large number of projects on the assessment of the impact of buildings on the environment. Dukley Marina promotes environmental protection by organizing ecological actions to clean the seabed [10]. Also, all marinas have waste disposal devices, which have been processed in the framework of the analysis of functional criteria.

Montenegrin marinas mostly fulfill the environmental standards and contribute to the sustainable development of the Montenegrin coast.

V. CONCLUSIONS

At the beginning of this research, a lack of scientific literature was noticeable in the field of marina benchmarking. However, this paper confirms that the benchmarking method is considered applicable and innovative in marina business.

The survey raises the question of the comparison of the marinas with the aim of determining the most competitive one, at the level of Montenegro in this case. This paper defines the framework for benchmarking analysis that consists of three aspects of marina operations: spatial, functional and environmental aspect, which are the basis for the classification of the criteria that are important to the users when choosing a marina.

The result of the research is obtained from a comparative analysis of the four dominant marinas in Montenegro. The results define the extent to which Montenegrin marinas meet the criteria discussed and which of the marinas can be selected as a leading one.

The comparison of the marinas led to the conclusion that almost all marinas meet the criteria established, while Porto Montenegro shows recognizable quality due to the consideration of the two out of the three criteria - spatial and, above all, functional criteria.

The paper is beneficial for the marina managers as it recognizes the advantages and disadvantages of the marina business when it comes to functional, spatial and environmental criteria. Furthermore, the paper determines the direction of the future development and improvement of the market position of marinas and may prove useful for the definition of the strategy of sustainable development of nautical tourism, at the level of Montenegro. Overall, the paper expands the volume of literature dealing with Montenegrin marinas and nautical tourism in general, since the number of studies that previously dealt with the benchmarking analysis in marina business is rather low.

Further research involving several directions would be useful. The defined marina benchmarking framework can serve as a starting point for a deeper analysis, which should take into account the primary research operations of a marina and the attitudes of marina customers and other stakeholders. Additionally, the Montenegrin marinas could be compared to the similar, nearby marinas (e.g. in the Adriatic region), and form a cluster marina based on the comparison conducted.
REFERENCES


Applying Optical System to Model the Motion of Human Leg Moving in Water According to Swimming Style Crawl

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ABSTRACT

In order to build an artificial leg with the purpose to examine different types and designs of swimming fins, it is necessary to model the motion of human leg moving in water according to a chosen swimming style. When the leg is represented by a number of key points, e.g. knee, ankle, and end of foot, the leg model can take the form of a sequence of key point positions in a chosen coordinate system. The paper presents application of an optical system to extract key points of moving swimmer leg in a video stream. In the tests reported in the paper, the focus was on swimming style crawl, two different swimming fins and three different speeds of leg motion were examined. All the video streams were recorded in a swimming pool.

KEYWORDS: artificial leg & optical system

I. INTRODUCTION

In order to design new swimming fins, e.g. touristic, rescue, or for special forces, a measurement system has to be used that is capable of objectively measuring forces generated by a human leg "equipped" with a fin. In the project no. POIR.τυ.τυ.τυ-ττ-ττψϊ/υϋ entitled “BioDive Fin - innovative biomimetic swimming fins for civil application", the objective is to design a new type of folded fin that would be attractive not only for professional divers/swimmers but also for a wider range of consumers. A partial objective of the project is to compare different fins, also the ones designed within the project, in the same conditions. To this end, the measurement system mentioned above can be used. In order for the system to reliably simulate motion of leg its should take the form of artificial leg, moreover, it should also behave as a leg while swimming. To achieve such effect, the model of leg motion is necessary which can be represented as a sequence of positions of leg key points, e.g. knee, ankle and the end of foot. The problem in this concept is to determine accurate positions of the key points during a pattern leg motion in water. One solution to this problem is to apply video recordings of a moving human leg with a special markings located in the key points and then to extract the markings in each shot of the video. The paper presents an optical system aiming at extracting the markings and determining their spatial parameters. The rest of the paper is organized as follows: section two shortly describes the whole process of building the model, section three presents the optical system, section four illustrates the model, and the final section summarizes the paper.

II. BUILDING THE MODEL

Building the model took place in a number of phases. In the first phase, color of markings had to be chosen. It had to give the greatest guarantee of separating the key point markings from the background. In order to select the most appropriate marking color, a number of colored markings were tested. They were attached to a fin and its move was recorded by means of underwater video camera – sample shot from the tests is presented in Fig 1. Then, different filters were examined to extract the markings from the background. Ultimately, it appeared that the yellow color yields the best effect and it is the easiest to extract. In the second phase, six movies were recorded which were the base for the further works, each of them corresponded to a different testing scenario. The scenarios differed in applied type of fin and speed of leg motion that in all cases took place according to a swimming style crawl. In all the scenarios three leg key points were marked with small yellow leafs, i.e. knee (key point no 1), ankle (key point no 2), and end of foot (key point no 3). Two types of fins were examined, i.e. a stiff standard diving fin (fin no 1) and a narrow, flexible, light recreational fin (fin no 2). Moreover, three different speeds of leg motion were tested, i.e. slow speed (speed no 1), average speed (speed no 2), and fast speed (speed...
The speeds depended on a professional diver who was involved in the tests and who was a pattern leg motion “generator”. Fixing speed was subjective, the diver simply tried to move the leg slower or quicker. A single combination of the leg speed and the type of fin corresponded to a single scenario recorded in a single movie. All the recordings took place in the swimming pool of the Hotel Mercury in Gdynia.

![Fig. 1. Fin with different coloured markings](image)

The third phase was devoted to implement the software for extraction of the markings from the video stream and in consequence for determining their position in a chosen coordinate system. This phase required both building a dedicated extraction algorithm and tuning its parameters. It took place in the iterative manner, partly by trial and error process – different solutions were implemented and then verified on recorded movies. The most effective algorithm that is an effect of all efforts in the third phase is detailed in the following section. The last phase was dedicated to running the algorithm, calculating different parameters of the leg motion and finally to analyzing achieved results. This phase is described in the fourth section of the paper.

### III. ALGORITHM FOR EXTRACTION OF MARKINGS

In order to extract yellow markings from video streams and to record their positions in a coordinate system compatible with image coordinate system (x axis pointing to the right, y axis pointing down) with the origin located in the start position of key point no 1 (knee), an algorithm was designed that works in eight steps – all the steps are separately run for each shot in a video stream [4,5]. The algorithm looks as follows:

1. Converting an input image (video shot) from RGB color model to HSV representation (H – Hue, S – Saturation, V - Value)
2. Extracting pixels that represent yellow markings
3. Thresholding
4. Erosion
5. Dilation
6. Locating blobs in the image and determining their centres, each blob represents one marking
7. Eliminating wrong blobs
8. If fewer than three blobs then estimating location of missing blobs (markings) based on data from previous video shots

The step no 1 is a result of initial tests which showed that operating on HSV image representation [1,2] yields better results than following colour spaces: LAB, YCrCb, RGB and Gray Scale.

In step no 2, the algorithm extracts pixels of definite HSV parameters from the image. Pixels which are in range <Min_H, Max_H>, <Min_S, Max_S>, <Min_V, Max_V> remain in the image, the remaining pixels are removed (the image is cleared in those pixels) [3]. The thresholds, Min_{H,S,V}, Min_{H,S,V} were separately adjusted to each video stream in order to enable the algorithm to effectively extract yellow
markings in all video shots. This task was performed manually, determining the minimal and maximal values of H, S and V components, which assure markers segmentation whilst removing another similar objects in the scene.

After step no 2 the image often still includes active (white) pixels which do not represent the markings, in order to decrease the likelihood of wrong marking indications, the image is thresholded – pixels which are below the threshold are eliminated. The objective of step no 2 where erosion [3] is applied is to remove small bright blobs form the image, if they exist they are eliminated from the image. In order to prevent removing markers from the image, the small 10x10 pixels structure elements were utilized, which enabled leaving segmented markers in every frame of the video stream and removing noise simultaneously [8].

In the erosion step, in addition to wrong small blobs, other blobs are also decreased in size, also the ones which represent the markings. In effect, they can even occupy only a single pixel. In order to highlight the right blobs, the dilation nonlinear filter [7] is used which extends size of originally sizeable blobs.

Step no 6 is dedicated to extracting blobs, they are identified and their centres are calculated.

Because there is still non zero likelihood of extracting wrong blobs from the image, the procedure is run with the purpose to eliminate them from further processing. To this end, position of the markings from the previous video shot is used. If the position of a blob significantly differs from all marking positions from the earlier shot, the blob is considered to be wrong and it is removed from the image.

The other situation which also needs an appropriate algorithm reaction is a missing marking blob. In such a case, the algorithm, in step no. 8, estimates position of missing blob based on positions of markings in the two earlier video shots. Estimation is linear.

The algorithm above was implemented as a separate window application in C++ programming language with the use of image processing OpenCV library. The application have two main windows (see Fig. 2), the first window shows black-and-white image with bright pixels representing key points, whereas the second window shows an original video stream with the markings surrounded by red circles. In addition, both windows are equipped with sliders whose objective is to tune parameters of the algorithm. After processing each video shot the application logs the output data to a file. The following output data can be logged:

- Pixel positions of markings. In order to use the positions in simulations with the artificial leg it is necessary to scale all them by value DR/DP where DR is a true distance between key point no 1 and key point no 2, whereas DP is a pixel distance between mentioned key points [6]. This way, instead of pixel positions, true positions in the coordinate system attached to a diver will be used.
- Angles between arms: (key point no 1 – key point no 2) – arm no 1, and (key point no 2 – key point no 3) – arm no 2. Since while swimming the leg moves not only in a vertical plane but also in the horizontal one, calculated pixel distances between key points can change. In consequence, the pixel positions of the key points cannot be used directly in simulations – arms of the artificial leg cannot change length. The solution to this problem is to apply angle parameters of the arms instead of the key point positions. In order to reproduce movement of the human leg it is only enough to reproduce angles of arm no 1 and 2. What is more, recorded angle parameters will also help with an appropriate design of the artificial leg. Maximal and minimal angles will indicate the range of move of leg moving components.
- Two other parameters which are produced by the application are changes in angles and angular velocities in consecutive shots of video stream. They can also be used in the design process of the artificial leg [9].
The algorithm described in the previous section was applied to six movies with recorded behaviour of a swimmer equipped with two types of fins. In this experiment, one swimmer was asked for moving his legs with 3 different speed, whereby the used speed was determined by swimmer. The achieved results are summarized in Fig. 3.

Figure 3 presents a position of the marks in a pixel coordinate frame for each speed. The obtained results indicate dependence of relative position of joints on the speed.
In Fig. 4, an angle’s plane of arms no 1 and 2 is depicted whereas in Fig. 5, a time course of angles for analysed speed are presented. In this case, the dependence on the speed was also found.

Time courses of angular velocities for analysed speeds are presented in Fig. 6. Obtained results indicate that increasing speed cause growth of a frequency and an amplitude.
Fig. 7. Position of key points for fin no 2

Fig. 7 presents a position of the marks in a pixel coordinate frame for second fin. The impact of design parameters of a fin was observed during experiment.

Fig. 8. Angles of arm no 1 and no 2 for fin no 2

A plane of arms’ angles is depicted in Fig 8, whereas a time courses of angular velocity for analysed speeds are presented in figure 9. In this case, the parameters of the fin had also noticeable impact on frequency and amplitude in comparison with the first fin.
The results depicted in all above diagrams lead to the following conclusions:

- Considering figure 3 and 7, no key point moves along one definite line up and down. There are two reasons for this, first, the key points do not move exclusively in a horizontal plane, they also move right and left, second, they also move forward and backward which is an effect of moves of hips. The consequence of this is that the future artificial leg with motionless key point no 1 (knee) will be unable to reliably reproduce behavior of swimmer leg,

- According to results presented in figure 4 and 8, angular moves of artificial arms range: (-30,30) deg – arm no 1, (5,90) deg – arm no 2,

- The obtained results presented in figure 6 and 9 allow to determine the maximum angular velocity of the arms equals to: 100 deg/s – arm no 1, 200 deg/s – arm no 2.

- The parameters of a fin have strong impact on a swimmer’s behavior. Therefore, the parameters of the movement of an artificial leg should be determined for each tested fin separately.

- Due to the fact that swimmer’s behavior varied over time, which was caused by fatigue, the averaged parameters of the movement should be determined. As a result of this observation, the one exemplary period of movement for each fin should be designed.

The obtained results are critical for construction of the artificial leg and should be taken into consideration when selecting individual components of the leg like for example servomotors, arm mechanical connections, etc.

V. SUMMARY

The paper reports efforts made in the first stage of the project entitled “BioDive Fin - innovative biomimetic swimming fins for civil application” and devoted to building a model of motion of swimmer leg “equipped” with a fin. The obtained results will be utilized in the next stage of the project when the artificial leg will be constructed and then used to compare different designs of fins. The model presented in the paper is in the form of a sequence of motion parameters of a moving swimmer leg. In order to determine the parameters, the motion of leg was first recorded with a video camera and then the video stream was appropriately processed to extract required parameters. In the paper, the method for extracting the leg parameters from the video stream is presented and the achieved results are shortly discussed.
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REFERENCES
Firefighting On-Board Ship - Modelling Based on Agents

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ABSTRACT
The maritime accidents rate is still high and despite the technology applied to all subsystems, the risk of accidents has not been significantly reduced. The major reason for the previous fact is that the maritime system involves people as elements of system. The model presented in this paper here observes ship as set of space covered with agents delegated to each part of the space. Modelling of firefighting system on-board ship was done using the theory of agent systems.

KEYWORDS: agents, firefighting on board ship, modelling & human error

I. INTRODUCTION
Modern ships and ship’s systems are technologically advanced and highly reliable. The construction of the ship and its equipment is continuously checked from the construction itself to the exploitation. [υ] Nevertheless, the maritime accidents rate is still high and despite the technology applied to all subsystems, the risk of accidents has not been significantly reduced. The major reason for the previous fact is that the maritime system involves people as elements of system. In accordance with Corovic and Djurovic human error has a significant impact on maritime accidents and at 76 to 96 percent of accidents, at least partially, is affected by some kind of human error. [φ]

By engaging agents for prevention and decision-making in a ship’s distress situation, it reduces or completely avoids a human error factor. Agents are software or circuit objects capable of autonomously receiving information from the environment, acting within their environment, and executing set of tasks for which they are anticipated. Agents are often used in the use of information and communication technology in those cases when it is necessary to replace human activity that is either too expensive or tiresome or dangerous to man. Hanzu-Pazara et al. concluded that the maritime system is a people system, and human errors figure prominently in these situations. [χ] Cohen et al. published research results by making a system, with panic situation measured. Research was based on the COgnitive Performance and Error (COPE) model by real-time feedback that was used during simulation-based training to learn to cope with stressful situations like fire on board ship with various tasks and scenarios. [ψ] Engaging agents avoids human errors that may occur in decision-making in stressful situations, like the distress situations. [ω]

With this paper we present a way of modelling an agent system for fire protection on board ship. This model is suitable for deployment within an agent simulation platform to develop appropriate algorithms for fire hazard handling. Developed algorithms must ultimately be embedded in the knowledge of agents or systems that would be implemented in the real marine fire-fighting system either as primary or as an auxiliary fire-fighting system.

II. AGENTS
Intuitively, an agent refers to an object that is self-contained in an environment, adapts to the environment in which it operates, has the ability to perceive the state in which its environment is located, by changing the state of the environment and having the ability to learn. Thus, Russell and Norvig name each object that perceives the environment through the senses and acts in the environment through the effector. [ι]

By definition Wooldridge and Jennings agents are entities that have the following characteristics [7]:
• Autonomy: Agents act without direct user intervention or some computer system components and have control over their actions and internal status,
• Ability to communicate with other agents or with the user,
• Reactivity: Agents perceive their environment (which can be a real world, collections of other agents, the Internet or some other environment, in this case ship systems) and react to changes and
• Proactivity: In order to accomplish their task, agents are not only responsive to changes in the environment, but are able to take the initiative by initiating changes in the environment.

Often, instead of the term agent, the term intelligent agent is used, emphasizing that an agent must possess a certain level of intelligent behaviour when performing its tasks. The definition of intelligence is certainly more complex than the agent definition. Intelligence is described with different attributes such as learning ability, understanding, planning and prediction, solving problems, synthesizing new ideas and modelling the outside world. We can also describe intelligence as possessing behavioural mechanisms aimed at solving the default goal. In the definition of Wooldridge and Jennings the ability to autonomously operate within the environment is a fundamental feature of an agent. Other features, social ability, reactivity, and proactivity fall into the elements of intelligent behaviour of agents.

An agent’s alternative definition states that an agent is a physical or virtual entity that is capable of acting in the environment; communicate directly with other agents; to guide their actions towards the set of goals; manage with their own resources; perceive the environment; to offer environmental services, and its behaviour strives to meet its own goals, taking into account the resources available to it and the state of the environment.

The system within which agents operate should be considered as the structure of the agents and the environment of their action as shown in Figure 1. Such a system should insure mechanisms for agents’ environment communication, mechanisms for communication of different agents, agent security safeguards mechanisms, and mechanisms that allow agents to move from one to the other environment (if there is a need for mobile agents). The basic structure of the agent can be presented as a structure consisting of: (i) agent interface, (ii) agent state, and (iii) agent knowledge.

The interaction of the agent and its environment requires a corresponding interface through which the agent has the ability to perceive the state of the environment as well as the effects of the environment, and changing the state of the environment. Agent states depends on the impact of the environment as well as the processes within an agent. Agent states represents a kind of agent memory. Agent knowledge contain information about outside world needed by the agent to perform its tasks as well as rules by which agent acts.

Agent’s desired goal is most commonly presented by the state where the agent tries to bring the environment through or the state as close as possible to desired state of the environment. This state is motivation for executing agent’s actions. The agent is approaching the achievement of the goal by executing available actions. The agent’s goal is important parameter used to decision-making process of action to be taken. An agent can have a function that the current state of the environment and the action that
it intends to execute associates the state of the environment that will result in the execution of the action. By introducing a metric into a set of possible environmental conditions, it is possible to determine the “distance” of the environment that will result in the action and the state of the environment that represents the target of the agent. In this way it is possible to decide on the action the agent will spend.

III. AGENT BASED FIREFIGHTING SHIP PROTECTION OVERVIEW

The model that will be described here observes ship as set of space covered with agents delegated to each part of the space. Fire-fighting is not domain within which we should permit agents to do machine learning roadmap which is filled with trial and error. This is domain where we want to use the consistency of machines in performing of strictly defined best procedures for firefighting, excluding a human factor that can be unreliable in distress situations. Therefore, there is an emphasis on the operation of reliable reactive agents. Agents receive an image of the world (ship) through environmental elements such as various detectors. Agents also act within the environment using environmental elements such as various valves. Environmental elements are all entities that will be modelled. The model should include crew members, all people on board respectively, so we consider them as environmental elements with the highest priority. Each element of the environment belongs to the appropriate class of elements of the environment. These classes include, for example, various areas within the ship, valves, doors, sound and light alarms, foam generators, CO₂ generators, IC cameras and smoke detectors. Each element of the environment is associated with one class, and each class of elements of the environment has associated corresponding properties.

The class of environmental elements will be labelled with $Cee$. Let set $CEE = \{Cee_1, Cee_2, \ldots, Cee_n\}$, $i \in \mathbb{N}$ is set that contains all environmental elements. Property configuration – values over the class of elements of the environment $Cee$ is each subset of the set

$$\{(a, b, c) | a \in Cee; b, c \in \text{string}[30]\}$$

where string[30] is set of all alphanumerical strings with a maximum length of 30 characters.

Property configuration – values over the class of elements of the environment $Cee$ will be labelled with $PV(Cee)$. First component of ordered triple $(a, b, c)$ from property configuration – values is called targeted element of the environment, second component is called property name, while the third component is called property value.

Assume that $e \in Cee$ for any class of environmental elements $Cee \in CEE$. The $e$ is called environmental element from class $Cee$, and those elements form set $PV(Cee)$ where the first coordinate element $e$ is called element’s $e$ properties. The attributes of the element $e$ are denoted by $p(e)$.

It is now possible to define a ship’s fire extinguishing environment:

Let $CEE = \{Cee_1, Cee_2, \ldots, Cee_n\}$, $i \in \mathbb{N}$ is set of all environmental elements classes. Firefighting ship environment is ordered pair $(CEE, PV(CEE))$, where

- set $PV(CEE) = \{PV(Cee_1), PV(Cee_2), \ldots, PV(Cee_n)\}$ where $P(Cee_i)$ property configuration – values over the class of elements of the environment $Cee_i$, $i \in \mathbb{N}$.

Set $PV(CEE)$ represents set of property configuration – values over the class of elements of the environment $CEE$.

Table 1 shows an example of an interpretation of this part of the model where the classes of environmental elements and the corresponding property - value structure are represented.
<table>
<thead>
<tr>
<th>Targeted element of the environment</th>
<th>property name</th>
<th>property value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space</td>
<td>ID space</td>
<td>identification number ID</td>
</tr>
<tr>
<td></td>
<td>fire state</td>
<td>“fire in space”, “no fire in space”, “high level of alertness”</td>
</tr>
<tr>
<td></td>
<td>permitted firefighting method</td>
<td>“CO2”, “foam”, “foam &amp; CO2”</td>
</tr>
<tr>
<td></td>
<td>people presence</td>
<td>people no in space</td>
</tr>
<tr>
<td></td>
<td>level_co2</td>
<td>no CO2 units</td>
</tr>
<tr>
<td></td>
<td>foam level</td>
<td>no foam units</td>
</tr>
<tr>
<td>Valves</td>
<td>valve type</td>
<td>“CO2”, “foam”</td>
</tr>
<tr>
<td></td>
<td>coordinates</td>
<td>ID space where valve is mounted</td>
</tr>
<tr>
<td></td>
<td>state of openness</td>
<td>“open”, “closed”</td>
</tr>
<tr>
<td>Doors</td>
<td>coordinates</td>
<td>ID two spaces where doors are mounted</td>
</tr>
<tr>
<td></td>
<td>state of openness</td>
<td>“open”, “closed”, “tripped”</td>
</tr>
<tr>
<td>Sound alarm</td>
<td>coordinates</td>
<td>ID space where sound alarm is mounted</td>
</tr>
<tr>
<td></td>
<td>activity</td>
<td>“alarm active”, “alarm inactive”</td>
</tr>
<tr>
<td>Light alarm</td>
<td>coordinates</td>
<td>ID space where light alarm is mounted</td>
</tr>
<tr>
<td></td>
<td>activity</td>
<td>“alarm active”, “alarm inactive”</td>
</tr>
<tr>
<td>Smoke detector</td>
<td>coordinates</td>
<td>ID space where smoke detector is mounted</td>
</tr>
<tr>
<td></td>
<td>detection state</td>
<td>level of detection state</td>
</tr>
<tr>
<td>IC camera</td>
<td>coordinates</td>
<td>ID space where IC camera is mounted</td>
</tr>
<tr>
<td></td>
<td>fire state detection</td>
<td>“fire in space”, “no fire in space”, “false alarms detector”, “high level of security”</td>
</tr>
<tr>
<td></td>
<td>human presence state detection</td>
<td>no of detected people in room, “caution-in-determinate state”</td>
</tr>
<tr>
<td>CO2 generator</td>
<td>activity</td>
<td>“in process of generating”, “inactive”</td>
</tr>
<tr>
<td>Foam generator</td>
<td>activity</td>
<td>“in process of generating”, “inactive”</td>
</tr>
</tbody>
</table>

In this model it is necessary to show as class of environment element all present people on board ship, since when fire extinguish method is applied, suitable method is dependent if burned space is occupied by people or not. Also, in some cases, it is not possible to start the extinguishing process before the evacuation of all persons ends in the burned area.

Now a model environment needs to be introduced with the model of agents:

Agent $a$ is ordered triple $(K, I, Ac)$ where:

- $K$ – agent’s knowledge of environment,
- $I$ – agent’s inner states and
- $Ac$ – actions that the agent can act within environment.

Consider the case when each part of the vessel space is assigned the appropriate agent. Let $\mathcal{C}ee_p$ be the class of environmental elements inside the ship spaces. Each member of $\mathcal{C}ee_p$ an agent who will have the task of fire guarding that part of the space is assigned. Thus, for each space with $s \in \mathcal{C}ee_p$ agent $A(s)$ is assigned. The agent’s environment is a space that has been assigned so that the knowledge
of this agent on the environment can be identified with the properties of all the elements of the environment that are located in the space where the agent is assigned.

The agent’s internal state reflects the conditions within which an agent decides about actions it will take in the environment to bring the state of the environment closer to the desired state. The agent has to follow the changes in the outside world as well as record their previous actions in order to be able to determine next action (in this case using the production rules that include the terms contained in the terms of the rule that contain the previous state of the environment as well as previous agent actions).

Actions that an agent can act within the environment represent those properties of the environment elements of the space where the agent is assigned to which agent can change its activity. For example, if in the space where the agent is assigned, the valve then acts in the agent’s action to affect the openness of the observed valve.

By executing an action, the agent transforms the environment, which is also possible to be modelled by means of the function. The function of the environment transformation in each sequence of agent and environment interaction assigns a set of states in which the environment can be found after the agent performs its activity. The so-defined function of the transformation of the environment has two essential characteristics. The first is that the state of the environment can be dependent not only on the last action the agent has made but also about the whole sequence of agents acting (therefore, about all previous environmental conditions as well as about all agents' actions in the sequence). Another feature of the environmental transformation function is that this function does not determine which state of the environment can be found after the agent’s action but only a set of possible states.

IV. CONCLUSION

In this paper we have presented one possible direction in modelling the ship’s fire protection. Modelling was done using the theory of agent systems. The implementation of this model with the robustness of the physical installation of the entire system enables rapid response in incident fire situations irrespective of any human error due to panic reaction. A model is shown where marine environment elements are used as sensors and effectors of an agent which, by using them, brings the environment to the desired state of fire absence. The model is defined independently of any agent’s programming framework so it can be realized within many of what simulation is for other developmental agent environments.

REFERENCES


Numerical Prediction of Radar Cross Section for Small Maritime Targets

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**ABSTRACT**

Radar Cross Section of maritime targets is very important parameter in the design of maritime radar systems. Furthermore, from the aspect of maritime security it is important for a maritime radar system to be able to detect small radar targets such as buoys and inflatable rubber boats. The methods of prediction of radar cross sections in the literature are diverse, however in this paper we use novel numerical method based on combination of boundary and finite edge elements which we have shown to be very accurate in one of the previous papers. Moreover, in order to correctly capture the geometry of the rubber boat we have subjected one of the boats to laser measurements of the geometry with the help of Croatian navy. The results show radar cross section computations of small maritime targets which can now be used as the parameter in the design of maritime radar systems.

**KEYWORDS:** radar scattering cross section, EM scattering, Computational electromagnetism & Hybrid BEM/FEM

**I. INTRODUCTION**

From the aspect of navigation safety, when navigating in coastal waters with dense maritime traffic, the ability to detect small vessels with very small radar scattering cross section (RCS) is of crucial importance. This is especially true for navigation near tourist destinations with large tourist populations during the summer seasons. Further difficulties for early detection of these vessels arise if the coast is indented and with large number of islands and deep coves. In such circumstances, early detection of these small vessels at short ranges is desirable feature, especially during night and in bad weather conditions. Detection probability is additionally decreased when the typical material composition of these small vessels is taken into account. Because these vessels are typically composed of plastic, wood and rubber they do not contribute to RCS as much as vessels with higher metallic content. For these reasons, in this paper, we numerically investigate RCS of buoy and rubber boat for two different polarizations (horizontal and vertical) and for different angles of incidence. As we shall see towards the end of the paper, these angles of incidence can be related to the height of ship’s radar installation and the distance from the buoy or rubber boat.

Numerical methods available for RCS computation generally fall in one of three distinct categories: ray-tracing methods, physical optics methods and full wave methods. Ray tracing methods are often complicated because multibouncing of rays need to be taken into account [1]. Furthermore, ray tracing methods do not take into account the changing electromagnetic properties of the materials used for interior of the vessel. Methods such as physical optics (PO) and physical theory of diffraction (PTD) can compute RCS with acceptable error, however these methods are not well suited for accounting the changing material properties in the interior of the ship. Thus, if we were to account for changing material properties inside the vessel we can use one of the following: FDTD (finite difference method), some hybrid combination of method of moments (MoM) with finite element method (FEM). However, these methods can only provide near field solution of electromagnetic scattering problem and they need to be subjected to near-to-far field transformation (NTFFT) in order to compute RCS, which is cumbersome procedure [2].

To avoid NTFFT transform, we use our own previously published method for RCS computation based on hybrid BEM/FEM with edge elements [3]. This method first finds the near field solution in the form of edge element coefficients and from these electromagnetic field values, using our own RCS equation, we compute RCS directly from near field values. Thus, the NTFFT transformation is avoided and sometimes this approach produces better results (e.g. the case of RCS computation at interior resonance frequencies, see. Reference [3]).
The results of the numerical computation of RCS of the buoy and rubber boat are presented in section 5. RCS of the buoy and rubber boat is expressed as the function of the angle between the line of sight connecting radar antenna and the vessel at the sea level. It is shown that detection probability of the rubber boat and buoy is very angle dependent for vertical polarization and that in order to maximize the detection probability of rubber boat at certain distance the radar antenna should be placed at some definite height above the sea level.

II. EDGE ELEMENT BEM-FEM

To compute the RCS of radar target the necessary step is the computation of backscattered electric and magnetic field at the exterior boundary of the computational problem shown in Fig. 1. This computed backscattered EM field is the near field solution of EM scattering problem and, as such does not represent the far field data necessary for RCS computation. In order to obtain the near field solution one needs to obtain the solution of general 3D electromagnetic scattering problem. This general 3D scattering problem is shown in Fig. 1., where the incident electric and magnetic fields are denoted as \( \mathbf{E}_i \) and \( \mathbf{H}_i \), backscattered fields are denoted \( \mathbf{E}_{\text{ext}} \) and \( \mathbf{H}_{\text{ext}} \) and interior fields are denoted \( \mathbf{E}_{\text{int}} \) and \( \mathbf{H}_{\text{int}} \). Interior and backscattered electromagnetic fields are the fields we wish to compute, while the incident electric and magnetic fields are known from radar radiation pattern. Because the electromagnetic properties of materials \( \epsilon, \mu, \sigma \) change inside computational domain \( \mathcal{V} \), we need to use computational method that can take these changes into account.

The method of computational electromagnetism that can take into account the change of these electromagnetic properties is hybrid BEM-FEM, which is the combination of boundary element method (BEM) and finite element method (FEM), and the method is thoroughly described in references [4]-[5]. Electric field exterior to computational boundary \( \partial \mathcal{V} \), shown in figure 1, can be described by Stratton-Chu electric field integral equation (EFIE) which in its time harmonic form can be written as [6]:

\[
a \mathbf{E}_{\text{ext}} = \mathbf{E}_i - i \omega \mu \int_{\partial \mathcal{V}} d\mathbf{S}' \times \mathbf{H}_{\text{ext}}^* G + \int_{\partial \mathcal{V}} \left( d\mathbf{S}' \times \mathbf{E}_{\text{ext}}^* \right) \times \mathbf{V}' G \\
- \int_{\partial \mathcal{V}} d\mathbf{S}' \frac{1}{\sigma + i \omega \epsilon} \mathbf{V}' \cdot (\mathbf{n}' \times \mathbf{H}_{\text{ext}}^*) \mathbf{V}' G
\]

(1)

Fig. 1. Outline of EM scattering problem. Volume of computational domain is denoted \( \mathcal{V} \) and the artificial boundary is denoted \( \partial \mathcal{V} \). Fields \( \mathbf{E}_i \) and \( \mathbf{H}_i \) are incident to \( \partial \mathcal{V} \) while \( \mathbf{E}_{\text{ext}} \) and \( \mathbf{H}_{\text{ext}} \) are backscattered fields.
For interior fields, that is for electromagnetic fields inside computational volume $V$ shown in Fig. 1., the time harmonic Faraday's law takes the following mathematical form:

$$\nabla \times \vec{E}_{\text{int}} = -i\omega \mu \vec{H}_{\text{int}}$$  \hspace{1cm} (2)

and time harmonic Maxwell-Ampere equation is given by:

$$\nabla \times \vec{H}_{\text{int}} = (\sigma + i\omega\epsilon)\vec{E}_{\text{int}}$$  \hspace{1cm} (3)

Taking the curl of equation (3) and combining with (2) yields the following differential equation:

$$\nabla \times \left( \frac{1}{\sigma + i\omega\epsilon} \nabla \times \vec{H}_{\text{int}} \right) + i\omega \mu \vec{H}_{\text{int}} = 0$$  \hspace{1cm} (4)

With computational methods for electrostatics the unknown fields $\vec{E}_{\text{int}}$ and $\vec{H}_{\text{int}}$ are usually approximated with nodal approximating functions. However, that is not appropriate for full wave methods. With full wave methods we use edge element approximating functions in order to preserve the continuity of tangential components of electric and magnetic fields (see ref. [3] for details). Edge elements approximate electric and magnetic fields using vector approximating functions $\vec{w}_i$ as:

$$\vec{E}_{\text{int}} = \sum_{i=1}^{n} \delta_i \vec{w}_i e_i$$  \hspace{1cm} (5)

$$\vec{H}_{\text{int}} = \sum_{i=1}^{n} \delta_i \vec{w}_i h_i$$  \hspace{1cm} (6)

where $n$ is the number of edges on the element, $e_i$ and $h_i$ are unknown coefficients associated with each edge of the element. Vector approximating functions $\vec{w}_k$ are associated with $k^{th}$ edge of the element by the following relation:

$$\vec{w}_k = N_i \nabla N_j - N_j \nabla N_i$$  \hspace{1cm} (7)

where $N_i$ and $N_j$ are nodal approximating functions associated with nodes of the element [7].

Due to physical jump conditions of electric and magnetic fields at the interface between two materials with different electromagnetic properties, all the exterior fields in equation (1) i.e. $\vec{E}_{\text{ext}}^i$ and $\vec{H}_{\text{ext}}^i$, can be replaced by interior fields $\vec{E}_{\text{int}}^i$ and $\vec{H}_{\text{int}}^i$. This is due to tangential continuity of electric and magnetic fields across the boundary where material properties change. With these conditions, equation (1) and equation (4) can be coupled, and combining with equations (5) – (7) the following system of equations is obtained:

$$\begin{bmatrix} G & -H & 0 \\ -D & 0 & F \\ 0 & F & F \end{bmatrix} \begin{bmatrix} e_b \\ h_b \\ h_v \end{bmatrix} = \begin{bmatrix} e_i \\ 0 \\ 0 \end{bmatrix}$$  \hspace{1cm} (8)

where $e_i$ are edge element coefficients computed from incident field $\vec{E}_{\text{ext}}^i$, $e_b$ and $h_b$ are edge element coefficients associated with edges at the artificial boundary $\partial V$ and $h_v$ are edge element coefficients associated with interior of the computational domain $V$. The hybrid BEM-FEM method of numerical computation of near electromagnetic field was rigorously tested over the period of several years in various physical settings (e.g. in ref [3]-[5] and in [8]).

III. COMPUTATION OF RADAR CROSS SECTION

Radar cross section is computed directly from the edge element coefficients computed in previous section. These coefficients are associated with near electric and magnetic field, that is, the near electromagnetic field can be reconstructed from edge element coefficients [3]. To compute radar cross section,
one has to convert the near field to far field. Previously, this transformation from near field to far field was achieved by the employment of some elaborate and computationally expensive numerical methods [2]. These methods are collectively known as Near-to-Far-Field-Transformation (NFFT). The necessity for NFFT can be circumvented completely and far field can be computed directly from edge element coefficients by the application of our previously published computational technique [3]. Radar cross scattering section \( \sigma \) is defined as ratio of backscattered and incident field:

\[
\sigma = \lim_{|\vec{r}| \to \infty} 4\pi |\vec{r}|^2 \left| \frac{\vec{E}_2}{\vec{E}_1} \right|^2 = \lim_{|\vec{r}| \to \infty} \frac{\vec{E}_S \cdot \vec{E}_S^*}{\vec{E}_I \cdot \vec{E}_I^*}
\]

(9)

where \( \vec{E}_S^* \) represents the complex conjugate of backscattered vector field \( \vec{E}_S \). It was shown in ref. [3] that this backscattered field can be written in compact form as:

\[
\vec{E}_S = \frac{e^{-ik|\vec{r}|}}{4\pi|\vec{r}|} \vec{F}_S
\]

(10)

where complex vector \( \vec{F}_S \) can elegantly be computed from edge element coefficients as the sum:

\[
\vec{F}_S(\vec{e}_p) = -i\omega \sum_{i=1}^{N} \sum_{j=1}^{3} \int_{\Delta_i} h_{b_j} e^{ikr \cdot \vec{e}_p} d\vec{S} \times \delta_j \vec{w}_j + ik \sum_{i=1}^{N} \sum_{j=1}^{3} \int_{\Delta_i} e_{b_j} e^{ikr \cdot \vec{e}_p} (d\vec{S} \times \delta_j \vec{w}_j) \times \vec{e}_p
\]

\[
-ik \sum_{i=1}^{N} \sum_{j=1}^{3} \int_{\Delta_i} h_{b_j} e^{ikr \cdot \vec{e}_p} d\vec{S} \frac{\nu \cdot (\vec{S} \times \vec{w}_j)}{\sigma + \tan \phi} \vec{e}_p
\]

(11)

Computation of \( \vec{F}_S(\vec{e}_p) \) from known boundary edge coefficients \( e_{b_j} \) and \( h_{b_j} \) is fast, and if necessary, the line integrals in equation (11) can be solved analytically to further improve the speed and accuracy of RCS calculation. Equations (9) – (11) are well tested on canonical models, were compared with Mie series analytical solutions and were tested in the case of dielectrically coated PEC sphere (see ref. [3]) where it has been shown that accurate results can be obtained even at resonance frequencies as shown in Fig. 2.

![Fig. 2. RCS plot of the metallic sphere coated with dielectric layer with relative permittivity \( \varepsilon_r = 4 \). This calculation was performed using EFIE formulation and hybrid BEM/FEM at resonant frequency of 300 MHz and was compared with Mie series solution.](image)
IV. MODELS OF RUBBER BOAT AND BUOY

From the standpoint of collision avoidance and from standpoint of early detection of small targets in military missions, the rubber boat is considered as the radar target of choice. The rubber boat model used for numerical RCS computation is the model of small service rubber boat sometimes used by Croatian Navy. The rubber boat was subjected to series of 3D laser measurements to accurately capture the geometry of the boat, as shown in Fig. 3.

![Photo of the rubber boat at laser measurement site. The relevant geometric features of the boat are captured at spatial points marked with green dots.](image)

Geometry capture software produced the set of 3D points and set of linear triangles from laser measurements, conveniently given in the form of STL (stereolithography) file. However, to produce the mesh of good quality with Ansys ICEM software the parasolid or similar input file is required. For that purpose, Geomagic software was used to convert from STL file to Parasolid x_t format and then the air and water volume surrounding the boat were added with Siemens SolidEdge CAD software as shown in Fig. 4.

![CAD model of the geometry for RCS computation. Upper half of the volume consists of air and the lower half of the volume consists of seawater. Rubber boat is partially immersed in water and partially immersed in air.](image)

CAD model of the rubber boat was loaded into Ansys ICEM meshing software to produce the good quality tetrahedral mesh shown in Fig. 5, where the volume of the air was removed to enhance the visibility of interior elements. Final computational models of the rubber boat consists of 285,064 tetrahedral elements and of 1,870 triangular elements used to model the boundary of the computational model.
Fig. 5. Tetrahedral mesh of the model shown in Fig. 4, with air volume removed. The model consists of 286,934 elements where 285,064 tetrahedral elements were used to model the interior of computational domain and 1,870 elements were used to model the boundary of computational domain.

Fig. 6. On the left hand side the CAD model of the navigational buoy is shown. On the right hand side the tetrahedral mesh of the buoy and seawater is shown without the tetrahedral mesh of air. Model consists of 986,260 tetrahedral elements and 1,870 triangular elements to model the computational boundary $\partial'\Omega$.

The CAD model of the standard navigational buoy used for RCS computation is shown in Fig. 6. The computational model shown in Fig. 6 consists of 986,260 tetrahedral elements and 1,870 triangular elements. Electrical parameters $\sigma, \varepsilon_r, \mu_r$ of the seawater, air, rubber and plastic were compiled from various sources from literature [9] and these are collectively shown in Table 1.

<table>
<thead>
<tr>
<th>#</th>
<th>Material</th>
<th>$\sigma$ [S/m]</th>
<th>$\varepsilon_r$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Seawater</td>
<td>3.00</td>
<td>88.00</td>
</tr>
<tr>
<td>2.</td>
<td>Air</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>3.</td>
<td>Rubber</td>
<td>0.00</td>
<td>2.50</td>
</tr>
<tr>
<td>4.</td>
<td>Plastic</td>
<td>3.00</td>
<td>3.00</td>
</tr>
<tr>
<td>5.</td>
<td>Industrial steel</td>
<td>$6.21\times10^6$</td>
<td>1.00</td>
</tr>
</tbody>
</table>
V. SCATTERING CROSS SECTION OF BUOYS AND RUBBER BOATS

The general setup for RCS computation is shown in Fig. 7, where the rubber boat is at distance \( l \) from the ship and is at height \( h \) above the sea level. The angle between the line connecting the radar antenna and rubber boat and the sea level is \( \theta \). Horizontal polarization (HP) and vertical polarization (VP) of the radar EM wave are shown in the same figure and \( \hat{k} \) indicates the direction of propagation of radar EM wave.

![Fig. 7. The rubber boat is at horizontal distance \( l \) from the radar antenna and the radar antenna is at height \( h \) above sea level. Angle subtended between the line connecting the antenna and boat and between sea level is \( \theta \).](image)

To find the radar cross section \( \sigma \) of the sea without the rubber boat we have first performed the series of calculations for the physical setup shown in Fig. 7, but without rubber boat. The results of numerical radar cross section calculation of \( \sigma \) for various angles \( \theta \) is shown in Fig. 8a for both HP and VP.

![Fig. 8. Radar cross section of the seawater (without rubber boat) for various incidence angles \( \theta \) is shown in (a) for horizontal polarization (HP) and vertical polarization (VP). Radar cross section of both rubber boat and seawater is shown in (b) for HP and VP.](image)

Then the same series of numerical calculations is performed for the configuration shown in Fig. 7, with the rubber boat included. This time, the radar cross section \( \sigma \) is the total cross section that includes reflections from both the sea and from rubber boat. These results are shown in Fig. 8b. The reason why these calculations were performed separately (without rubber boat and with rubber boat) is to find how much radar cross section of the rubber boat distinguishes itself from the radar cross section of the sea. The ratio \( \sigma / \sigma_s \) shows how much radar cross section of the rubber boat is distinguished from the radar cross section \( \sigma_s \) of the empty sea and it is shown in Fig. 9.
The ratio $\sigma/\sigma_5$ as the function of incidence angle $\theta$ for buoy is shown in Fig. 10. for both vertical and horizontal polarization. In Fig. 11, we show the magnitude of electric field along with electric field vectors for chosen angles of incidence $\theta$ and polarizations.

Fig. 9. The ratio of cross section $\sigma/\sigma_5$ is shown for rubber boat as the function of angle $\theta$ is shown for both HP and VP.

Fig. 10. The ratio of cross section $\sigma/\sigma_5$ for buoy is shown for horizontal polarization in (a). In (b) the ratio $\sigma/\sigma_5$ for buoy is shown for vertical polarization (VP).

Fig. 11. On the left the magnitude and vector plot of near electric field with air omitted for $\theta = 3^\circ$, horizontal polarization (HP) is shown. To the right vector plot of electric field in air around buoy is shown for $\theta = 22^\circ$ is shown.
VI. CONCLUSION

RCS of the rubber boat and navigational buoy is computed for physical setting shown in Fig. 7, for different angles $\theta$ and for both vertical and horizontal polarization of the radar EM wave. For numerical computation of near field hybrid BEM/FEM with edge elements is used. Reason for this hybridization of BEM and FEM lies in the fact that BEM terminates the computational domain in physically correct way, otherwise we would have to use perfectly matched layers (PML) or absorbing boundary conditions (ABC’s) which are known to be less accurate than BEM.

Having computed the results of near field, these results were used as input for our own RCS computational method which uses this values directly without the need for NTFFT transformation. This method falls in the class of the full wave methods and it can account for the change of electric and magnetic properties of materials inside the computational domain.

To be able to distinguish the radar cross section of the sea and of the rubber boat and buoy we have first computed the RCS of the sea patch without the rubber boat or buoy and these results are shown in Fig. 8a. Then we have computed total RCS of both rubber boat and sea as shown in Fig. 8b. The measure of how much rubber boat is distinguished from the RCS of the sea itself is shown in Fig. 9. This measure is expressed as simple ratio between RCS of the sea and RCS of both sea and rubber boat. Similarly, for navigational buoy we have computed the ratio of RCS of the both buoy and the sea and the seawater itself. This was done for various angles of incidence of the radar EM wave and for both vertical and horizontal polarization and the results are shown in Fig. 10.

It should be noted that from Fig. 9 it follows that the detectability of the rubber boat differs for vertical polarization (VP) and horizontal polarization (HP). From Fig. 9, it follows that detectability of rubber boat for horizontal polarization (HP) is approximately constant for the range of angles $\theta$. However, for vertical polarization the detectability of rubber boat varies significantly with angle $\theta$. For the case of navigational buoy as it is evident from Fig. 10, the detectability of the buoy is best for the smallest angle $\theta$. Then there is a range of angles for which buoy is not detectable since ratio $\sigma/\sigma_s < 1$. Therefore, this is the subject of our ongoing research about how the angle of incidence influences detectability of small objects and expected result is to provide guidelines for the placement of radar system on board of ships.

To be able to continue this investigation the capabilities of our software need to be improved to further increase complexity of our models. Currently there, are two main limitation of our full wave method: the size of computational model (the number of unknowns) and with computational time. However, an effort is underway to address these issues so that much larger ship models could be used for RCS computation.

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Some Problems in Establishing Maritime Zone Surveillance Dataset

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ABSTRACT
In order to develop reliable maritime zone surveillance algorithm, a dataset for possible real situations should be available. Its purpose is to compare various algorithms and versions of the same algorithms under the same conditions. This research is attempt to provide such reliable dataset designed specifically for maritime scenes. In this paper, we share experiences in ground truth determination from video sequences of marine zone surveillance. We present new experimental data and report difficulties in ground truth determination. Some of the difficulties are avoidable under well weather conditions. Technical details of Matlab “Ground truth labeller” application are discussed.

KEYWORDS: maritime zone surveillance, ground truth, ground truth labeller, weather conditions & moving vessels detection

I. INTRODUCTION
The problem of ground truth (GT) generation for video sequences is very diversify. Generally, it is easier to generate the GT for indoor scenes than for outdoor scenes. Unfortunately, much applications of the video surveillance are the outdoor applications.

Generation of the GT in a video is very intensive manual labour. Manual GT generation is the only generally accepted way to perform such operation. Hence, there are many attempts to make easier GT generation. A high definition GT database is presented in [1]. In order to elaborate their method, authors manually labelled seven hundred frames spending φχτ man-hours.

Report by NISTIR [2] discussed different types of GT systems. They identified four ways to acquire GT. Goal was to use it in object recognition and tracking. These types of systems are: physic simulation for GT, manual annotation/labelling, platform-based, and physically-based GT systems. They concluded that there is no universal solutions for GT measurements. There are only partial solutions for specific applications with many drawbacks.

Research in [3] proposed three methods for creating GT databases and benchmarks in case of multiple sensors. This can be grouped in multisensory fusion ways of GT generation, which is not the scope of this research, (we are currently interested only in video signals). However, combination of various sensors has a future due to advances in autonomous vehicles and artificial intelligence.

Closer to our research is the research performed in [4], because they use Matlab App. Specifically, authors in [4] created an app using Matlab app Designer Interface. It is packed in Matlab Compiler Runtime for execution out of the Matlab. The advantage of using this app instead of Paint or similar bitmap graphical program is in the fact that clicked pixels are stored in Matlab format and easy to use further.

Lack of user-friendly GT generators resulted in several developed software, which could be useful in some situations. An example is TSLAB [5]. This tool allows three kinds of labels: moving objects, shadows and occlusions, which are created at both the pixel level and the object level. This helps in implementation of both moving object detection strategies and tracking algorithms [5].

FAst Semi-automatic Tool for Ground Truth generation (FAST-GT) is presented in [6]. It is a generic framework, which reduces the necessity for manual intervention, and, consequently, speeding-up determination of the GT.
Due to many problems in maritime surveillance, it would be expected to have more papers in this area. Maritime surveillance has been an interesting research area due to protecting Exclusive Economic Zones, and territorial waters against plundering, smuggling, illegal immigration, piracy, and terrorism [7]. Hence, the paper deals with maritime surveillance systems and anomaly detection, which is a crucial step for further processing, such as boat/ship classification, tracking, and/or behaviour analysis. The authors proposed fusion technique to overcome some specific problems of background subtraction algorithms.

A comprehensive review of vessel detection and classification is presented in [8]. This paper deals with optical images, but spaceborne, which open a set of new problems, which are not usually important when camera is on shore. The authors encourage the organizations to prepare free, open access data sets together with GT data with goal that future vessel detection methods can be tested and evaluated.

In this paper, we present some problems in answering the call from [8]. We report actual problems in determination of the GT in real maritime scenes. First problems were reported in [9, 10] as preliminaries for the work on the project.

This paper is organized as follows. The second section discuss some methodology issues. The third section presents observed cases. Finally, conclusions are given.

II. METHODOLOGY

A. Selecting a Tool for GT Generation

The first question is what tool to use. If someone choose to segment every frame in a video sequence by pixels in a graphic suite, it can be done, but it is very extensive and slow job requiring many man-hours. If the graphic suite is user-friendly, it can be expected that performed actions will result in precise results. However, when zooming to the level of pixels, there is a limit when pixels are too fuzzy and too grainy to be reliable. Accordingly, a zoom factor should be reduce to perform the operations. So, this extensive work does not necessarily produce absolutely reliable results. Logical question is why to perform such extensive job when the results will not be so proportional to the efforts.

Alternatively, several tools for image annotation or labelling have been developed over the years, which can be used to obtain similar level of the precision with less man-hours. Some of them were mentioned in the Introduction Section. All of these tools have advantages and disadvantages which should be balanced when choosing the tool for work.

Since many scientists work with Matlab, it would be preferable that the benchmarks, resulting from the work on GT generation, is easy to use in Matlab. So, we did not have dilemma that some sort of Matlab file should be the result. Recently, Matlab presented Ground truth labeller application, as a part of Automated Driving System Toolbox. Due to compatibility with the Matlab workspace, options of saving in Matlab file, as section, or by exporting labels as variables, it is an ideal tool for Matlab users.

B. Approach to GT Labelling

Currently, we are using manual GT generation. Used app offers polygon selection for labelling or brushing the pixels. In practice, general contours can be selected by clicking the contours of the moving object, and some details can be brushed or erase.

Manual GT generation opens several issues regarding human errors and reliability. Besides standard problems, such as tiredness, nervous expectations to finish the job, and hand precision, several issues arise. It is noticed that human can draw a silhouette by memorizing shape and expected position or by perception of the moving object (no matter it can be seen completely) in an image. It is emphasised in cases when closure of the object’s silhouette is not clear (fuzzy, unclear, or invisible due to weather conditions or by zooming effect). This opens a question: it is better to mark the position of the moving object by human perception, or it is better to mark just the observable pixels. This problem is illustrated in Fig. 1. Fig. 1 shows the object under sunny weather and in snowing weather. Fig. 1. a) shows how many
Some Problems in Establishing Maritime Zone Surveillance Dataset

Details the specific object have. Fig. 1.b) shows that in real situation, even general contour can be a problem, not to mention all the details.

![Image](image_url)

Another approach is to clear the image from the weather conditions, and then to mark the ground truth. This approach opens additional problem: is the algorithm for “clearing” corrupted the original data and how the cleared image can be reliable.

Alternative to human manual ground truth generation is to try to apply some automatization algorithm or artificial neural network. Basically, we need some sort of artificial intelligence (AI). But, this requires a training sequence in order that AI learns to do the job.

Chosen Matlab Ground Truth Labeller App has also several automated algorithms, which can be used to track selected objects, but there are not currently working with random shaped. These algorithm prefer rectangular shapes. This approach is a lot faster than the manual GT labelling, but it usually includes more background pixels into the motion mask.

### III. RESULTS — EXAMPLE CASE

One of the problems in the GT generation is illustrated with Fig. 2. We can see a seagull, which flies over the boat and the tugboat. However, due to resolution, in several frames it can be mistaken as a human who is jumping from the tugboat to the boat. Obviously, it is not a kind of movement we are interested
in. Hence, we have not labelled it as moving object, because we are interested in marine moving objects. From this example, we can see that GT generation is not an easy task for some algorithm, even which shows elements of smartness or intelligence. This reduces a chance to have good labelling without hard artificial intelligence algorithm with supported database of possible distraction objects.
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Fig. 2. Zoomed part of the image with detected moving boat (as it appears): a) a moving object moves from the tugboat to the boat, b) the moving object is in touch with the boat, c) the moving object is over the boat (it looks like a man is on the boat and the objects cannot be distinguished), d) moving object is not on the boat anymore.

Fig. 2 shows that it is possible to be mistaken about the objects. The seagull merely flies in front of the camera.

Most common problems are also shadows and fuzzy contours due to low contrast of the moving object from the background. This is illustrated in Fig. 3.
IV. CONCLUSIONS

This paper describes some observations on actual problems, which occurred during the realization of the project. The goal of the project is to obtain a reliable and as precise as possible benchmark for surveillance of the maritime zone in various weather conditions. The presented case shows problems occurring under cloudy weather: low contrast due to low sunlight, shadows, and birds flying in front of the camera at some distance, which are all real problems.

The final results of the project will be presented at the open access web page. We hope that it would help in further researches in this field.

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Stabilization of Electrical Parameters of The Ship’s Electric Power Supply Using Fuzzy Controller

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ABSTRACT
Projecting of automatic control systems is complex process which rely on simultaneous optimization of cooperating subsystems which has usually different physical nature. Usually in the first phase of control system projection, basis on physical law and other information, the mathematical model of controlled object is created. In next step formed equations are transformed so it is possible to work out the simulation model of control system. After using simulations research to verifying the correctness of model and after introducing the required modification the control system can be constructed. Using described projection scheme it is possible to compare many of control conception and chose the optimal one.

The paper presents dynamical models of controlling voltage and frequency of ship’s electric supply set. The simulation model of synchronous current generator, implemented in Matlab/Simulink, was described. For worked out simulation model the projected control systems using classical regulators P and PD type as well as fuzzy regulators were presented. For this regulators the simulations research were made for situation of resistance, inductive and capacitive loading. Example results were presented as a step response of voltage generated by electric generator and rotator speed of electric supply engine. Researches allows to valuation the quality of control process using classical regulators and fuzzy regulators. The following indicators were adopted as a criterion for the assessment of the quality of audits: maximum value of generated voltage and engine speed; the duration of the transitional process and static error. Such formulated quality criteria allow for comparison of developed control systems.

KEYWORDS: stabilization, fuzzy controller & electric power supply

I. INTRODUCTION
Taking into account the requirements for control systems of voltage marine synchronous generators which are defined by the national standards and the Polish Register of Shipping it should be taken into account that these systems should provide:

- maintaining the voltage change in the steady state within ±2.5% at the set values of the inductive factor of power in the range of 0.6 to 1 and a load of the generator in the range of 0 - 100% of rated power,
- maintaining voltage changes in a transient state, so that the sudden load change of symmetrical generator running at rated speed and at rated voltage, did not cause a reduction in the voltage to less than 85%, or increase the voltage to a value higher than 120% of rated voltage. After such a change the voltage of the generator should be restored to the nominal value with a tolerance of ±3%, after a period of time no longer than 1.5 s,
- at idle of the generator and rated voltage as well as frequency, it is possible to start an unloaded induction cage motor, if the initial value of the starting current of the motor is not more than 2.5 times the rated current of the generator [5].

Rules of the qualifying institutions puts the following requirements to systems for control of rotational speed of marine diesel engines [3]:

- the load varying between 25% and 100% of rated load where maximum speed fluctuations should be within ±1%,
- the ability to change rotational speed within ±10%,
- static characteristics of the regulators of generator’s drive motors intended for parallel operation should be such that in range from 20% to 100% of generators accumulative load,
each generator load did not differ more than 10% of the biggest power generator operating in parallel,

- after a sudden completely removing the rated load temporarily change of engine rotational speed should not exceed 10% of the nominal speed and the speed determined after 5 s should not differ by more than 5% of speed before removing the load,
- after step change of load about 50% of the rated load and at the step weight on about remaining 50% of load, momentary change of rotational speed shall not exceed 10% of rated rotational speed, and the rotational speed determined after 5 seconds from the step change of load should not differ from the rotational speed before load by more than 5% of engine rated rotational speed.

To fulfill the given requirements each ship’s electric power supply set is equipped with automatic control systems in which there are two regulators, one has the task of adjusting the generated by the generator voltage, and the second controls the frequency. The main tasks of the control system of synchronous generator voltage is to maintain constant voltage at its terminals. Since most generators used in ships is self-excited synchronous generators wherein the coil winding is powered by its own rectified voltage generator. This solution means that excitation voltage is not constant, but decreases with increasing load. The main tasks of the control system of synchronous generator frequency is to maintain a constant frequency in both the states of static and dynamic. This is directly connected to the maintenance of constant rotational speed of generator’s driving motor. It follows that a major problem in the design of this type of system is the issue of the selection of controls systems which fulfill the requirements given to the generated electricity on ships.

II. SIMULATION MODEL OF SHIP’S ELECTRIC POWER SUPPLY SET

Developing a model of the system or the phenomenon involves clarifying the fundamental mathematical relationships between certain physical phenomena. At the same time, it is missed many details and features of real object irrelevant from the point of view of the modeling. To consider a mathematical model of the synchronous machine has adopted the following simplification [2, 4, 6]:

- it is assumed symmetry of three-phase windings of the stator and rotor,
- it is assumed that the magnetomotive force in the gap along the pole pitch has sinusoidal distribution,
- it is neglected hysteresis, saturation, anisotropy and eddy currents in the magnetic circuit,
- it is assumed that the operating point of the magnetic circuit is located in the linear part of the characteristics of the magnetization, which in practice means accepting fixed self-inductance values as well as cross-inductance,
- the generator is carried out without attenuating windings with the rotor pole pieces made from solid steel.

Taking into account the assumptions the equation describing the dynamics of the synchronous generator can be represented as follow [2, 4]:

\[
\begin{align*}
\frac{du_{sd}}{dt} &= \frac{dF_{sd}}{dt} - NF_{sq} + R_s i_{sd} \\
\frac{du_{sq}}{dt} &= \frac{dF_{sq}}{dt} - NF_{sd} + R_s i_{sq} \\
\frac{dF_f}{dt} &= -\frac{1,5R_f M_{wd}}{L_{sd} L_f - 1,5M_{wd}^2} F_{sd} - \frac{R_f L_{sd}}{L_{sd} L_f - 1,5M_{wd}^2} F_f + u_f \\
F_{sq} &= L_{sq} i_{sq} \\
M_e &= p(F_{sd} i_{sq} - F_{sq} i_{sd})
\end{align*}
\]
where:
\( M_e \) - electromagnetic moment,
\( N \) - the speed of rotation of the magnetic field,
\( u_f, i_f \) - voltage and excitation current brought to the side of the stator,
\( F_f \) - the magnetic flux associated with the winding excitation brought to the site of the stator,
\( p \) - the number of pole pairs,
\( R_f, L_f \) - resistance and self-inductance of winding excitation brought to the site of the stator,
\( L_{sd}, L_{sq} \) - self-inductance of the stator windings in the longitudinal and transverse axis,
\( M_{wd} \) - mutual inductance between the excitation winding and the replacement of the stator winding in the longitudinal axis,
\( R_s \) - stator resistance,
\( F_{sd}, F_{sq} \) - space vector of the stator magnetic flux in the longitudinal and transverse axes,
\( i_{sd}, i_{sq} \) - stator current in the longitudinal and transverse axes.

Complementary to the previous system of equations is equation of moments written in the following form:

\[
n = \frac{1}{J} \int_0^t (M_m - M_e) dt - T_f n
\]  

where:
\( M_m \) - mechanical torque applied from the outside produced by the combustion engine,
\( J \) - the moment of inertia of the rotating mass,
\( n \) - the angular speed of rotation of the rotor,
\( T_f \) - coefficient of friction.

These equations correspond to the ideal synchronous machine with the adoption of the classic simplifying assumptions. On their basis, in MATLAB / Simulink, a simulation model of electric power supply set installed on ships type Oliver Hazard was developed. Its block diagram is shown in Fig. 1.
Using the presented model were carried out verification studies of the simulation model of synchronous generator. Verification was made by measuring the characteristics of idling and regulatory and compare them with the real condition characteristics [6, 8]. The test results are shown in Fig. 2.

![Characteristics of the real generator and the simulation model](image)

**III. FUZZY CONTROLLER**

For the purpose of controlling the ship’s electrical power supply set were developed fuzzy controller which task is to stabilize the rotational speed of the internal combustion engine driving the generator so during the load changes to ensure the maintenance of the rated voltage and frequency [1, 7].

There were developed fuzzy P and PD controllers for which the membership functions for the fuzzy sets for inputs has form as it is presented on Fig. 3. The membership functions for the deviation were presented on Fig.3a and for derivative error on Fig. 3b.

![Membership functions for fuzzy sets](image)

Interference was made on the basis of established database of rules, where the rules of conclusion were conducted according with table 1. In the table were determined: DU - a big negative, SU - medium negative, MU - small negative, Z - zero, DD - big positive, SD - medium positive, MD - small positive. Rules in database were defined on the basis of expert knowledge.
TABLE I. DATABASE OF RULES

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Defuzzification of resulting membership function of conclusions rule base was carried out by the method of center of gravity according to the membership function shown in Fig. 4.

![Fig. 4. Fuzzy sets used in the process of defuzzification](image)

IV. SIMULATION RESEARCHES

A. Researches and Results

Using the model of the controlling ship’s power supply set were carried out studies for different types of controllers. In these systems, were used the classic type regulators P and PD which were set up using Ziegler – Nichols method and fuzzy regulators. The rotational speed as well as the voltage generated by power supply set in conditions of change the load for the various types of loads and change the position of the fuel terminal and the excitation voltage were studied. Examples of the results of the simulation are shown in the figures bellow.
Fig. 5. The course of rotational speed during step change of load from $\alpha$ to $60\%$ of rated power for regulators P and PD classic and fuzzy: a) for inductive load, $\cos(\phi) = 0.8$; b) for capacitive load $\cos(\phi) = 0.82$.

Fig. 6. Course of the generator’s voltage during step change of load from $\alpha$ to $60\%$ of rated power for regulators P and PD classic and fuzzy; a) inductive load $\cos(\phi) = 0.8$; b) the capacitive load $\cos(\phi) = 0.82$.

Fig. 7. The course during step change of load a) the speed and position of the fuel terminal, b) the value of the output voltage and the excitation voltage

B. Conclusion
When evaluating the duration of transition process it is clear to see the advantage of PD controller over P controller, wherein in both cases fuzzy controllers provide better quality control. Assuming permissible deviation from the setpoint of speed $\pm 1$ rpm, the time of practical set up of rotational speed during step change in load from $\alpha$ to $60\%$ of rated power at $\cos(\phi) = 1$ was for the regulator type P 2.3 sec, for the
The maximum voltage increase, the error in the steady state and the duration of the transient process of applying both classic and fuzzy controllers are within the limits set by the Society for Qualifying.

The further direction of research on the use of fuzzy regulators to stabilize the electrical parameters of the ship’s power supply set will be focused on the development of fuzzy PID controllers.

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Using Particle Swarm Optimization for Tuning Course Controller of Biomimetic Underwater Vehicle

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ABSTRACT

In recent times, we may notice some new designs of underwater vehicles, which imitate living underwater organisms, e.g., a fish. These vehicles are called biomimetic. They are driven by undulating propulsion, imitating wavy motion of fins. In the paper, problem of tuning settings of course controller for Biomimetic Underwater Vehicle (BUV) using Particle Swarm Optimization (PSO) is undertaken. This problem was resolved using numerical research.

KEYWORDS: biomimetic underwater vehicle & course control

I. INTRODUCTION

In the recent years, a dynamical development of underwater robotics has been noticed. One of the latest innovative constructions in this field are autonomous biomimetic underwater vehicles (BUVs) [1][2][3]. They imitate underwater living organisms, e.g., fishes, marine mammals, etc. They can imitate both the construction and kinematics of motion. BUVs are driven by undulating propulsion imitating real fins, e.g., of a fish – Fig. 1.

Such vehicles have the following features: (1) their propulsion is more energy efficient and (2) more silent [4] than classical propulsion based on screw propellers (based on initial research carried out in Polish Naval Academy), (3) they are very difficult to differentiate from the real inhabitants of underwater environment (larger secrecy and potential range of operation – Fig. 1).

The paper includes results of the research on BUVs carried out within two projects. The projects were preceded by the works on technology demonstrators of BUVs called CyberFishes (Fig. 1). The first of mentioned above projects is carried out in Poland by the consortium consisted of the following scientific and industrial partners: Polish Naval Academy PNA – the leader, Cracow University of Technology CUT, Industrial Institute of Automatics and Measurement PIAP and Forkos Company [5]. The main objective of the proposed project is to build heterogeneous torpedo-shaped BUVs with undulating propulsion for selected scenarios of underwater ISR. One of the two BUVs built in this project is illustrated in the Fig. 2.

The mathematical model of this vehicle is presented in next section. The second project was started in connection with Unmanned Maritime Systems Programme in European Defense Agency. The project is carried out by the consortium consisted of the mentioned above Polish partners and also Bundeswehr Technical Center for Ships and Naval Weapons WTD 71 in Eckernförde, Germany and three partners from Portugal: CINAV from Lisbon and University of Porto and OceanScan. The main objective of the
project is to build BUVs similar to real inhabitants of underwater environment, prepared for their swarm operation.

As it was showed above, the research on BUVs are consistent and are developing in the direction of autonomous vehicles cooperating in a swarm. This development requires many different researches focused on control algorithms, e.g. [6], starting with low-level control and providing to semi– or fully–autonomous behaviors at the end of the research. Low-level control system is understood as a set of controllers of motion parameters of BUV, e.g. of course, depth, etc.

In this paper, the mathematical model of biomimetic underwater vehicle is described in details in the next section. Then, in the third section the description of course controller structure and tuning method of its settings are presented. In the next fourth section, the results of numerical research on course controller settings tuning and the results of final operation of proposed BUV are illustrated. In the fifth section, the conclusions are formulated. At the end, the acknowledgment and references are inserted.

II. MATHEMATICAL MODEL OF BUV

Usually, an underwater vehicle is considered as a rigid body with the following features [7]:
- it has three planes of symmetry,
- it moves in six degrees of freedom,
- it moves at a low speed in a viscous fluid.

Motion of the vehicle is described by means of two reference systems: (1) the movable coordinate system associated with the vehicle $x,y,z_0$ and (2) the immovable coordinate system associated with the Earth $xyz$. The origin of the movable coordinate system $O$ responds to the center of gravity of the vehicle, while its axes are defined as: (1) $x_0$ is a longitudinal axis directed from the stern to the bow, (2) $y_0$ is a transverse axis directed to the starboard, and (3) $z_0$ is a perpendicular axis directed from the top to the bottom. Changes of the position of the movable coordinate system $x,y,z_0$ are described with respect to coordinate system $xyz$ associated with the Earth. Due to the fact that the vehicle moves at a relatively low speed, acceleration of points on the Earth’s surface is ignored and the coordinate system $xyz$ is considered as a stationary. Therefore, the centrifugal and centripetal forces and moments of force caused by the spin of the Earth may be neglected.

Taking into account mentioned above assumptions, to simulate motion of BUV, a nonlinear model of underwater vehicle in 6 degrees of freedom [2] was used. The motion of the vehicle is described by 6 differential equations, very often presented in the compact matrix form:

$$M(\dot{\psi}) + D(\psi)\psi + g(\eta) = \tau$$

(1)
here:
\( \nu \) – vector of linear and angular velocities in the movable system,
\( \eta \) – vector of vehicle position coordinates and its Euler angles in the immovable system,
\( M \) – matrix of inertia (the sum of the matrices of the rigid body and the accompanying masses),
\( D(\nu) \) – hydrodynamic damping matrix,
\( g(\eta) \) – vector of restoring forces and moments of forces of (gravity and buoyancy),
\( \tau \) – vector of control signals (the sum of vector of forces and moments of force generated by propulsion system \( \tau_p \) and by environmental disturbances \( \tau_d \)).

The left side of the equation (1) includes forces and moments of force caused by the following physical phenomenon: an inertia of the body of the vehicle and an inertia of an accompanying masses of a viscous liquid, a hydrodynamic dumping of water environment, a balance of a gravity and a buoyancy. While the right side of the equation (1) represents the vector of forces and moments of force acting on the vehicle generated by a propulsion system and additional environmental disturbances (under surface of water especially a sea current). The parameters of the matrices included in the left side of equation (1) were calculated based on the dependencies included in [7]. The vector of forces and moments of force \( \tau_p \) generated by the new type of propulsion system called undulating propulsion were calculated using equations included in [8]. The calculation of the vector \( \tau_p \) should take into consideration specific configuration, i.e. a number, a location and a surface of acting of each fin [8].

The control object (Fig. 2) is equipped with two side fins and one tail fin. All the fins consist of one movable segment. Each fin generates a thrust with the value changing in time depending on the control parameters of the fin, especially amplitude and frequency of the fin oscillation [9]. The thrust generated by the fin depends also on the construction parameters of a fin (a stiffness of fin membrane, a shape and dimensions of the fin, etc.). The research focused on influence of construction parameters of fin on generated thrust and consumed power are in progress.

III. COURSE CONTROLLER

A. Structure

Two control methods were used for the course control. The first controller is a proportional-integral-derivative action controller (PID) and the second is a slide mode controller (SMC). Moreover, two variants of the course controller were examined. The first variant of controller produces on its output only a depletion angle of the fin with the constant frequency of its oscillation, while the second variant of controller generates both the depletion angle and the frequency of oscillation of the tail fin.

The action of the PID controller is described by the following formula in the discrete form:

\[
    u(k) = K_p \cdot e(k) + K_i \cdot \sum_{k=1}^{k_{\text{max}}} e(k) + K_d \cdot \Delta e(k)
\]

Where \( u(k) \) is a control signal in \( k \) step of simulation. Variable \( e(k) \) is an error signal in \( k \) step of simulation, while \( \Delta e(k) \) is a change of error signals in \( k \) step of simulation (\( e(k) - e(k-1) \)). Constant quantities called gain factors are: \( K_p \), \( K_i \) and \( K_d \).

While the sliding mode control (SMC) is calculated using the following formulas in the discrete form:

\[
    s(k) = \frac{\lambda \cdot e(k) + \Delta e(k)}{\varphi}
\]

if \( |s(k)| > 1 \), then \( s(k) = \text{sign}(s(k)) \)

\[
    u(k) = k_s \cdot s(k)
\]

Where \( u(k) \) is a control signal in \( k \) step of simulation and \( s(k) \) is a normalized control signal in \( k \) step of simulation. Variable \( e(k) \) is an error signal in \( k \) step of simulation, while \( \Delta e(k) \) is a change of error signals in \( k \) step of simulation (\( e(k) - e(k-1) \)). Constant quantities are: \( \lambda \), \( \varphi \), \( k_s \).
To achieve efficient action of the controllers, determination of constant quantity values is necessary, i.e. $K_p$, $K_i$ and $K_d$ for the PID controller and $\lambda$, $\phi$, $k_s$ for the SMC controller.

B. Tuning method

In the paper, the Particle Swarm Optimization (PSO) was used for finding optimal values of the settings of the PID and SMC controllers. The inspiration for the PSO is flocks of birds or insects swarming. Each particle is attracted to some degree to the best location it has found so far, and also to the best location any member of the swarm has found. After some steps, the population can coalesce around one location, or can coalesce around a few locations, or can continue to move [10]. PSO is a population-based algorithm and it is similar to the genetic algorithm. A collection of individuals called particles move in steps throughout a region. At each step, the algorithm evaluates the objective function at each particle. After this evaluation, the algorithm decides on the new velocity of each particle. The particles move, then the algorithm reevaluates [11]. PSO was originally introduce for simulating social behavior [5].

Similar to the other population-based algorithm, one of the key problem in PSO is to properly formulate cost function which is used for estimation of solutions encoded in particles. In the research, the following simple cost function was defined:

$$f_{\text{cost}}(k) = \sum_{k=1}^{k_{\text{max}}} |e(k)|$$ (6)

Where $f_{\text{cost}}(k)$ is a cost function and the variable $e(k)$ is an error signal in $k$ step of simulation (in case of course controller $e(k)$ is an error of course, i.e. difference between current and desired values of a course.

Based on the literature [12][13] the following parameters of PSO were accepted:

- MaxStallIterations (relative change in the best objective function value $g$ over the last MaxStallIterations iterations is less than FunctionTolerance): 20,
- MinNeighborsFraction (MinNeighborsFraction option sets both the initial neighborhood size for each particle, and the minimum neighborhood size): 1,
- SwarmSize: 100.

IV. RESULTS OF RESEARCH

A. Tuning process

In the Table I, the results of tuning PID and SMC course controllers in the following variants:

- variant I – output signal is depletion angle of the fin with the constant frequency of the fin oscillation,
- variant II – output signals are depletion angle of the fin and frequency of the fin oscillation are presented.

In the case of variant II, the settings for two controllers are needed (the first controller for generating depletion angle and the second for generating frequency of the fin oscillation).

<table>
<thead>
<tr>
<th>PID</th>
<th>Settings</th>
<th>Cost function</th>
<th>$K_p$</th>
<th>$K_i$</th>
<th>$K_d$</th>
<th>$K_{\phi}$</th>
<th>$K_{\lambda s}$</th>
<th>$K_{\lambda e}$</th>
<th>$K_{\phi e}$</th>
<th>$K_{\lambda e}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>PID</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>variant I</td>
<td>226.5</td>
<td>-182.2</td>
<td>141.8</td>
<td>131.3</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>variant II</td>
<td>155.1</td>
<td>-200</td>
<td>146.5</td>
<td>199.8</td>
<td>1999</td>
<td>1999</td>
<td>-1976</td>
<td>–</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMC</td>
<td>Cost function</td>
<td>$\lambda_s$</td>
<td>$\phi_e$</td>
<td>$k_{\lambda s}$</td>
<td>$\lambda_e$</td>
<td>$\phi_e$</td>
<td>$k_{\lambda e}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>variant I</td>
<td>160.9</td>
<td>0.0311</td>
<td>0.0027</td>
<td>49.65</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>variant II</td>
<td>91.18</td>
<td>0.032</td>
<td>0.0028</td>
<td>49.77</td>
<td>1e-0</td>
<td>0</td>
<td>1645</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Based on the received results (Table I) the smallest value of the cost function was received for SMC course controller in variant II. This controller was selected for the next research (Fig. 4). This controller was compared with PID course controller in variant II (Fig. 5).

The Fig. 3 illustrates changes of the cost function during tuning PID settings of course controller in variant I. As it can be seen, the best values of the cost function were received after approx. 20 iterations. After the next 100 iterations almost no improvement was observed.

**B. Course control**

![Fig. 3. Changes of cost function during tuning PID course controller in variant I using PSO](image)

![Fig. 4. Changes of course \( \psi \), depletion angle \( K \) and frequency \( F \) of the tail fin oscillation for SMC](image)
Comparing SMC (Fig.4) and PID (Fig. 5) course controllers operation, the following conclusions can be drawn:

- SMC controller can achieve the desired value of a course faster and without the first over-regulation,
- PID controller characterizes with the first over-regulation equal to approx. 6 deg,
- Both SMC and PID controllers in variant II characterize more efficient operation than their counterparts in variant I.

![Graphs showing course, angle, and frequency changes](image)

**Fig. 5. Changes of course $\psi$, depletion angle $K$ and frequency $F$ of oscillation of the tail fin for PID controller**

### V. SUMMARY

Designed mathematical model of the motion of biomimetic underwater vehicle allowed to design and then to compare the PID and the SMC controllers of the BUV. PSO algorithm enabled us to find settings of the controllers in the automatic way in accordance with defined cost function.

SMC controller is more efficient and precise than PID controller. However, SMC controller causes more intensive operation of tail fins, i.e. a few fading oscillations of the angle deflection at the end of control process (Fig. 4).

In the future research, the next controllers, e.g. of depth are planned to be construct and tuned using optimization algorithm, e.g. PSO.

### ACKNOWLEDGMENT

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### REFERENCES


Analysis of Croatian Sea Ports Ballast Water Quantity
From 2014 To 2017

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ABSTRACT
The aim of this study is to analyse parameters of ballast water entering eight port sea area authorities in Croatia: Pula, Senj, Ploče, Split, Šibenik, Zadar, Rijeka and Dubrovnik from φτυψ to φτυϋ. In accordance with the aim, official data was gathered from Ministry of Sea, Transport and Infrastructure through observation and analysis of different indicators: number of vessels with ballast water, amount of ballast water transported, total volume of ballast water capacity, number of vessels which discharged ballast water, amount of ballast water discharged; slowly decreasing trend of amount of ballast water was identified from φτυψ to φτυϋ. Further research should include in-depth analysis of preparedness of Croatian sea ports towards successful implementation of BWM convention.

KEYWORDS: ballast water management, ecology, Croatian port authorities

I. INTRODUCTION
According to IMO it is estimated that 10 billion tonnes of ballast water is transported per year, with 7000 species being transferred in ballast water every hour of everyday. One new invasion happens every 9 weeks, with 2.4 billion people living within 100km of the coast, while 80% of World trade is carried by ships [1]. International convention for the control and management of ships ballast water and sediments (BWM), within Article 1 defines: “Ballast water is the water with its suspended matter taken on board in order to achieve acceptable level of stability, trim, list, draught, and stresses of the ship” [2]. Depending on size, vessels can take from few thousands to over 100,000 tones of sea water for ballast [3]. Figure 1 shows conventional bulk carrier with ballast water tanks.

Ballast water has emerging risks which include economical effect such as damage in tourism, or human health and ecological impact as a result of possible transfer of non-native species such as algae, bacteria, viruses, fish larvae, or crustaceans [5,6]. In Adriatic Sea, invasive species are green algae Caulerpa taxifolia and Caulerpa Racemosa, and it is particulary important to explore scientific methods which would slow down their growth, especially in the protected area [7]. Constant decline of time from loading to discharge of ballast water has impacted better survival rate of non-native species during the voyage [8].
Furthermore, economic global impact of ballast water is estimated at around 10 billion Euros with increasing trend [9].

With aim to minimise and prevent risks arising from the transfer of harmful organisms and pathogens, BWM is adopted in London 2004. Convention stated as obligatory to each Party to ensure that in ports and terminals where cleaning and repair of ballast tanks occurs, adequate facilities are provided for the reception of sediments, which can’t cause delay to ships and are required to provide for the safe disposal of sediments that does not impair or damage their environment, human health, property or resources of those of other states [10]. While convention doesn’t provide exact requirements regarding facilities, parties are obligated to endeavour, individually or jointly to promote and facilitate scientific and technical research and monitor the effects in waters under their jurisdiction [υτ]. Furthermore, within Article 13 it has been required that parties provide support for those which request technical assistance, to train personnel, to ensure relevant technology, to initiate research and development programmes, and to undertake other action aimed at the effective implementation of Convention. Convention is made from basic part and supplement which includes technical standards and requirements as written in Regulations for the control and management of ships’ ballast water and sediments. Regulations are divided in five sections: General Provision (A), Management and Control Requirements for Ships (B), Special Requirements in Certain Areas (C), Standards for Ballast Water Management (D) and Survey and Certification Requirements for Ballast Water Management (E). On 8th September 2017, the Convention entered into force in the Republic of Croatia, and it is from great importance to identify current situation regarding vessels carrying ballast water in Croatia, and to point activities necessary to meet requirements of Convention properly [υυ].

Consequently, the problem is addressed globally [υφ] and it is of great scientific importance to do trend analysis, even annually, which includes data about quantity and origin of ballast water [υχ, υψ]. Data collection and analysis of ballast water parameters help minimise risk connected with ballast water negative impact, which include impact on health, ecology and economy. In accordance with previously stated facts, the aim of this paper is to do analysis of Croatian sea ports Pula, Senj, Ploče, Split, Šibenik, Zadar, Rijeka and Dubrovnik ballast water parameters from 2014 to 2017.

II. METHODOLOGY

Data are obtained by direct e-mail communication with Croatian Ministry of Sea, Transport and Infrastructure. During communication with officials, it was clearly stated that all data will be used for the purpose of the scientific research. Different indicators for 2014-2017 yrs for sea ports Pula, Senj, Ploče, Split, Šibenik, Zadar, Rijeka and Dubrovnik were requested and gathered: number of vessels with ballast water (NVBW), ballast water transported (BWT), total volume of ballast water capacity (VCBW), number of vessels which discharged ballast water (NDBW), ballast water discharged (BWD).

III. RESULTS

Table I. shows number of vessels with ballast water (NVBW), ballast water transported (BWT), total volume of ballast water capacity (VCBW), number of vessels which discharged ballast water (NDBW), ballast water discharged (BWD) for 8 Croatian sea ports: Pula, Senj, Ploče, Split, Šibenik, Zadar, Rijeka and Dubrovnik (PA).
Table I. Ballast water variables of Croatian sea ports in 2014

<table>
<thead>
<tr>
<th></th>
<th>NVBW</th>
<th>BWT [10^6 m³]</th>
<th>VCBW [10^6 m³]</th>
<th>NDBW</th>
<th>BWD [10^6 m³]</th>
</tr>
</thead>
<tbody>
<tr>
<td>PULA</td>
<td>513</td>
<td>0.550</td>
<td>1.636</td>
<td>378</td>
<td>0.088</td>
</tr>
<tr>
<td>SENJ</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>POLOCE</td>
<td>240</td>
<td>1.777</td>
<td>2.143</td>
<td>79</td>
<td>0.161</td>
</tr>
<tr>
<td>SPLIT</td>
<td>1.002</td>
<td>0.820</td>
<td>1.873</td>
<td>284</td>
<td>0.413</td>
</tr>
<tr>
<td>Sibenik</td>
<td>107</td>
<td>0.095</td>
<td>0.340</td>
<td>62</td>
<td>0.188</td>
</tr>
<tr>
<td>ZADAR</td>
<td>205</td>
<td>0.098</td>
<td>0.305</td>
<td>24</td>
<td>0.030</td>
</tr>
<tr>
<td>RIJEKA</td>
<td>832</td>
<td>2.698</td>
<td>8.974</td>
<td>296</td>
<td>1.828</td>
</tr>
<tr>
<td>DUBROVNIK</td>
<td>696</td>
<td>0.456</td>
<td>1.695</td>
<td>1</td>
<td>0.001</td>
</tr>
<tr>
<td>Total</td>
<td>3595</td>
<td>6.497</td>
<td>16.970</td>
<td>1124</td>
<td>2.621</td>
</tr>
</tbody>
</table>

From Table I, it can be seen that from 3595 vessels 1124 of them discharged 2.621 million m³ of BW, from which Rijeka was absolutely dominant with 1.828 million m³ of BW (69.74%) discharged. Those data are expected due to the fact that Rijeka is biggest cargo port in Croatia, with tendency of further development which probably implicates further rise of BW quantity. On the other side, sea port Dubrovnik, one of the most famous Mediterranean cruising destination had only one vessel with BW. Because of unavailability of the raw data, data was not presented for sea port of Senj. Although Pula sea port had largest number of vessels which discharged ballast water (378; 33.63%) it was not dominant in ballast water discharged with only 3.36% of total amount. Furthermore, Table II. Shows ballast water quantities for year 2015.

Table II. Ballast water variables of Croatian sea ports in 2015

<table>
<thead>
<tr>
<th></th>
<th>NVBW</th>
<th>BWT [10^6 m³]</th>
<th>VCBW [10^6 m³]</th>
<th>NDBW</th>
<th>BWD [10^6 m³]</th>
</tr>
</thead>
<tbody>
<tr>
<td>PULA</td>
<td>402</td>
<td>0.446</td>
<td>1.332</td>
<td>263</td>
<td>0.080</td>
</tr>
<tr>
<td>SENJ</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>POLOCE</td>
<td>233</td>
<td>0.486</td>
<td>1.778</td>
<td>64</td>
<td>0.100</td>
</tr>
<tr>
<td>SPLIT</td>
<td>916</td>
<td>0.748</td>
<td>2.012</td>
<td>257</td>
<td>0.547</td>
</tr>
<tr>
<td>Sibenik</td>
<td>96</td>
<td>0.108</td>
<td>0.208</td>
<td>51</td>
<td>0.077</td>
</tr>
<tr>
<td>ZADAR</td>
<td>179</td>
<td>0.082</td>
<td>0.275</td>
<td>34</td>
<td>0.022</td>
</tr>
<tr>
<td>RIJEKA</td>
<td>809</td>
<td>5.097</td>
<td>10.287</td>
<td>283</td>
<td>1.595</td>
</tr>
<tr>
<td>DUBROVNIK</td>
<td>702</td>
<td>0.345</td>
<td>1.348</td>
<td>9</td>
<td>0.003</td>
</tr>
<tr>
<td>Total</td>
<td>3337</td>
<td>7.316</td>
<td>17.243</td>
<td>971</td>
<td>2.424</td>
</tr>
</tbody>
</table>

As expected, in 2015, PA Rijeka recorded biggest quantities of discharged BW, while total of 2,424 million m³ of BW was discharged in Croatia what is a slight decrease as comparing to 2014. It can be observed that increasing trend exists for PA Split, with growth of 0.134 million m³ from year 2014. Same as for 2015, data for Senj were not presented. Dubrovnik, similarly to the 2014, did have only 0.003 million m³ of ballast water discharged. Table III. shows ballast water quantities for year 2016.
Table III. Ballast water variables of Croatian sea ports in 2016

<table>
<thead>
<tr>
<th></th>
<th>NVBW</th>
<th>BWT (10^6 m³)</th>
<th>VCBW (10^6 m³)</th>
<th>NDBW</th>
<th>BWD (10^6 m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PULA</td>
<td>455</td>
<td>0.408</td>
<td>1.269</td>
<td>282</td>
<td>0.262</td>
</tr>
<tr>
<td>SENJ</td>
<td>2</td>
<td>0.0003</td>
<td>0.002</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>PLOČE</td>
<td>214</td>
<td>0.708</td>
<td>2.876</td>
<td>41</td>
<td>0.562</td>
</tr>
<tr>
<td>SPLIT</td>
<td>988</td>
<td>0.797</td>
<td>1.845</td>
<td>211</td>
<td>0.274</td>
</tr>
<tr>
<td>ŠIBENIK</td>
<td>107</td>
<td>0.095</td>
<td>0.212</td>
<td>53</td>
<td>0.078</td>
</tr>
<tr>
<td>ZADAR</td>
<td>183</td>
<td>0.099</td>
<td>0.358</td>
<td>12</td>
<td>0.016</td>
</tr>
<tr>
<td>RIJeka</td>
<td>755</td>
<td>3.222</td>
<td>10.572</td>
<td>229</td>
<td>1.088</td>
</tr>
<tr>
<td>DUBROVNIK</td>
<td>639</td>
<td>0.389</td>
<td>1.397</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>3353</td>
<td>5.720</td>
<td>18.533</td>
<td>828</td>
<td>2.279</td>
</tr>
</tbody>
</table>

Port of Split is third biggest passenger port in Mediterranean, and while all other ports had decreasing trend, sea port Split had risen from 0.412 million m³ in year 2014, to 0.546 million m³ in year 2015. In 2016 there was 0.274 million m³ of BW after which deceasing trend was recorded again in 2017 with 0.189 million m³ of BW. Similarly to previous 2 years, sea port Rijeka was absolutely dominant with 1.088 million m³ of BW (47.74%) discharged. On the other side, sea port Dubrovnik and Senj did not have vessel with BW. As previously mentioned, Pula sea port had largest number of vessels which discharged ballast water but it was not dominant in ballast water discharged. Table IV. shows ballast water quantities for year 2017.

Table IV. Ballast water variables of Croatian sea ports in 2017

<table>
<thead>
<tr>
<th></th>
<th>NVBW</th>
<th>BWT (10^6 m³)</th>
<th>VCBW (10^6 m³)</th>
<th>NDBW</th>
<th>BWD (10^6 m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PULA</td>
<td>338</td>
<td>0.306</td>
<td>0.885</td>
<td>173</td>
<td>0.128</td>
</tr>
<tr>
<td>SENJ</td>
<td>1</td>
<td>150</td>
<td>0.0006</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>PLOČE</td>
<td>231</td>
<td>0.451</td>
<td>2.021</td>
<td>57</td>
<td>0.292</td>
</tr>
<tr>
<td>SPLIT</td>
<td>1010</td>
<td>0.747</td>
<td>1.841</td>
<td>355</td>
<td>0.189</td>
</tr>
<tr>
<td>ŠIBENIK</td>
<td>134</td>
<td>0.116</td>
<td>0.295</td>
<td>56</td>
<td>0.078</td>
</tr>
<tr>
<td>ZADAR</td>
<td>162</td>
<td>0.152</td>
<td>0.614</td>
<td>6</td>
<td>0.005</td>
</tr>
<tr>
<td>RIJeka</td>
<td>754</td>
<td>3.478</td>
<td>0.012</td>
<td>206</td>
<td>1.055</td>
</tr>
<tr>
<td>DUBROVNIK</td>
<td>560</td>
<td>0.337</td>
<td>1.250</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>3190</td>
<td>5.291</td>
<td>18.605</td>
<td>853</td>
<td>1.749</td>
</tr>
</tbody>
</table>

As it can be seen through Table V., almost all identified trend are continued in 2017. In accordance, 853 vessels discharged 1.749 million m³ of BW from total of 5.291 million m³ of BW which entered Adriatic Sea, which is slightly less compared with 2016 (Table 3) when 828 vessels discharged 2.279 million m³ of BW from total 5.720 million m³. As in previous years, sea port Dubrovnik and Senj did not have vessel with BW. For whole observed period sea ports Ploče, Šibenik and Zadar had relatively small variations in all observed variables. Overall analysis indicates non-linear decreasing trend of discharged ballast water. More precisely, observed decreasements are 7.5% (197 million m³), 6.0% (145 million m³) and 23.2% (530 million m³) from 2014 to 2015, from 2015 to 2016 and from 2016 to 2017, respectively. While observing overall results, it can be concluded that existence of non-linear dynamics of variations in presented variables is present and that future observations should take them in account.
IV. CONCLUSION

Emerging risks from transfer of invasive species via ballast water are recognised as one of the challenges on global scale, and it is scientifically relevant to analyse data and trends regarding quantities and origin of BW. Informations are relevant to help prevent possible potential hazard on human health and to minimise threats to biological safety, and to minimise material damage. Furthermore, to eliminate the risks emerging from ballast water transfer, it is necessary to track data and analyse all the relevant parameters introduced and observed in this paper. For years observed in paper, non-linear deceasing trend with decrease of 7.5%, 6.0%, and 23.2% successively from 2014 to 2017 was identified. Despite the progress achieved in the last years in the terms of implementing international regulatory, and ratification of the International convention for the control and management of ships ballast water and sediments, there are challenges and opportunities to fulfil the requirements of the Convention. Consequently, it is from great importance to identify current and extrapolate future situation in Croatia and to point to necessary activities which would be suitable to meet the requirements of the Convention.

REFERENCES


Impact of Slow Steaming on The Fuel Consumption of a Container Ship

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ABSTRACT

Slow steaming approach refers to a significant reduction in ship speed, nowadays commonly applied in cargo shipping. This approach is very important from both an economic and environmental point of view, since it can lead to significant savings in the fuel consumption. However, it should be noted that in slow steaming, the ship operates in different conditions than the ones for which is designed. Also, it increases the voyage time and therefore reduces the number of voyages per year. During the sail, ship encounters different sea states on its route and the total resistance can be significantly increased due to the added resistance in waves, especially at heavier sea states. The added resistance in waves is one of the main causes of an increase in the fuel consumption. The total resistance of a container ship at different sea states is calculated utilizing the Computational Fluid Dynamics (CFD) based on the viscous and potential flow theory. In this paper, the savings in the fuel consumption due to slow steaming approach are estimated for a container ship trade route. The obtained results may give a valuable insight into the pros and cons of slow steaming approach.

KEYWORDS: calm water resistance, added resistance, total resistance in waves, container ship, fuel consumption, computational fluid dynamics & Bretschneider wave spectrum

I. INTRODUCTION

Maritime transport is currently one of the most important modes of transport and will remain like this for a long time. According to International Chamber of Shipping, around 90% of world trade is carried by the international shipping industry. Because of the competitive freight costs, shipping trade continues to expand and bring benefits to consumers around the world [1]. Maritime transport is the most cost-effective mode of transport. Significant advances in shipping technology and the ability of ships to transport an increased capacity of goods have given even more importance to this mode of transport [2].

The launch of container shipping is considered as one of the most significant progresses in the maritime cargo industry. Containerization have changed and revolutionised the way in which cargo is ferried and transported across the world, while increasing the safety and security of the transported cargo. Nowadays, many large shipping companies mainly deal with containerized cargo. Container ships are designed and constructed to transport huge amounts of various cargo. The cargo capacity of container ships is measured in terms of Twenty-foot Equivalent Unit (TEU), an inexact unit of cargo capacity based on the volume of a 20-foot-long (6.1 m) intermodal container. Due to their ability to transport high cargo capacities, some of the largest ships in the world are container ships [3]. The world’s largest container ship is OOCL Hong Kong, Ultra Large Container Vessel (ULCV), with a length of 399.87 m and cargo capacity of 21,413 TEU [4].

Driving such large ships requires a lot of power and consequently large fuel consumption, especially on large routes and heavier sea states. Reducing the fuel consumption and carbon emissions are two most important measures of shipping industry in order to minimize environmental impact, as emissions are in direct relation to fuel consumption. Even though maritime transport is the least polluting mode of transport per transported tonne of cargo, the International Maritime Organization (IMO) has proposed and implemented energy efficiency and Green House Gas (GHG) regulations [5]. In recent years, shipping companies are faced with continuously increasing regulatory requirements. From January 1st, 2013 Ship Energy Efficiency Management Plan (SEEMP) and Energy Efficiency Design Index (EEDI) entered
More sea areas have been proclaimed as Emission Control Areas (ECA) in which stricter controls were established to minimize airborne emissions from ships (sulphur oxides (SOx), nitrogen oxides (NOx), ozone depleting substances (ODS), volatile organic compounds (VOC)) [6]. From January 1st, 2018 onwards European Union (EU) has adopted a Regulation on monitoring, reporting and verification of CO₂ emissions. The main purpose of this regulation is to promote the reduction of CO₂ emissions by introducing a robust system of monitoring and reporting of data on annual fuel consumption, CO₂ emissions and other energy efficiency-related parameters for ships above 5,000 gross tonnes, related to EU ports [7]. These regulatory measures will increase the cost of fuel and stimulate the achievement of greater energy efficiency, which is directly related to the total resistance of a ship.

The total resistance of the ship in waves consists of calm water resistance that is constant at a given constant speed and oscillating resistance due to motions of the ship, depending on the encounter wave frequency [8]. Planning a route in which greater sea states are avoided can have a large impact on fuel consumption. A way to reduce fuel consumption, and therefore fuel costs, is slow steaming [9]. The concept of slow steaming introduced for container shipping by Maersk Lines, has later been applied to other types of ships including tankers and dry bulk ships, whose operating speeds are traditionally low. Slow steaming has reduced the fuel consumption, which in turn has led to significant decrease in carbon emissions [10].

In this paper, the total resistance in waves composed of calm water resistance and added resistance in waves is calculated for a container ship at sea states with the significant wave height lower than 0.5 m corresponding to the North Atlantic. The obtained numerical results are validated against the experimental results available in the literature. For the purpose of spectral analysis, the significant wave height and zero crossing period are defined based on the wave statistics for the chosen route. The ratio of the fuel consumption for the slow steaming and the design speeds is calculated for the chosen route.

II. METHODOLOGY

Numerical simulations of the flow around Krilo Container Ship (KCS) and KCS model are performed within commercial software packages HydroSTAR and STAR-CCM+ in order to determine the total resistance at certain sea states. KCS has a typical hull form of modern commercial container ships. Ship route analysed within this paper is common in today’s container transport. Therefore, the obtained results might point out the importance of speed reduction during the sail at certain sea states. The body plan of KCS is shown in Figure 1. and main particulars are given in Table 1. KCS 3D model is shown in Figure 2. Numerical simulations are performed for two Froude numbers (Fn), which correspond to the design and the slow steaming speeds, i.e. Fn=0.26 and Fn=0.195.
<table>
<thead>
<tr>
<th>Main particulars</th>
<th>Model scale</th>
<th>Full scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length between perpendiculars, $L_{PP}$ (m)</td>
<td>7.2786</td>
<td>230</td>
</tr>
<tr>
<td>Length of waterline, $L_{WL}$ (m)</td>
<td>7.3577</td>
<td>232.5</td>
</tr>
<tr>
<td>Maximum beam of waterline, $B_{WL}$ (m)</td>
<td>1.0190</td>
<td>32.2</td>
</tr>
<tr>
<td>Depth, $D$ (m)</td>
<td>0.6013</td>
<td>19</td>
</tr>
<tr>
<td>Draft, $T$ (m)</td>
<td>0.3418</td>
<td>10.8</td>
</tr>
<tr>
<td>Displacement volume, $V$ (m$^3$)</td>
<td>1.6490</td>
<td>52030</td>
</tr>
<tr>
<td>Hull wetted surface area, $S_W$ (m$^2$)</td>
<td>9.4379</td>
<td>9424</td>
</tr>
<tr>
<td>Block coefficient, $C_B$</td>
<td>0.6505</td>
<td>0.6505</td>
</tr>
<tr>
<td>Midship section coefficient, $C_M$</td>
<td>0.9849</td>
<td>0.9849</td>
</tr>
<tr>
<td>Longitudinal centre of buoyancy, $LCB$ (%$L_{PP}$)</td>
<td>-1.48</td>
<td>-1.48</td>
</tr>
<tr>
<td>Vertical centre of gravity, $VCG$ (m)</td>
<td>0.2304</td>
<td>7.28</td>
</tr>
<tr>
<td>Roll radius of gyration, $k_{xx}/B$</td>
<td>0.40</td>
<td>0.40</td>
</tr>
<tr>
<td>Pitch radius of gyration, $k_{yy}/L_{PP}$</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>Yaw radius of gyration, $k_{zz}/L_{PP}$</td>
<td>0.25</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Fig. 2. KCS 3D model

A. Calm water resistance

Numerical simulations of viscous flow around KCS model are performed within commercial software package STAR-CCM+, in order to determine the calm water resistance. Within numerical simulations, Reynolds Averaged Navier-Stokes (RANS) equations and averaged continuity equation are used as governing equations [11]:

$$\frac{\partial (\rho \bar{u}_i)}{\partial t} + \frac{\partial}{\partial x_j} (\rho \bar{u}_i \bar{u}_j + \rho u'_i u'_j) = -\frac{\partial P}{\partial x_i} + \frac{\partial \tau_{ij}}{\partial x_j}$$  \hspace{1cm} (1)

$$\frac{\partial (\rho \bar{u}_i)}{\partial x_i} = 0$$  \hspace{1cm} (2)

where $\rho$ is the fluid density, $\bar{u}_i$ is the averaged Cartesian components of the velocity vector, $\rho u'_i u'_j$ is the Reynolds stress tensor, $P$ is the mean pressure and $\tau_{ij}$ is the mean viscous stress tensor defined by:

$$\tau_{ij} = \mu \left( \frac{\partial \bar{u}_i}{\partial x_j} + \frac{\partial \bar{u}_j}{\partial x_i} \right)$$  \hspace{1cm} (3)

where $\mu$ is the dynamic viscosity.
Realizable $k-\varepsilon$ turbulence model [12] is used for closing a set of equations (1) and (2). Volume of Fluid (VOF) method is used for tracking and locating the free surface. This method introduces a new parameter, the fraction of $i$-th fluid in the cell ($\alpha_i$). Thus equations (1) and (2) are solved only for one fluid and $\alpha_i$ is determined using the averaged continuity equation. Finite Volume Method (FVM) is used for the discretization of equations (1) and (2), which are solved in segregated manner. First order Euler implicit scheme is used for temporal discretization, while second order upwind scheme is used for the discretization of convective terms. Computational domain is discretized with unstructured hexahedral mesh, which is refined in the region near the expected free surface, around the KCS model and for capturing the Kelvin wake, Figure 3. Six prism layers are made around the KCS model, in order to keep the non-dimensional wall distance ($Y^+$) value above 30. Thus, wall functions can be used, because the first cell from the wall is in the log-law region. Only half of domain is modelled, since symmetry condition is applied. The mesh consists of 0.5 M cells, which is proven to be sufficient for obtaining the reliable prediction of resistance [13].

The domain boundaries are placed $L_{pp}$ away from the ship model in all directions. In order to prevent VOF wave reflection, VOF wave damping is applied using the damping function implemented in software package [14]. It should be noted that VOF wave damping length is set according to the $dvar$ function as follows:

$$dvar \approx \frac{L_{pp}}{2} + \frac{L_{pp}}{2} \cos^2\left(\frac{\pi \cdot t}{2 \cdot 107}\right)$$

(4)

where $T$ is the period defined as ratio between $L_{pp}$ and KCS model speed.

Applied boundary conditions are as follows: velocity inlet for inlet, top and bottom boundary, pressure outlet for outlet boundary, symmetry condition for side and symmetry boundary and no-slip wall for hull surface. Numerical simulations are initialized with the initial velocity and pressure field. Time step used in this study is $T/200$, while the simulation is stopped after $20T$.

The obtained results for the calm water resistance ($R_c$) for KCS model are extrapolated to the full scale values using the extrapolation procedure described in [14]. Index $M$ represents physical property for model scale, and index $S$ represents physical property for ship scale. The total resistance coefficient in calm water can be divided as follows:

$$C_T = (1 + k)C_F + C_W$$

(5)

where $k$ is the form factor and for KCS is equal to $k=0.1$ [2], $C_W$ is the wave resistance coefficient, assumed to be the same for model and ship ($C_{WM} = C_{WS}$) and $C_F$ is the frictional resistance coefficient defined according to the ITTC 1957 model-ship correlation line:
\[ C_F = \frac{0.075}{(\log Rn - 2)^2} \]  

(6)

where \(Rn\) is the Reynolds number.

In order to obtain \(C_{sw}\), firstly \(C_w\) has to be determined as follows:

\[ C_w = C_{TM} - (1 + k)C_pM \]  

(7)

where \(C_{TM}\) is calculated according to:

\[ C_{TM} = \frac{2R_{TM}}{\rho_w \nu_M S_M} \]  

(8)

where \(R_{TM}\) is the calm water resistance of KCS model obtained from numerical simulation, \(\rho_w\) is the water density and \(\nu_M\) is the KCS model speed.

After \(C_w\) is determined, \(C_{sw}\) is calculated according to the equation (6) and then \(C_{SS}\) can be easily determined utilizing equation (5). The calm water resistance of full scale ship can be calculated according to the following equation:

\[ R_{SS} = \frac{1}{2}C_{SW} \rho_s \nu_s^2 S_s \]  

(9)

where \(\rho_s\) is the sea water density.

B. Added resistance in waves

The added resistance of a ship in waves is one of the main causes of an involuntary speed reduction and an increase of the fuel consumption. Considering its direct effect on \(CO_2\) emission, it is very important to estimate an increase of the total resistance due to waves especially at heavier sea states. In severe sea states, ship may experience an increase in resistance larger than the one that is commonly taken into account as a percentage of the calm water resistance known as Sea Margin (SM).

The added resistance in waves is the second order wave force and is considered to be independent on the calm water resistance. Viscous part of the added resistance in waves is negligible, thus it is justified to calculate the ship added resistance using numerical tools based on the potential flow of fairly perfect fluid. Despite the fact that numerical tools based on the viscous flow theory are proven to be more accurate and sophisticated than the ones based on the potential flow theory, the latter ones are still widely used in hydrodynamic calculations due to their robustness, low required computational time and reliability [15].

In this paper, the added resistance of KCS container ship is determined utilizing the commercial software package HydroSTAR v.7.3 [16], based on the potential flow theory at regular head waves. Ship advancing speed is taken into account through the encounter frequency of incoming waves. The obtained results are validated, i.e. compared with the experimental data available in the literature.

Panel method within software package HydroSTAR provides the first order wave radiation and diffraction solution as well as the solution of the second-order wave loads. The velocity potential, used to describe the flow around ship hull, satisfies Laplace equation \(\nabla^2 \Phi = \Delta \Phi = 0\) in the entire computational domain and consists of incoming wave potential \(\Phi_i\) and perturbation potential \(\Phi_p\) due to presence of the ship. Perturbation potential can be decomposed on its diffraction and radiation part.
In panel method, body is discretized using flat panels with sources and dipoles of constant strength on each panel. Integral equations, known as Boundary Integral Equations (BIE), are then solved for the unknown strength of sources and dipoles, based on so called Green function. Hull of the KCS container ship is discretized using quadrilateral panels as can be seen in Figure 4.

In the frequency domain the velocity potential can be expressed as the real part of complex function \( \Phi_s \) with Green function as the fundamental solution of Laplace equation is formulated in order to satisfy boundary condition on the linearized free surface, on the seabed and hull, and radiation condition in the far field as follows:

\[
-k\phi + \frac{\partial \phi}{\partial z} = 0 \quad \text{on } z = 0
\]  
\[
\frac{\partial \phi}{\partial n} = \nu_\phi \quad \text{on the wetted surface}
\]  
\[
\frac{\partial \phi}{\partial z} = 0 \quad \text{on the seabed}
\]  
\[
\lim_{R \to \infty} \left[ \sqrt{R} \left( \frac{\partial \phi}{\partial R} - ik\phi \right) \right] = 0 \quad \text{in far field}
\]

where \( k \) is the wave number, \( n \) is the unit surface normal of boundary element and \( \nu_\phi \) is the normal velocity on the boundary element. Radiation condition, which requires that the velocity potential disappears in the infinite boundary \( R \to \infty \) around the ship hull is automatically satisfied when fairly perfect fluid is considered.

With known velocity potential, pressure on each panel can be calculated with modified Bernoulli equation. Forces and moments acting on ship hull are then calculated by the direct pressure integration along the wetted surface \( S \) and waterline \( L \) in their mean position, by the so-called near-field formulation as follows:

\[
F_i(\omega) = \frac{\rho}{2} \int \left[ \left( \nabla \phi \cdot \nabla \phi^* \right) \bar{\mu} - \phi^* \nabla \phi - \phi \nabla \phi^* \right] dS - \frac{\rho \omega^2}{2g} \int \left( \phi \phi^* \right) \bar{\mu} dL
\]

where \( \omega \) is the frequency of incoming wave, \( \phi \) is the first order velocity potential, \( \phi_n \) is the normal derivative of first order velocity potential on hull surface, \( \phi^* \) is the complex conjugate of first order velocity potential and \( \phi_n^* \) is the complex conjugate of normal derivative of first order velocity potential on hull surface.
Since the added resistance in waves is determined through the quadratic transfer function (QTF) approximated by zeroth-term only, the obtained force is a constant value at each given frequency of incoming wave. In order to determine the ship response at irregular waves related to actual sea states, the wave energy density spectrum is used. It represents the energy of particular harmonic component of the irregular wave.

In this paper, the ship added resistance at actual sea state corresponding to the North Atlantic is obtained using the Bretschneider or two-parameter Pierson-Moskowitz sea spectrum recommended for the North Atlantic. One parameter of the spectrum is significant wave height $H_s$, i.e. mean wave height (trough to crest) of the highest third of the all wave heights and second parameter is zero crossing period $T_z$, i.e. mean time interval between upward or downward zero crossings of a wave. The Bretschneider wave spectrum is defined by the following expression:

$$S_z(\omega) = \frac{H_s^2}{4\pi} \left(\frac{2\pi}{T_z}\right)^4 \omega^{-5} \exp\left(-\frac{1}{\pi} \left(\frac{2\pi}{T_z}\right)^4 \omega^{-4}\right)$$

(15)

where $\omega$ is the wave frequency.

The spectral function of the ship added resistance in waves is obtained by multiplying drift force at certain frequency and the corresponding ordinate of the wave spectrum. The first spectral moment, i.e. integral of the spectral function, is obtained using the trapezoidal rule of integration. The mean value of the added resistance at the defined sea state is thus based on the absolute values of the drift forces and the contribution of wave energy over the whole frequency range of interest. It should be noted that mean added resistance of ship advancing in waves is calculated based on the encounter frequency of the incoming waves as follows [17]:

$$\bar{R}_{AW} = 2\int_0^\infty R_{AW}(\omega_e) / \zeta_s^2 S_z(\omega) d\omega_e$$

(16)

where $R_{AW}(\omega_e) / \zeta_s^2$ stands for the drift force at certain wave frequency obtained using hydrodynamic software HydroSTAR [16], $\zeta_s$ is the unit wave amplitude and $\omega_e$ is the encounter frequency defined as follows:

$$\omega_e = \omega - \omega^2 / gv \cos \beta$$

(17)

where $v$ is the ship advancing speed and $\beta$ is the wave heading.

III. RESULTS

In this section, the obtained numerical results for the calm water resistance as well as the added resistance in waves are presented. Furthermore, the benefit of speed reduction is shown in terms of fuel consumption.

Numerical simulations of viscous flow around KCS model are performed and the obtained results are validated against the experimental results available in the literature [18], Table 2. The relative deviation between the numerical and experimental results is calculated as follows:

$$RD = \frac{C_{T,CFD} - C_{T,EXP}}{C_{T,EXP}} \cdot 100\%$$

(18)

**TABLE II. VALIDATION OF THE CALM WATER RESISTANCE COEFFICIENT**
The obtained wave patterns for two $Fn$ are shown in Figure 5.

The obtained values of the calm water resistance for KCS model are extrapolated according to the procedure described in section Methodology. For $Fn=0.260$, which corresponds to the design speed $V_d = 24$ knots, the calm water resistance is equal to 1435.87 kN. For $Fn=0.195$, which corresponds to the slow steaming speed $V_s = 18$ knots, the calm water resistance is equal to 692.56 kN.

The results for the added resistance in regular waves of unit amplitude are validated against the experimental data available in the literature [19] at $Fn=0.260$, Table 3.

<table>
<thead>
<tr>
<th>$\omega$, rad/s</th>
<th>$\frac{R_{AW}}{\left(\rho g h^2 A^2 L_{PP}\right)}_{\text{EXP}}$</th>
<th>$\frac{R_{AW}}{\left(\rho g h^2 A^2 L_{PP}\right)}_{\text{CFD}}$</th>
<th>RD, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4263</td>
<td>5.750</td>
<td>6.245</td>
<td>8.611</td>
</tr>
<tr>
<td>0.4504</td>
<td>8.717</td>
<td>9.026</td>
<td>3.543</td>
</tr>
<tr>
<td>0.4896</td>
<td>11.155</td>
<td>10.920</td>
<td>-2.106</td>
</tr>
</tbody>
</table>

Spectral analysis, as described in section Methodology, is performed in order to obtain the mean added resistance for certain sea states. Results calculated for regular waves of unit amplitude in the defined frequency range for two $Fn$ are used for spectral analysis. In order to simulate real sailing conditions of container ships, the common container ship route Southampton-Boston is chosen. The route length is equal to 3000 nm. Significant wave height as well as zero crossing period which define certain sea state, are chosen based on Global Wave Statistics [20]. The chosen route pass through sea areas 15 and 16 in the North Atlantic, Figure 6.
Fig. 5. Wave patterns for $Fn=0.195$ (top) and $Fn=0.260$ (bottom)

Fig. 6. Considered sea areas in the North Atlantic

Bretschneider spectrum for certain sea states is shown in Figure 7. It can be seen that most of the spectral energy is contained in waves of lower frequencies.

Fig. 7. Bretschneider spectrum for certain sea states
Under the assumption of constant specific fuel consumption and propulsive efficiency, the ratio of the fuel consumption per route for the slow steaming and the design speeds $B_s / B_d$ is calculated as follows:

$$\frac{B_s}{B_d} = \frac{R_{nw,s} V_s t_s}{R_{nw,d} V_d t_d} \cdot 100\%$$

(19)  

where $R_{nw,d}$ is the sum of the calm water resistance and the added resistance in waves at the design speed, $R_{nw,s}$ is the sum of the calm water resistance and the added resistance in waves at the slow steaming speed, $t_d$ is the route duration at the design speed and $t_s$ is the route duration at the slow steaming speed. Route duration at the design and slow steaming speed for chosen route can be seen in Table 4.

<table>
<thead>
<tr>
<th>$F_n$</th>
<th>$V$, kn</th>
<th>$t$, h</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.260</td>
<td>24</td>
<td>125</td>
</tr>
<tr>
<td>0.195</td>
<td>18</td>
<td>167</td>
</tr>
</tbody>
</table>

Table IV. Route duration at the design and slow steaming speed

Fig. 8. The ratio of the fuel consumption per route for area 15
In sea areas, such as area $\upsilon_\omega$ and $\upsilon_\iota$, different sea states occur with certain probability of occurrence. The ratio of the fuel consumption per route changes with the sea state, as the ship added resistance in waves is dependent on both $H_S$ and $T_z$. Thus, within Figures 8 and 9, $1 - B_S / B_D$ is calculated for each sea state and presented in percentages for both sea areas. Furthermore, number of occurrences of certain sea state is given within each bin. It should be noted that calculations have been performed for significant wave heights up to 5.5 m. It can be seen that higher relative savings in the fuel consumption will be achieved for lower sea states. The highest relative saving in the fuel consumption is achieved for sea state defined with $H_S = 0.5$ m and $T_z = 4.5$ s and is equal to $51.75\%$. For lower sea states, the portion of the calm water resistance in total resistance in waves is larger than for higher sea states. It should be noted that for the design speed the calm water resistance is significantly higher than the calm water resistance for the slow steaming speed. Thus, the obtained percentage savings in fuel consumption at heavier sea states are lower compared to ones for lower sea states. However, it should be noted that estimated savings are presented in relative way as the ratio of fuel consumption at the slow steaming and the design speed rather than taking into account the actual fuel consumption at certain sea state. Thus, for rougher sea states, the absolute value of fuel consumption is higher compared to the one at the lower sea states.

**IV. Conclusion**

The total resistance in waves for a typical container ship was calculated at the design and the slow steaming speeds. The calm water resistance was calculated utilizing CFD based on viscous flow and the added resistance in waves was calculated using CFD based on potential flow. The obtained numerical results show satisfactory agreement with the experimental results available in the literature. The calm water resistance was determined for KCS model and the obtained results are extrapolated to full scale values. The added resistance in waves was calculated at regular waves of unit amplitude. Spectral analysis for certain sea states corresponding to the North Atlantic was performed based on the Bretschneider spectrum, defined by significant wave height and zero crossing period. The ratio of fuel consumption at the slow steaming and the design speeds was determined as well. The results show the importance of the speed reduction in terms of fuel consumption per route. Under the assumption of complete combustion, the decrease of fuel consumption is equivalent to the decrease of CO$_2$ emission, which is of great importance from the environmental point of view. However, it should be noted that the route duration
at the slow steaming speed is larger compared to one at the design speed, which causes larger route costs as well as lower number of routes per year, i.e. lower profit per year.

For that reason, the part of future work will include economic analysis that will clarify weather savings in fuel at reduced ship speed are economically justified regarding higher ship expenses and lower profit.

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Integrated Systems for Processing All Types of Waste on Ships

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ABSTRACT
This paper describes the integrated systems for processing different types of waste on ships. Today, the increasing cruise industry, as part of shipping industry, causes more possibility for pollution from ships. IMO through MARPOL Convention has defined strict requirements regarding environmental pollution prevention from ships. Manufacturers of the marine equipment and ship owners cooperate in applying the state-of-the-art technologies for waste processing. That technology constantly develops in order to comply with international legislative for pollution prevention.

In this paper, working principle of machines for hard waste processing, systems for waste water processing and systems for bilge water processing are explained and at the end integration of systems for waste processing is shown.

In spite of the efforts to process waste on board a ship as much as possible, still significant quantities of waste must be delivered ashore for processing, and some of it cannot be processed at all with the existing technologies. Such existing technologies comply with the present international legislative for environmental protection. But, such legislative is valid for the existing technologies and not good enough to have environment protected well enough.

Searching for new technologies and such system integration must be proceeded with for better protection of marine environment and less pollution of sea and land from vessels, especially from ships with high power installed, carrying polluting cargo or large number of persons.

KEYWORDS: waste, environmental pollution, bilge water & integrated system

I. INTRODUCTION
The marine environment, which is primarily water and air, is exposed to very intense environmental damaging effects from ships. Modern power plants still have a relatively low level of energy efficiency. Diesel-engine propulsion converts slightly more than 50% of the thermal energy into mechanical work. A huge amount of heat energy goes into the water through the cooling system and into the air through exhaust and flue gases. This energy continually increases the entropy of the oceans and the atmosphere. Exhaust and flue gases contain harmful ozone depleting substances and causing the climate changes on Earth. In the sea water, oily water, different solid waste, black and grey water come from ship's passenger and crew areas. Thousands types of bulk cargoes, liquid and other cargoes are transported by sea, and their numbers are increasing every day, although more than 50% of them are considered to have a particularly damaging effect on the environment. Part of these cargoes appear in the sea as a result of poor handling, damage to hulls and tanks, while part of the cargo that is prone to evaporation, ventilating the tanks gets into the air. Today, the problem of pollution caused by passenger ships is increasingly pronounced, resulting in increasingly stringent international regulations aimed at preventing pollution from ships. The MARPOL convention with its annexes is a comprehensive international legal document that prescribes high standards of protection of the sea and the marine environment.

Cruise ship is particularly in focus because it has a large number of passengers and crew members, and that results in large daily production of all kinds of waste. This applies especially to the amount of waste food, the amount of waste water and the waste incineration process. Proper handling of waste is essential because of the fact that cruise vessels mainly operate in specially protected areas of the World such as: Mediterranean Sea, Alaska, Baltic Sea and the like. Cruising industry is a part of the world's fastest-growing tourism, with the number of passengers on ships growing twice as fast as any other type of tourism in the last 10 years, and the average size of the passenger ship increases by 30 m every 5 years for the last 20 years. As this branch of tourism continues to grow rapidly, there is an increased concern
to the impact of passenger ships on the quality and purity of the sea. Cruisers are like traveling cities, some sailing with more than 8,000 persons on board. Such ships provide passengers with similar conditions such as luxurious hotels ashore, including swimming pools, hairdressers, restaurants and chemical cleaners. As a result, they produce the same amount and type of waste as large hotels. Wastewater from these ships contains sewage water and toxic chemicals. Sewage water is carrier of bacteria and viruses that are detrimental to human health, and can also be deadly for species in the sea, including corals. So that waste, oil and industrial waste are collected on board for disposal ashore, or processed onboard according to a required procedures.[3]

II. METHODS AND MATERIALS

Data from secondary sources were used to produce this paper, from various domestic and foreign sources: books related to the topic of work, professional journals and various publications published on the internet. Scientific methods of induction and deduction, descriptive and compilation methods were used during the work. Based on the analysis of individual facts, inductive method, general and individual conclusions were drawn by means of the deductive method. The descriptive method was used in the description of facts, processes and subjects without scientific interpretations and explanations. The compilation method was used to take over other observations, attitudes, conclusions, and insights.

A. International regulations for pollution prevention from ships

The International Convention on the Prevention of Pollution from Ships, known as the MARPOL, is an international contract aimed at eliminating intentional or accidental pollution of the marine environment from ships by all harmful substances for humans, species, and the use of the sea. The MARPOL Convention was signed on February 17, 1973 in London, but it did not enter into force. It has been amended by the 1978 Protocol. The present Convention, the 1978 Convention of 1978, entered into force on 2 October 1983. As of 31 December 2005, 136 countries whose fleets represent 98% of the world’s tonnage are party to the Convention. The Convention includes regulations aimed at preventing and minimizing pollution from ships - both accidental pollution and that from routine operations - and currently includes six technical Annexes. Special Areas with strict controls on operational discharges are included in most Annexes.

Annex I Regulations for the Prevention of Pollution by Oil (entered into force 2 October 1983) covers prevention of pollution by oil from operational measures as well as from accidental discharges. Annex II Regulations for the Control of Pollution by Noxious Liquid Substances in Bulk (entered into force 2 October 1983) details the discharge criteria and measures the control of pollution by noxious liquid substances carried in bulk. Annex III Prevention of Pollution by Harmful Substances Carried by Sea in Packaged Form (entered into force 1 July 1992) contains general requirements for the issuing of detailed standards on packing, marking, labelling, documentation, stowage, quantity limitations, exceptions and notifications. Annex IV Prevention of Pollution by Sewage from Ships (entered into force 27 September 2003) contains requirements to control pollution of the sea by sewage; the discharge of sewage into the sea is prohibited, except when the ship has in operation an approved sewage treatment plant. Annex V Prevention of Pollution by Garbage from Ships (entered into force 31 December 1988) deals with different types of garbage and specifies the distances from land and the manner in which they may be disposed of. Annex VI Prevention of Air Pollution from Ships (entered into force 19 May 2005) sets limits on sulphur oxide and nitrogen oxide emissions from ship exhausts and prohibits deliberate emissions of ozone depleting substances; designated emission control areas set more stringent standards for SOx, NOx and particulate matter. A chapter adopted in 2011 covers mandatory technical and operational energy efficiency measures aimed at reducing greenhouse gas emissions from ships.

B. Ship’s waste

Waste is defined as any substance or object specified in the categories of waste specified in Annexes MARPOL 73/78. Definitions of different types of waste:
Ship-generated waste is entire ship waste, including sewage and other remains that are not remains of the ship’s cargo, which was generated during the voyage of the ship.

The remains of cargo are the remnants of any cargo in the hold or tanks that remain from or after unloading operations, cleaning or washing of ship’s holds, decks or tanks.

Ship’s municipal waste is waste generated on board ships, which is in its properties and composition similar to waste from households.

Hazardous waste is any waste containing substances having any of the following properties: explosively, reactivity, flammability, irritability, dangers, toxicity, infectivity, carcinogenicity.

Non-hazardous waste is waste that does not have any of the properties of hazardous waste.

Oily wastewater is a liquid mixture of water with any of oil contents.

Waste oils are liquid or semi-liquid products originating from different applications and during use, storage and shipping become unsuitable for use in the intended purpose (e.g., used motor oil, heavy oil separator sludge).

Kitchen waste means any spoiled or healthy part of the food and includes fruits, vegetables, dairy products, poultry, meat products and food residues generated on board.

**III. RESULTS - DEVICES AND SYSTEMS FOR SHIP’S WASTE COLLECTING AND PROCESSING**

Shipbuilding industry and marine equipment manufacturers have developed systems and devices that provide treatment of waste on board cruise ships to achieve the goal that a cruise ship is fully compliant with the regulations of the MARPOL Convention.

For the purpose of the elimination of pollution potential, the IMO Convention (MARPOL 73/78) requires the installation of equipment for the prevention of pollution of the sea by garbage and waste on board ships. Most ships have one of the following devices: The device for collecting garbage, the device for garbage processing, the device for burning garbage and waste.

The waste management facilities on board include: incinerators, crushers, compactors, (press, with the aim to reduce the bulkiness of the waste), food processing system, the system for processing of raw sewage. Manufacturers of such equipment are constantly improving and upgrading existing systems to reduce pollution from ships and to achieve very strict regulations set by the MARPOL Convention and the national legislation of individual countries.

**Incinerator.** The purpose of incineration is the incineration of waste, saving space required for storage of waste and saving financial costs that would be required for the submission of waste on land. Ship incinerator is device in which can burn the food waste, waste from rigid plastic and paper, wood, aluminium cans or even glass. The incinerator automatically burns oil and fuel sludge, sludge that is generated in a wastewater treatment plant, bio-waste from food residues and wastewater system. In order to achieve combustion without unpleasant smells and many fumes, it is necessary to keep combustion gases for a longer time at a temperature of 700-800 °C. Therefore, the incinerator is fitted with two combustion chambers, primary and secondary. The secondary combustion chamber is constructed as a cyclone to generate turbulence of the combustion gases and to increase the heavier pieces of ash and particles easier to separate. The incinerator consists of 3 main parts:

- Incinerator filling section. The main function is to fill the incinerator in the specified quantities and the separation of dry waste silo and the first combustion chamber due to the high temperatures.

- Primary combustion chambers. This section begins burning and continues later in the secondary chamber. The combustion air is blown into the primary combustion chamber and is mixed with the combustion gases, which enhances the combustion of dry waste. In this part the temperature is
between 600-900 °C. Combustion gases from the primary chamber enter the secondary chamber after the flow in the cyclone exits the cooler at the top of the cyclone (secondary chamber).

- Secondary combustion chambers. In this section complete combustion of waste occurs. With additional airflow, the combustion is increased. Large amount of gas also helps in the complete combustion of all components. In this part the temperature is 800-1000 °C. After the secondary chamber, the gas streams in the cooler where the outside air is mixed with the exhaust gases and in this way the flue gas temperature drops to 350 °C.

During the combustion of the waste in incinerators negative pressure is to be maintained (slight vacuum). Therefore, it is necessary to install the fan in the chimney of the incinerator. The temperature in the firebox in exceptional cases reaches up to 1400 °C, and on the outside of the incinerator the temperature should not exceed 60 °C.

**Food waste processing system** is an important system on ships with a large number of persons (cruisers). The system is designed for the collection and treatment of organic waste from kitchens and the food preparation stations (Fig. 1). It consists of a vacuum system, a bone grinder, a water separator, a thermal dryer, an incinerator and a filtration module for incinerator exhaust flues.

![System layout](image)

Waste food is collected at the Waste Disposal Station where it has to be sorted out. All bones from waste food must be specially separated because they must be crushed. Bone grinding is done with the help of a special device called bone-crusher. Food waste is drained into waste collection tank (4). Food is transmitted through the system by the vacuum generated by the vacuum station (5). The pipeline is designed to be constantly under vacuum. Emptying the food waste collection tank into the de-watering unit (6) occurs automatically at a certain level in the tank and when the unit receives a signal that it is ready for discharge. The pumps (9) will gradually empty the tank to a low level in the tank. Food wastes will be transferred to one of the de-watering units (6), and then into the appropriate de-watered sludge tank (7). After treatment in the de-watering unit, dried food waste is transferred to the de-watered sludge tanks whereby by the help of the de-watered sludge pump it is transferred to a ship incinerator or to an additional drying treatment in the dryer if the waste is still too wet. The remains after the process is just ashes that are stored and later delivered ashore. The last step is the exhaust gas filtration
from the drying unit to avoid unpleasant odours and the spread of biological particles through the air exhaust system. The treatment consists of a closed exhaust system, which means that the hot exhaust gases are cooled so that the particles are condensed from the air and the liquid drains back into the system for treatment of waste water.

**Crushers and solid waste compactors.** The crushing purpose can be different, such as reducing the volume for transport or storage or crushing to a certain size for further recycling. Crushers are built on ships of several sizes, options and cutting configurations, all of which are recommended for cutting of dry ship waste, such as: plastic wastes, bottles, paper and organic wastes on a ship.

The compactor is a device that reduces the volume of waste by approximately 70% of its initial state. The compactor works with 1-2 tons of pressure. The compactor can handle materials such as: paper, plastic, glass bottles and cans. Although some manufacturers say that wet wastes can be processed, it is better to put it in a waste treatment system. They do not consume much electricity. Using the compactor is ecologically very desirable because it saves space that would be occupied by untreated waste. Combining the compactor and crusher total volume of ship waste can be minimized. This ensures that on-board waste takes up minimal space on board during some long voyages.

**Sewage treatment** – (Advanced Sewage Treatment Plant) - an advanced automatic sewage treatment system specially designed for use on ships and is designed for the processing of the following waste water: galley water, grey water, laundry water, faecal water from the toilets (black water), waste water from the sedimentation system.

Wastewater on board consists of various ingredients mixed in different ratios. Prior to actual treatment, the grey and black water is collected by pipes in storage tanks to equalize and ensure a stable flow into the existing wastewater treatment plant, which is very important in the operation of this plant. The wastewater components are classified as proteins, fats, urea, detergents, sand, chemicals and microorganisms - bacteria and viruses. These components can be divided into: - Particles, Bio-degradable organic substances, - Nutrients, - micro-organisms. To meet all standards, the system must handle all 4 categories of components. In order to comply with the Alaska rules for continuous discharge of waste water, the wastewater effluent must comply with the requirements: TSS (total suspended solids) <30 mg / l, -BOD5 (biological oxygen demand) <30 mg / l, - fecal coliforms <20/100 ml with 90% samples below 40/100 ml, - pH - between 6 and 9, - total chlorine <10 mg / l.

The system is based on a mechanical separation of particles from the water, the biological processing of organic substances, the chemical process for the separation of nutrients and colour, and finally removal or eliminating of viruses and bacteria by UV rays or chlorination. The sedimentation system is based on separating the water from the sludge by centrifuge and then by drying it in the desiccator and burning in the Incinerator. The most modern and efficient sewage treatment system installed on passenger ships consists of a process comprising five phases:

1. **Pre-Treatment Module** - consists of a filter that mechanically separates solid particles and waste.
2. **Biological Treatment Module** - serves for the degradation of biodegradable ingredients from wastewater. They are degraded by the cultivated bacteria that convert the biodegradable ingredients into energy, water and carbon dioxide.
3. **Flotation Module** - This module performs a chemical treatment for the removal of nutrients (phosphorus and carbon) and colour. In this module, these particles react with coagulants and polymers to form waste material that can then be physically removed.
4. **Polishing Module** - Filtration through a fine filter that separates any residual particles in the water. Separated particles from the filters are returned to the grey water system.
5. **UV module** - this is a disinfection unit for processed waste water. UV rays or chlorine effectively kill bacteria and many viruses.
The system for processing and incineration of bio-sludge. A large amount of waste produced from the wastewater treatment system as well as the food waste treatment system requires further treatment, and it is highly important to reduce its volume, remove moisture from it and disinfect it. Bio-waste processing system consists of 3 parts: 1. Water removal system, 2. Bio-mass dryer 3. Bio-mass system.

1. A water removal system is designed for wet sludge from the food waste processing system and from the wastewater treatment system. The removal of water from the bio-sludge begins with sludge from the Pre-filter and from the Flo- tation Unit where it is deposited in the sludge tank. From the sludge tank, the pumps are transferring sludge to a water separator called "Decanter". Rejected water flows back into the wastewater treatment system, and the sludge waste is removed in the collecting tank. From this tank sludge pump transfers it in the dryer in which removes residual moisture to finally could burn in incinera-
tors. The removal of water from the bio-waste from the kitchen waste treatment system is processed in such a way that crushed waste from the kitchen is transferred by pumps from a collecting tank to a waste tank with water separation. The function of this unit is to remove liquid from crushed food waste. Food waste without wastewater is drained into the waste tank and the fluid is drained by gravity into a special tank.

2. A Bio-Sludge Dryer has the purpose of drying a biomass for incineration. The bio-sludge is pumped into the dryer. It will remove the residual liquid from the bio-sludge and dry it to a humidity of about 80% and send it to the bio-mass tank using screw carriers. Another option is to place the bio-sludge directly from the tank by pumping it into the bio-deposit grinder at the top of the incinerator.

3. The Bio-Mass System has a bio-mass tank that collects all of the mass from the dryer. This system doses bio-mass to the incinerator in equal proportions and mixes it with dry waste.

Areas of permitted discharges raw sewage from ships. Discharge of black waters from ships is prohibited in accordance with MARPOL Annex IV in a zone of less than 3 nautical miles from the nearest land unless they are properly treated in the treatment plant. In the zone between 3 and 12 nautical miles it is allowed to discharge if the black water is properly treated in the disinfection device. Outside of 12 NM discharge and untreated sewage (black waters) are permitted provided that the vessel is in navigation and that its speed is greater than 4 knots. Also, if the vessel is using a collecting tank, it must not be pumped into the sea if the ship is not in navigation and 12 NM away from the coast.

Bilge water treatment plants. Bilge water is a mixture of water with all kinds of dirt, oil, liquid fuel, sludge, waste oil and other products of the petrochemical origin. According to the MARPOL Annex I, it is prohibited to discharge bilge water with oil content exceeding 15 ppm. Therefore, to satisfy this
requirement, the vessels will be fitted with bilge water separators. A bilge water separator separates oil and other hydrocarbons from the bilge water. Thus, purified water can be discharged out into the sea, and the collected oil and grease collecting and burning on ships in the incinerator, or simply disposed to land in the ports to the land plants.

Fig. 3. Integrated systems for processing all type of waste on ships. Source: Scanship
**Exhaust gas purification plants from ships.** IMO sets limits on sulphur oxide and nitrogen oxide emissions from ship exhausts and prohibits deliberate emissions of ozone depleting substances; designated emission control areas set more stringent standards for SOx, NOx and particulate matter. The IMO legislated to introduce a 0.5 % sulphur cap for all shipping vessels from 2020 with the aim of protecting human health and the marine environment from noxious sulphur dioxide emissions. The shipping industry is reacting responsibly by fitting vessels with exhaust gas cleaning systems (EGCS), so-called marine scrubbers, or by switching to low sulphur fuel. Exhaust gas scrubbers have high efficiency in limiting SOx emissions.

The sulphur scrubbers that need to be installed on ships to reduce sulphur emissions exist in three forms:

Open-loop scrubbers (exhaust gases are washed and the washing water, together with the harmful substances that it contains, are discharged into the sea). Water scrubbing technology relies on the natural alkalinity of the seawater. The liquid is sprayed on the exhaust gasses in order to neutralize the sulphur oxides and remove some of the particulate matters.

Closed-loop scrubbers, the scrubbing are generally performed with freshwater treated with additives that increase its alkalinity (caustic soda). The liquid is recycled back into the scrubber after each passing through the tower and, occasionally, additives and freshwater/seawater are added to maintain efficiency levels and correct chemical composition (exhaust gases are washed and harmful substances collected in a tank which is emptied in port for appropriate further treatment).

Hybrid scrubbers (which can be set for either open-loop or closed-loop operation and depending on design may operate with either freshwater or seawater when in closed loop mode). For ships that operate along routes with variable alkalinity, the safe choice would be using a hybrid type scrubber that can switch between the two operating modes.

Viewed as a whole, the only one of these types of scrubber that is genuinely environmentally sound is the closed-loop type; as such scrubbers do not result in emissions either into the atmosphere or into the water provided that the waste is treated after collection in ports. While open-loop scrubbers comply with the requirements of the Sulphur Directive and reduce emissions into the atmosphere from shipping, their use results in heavy metals and sulphur, etc., ending up in the sea together with washing water. The IMO regulates all these matters extensively (IMO resolution MEPC.184 (59)), but the existing regulations do not prevent pollution from entering the sea. Hybrid scrubbers can operate in either open or closed loop mode.

**IV. Discussion**

Advanced Integrated Waste Treatment System - a system that consists of several separate systems that are interconnected. This system successfully processes and prepares for recycling all types of waste that a passenger ship can produce. The MARPOL Convention provides that each ship with more than ψττ RT or more than υω m is equipped with a faecal or disinfecting device or a collection tank of the appropriate capacity. It is an advanced automated system that consists of several processes. The first process is the treatment of black water or wastewater in the pre-filter where solid particles and mechanical impurities are separated from it. The next step is treatment in the bio reactor where aerobic bacteria break down organic matter and convert them into energy, water and carbon dioxide. Thereafter, a chemical treatment is followed in the flotation unit where the particles react with the coagulant and the polymer and form larger particles of waste material that are subsequently physically removed from the water. At the end of the process the waste water passes through a fine polishing filter that removes any residual dirt, and at the very end is disinfected with ultraviolet rays in the UV unit. Clean disinfected effluent water is stored in tanks or directly pumped into the sea. All these devices must be tested and approved by recognized international bodies. Each ship must have an international certificate for the prevention of sewage pollution.
For solid flammable waste, incinerators are used, a crushing system and combustion of various waste onboard and dried waste from the wastewater treatment system and from the food processing system. At the end of this process, remain ashes that can be delivered on the shore as non-hazardous waste. The food processing system is used for the processing of organic waste from the kitchen. Food waste is crushed and transported by vacuum from collecting cells to a water separation system and drained, then dried and finally incinerated.

The bio-sludge processing and incineration system serves for the processing of wet sludge from the food waste processing system and from the wastewater treatment system.

For disposal of waste for recycling, three additional devices are in use to reduce the volume of wastes for recycling ashore. Glass crushers are used for glass, cardboard and paper presses and for aluminium packaging a special press that buckles aluminium into large cubes for lighter transportation.

Devices for purification of exhaust gases from ships using large amounts of water (saltwater or freshwater) and operate on the principle of absorption of contaminants or components of exhaust gases. It is undisputed that such devices contribute to a lower emission of harmful gases and particles in the atmosphere around the ships.

Antipollution equipment manufacturers successfully produce equipment to reduce pollution from ships by water, gases, waste or garbage that can be recycled or processed on ships themselves. The following diagram shows the most important sources of pollution and their processing on ships.

However, operational practices or methods of exploitation in day to day exploitation of ships show a large degree of deviation from the recommended procedures or the ways in which these systems do not contribute to the conservation of the environment as predicted by the MARPOL Convention.

Thus, according to the sources from direct operators in the maritime industry (management levels on ships), day-to-day waste handling procedures differ for various shipping companies, ship types, and navigation areas. Thus, the collection devices for black and grey water, waste from the kitchen, are used in full capacity. However, the processing systems of black waters are not often used. This is because most of the cruise ships have the capacity of tanks for collecting black and grey water is such a way that the ship has autonomy of 1 or 1.5 days. Cruise ships that produce the largest quantities of black water have itinerary so that they usually sail every day between different ports during night, while on a day time they stay in the harbour because travellers go sightseeing around the city. In such schedules cruise ships empty their tanks of raw black and grey water in navigation between ports, where the distance from the...
coast is greater than 12 nm which is allowed under MARPOL Convention Annex IV. Only in the home port, every 7 or 10 days, the cruisers remain 2 days due to the shifts of the passengers and receiving the supply, and then they do not have enough capacity but then use the systems for the treatment of black waste water.

Better is the situation with solid waste, such as paper, plastic, chemicals and glass. This type of waste is crushed, compacted and prepared for delivering ashore for disposal and recycling. Or part of this flammable waste is sorted and burned on a ship’s incinerators. As it is incinerated dry bio-waste, and fuel and oil sludge is collected from the bilge separators, fuel and oils separators.

Although the use of the exhaust gas scrubber is permitted by MARPOL Annex VI, there are two problems in practice. The first is that open-loop type scrubber water is released to the sea around the ship. Water from scrubber is contaminated by many carbon particles and sulphur during the process of exhaust gases cleaning. In this way it really protects the atmosphere around the ship, but all of these harmful substances are channelled into the sea around the ship and hence pollute the environment. The consequences for the sea around the ship and also for the ship itself are huge. Many ships with open-loop scrubber experienced extremely strong corrosion of the hull due to the discharge of this water into the sea. The result is therefore rapidly reducing the thickness of the metal sheet and often the side plates must be changed at this location during docking. Because of these effects on the sea, many countries and ports in Europe, and even Singapore and recently China have adopted a ban on the use of Open loop scrubber in their ports, which is more stringent national regulation and in itself requires the MARPOL Convention.

Closed loop scrubbers have another problem because they are used in in the closed system of water, which is not discharged into the sea, but the system uses large amounts of soda caustic and such water contaminated with caustic soda must be disposed ashore for further recycling. So again, the pollution problem is redirected to the land, and ways have to be found ashore to dispose this water from scrubbers that are contaminated with caustic soda. This is an issue that is only redirected pollution from ship to shore, but it is not solved on board.

Since the beginning of 2019, China has introduced stricter rules on sulphur and nitrogen oxide emissions from ships in coastal areas, Hainan waters, and the inner rivers of Yangtze and Xijiang, according to the Ministry of Transport. The ban on wash water also came into force on the first day of 2019. Also, ship operators are not allowed to discharge of any residue of water from washing or burn it on the ships. China’s effective ban on open-loop scrubbers is similar to action Singapore took in November to outlaw the discharge of wash water in port waters there from Jan. 1, 2020.

V. CONCLUSION

MARPOL (International Convention for the Prevention of Pollution from Ships) the convention adopted by the IMO deals with the prevention of marine pollution and the air that threatens the ships. It consists of six annexes. Marine equipment manufacturers are making efforts to produce such devices and equipment that can meet the requirements of the MARPOL Convention to prevent pollution from ships. Today’s anti-pollution systems on ships are quite complex, integrated and meet MARPOL’s requirements. However, the operating practices and procedures on board ships have not yet reached this stage of development where we could say that today’s ships are not “producers” of pollution. In recent years a lot of progress has been made in the development of equipment and awareness of ship operators in the protection of nature. But still operational practice shows that many companies want to go cheaper in all these processes, equipment installation and methods of using pollution control equipment, so there is still a lot of effort to be made in the marine industry to achieve the desired results in environmental protection related to pollution from ships. Therefore, regardless of the well-equipped ships with modern integrated systems for processing waste on ships that meet all the requirements of the Convention, many states or local authorities adopt their national regulations that are more stringent than the MARPOL Convention. These national regulations of the states and local authorities of certain ports
which do not allow at all the discharge of waste water effluent from ships or wash water from exhaust gas scrubbers.

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The Utilization of Renewable Energy Sources on Vessels

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ABSTRACT

If we discuss about navigation before and now there is quite a visible change – humanity has come from simple vessels with oars to large ships that can transport any type of cargo we can imagine. Could it be possible to prosper even more with this knowledge? Could we completely switch on vessels that would use the energy of the Sun and wind in order to reduce the pollution of the environment? Well, this paper is going to refer to exactly that issue – the usage of the energy of the Sun and wind and how it can be applied on ships and help with reduction of the emission of CO₂, SOx and NOx. We will try to compare the costs of installation of this new equipment on old ships with the costs of construction of new ships with this equipment embedded. Special routes will be discussed due to adaptation to areas which have more Sun or wind. The goal is to apprehend how this usage of energy can affect the maritime affairs in the future and how efficient would be to shift to this type of energy exploitation.

KEYWORDS: renewable energy, solar panel, EEDI & new concepts

I. INTRODUCTION

It is a known fact that the number of vessels constantly grows day after day. It is important to emphasize that one part of the merchant vessels is being removed simultaneously due to their deterioration. With the ever growing number of vessels, the total amount of exhaust gases also increases. International Maritime Organization (IMO) continually devotes all its efforts in bringing new solutions for reducing the limits of permitted emissions of noxious gases for the ocean and maritime environment. Regarding the requests of IMO against reducing greenhouse gases for at least ωτ% until the year φτωτ, the ship owners and shipyards are working on new ideas which are in accordance with these requests. The first step would be transition on LNG as the propulsion which represents the purest and ecologically most acceptable fossil fuel. The utilization of LNG reduces the exhaust of SOx up to ύϋ%, NOx up to ύτ% and COφ up to ϊτ%. These percentages can vary depending on the engine type. Today it is aspired to include the renewable sources in maritime industry and their practical implementation to achieve additional reduction of air pollution, and simultaneously reduction of costs i.e. enhancement of income. The vessels are starting to use wind again as a method of propulsion while at the same time the exploitation of Solar radiation is being introduced as the second inexhaustible source of energy.

II. THE ENERGIES OF THE WIND AND SUN

Despite remarkable improvements which were achieved in technology which is being applied today in construction and exploitation of ever growing vessels there is still an issue with the amount of pollution which is being caused by these vessels. The highest share in this pollution represents the exhaust gases which incurred by combustion of heavy fuels. The first step in reducing this percentage would be introducing LNG as a propulsion fuel, afterwards the application of the energy of wind and development of solar panels and the enhancement of their effectiveness in order to introduce and apply the energy from solar radiation. The world shipbuilding starts a whole sequence of ideas for utilization of these renewable sources of energy. The energy of wind itself would be used as an additional propulsion of the vessel. In contrast, the energy of the Sun would be used as an additional source of electrical energy. With the combination of these energies better more efficient results would be reached.
A. The energy of the wind

One of the ways of exploiting the wind on vessels is in sight of “kite ships”, where you set up a device on the bow which releases a big parachute on heights between 100 – 500 meters under the influence of constant winds. The surface of these parachutes move above 500 m² what depends on the size of the vessel on which is this system embedded. The implementation of the “kite sail” enables the reduction of fuel usage in average of 20%. In order to take advantage of this potential, it is necessary to adapt the routes on which the kite sail ships will sail. In order to exploit the full strength of this system, the vessels should sail on routes where the speed of the wind is big enough. The system upon installation minimally reduces the deadweight tonnage of the vessel. The management of this system is not too complicated and it is made from the commanding bridge through computer commands. Upon usage of the kite sail it is possible to work with it in two different ways. The first way is its utilization in order to reduce the fuel consumption and maintain the same speed of the voyage. The second way is a simultaneous work of the ships engine with the engagement of the kite sail in order to enhance the speed of the vessel with the same consumption of fuel. Both ways have their advantages and those are: fuel saving and consequently reducing of costs and enhancing the speed while at the same time achieving better exploitation effect of the vessel. On the other hand, exploitation of winds energy is the utilization of sails which will in this case, on large vessels, be driven by hydraulic devices and they will do the rotation of the sails, their tension and do the lifting and descending. All this will be controlled by sensors.

B. The energy of the Sun

Solar energy is classified in relatively new renewable energy sources because its serious exploitation has just recently started. The obstacle in exploiting solar energy is the efficiency of solar panels which percentage utilization sensibly varies regarding the environmental conditions. This system would bring the best results on the geographical latitudes with the highest insolation. The problem with this system is the heating of panels (temperature rise) what results in reduction of efficiency. The second problem which decreases efficiency is sea salt which is covering the panels. At this moment in the ideal conditions the efficiency of solar panels is on average 30% while that percentage in reality under the real conditions (the amount of Sun radiation, cloudiness, season, temperature, etc.) amounts 15 – 20%. In order to fully use the potential of solar panels, it is important to follow the angle under which the Sun beams reach the solar panels. In order to achieve better efficiency, it is necessary to adjust the angle using the swivel devices. The problem related to this is the rotary motion due to the ship sailing in rough seas. The problem of heating could be resolved with cooling the panels by placing a system of pipes through which the seawater would flow.

New technical solutions are the basis for the adjustment of this system and its exploitation. In order to exploit the solar energy in a higher percentage, the idea is the use of devices that are used to measure the insolation. These devices are called pyranometers and could be used to provide data on the amount of solar radiation. These devices would be installed on the vessels operating in various international
maritime routes and they would collect data that would frame a database. This database would be used as a basis for the development of optimal routes for vessels that use solar energy. This device measures the solar radiation that falls on a horizontal surface in watts per square meter. There are two different types of pyranometers. Although they give the same result they reach it in two different ways. One type is a thermopile pyranometer which measures sunlight from the heat it generates. And the other type is a chip pyranometer which measures sunlight from the electricity it generates. For the study use of this database the second type would be more suitable.

III. APPLICABILITY ON VESSELS

First of all, it is important to determine how renewable energy sources can contribute to maritime affairs and what can they provide. It is evident that with the use of renewable energy sources the emissions greatly reduce and at the same time savings achieve and costs reduce. The question is how much is actually the use of renewable sources of profitable and efficient. If for a moment we ignore the benefits which they bring in terms of reducing harmful emissions, and pay attention to the energy they produce it is obvious that the energy is several times less than the energy derived from engines and generators.

The technology that we now possess did not progress sufficiently in order to completely replace the work of previous vessel systems, which are fuel driven on large ships, with renewable energy sources. Small coastal boats for transport of relatively small number of passengers on short lines can already today use the fully environmentally supplied energy. Those ships are fully electrically driven and they procure this energy from solar panels mounted on the ship itself and on the quay. Such ships are favorable for short trips in areas that annually have a lot of sunny hours. Large ships, for now, cannot fully pass on this type of propulsion which will provide energy from renewable sources because it is still too small in relation to the capacity of energy required on board. On large ships the energy obtained in this way would provide just the extra energy that has been used to replace some of the smaller generators, in case of a black out, for an additional power supply of certain units and devices, to operate certain devices, etc.

It should be noted that it is not possible to apply energy of renewable sources on all vessels because all vessels are not suitable for this, some because of its shape and construction, and some because of the area of navigation. Vessels to which the energy from renewable sources might be applied are as noted above small coastal boats, catamarans, trimarans, then of larger ships and bulk carriers and car carriers. Generally, that would be all those ships that have a large flat surface that can be used to install solar panels.

The obstacle with the setup of solar panels and devices which perform their rotation, and if taken into account - their cooling devices, it all leads to an increase in mass on the ship and hence the partial reduction of the ships deadweight tonnage. If the solar panels are installed on the top deck of ships like car carriers which is not used, in this case they do not pose as an obstacle to the exploitation of the ship. In contrast to these ships, with bulk carriers they would be set up on the hatch covers and would thus represent a problem in their operation. The reason for this is the connection of the panels alone with the central unit of processing and storing of electrical energy, and the cables would connect or disconnect in that way every time.

It would be possible to use both the wind energy and Sun energy on vessels by combining sails with solar panels. Solar panels could be positioned vertically regarding the deck of the ship while behind them the sails would be spread. Thus, in the same period of time we would get more energy.

Conversion of existing ships and their reconstruction will require certain not so little financial investments which smaller ship owners certainly will not be able to afford. As technology progresses so will start the construction of ships which will be designed to contain all the necessary devices for exploiting the energy from renewable sources. Thus will all ships that do not use the energy from renewable sources become outdated faster and become uncompetitive also like smaller ship owners will become
uncompetitive in the market. The new and modern ships will be able to afford only the world’s largest shipping companies. When it comes to the construction of new ships and conversion of existing so will come the adaptation of new laws and regulations and technical requirements for the construction of ships.

**A. Energy Efficiency Design Index**

EEDI (Energy Efficiency Design Index) for new ships is the most important measure which aims in the direction of promoting the utilization of more energy efficient equipment and engines. The intention of EEDI is to guarantee that new ships are made to be energy efficient. The EEDI was made obligatory for new ships and the Ship Energy Efficiency Management Plan (SEEMP) for all ships at MEPC 62 with the admission of amendments to MARPOL Annex VI, by Parties to MARPOL Annex VI. The EEDI offers a specific digit for a peculiar ship design, formulated in grams of carbon dioxide (CO₂) per ship’s capacity-mile and it is calculated by a formula which is based on the technical design parameters for a given ship.

**IV. Concepts of future**

There are already several concepts of ships of the future which will use renewable energy sources. Here of course we must not forget the very energy they could be produced by the sea i.e. the sea currents. For now, the future would represent the hybrid ships that would use the fuel, Sun, wind and fuel cells as propulsion. Of all types of merchant ships first that would be the most adapted to the technology of the future would be car carriers because of their large usable free surface on the top deck. Of all passenger ships that would be small passenger ships which already exploit the solar energy by being fully covered with solar panels. On some types of ships such as LNG and LPG carriers the application of this technology will be almost impossible because of the structure itself, while some ships cannot be adapted to new technologies at all. One of the concepts is the container ship completely covered with solar panels. This will primarily be a major problem in the affairs of loading and unloading containers because they will have to provide additional storage space for panels before port operations themselves. Catamarans that would use windmills as part of the structure and so received a portion of energy are also one of the concepts. Ships which should be paid most attention are autonomous ships whose energy for ship propulsion and operation of its equipment would be completely provided by renewable energy sources.

![Solar Wing sails](Fig. 2)
V. CONCLUSION

With today’s achievements in technology it is not possible to build large merchant ships that would only use renewable energy sources. For now, only smaller boats on short relations can exploit solar energy and wind energy as the only source. All ship owners will not be able to afford the transition to the new technology because of required financial investments which will lead to disproportion on the market. Integrating renewable sources of energy on an adequate way can considerably lessen maritime pollution and emission of greenhouse gases. They will also provide a reduction in costs of a ships exploitation by producing additional energy. It is necessary to create a database of the wind speeds and insolation on the basis of which there will be optimized routes which will be used to increase the efficiency and utilization of the wind and solar energy. The transition to the new technology itself will not be cheap but will in time upon the exploitation reach savings by reducing the portion of travel costs. Most importantly it will decrease pollution of the sea and the marine environment and demonstrate environmental awareness and concern for the environment.

REFERENCES


An Analysis of the Influence of Abrasive Particles in Fuel on the Degree of Damage to Piston Rings

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ABSTRACT
Internal combustion engines belong to a group of heat engines that convert the thermal energy of the fuel combusted into mechanical energy. The process of fuel combustion, separation of the heat of the working fluid and the transformation of a part of the heat into mechanical energy happens within a cylinder. The fuel that ships are loaded with has to comply with the ISO Standard, which prescribes precisely the maximum amount of impurities allowed in fuel.

The total amounts of aluminium (Al) and silicone (Si) impurities are seen as catalytic impurities with high hardness. Even after the treatment, these impurities can damage piston rings, cylinder liners and the main engine itself. The upper part of the piston contains the grooves for piston rings, while the number of grooves depends on the pressure of combustion strokes and the crankshaft revolution. The upper grooves contain compression rings, while the lower grooves contain oil rings.

If abrasive impurities reach the combustion chamber, they can get stuck between a groove and piston ring, and, in just a few hours, can cause wear of the cylinder liner. Similarly, the wear of a piston ring and, consequently, its breakage, can happen if the impurity size is higher than the layer of oil for lubrication. All these factors can cause a complete failure of the main engine of a ship.

The specificity of different materials that are used in the shipping industry and that can resist abrasive wear, should be considered on the basis of the analysis of the piston ring samples from the ships under investigation. Furthermore, the measures preventing abrasive wear should be proposed based on the application of the contemporary laboratory methods for material research.

KEYWORDS: piston rings, materials, abrasive wear, fuel impurities, technology for engine monitoring

I. INTRODUCTION
Piston rings are metal seals which separate the combustion chamber from the crankshaft housing and ensure the transmission of heat from the piston to the cylinder skirt. Additionally, they should prevent the leakage of oil (that was used for lubrication) from the housing to the combustion chamber, and ensure that the layer of lubricant on the cylinder surface is even. In order to achieve this, piston rings should be in contact with the cylinder liner and the groove which is located exactly in the engine piston. The forces acting upon piston rings depend on the gas pressure and the direction of piston movement [1].

The materials the piston rings are made of should be investigated and analysed precisely, in order to resist the complex stresses which emerge under mechanical and tribological encumbrance. In that regard, the use of the materials of high hardness is crucial. In addition to the obvious importance of the choice of a material of a greater microhardness, piston rings should also have a considerable elasticity in their base material. The base with greater modulus of elasticity can bear a greater encumbrance, and will, consequently, last longer. Elasticity modulus is represented as the relation between stress-strain, pressure, and bending stress. It is also highly important that piston rings work in optimal lubrication conditions.

Furthermore, thermophysical properties, like thermal conductivity and expansion, are the main factors determining the performance of piston rings. High temperatures in the combustion chamber for the Wartsila RTA engine analysed are shown in technical overview [2]. In addition to the characteristics listed, the resistance to corrosion and micro treatment also receive a lot of attention. Altogether, the characteristics define the complex characteristics of the material piston rings are made of.
Contemporary two-stroke engines achieved a relatively low oil consumption - 0.8 g/kWh - which is almost the consumption of four-stroke engines. The illustration of the sets of the piston rings that are used nowadays in two-stroke diesel engines are shown in Fig. 1. From this Figure, it can be concluded that the analysis of the chemical composition of the upper and one lower ring is sufficient for the Wartsila two-stroke engine, while the MAN engines have a completely different structure.

The problem that ship engineers usually face is the lack of information about the type of piston rings on each cylinder, which is the result of an imprecise keeping of the ship’s records. The engineers cannot choose the type of piston rings to be used as there is usually a pre-ordered supply on board. However, raising awareness about the importance of the composition of the coating material among engineers would result in their advising the people in charge of spare parts purchase (usually Economists) on the types of piston rings that are more appropriate for the engine performance during the combustion of the fuel with an increased amount of catalytic impurities.

II. ABRASIVE PARTICLES IN MARINE FUEL

Cat Fines, the previously mentioned catalytic impurities in fuel, are the chemical compounds (silicon dioxide SiO₂ and aluminium trioxide Al₂O₃) in the form of small, powder-like balls, whose diameter is 0.1 mm or less.

Catalysts are added to raw petroleum in order to improve the efficacy of the refining process. The catalysts have a total hardness of 8.2 according to Moh’s scale, which rates the hardness of diamond at 10 [4]. Despite the fact that the largest part of catalysts is separated in refineries after the cracking process, one part of catalysts remains in heavy fuel oil. This remainder is cleaned in ship separators and filters, but still a small amount of catalysts reaches the engine cylinder together with fuel. During fuel combustion, the balls burst, thus creating the remains with sharp edges.

According to the ISO 8217 Standard from 2017, the fuel that is used frequently on board can contain a maximum of 60 mg/kg of catalytic impurities, while engine manufacturers allow a maximum of 15 mg/kg prior to reaching the main engine [5,6]. Even amounts smaller than those mentioned can cause serious damage to the engine if they exceed the amount of oil for lubrication, or if they get stuck between a piston ring and a groove [7]. An adequately low temperature of the oil for lubrication could prevent abrasive wear, as the low oil temperatures increase oil viscosity and thickness on sliding surfaces, thus preventing the potential abrasive wear. However, temperatures above 230°C, which usually characterise the working conditions of the main engine (Fig. 2), initiate a sudden increase in the degree of wear due to the remains of catalytic impurities and the reduction of an oil layer.
The impurities mentioned are definitely not the only ones in the bunkered fuel (loaded), but the appearance, monitoring, control and analysis of these impurities are of the utmost importance for this paper.

III. The Analysis of the Piston Rings in Two-Stroke Marine Engines: Composition, Hardness and Elasticity

The piston rings that seal the piston are most frequently made of grey iron that can be alloyed by chromium, molybdenum, vanadium, titanium, nickel, copper, etc. in varied percentages [8]. The chemical analysis of the piston rings’ base in the Wartsila RTA engine indicated that the rings are made of grey iron, as shown in Table I. The layer of oil is also necessary to facilitate a better sealing of the combustion tanks. The oil layer not only lubricates the moving parts and reduces the friction, but also seals the small cracks between the liner and rings.

| TABLE I. THE CHEMICAL XRF (X-Ray Fluorescence) ANALYSIS OF THE PISTON RING’S BASE IN THE RTA ENGINE [8] |
|--------------------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|                  | %C  | %Si  | %Mn  | %S   | %Cr  | %Ni  | %Cu  | %Mo  | %V   | %Fe  |
| Top ring CC      | 3.29| 2.0  | 0.80 | 0.005| 0.11 | <0.1 | 0.80 | 0.48 |     | Base |
| Top ring RC      | 2.84| 1.3  | 0.80 | 0.005| 0.14 | 0.40 | 1.0  | 0.69 | 0.17 | Base |
| Second ring CC   | 2.95| 1.3  | 0.75 | 0.051| 0.09 | 0.44 | 1.16 | 0.71 |     | Base |

The base of the analysed samples is made of iron. When it comes to chemical composition, the base is made of grey iron [9], which is actually cast iron whose structure is in a metal matrix and composed of graphite lamells. Grey iron is used widely, due mostly to a positive relation between its characteristics and price. In addition to the outstanding tranquilization of vibrations and mitigation of thermal shocks, grey iron is also easy to machine and cast (even in complex shapes). These characteristics promote the usage of grey iron, especially because the work of the marine engine is characterised primarily by the vibrations and thermal shocks. The comparison between the piston rings with different bases and positions on the piston, indicates the difference in the percentage of carbon and silicon - the lower (second) ring has a higher percentage of carbon than the ring labelled as RC, while their Si percentage is the same. The Table shows that the upper ring sample has the highest percentage of carbon (3.29 %) and Si (2 %) and the lowest percentages of nickel (<0.1), copper (0.8 %) and molybdenum (0.48 %).

The hardness and ductility of grey iron are limited, but could be increased through alloying and the application of an adequate thermal treatment. The best results, in all conditions, are obtained with a fully honed cylinder liner in combination with a chrome-ceramic protective layer of the piston rings. The chrome-plated ceramic layer has a great resistance to abrasive adhesive matter and corrosion.
A. The Chemical Analysis of the First Piston Ring

Besides the completely sheathed, ceramic, chrome-plated CC (Fig. 3a) piston rings, there are also alternative piston rings, KoP and Ko (Fig. 3b), whose profile is different and designed for different engine versions e.g. RTA52, RTA52U, RTA62, RTA62U, RTA72 and RTA72U. The KoP piston rings have a gap at an angle. K indicates the correction at the end of the piston ring, o indicates the absence of corrections, while P indicates the profiling of a piston ring.

![Fig. 3. The CC chrome-plated and the KoP rings, 1-KoP-profile, 3-Ko](image)

According to the Maurer diagram, the CC upper ring belongs to ferrite grey cast iron (A- in the diagram), while the RC piston ring and the lower, chrome-plated CC ring, due to their composition, belong to the pearlite grey cast iron (B- in the diagram of Fig. 4) [11]. The positive characteristics of grey iron are a relatively low production cost, resistance to abrasion, and it is also easy to alloy and machine. Grey iron has good sliding properties because the graphite acts as a lubricant, and, due to the internal graphite lamellas, grey iron mitigates oscillations, which is very important for the engine’s performance.

![Fig. 4. Types of grey cast iron (A, B) on Maurer diagram of depending on carbon and silicone percentages](image)

Ferrite is soft, rigid and very ductile, but its strength is relatively low. Pearlite grey cast iron (characteristic for the RC and chrome-plated lower ring) is the strongest among the types of grey iron listed, although, it is not the best material for the base, as the base has to be flexible in order to prevent ring breakage.

For this purpose, it was the chosen sample of piston ring for detailed characterization. On Fig. 5a the place of the analysis of the piston ring structure is shown, and, next to it, is located the typical optical microstructure of this surface in polished state (Fig. 5b), where there are clear visible lamellas and a
matrix. Below (Fig. 5c) is presented an optical microstructure of this surface in etched state, which was obtained after chemical etching with 4% nital (HNO₃ and C₂H₅OH) – 5 s, as well as the coating structure and the thickness of the coating on the piston ring (Fig. 5d) in cross-section. Four percent nital solution, which is often used for carbon steel, was used as the metallographic etching solution. This analysis was necessary in order to determine the metallizing structure of the metal, fusion and heat zone. The properties analysed include the ball size and the amount of carbon and ferrite.

The use of a Sirion high-resolution Scanning Electron Microscope indicates that the spectrums marked in Fig. 6a contain a large amount of chromium (Cr), along with other elements. Therefore, it can be concluded that this ring corresponds to the CC ring, and the coating thickness (Fig. 6b) can be measured more precisely, i.e. the thickness varies between 408 μm and 415 μm.
The analysis of the upper piston ring labelled as RC (running in coating), was done in the same way as for the previous ring whose coating was chromium sheathed. Piston rings are specially sheathed to facilitate the engine’s performance; however, in certain engine types RC piston rings are made for lower rings or can be used as an alternative for lower rings. The RC upper rings can also be chosen as a cheaper solution, but this decision should be noted clearly.

Fig. 7a shows the appearance of the piston ring sample, as well as the places where the microhardness was measured by means of a Zwick 3212 tester according to Vickers (HV 0.2). It is important to note that microhardness on the transversal section of coating could not be measured. Lower (HV 0.2 i.e. 1.961) and higher (HV 5 i.e. 49.03) strengths were used in order to obtain the pyramid print, but the print was not visible, even with electron microscope, due to the uneven, rough surface. Polishing the surface would result in wear of the coating, in which case the measuring would not be satisfactory. Fig. 7b presents the characteristics microstructure of this surface after the polishing process, while Fig. 7c shows the optical micrograph of the ring structure and the joint of the base and coating. The comparison of the pictures of the RC piston ring and the CC ring indicates that the RC ring base contains a lamellar structure. On the right side is located Fig. 7d, where is visible the etched optical microstructure, with very similar characteristics as those on the polished state.
Fig. 7. The surface analysis of the first RC ring scanned by means of optical and electron microscopes [8]

Fig. 8a show the same ring but indicates the sites where the composition of the micro-surface was analysed by an SEM microscope with EDX detector, while Fig. 8b shows the thickness of the coating layers more precisely. It is obvious that the coating contains two layers of nickel and molybdenum, whose percentage in the surfaces analysed is above 95%. The data are presented in the Table below the Figures.

It can be concluded that the microstructure is the first difference between the CC and RC rings in the same position. In addition to the different microstructure, (the shape and size of lamellas), there is an obvious difference in the chemical elements used as a reinforcement and improvement, based on grey iron [8]. The CC ring is chrome-plated, while the RC ring is nickel-plated, as its outer coating is made of nickel and the layer underneath is made of molybdenum and serves as a connection with grey iron.
The chemical analysis of the first RC ring at selected regions on the surface (spectrums) scanned by means of the SEM technology. The comparison of the data on hardness, shown in Fig. 8, with the data on the RC ring obtained in the laboratory (Table II) indicates that, according to Vickers (HV), the microhardness of the chrome-plated piston ring (CCC) is higher than the microhardness of the nickel-plated piston ring (RC). This means that the RC ring can bear greater encumbrance if abrasive wear occurs in the engine.

![Fig. 8.](image)

**Table II.** The measuring of microhardness according to Vickers (HV 0.2) on the RC piston ring sample.

<table>
<thead>
<tr>
<th>Cross-section RC ring</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Trans.sec.coating</td>
<td>Coating</td>
<td>Bbase material</td>
<td></td>
</tr>
<tr>
<td>N/A</td>
<td>337</td>
<td>353</td>
<td></td>
</tr>
<tr>
<td>N/A</td>
<td>409</td>
<td>306</td>
<td></td>
</tr>
<tr>
<td>N/A</td>
<td>401</td>
<td>325</td>
<td></td>
</tr>
<tr>
<td>N/A</td>
<td>494</td>
<td>265</td>
<td></td>
</tr>
<tr>
<td>N/A</td>
<td>278</td>
<td>289</td>
<td></td>
</tr>
<tr>
<td>N/A</td>
<td>394</td>
<td>301</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>385.5</td>
<td>306.5</td>
<td></td>
</tr>
<tr>
<td>Min.</td>
<td>278</td>
<td>265</td>
<td></td>
</tr>
<tr>
<td>Max.</td>
<td>494</td>
<td>353</td>
<td></td>
</tr>
<tr>
<td>STDEV</td>
<td>72.86</td>
<td>30.21</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 9. The microhardness of different coatings on the piston ring – as reference data.
For example, the full label of the ring for the Wartsila engine (WCH) is GGV SCP1CC16. The parameters the engineers use for reference are the first three letters of the label of the unknown base material, i.e. of (analysed) SC letters indicate that the ring profile is a flat cut; P1 indicates the first ring position; CC letters indicate ceramic chromium (coating), and 16mm is the ring height. As Wartsila does not manufacture the rings, they are purchased from more or less renowned suppliers whereby the ring quality is questionable.

B. The Chemical Analysis of the Second Ring

As already indicated in Table I., the second piston ring on the RTA58 engine is made of grey iron and its coating is chrome-plated (CC). Therefore, Fig. 10a only confirms that the coating material is chromium (in spectrums 1 and 2), since the structure of the chrome-plated ring was explained previously. The micro-surfaces of the ring coating contain 96.5 % and 97.6 % of chromium. The base material contains a percentage of carbon that is 0.11 % higher than in the case of the first ring, while the percentage of silicon is the same. The thickness of chromium coating (Fig. 10b) varies between 221 μm and 241 μm.

Spectrum In Stats.  C   O   Si  Cr  Fe  Total
---  ---  ---  ---  ---  ----
Spectrum 1  Yes  0.99  2.53  96.48  100.00
Spectrum 2  Yes  0.90  1.46  97.64  100.00
Spectrum 3  Yes  1.43  1.32  97.25  100.00
Spectrum 4  Yes  47.52  0.77  51.71  100.00
Max.      47.52  2.53  1.32  97.64  97.25  51.71 100.00
Min.      0.90  1.46  0.77  96.48  51.71

Fig. 10. The chemical analysis of the second CC ring on the micro-surfaces (scanned by means of the EDX detector - SEM technology) [8]

IV. The Recommendations for the Preventive Maintenance of Piston Rings

The opportunities for the research of the condition of the cylinder liner and piston rings are limited (except in cases when the piston is removed from the cylinder). However, the wear of the piston ring coating could be measured. The measuring requires a special measuring tool and an approach to the rings through the drainage channels. After the thickness of coating is measured, the average wear and remaining life expectancy of a ring could be calculated through a formula. In case of the initial phase of wear, the parts of cylinder liner and piston rings will appear in the form of powder in the scavenging drainage (waste) cylindrical oil.
A. The Measuring and Calculation of the Wear of the Piston Ring Coating

The wear of material is inevitable, and important when it comes to the choice of the material piston rings and cylinder liners are made of. It is highly important that the material lasts throughout the life expectancy assumed (the period between two overhauls). The coating can be damaged and worn, because it is, like all other parts, affected by the working conditions, engine encumbrance, the quality of the fuel used, etc. The wear and condition of the coating could be determined by means of the CC coating thickness measuring tool, Fig. 11.

Wartsila recommends a control after each 1500-2000 main engine hours [13]. Before measuring, it is important to calibrate the tools in accordance with the instructions and clean the work surfaces of the piston rings at the measuring points P1-P9. The tool sensor is then placed beside the middle of the piston ring. The condition of the piston rings is analysed once the measuring is completed and all the values noted.

![Position of the coating thickness measuring tool](image1.png)

![View of a partly worn CC coating on a piston ring](image2.png)

A properly conducted measurement, according to the description above, can determine the wear of each piston ring precisely. The rings can be used if the remaining thickness of the coating is above the standards prescribed (according to the Wartsila company Standards):

- Upper ring > 0.05 mm
- Lower ring > 0.02 mm

A piston ring should be replaced if its wear is higher than expected. However, if there is a partial wear of a piston ring, as represented in Figure 12, the piston ring should be repaired as soon as possible. Once the measuring is performed and all the parameters known, the average wear of a piston ring per hour and its life expectancy could be calculated mathematically by means of the following formula:

\[ WR = \frac{(D1 - D2) \times 1000}{T2 - T1} \]  

\( WR \) – average wear [mm/1000h]
Another formula could indicate the remaining life expectancy of a piston ring if all the parameters are known:

\[
LT = \frac{(D_2 - D_{\text{min}}) \times 1000}{WR}
\]

LT – remaining life expectancy [h]

D2 – current coating thickness [mm]

Dmin – minimal coating thickness [mm]

WR – average wear [mm/1000h]

B. The Analysis and Diagnostics of the Waste Oil from the Engine Cylinder (LinerSCAN)

The preventive maintenance of a marine engine includes: The use of quality fuel, thorough elimination of impurities during their accumulation, proper fuel separation, the analysis of the efficacy of the separator, fuel filtering, and the right choice of a quality material for the piston ring production. Additionally, there are now portable laboratories and measuring tools that determine the amounts of abrasive particles in fuel. Even in small quantities, the abrasive particles are always contained in fuel and can damage the engine. Operational cost per cylinder is presented in [14]. The most considerable is the expense for cylinder oil, while other expenses are related to the piston, piston rings, engine skirt and maintenance. The monitoring of wear from cylinders is also highly important, and can be performed through the analysis of the scavenging waste oil from the cylinders.

The analysis can detect a sudden increase in the amount of metal particles, which would mean that an unplanned wear has begun. In that case, immediate action should be taken in order to mitigate the negative consequences that can lead to further problems, and even the failure of the marine engine.

LinerSCAN measures the amount of iron in the waste oil from the cylinder by means of magnetometry, whereby the sample is tested within a magnetic field. The usage of this method relies on a basic physical effect – the change of inductance due to the presence of a magnetic material. It is proven that the analysis of scavenging drain oil for iron powder, from the drainage channels of each cylinder, indicates relative changes in the wear of the cylinder liner or piston rings. The system emphasises the periods of greater exposure to an encumbrance, identifies and signals the beginning of a more significant wear, and other problems, such as the presence of catalytic impurities in fuel [14]. LinerSCAN has multiple advantages:

- Financial benefit
- The optimization of power supply rate
- Timely alarm in case of a significant problem with low-sulphur fuel
- The improvement of preventive maintenance
- The increase of the life expectancy of cylinder liners and piston rings
- The prevention of engine damage and failure
- The return on investment, sometimes in less than a year

The importance of LineSCAN installation is best illustrated by the following examples:
The graphics show the way LinerSCAN detects the amount of iron particles in the cylinder waste oil in real time. Fig. 13 presents a rapid increase during the analysis of the entire engine. The rapid increase in the amount of iron particles from 600 ppm to 1700 ppm started after 47,000 engine hours, the amount of particles reached 1900 ppm after 18 minutes, and 2000 ppm after 30 minutes. Such increase is a signal for the ship’s engineers to take preventive measures and analyse the system. Further control focused on the fuel separation system, such as the parameters on the main engine and on cylinder number 6, which recorded the largest increase in the amount of iron particles, but did not deviate from the previous values.

The attempts to reduce the amount of abrasive particles in fuel included the drainage of the oil tanks, filter cleaning and, above all, the cleaning of the elements of the centrifugal separator, and returning the elements into the system. The second fuel separator was also prepared for a serial fuel separation. An additional separator would be used in case the previous attempts of a better fuel separation did not give concrete results. However, this was not necessary, since the concentration of iron particles in the fuel started to decrease. The presence of catalytic impurities in fuel was obvious, although the analysis did not detect large amounts. Fig. 14 shows a sharp decrease in the amount of iron particles, which varies between 1800 ppm at 47045 engine hours and only 200 ppm at 47100 engine hours.

Fig. 15 supports the analysis, as it shows a rapid increase and an increased (extreme) wear (marked in red) during the combustion of fuel with catalytic impurities [15]. The desludging interval of the removal of the impurities accumulated from the purifier was 2 hours, which is typical for ship systems.
The use of the LineSCAN tool in the case analysed was a preventive reaction that inhibited further damage, i.e. the wear of the metal parts of the piston rings and cylinder liners. The sudden increase, as well as the decreasing tendency of the amount of iron particles, were notable in the system. The decrease was noted after the preventive maintenance with drainage oil in five-minute intervals only.

V. CONCLUSION

The piston ring damage and breakage can cause increased fuel and oil consumption, improper engine performance, reduced engine power, etc. which hinder smooth engine performance and could, consequently, result in a complete failure of the engine. The chemical analysis of the base and coatings of the piston ring samples from the ship under investigation shows that the CC piston ring has a better structure, thicker chromium coating on the surface, and its base material (grey iron) has a higher percentage of carbon and silicon, which makes this material better for the production of the first piston ring [11,16]. Moreover, the microhardness of the CC piston ring is several times higher than the microhardness of the nickel-plated ring. In the case of sudden wear of the piston rings due to abrasive particles in fuel, the only solution is the use of higher-quality materials for the base and coating of piston rings. In this particular case, the CC piston rings have proven advantages.

One of the methods for the control of the piston rings condition is the visual method through the scavenging receiver/port, or through the lateral ports of the fuel pump. However, the degree and percentage of wear and the remaining life expectancy cannot be determined without measuring the coating thickness.

The use of quality materials, along with contemporary monitoring of the amount of iron particles in the scavenging drain oil, would give the best results within the abrasive working conditions of the engine. The paper elaborated the efficient performance of the LineSCAN tool during five-minute scanning and measuring, and the diagram view of the parameters in relation to the main engine hours. The measuring interval could be shortened, in which case a sudden increase in wear would be noted quickly. This would provide enough time for the ship’s engineers to react immediately and try to reduce further damage. As in the case analysed, prevention is possible through the improvement of the performance of the fuel cleaning system, or the use of a higher quality fuel that contains less catalytic impurities e.g. diesel fuel, or in modern dual-fuel engines, through gas use in that system.

In the forthcoming period, it will be important to mark the piston rings in accordance with the Technical Code like other important main engine parts. In that way, the quality of production of piston rings would be controlled, and the possibility of the use of low-quality or reconditioned rings would be reduced significantly [17]. In order to achieve the necessary quality and provide the crew with an insight into the chemical composition of each ring, it is necessary to prescribe a Standard that would be binding for unauthorised ring manufacturers.
ACKNOWLEDGMENT

The research was carried out as part of the bilateral project “Development of examination techniques and control of metallic materials on ships” BI-ME/18-20-024 (2019-2020) between Slovenia and Montenegro under the auspices of the Slovenian Research Agency and Ministry of Science, Monte Negro.

Note:
The responsible proof reader for the English language is Shelagh Hedges, Faculty of Mechanical Engineering University of Maribor, Slovenia.

Abbreviations:
CC - ceramic, chrome-plated piston rings
RC - running in coating piston ring
KpP - piston ring with different profile and designed
RTA - low-speed engines, which are produced by specialised engine manufacturing companies under licence from WinGD
SEM - Scanning Electron Microscope
Si - silicium
EDX detector - Energy-dispersive X-ray detector
WCH - Wartsila engine

REFERENCES

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Analysis of Surge Protection Performances at Ships

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ABSTRACT
Electric and electronic devices based on solid-state circuits and/or microprocessors are widely used in low-voltage installations of ships’ electric power systems. In most of cases, these advanced electric and electronic devices have weak surge withstand capability and therefore they are susceptible to damage or operational upset due to voltage and current surges.

Increased electromagnetic sensitivity of these devices requires appropriate surge protection. One solution that has proved to be effective in mitigating the effects of surges is the use of surge protective devices (SPDs). SPD is device that is intended to limit transient overvoltages and divert surge currents.

In low-voltage power installations at ships, common practice is application of only one SPD within part of the installations (usually called one-stage protection system). However, it is necessary to determine limitations of such configuration regarding protection performances for different combinations of influencing parameters.

Analysis of performances of one-stage protection system for different types of equipment, typically founded in low-voltage ship’s power installations, is given in the paper. Performed analysis should point on characteristics of equipment loads and lengths of connecting cables, for which appropriate surge protection performances can be achieved. Obtained results could be used for determination of protection distances, which are useful for techno-economical optimization of configuration of surge protection systems.

KEYWORDS: low voltage power installations, surges, surge protective devices & protection distances

I. INTRODUCTION
The All-Electric-Ship is concept that implies the replacement of a ship’s mechanical, pneumatic and/or hydraulic power systems with an electric power system [1]. The reliability and quality of power supply in ship’s electric power systems can be endangered due to different reasons. One of the most common cause of disturbances involving ship’s electric power system is occurrence of surges. Surge voltages and surge currents originate from two major sources, lightning and switching. A third phenomenon that needs recognition is the occurrence of surge voltages resulting from interactions between different systems, such as the power system and a communications system, during surge events occurring in one of the systems [2].

In the paper, only effects of lightning surges and appropriate protection measures will be analyzed. Lightning is a natural and unavoidable high-energy phenomenon that affects ship’s electrical system (power systems as well as signal and communication systems) through several mechanisms. The obvious effect is a direct flash to the elements of external lightning protection systems or exposed conductors of electric power or communication systems, but other coupling mechanisms into power circuits can also produce overvoltages and associated surge currents [2].

Regardless of mechanism of their occurrence, lightning surges are sources of operational upset, disturbances and/or damage of equipment within ship’s electric power system [3], [4]. This is particularly case for electric and electronic devices based on solid-state circuits or microprocessors, which are nowadays widely used in ship’s electric power system, especially in low-voltage installations. In most of cases, these advanced electric and electronic devices have weak surge withstand capability, which makes them very vulnerable to voltage and current surges.

Increased electromagnetic sensitivity of equipment in ship’s electric low voltage installations requires appropriate protection against voltage and current surges. One solution that has proved to be effective in mitigating the effects of surges is the use of surge protective devices (SPDs) [5]. SPD is device that is
intended to limit transient overvoltages and divert surge currents. It contains at least one non-linear component [6].

Protection systems can be realized with application of one SPD or more SPDs deployed in cascade arrangement. Appropriate configuration of protection system and its effectiveness depend on many parameters. In order to achieve appropriate protection performances it is necessary to analyze response of equipment to be protected on appearance of surges that can be expected to occur in observed power system. In low-voltage power installations at ships, common practice is application of only one SPD within part of the installations (usually called one-stage protection system). However, it is necessary to determine limitations of such configuration regarding protection performances for different combinations of influencing parameters.

Analysis of performances of one-stage protection system for different types of equipment, typically founded in low-voltage ship’s power installations, is given in the paper. Performed analysis should point on characteristics of equipment loads and lengths of connecting cables, for which appropriate surge protection performances can be achieved. Obtained results could be used for determination of protection distances, which are useful for techno-economical optimization of configuration of surge protection systems.

II. SURGE PROTECTION SYSTEM

In low-voltage power installations on ships, SPDs are usually installed on sub-distribution boards, which are intended to provide power supply for several circuits with different connected devices. For the purpose of analysis of protection system performances, it is sufficient to observe one such circuit with device to be protected. Equivalent model of protection system with one SPD installed within observed circuit is given in Fig. 1. Determination of protection performances assumes surge testing of the analyzed system. Surge testing should to be performed with voltage and current surges that are best replica of real surge environment that can be expected in the protected circuit. However, there are no sufficient information regarding surge environment in low-voltage power supply installations of ship’s power systems. Equivalency can be made with similar land-based systems [5]. International standards in this field recommend surge testing with set of representative standard and additional surge waveforms [7], [8], [9]. In case when impedance of the protected circuit can be changed due to insulation breakdown or presence of SPD, it is appropriate to use representative Combination Wave for surge testing. Namely, Combination Wave is delivered by Combination Wave Generator (CWG), which has to provide 1.2/50μs open circuit voltage waveform (which is usually used for testing of insulation level), and 8/20μs short-circuit current waveform (which is usually used for testing of SPD absorption capability). Actual voltage and current waveform of the CWG during surge testing depend on impedances of the tested system at particular moment. However, level of stress provided by CWG can only be determined with amplitudes of open-circuit voltage waveform and short-circuit current waveform. These amplitudes depend on characteristics of propagation and dispersion of surge voltages and currents. Analyses have shown that for surge currents presented at the service entrance of low-voltage installation, the increasing impedance opposing (impeding) the flow of surge currents further into the installation reduces the surge current that can be delivered along the branch circuits. In contrast, a voltage surge, with an amplitude below the point of flashover of clearances and presented at the service entrance of a low-voltage installation, can propagate, practically unattenuated, to the end of a branch circuit when no low-impedance load (equipment or local SPD) is present along the branch circuit [2]. These results lead to development of location categories concept.
According to this concept, a low-voltage power installation can be divided into categories, for which amplitudes of different representative surge waveforms are specified [9]. Due to relatively compact design of electric power systems and limited impedances [5], it can be taken into account that protected circuit given in Fig. 1 belongs to location category B. For this category, amplitude of CWG’s open-circuit voltage is 6kV, while amplitude of CWG’s short-circuit current is 3kA [9].

Equipment under test (EUT) is model of sophisticated modern electric and/or electronic devices. These devices usually have weak surge withstand capability i.e. relatively low value of impulse withstand voltage. It is assumed that analyzed EUT belongs to the equipment of the overvoltage category I according to IEC 60664-1 [10], for which value of withstands impulse voltage is 1.5kV. This means that appearance of voltages with values higher than impulse withstand voltage of equipment can cause insulation breakdown and failure of EUT [11]. SPD is metal-oxide varistor with protection voltage of Up=1250V. This value is selected to be below of value of impulse withstand voltage of EUT’s model, which is main prerequisite for overvoltage protection. Cable between SPD and EUT is PVC-insulated cables 3x2.5mm2 with electric parameters: R=0.00561Ω/m, L=0.324μH/m, C=0.1368nF/m, G=0s/m [12].

### III. Analysis of Protection Performances for Different Types of EUT

Observed protection system given in Fig. 1 is modelled in simulation software MATLAB Simulink in order to perform analysis of its protection performances. Maximal values of voltage across EUT are used as criteria for assessment of protection performances. Analyses are conducted for different types of EUT’s load and for wide range of load’s powers. Influence of different lengths of cable between SPD and EUT in range of 1m to 100m are taken into account.

#### A. Resistive load of EUT

In case when EUT is purely resistive load, dependence of maximal values across EUT on length of cable between SPD and EUT is given in Fig. 2, for three values of load’s active power: P=10W, P=400W and P=1000W. As it can be seen from Fig. 2, maximal values of voltages across EUT strongly depend on length of cable between SPD and EUT in case of lower values of load’s active power (cases with P=10W and P=400W). For relatively high values of load’s active power (case with P=1000W) maximal values of voltage across EUT do not depend on cable length. In cases with P=10W and P=400W, maximal values of voltage across EUT increase with increase of length of cable. This is consequence of reflection of voltage wave on the connection point of load in the circuit. Namely, surge voltage wave propagates through cable and arrives on connection point of load impedance with cable. Load’s impedance, in case of lower values of load’s active power, is higher than impedance of cable. These conditions cause reflection of surge voltage wave and, as consequence, increase of voltage across load. Further, this process repeats and causes oscillation of voltage across EUT during time. As illustration, voltage waveform across EUT as well as across SPD in case of load’s active power P=10W and cable length of 100m is given in Fig. 3.
In case of short cable between SPD and EUT, amplitudes of oscillations are suppressed due to vicinity of SPD. As illustration, voltage waveform across EUT in case of load’s active power $P=10W$ and cable length of $d=100m$ is given in Fig. 4. It can be seen that waveform of voltage across EUT is very close to waveform of voltage across SPD. In case of load’s active power of $P=1000W$, load’s impedance is lower than impedance of cable. Therefore, there is no reflection of surge voltage wave on load’s impedance and, consequently, there are no oscillations of voltage waveform across EUT. As illustration, voltage waveform across EUT in case of load’s active power $P=1000W$ and cable length of $d=100m$ is given in Fig. 5.
Further, obtained results in Fig. φ show that maximal values of voltage across EUT exceed value of impulse withstand voltage of EUT (1500V) in case of lower values of load’s active powers and longer cables. The value of cable length for which maximal value of voltage across EUT is lower than impulse withstand voltage represents protection distance of SPD. It can be concluded that protection distance is shorter for smaller value of load’s active power. Namely, for case of P=400W value of SPD protection distance is approximately 17m, while for case of P=10W value of SPD protection distance is approximately 4.2m.

B. Inductive load as EUT

In case when EUT is inductive load, dependence of maximal values across EUT on length of cable between SPD and EUT is given in Fig. ϊ, for three values of load’s reactive power: Q=10VAr, Q=100VAr and Q=500VAr. Obtained results show that maximal voltages across EUT with inductive load do not depend on load’s inductive power. However, maximal values of voltage strongly depend on value of cable length. For longer cables, maximal values of voltage are higher and exceed value of EUT’s impulse withstand voltage. This is consequence of reflection of surge voltage wave on very high impedance of load. This high impedance originates from high frequencies at waveform front of incoming surge voltage wave. Regardless of load’s inductance, these high frequencies cause high value of load’s impedance. SPD protection distance in case of EUT’s reactive load is approximately 4m, regardless of value of load’s inductive power. As illustration, voltage waveform across EUT in case of load’s reactive power Q=100VAr and cable length of 100m is given in Fig. 7.

![Fig. 6. Maximal voltages across EUT for case of inductive load](image1)

![Fig. 7. Voltage waveform across EUT in case with load’s reactive power Q=100VAr and cable length of d=100m](image2)
C. Capacitive load as EUT

In case when EUT is capacitive load, dependence of maximal values across EUT on length of cable between SPD and EUT is given in Fig. 8, for three values of load’s reactive power: $Q=-10\text{VAr}$, $Q=-100\text{VAr}$ and $Q=-500\text{VAr}$. Obtained results show that in case of capacitive load maximal values of voltage across EUT depend both on value of load’s capacitive power as well as on cable length. In case of lower values of load’s capacitive power ($Q=-10\text{VAr}$ and $Q=-100\text{VAr}$) maximal voltages across EUT are higher than in case of very high value of load’s capacitive power ($Q=-500\text{VAr}$) for every cable length. However, most important fact is that maximal values of voltage across EUT in case of lower load’s reactive powers are higher than value of EUT’s impulse withstand voltage for every cable length in range from $1\text{m}$ to $100\text{m}$. In other words, SPD protection distance for these equipment is shorter than $1\text{m}$, i.e. there are no adequate protection with selected SPD except in case of parallel connection of SPD via EUT terminals with cable which length is very short. As illustration, voltage waveform across EUT in case of load’s reactive power $Q=-10\text{W}$ and cable length of $100\text{m}$ is given in Fig. 9, while voltage waveform across EUT in case of load’s reactive power $Q=-100\text{W}$ and cable length of $100\text{m}$ is given in Fig. 10.

![Fig. 8. Maximal voltages across EUT for case of capacitive load](image1)

![Fig. 9. Voltage waveform across EUT in case with load’s reactive power $Q=-10\text{VAr}$ and cable length of $d=100\text{m}$](image2)
D. Resistive-inductive load as EUT

As cases that are more realistic, it is worthwhile to analyze resistive-inductive character of EUT’s load. Dependence of maximal values across EUT on length of cable between SPD and EUT is given in Fig. 11, for cases of combination of load’s active power of $P=400\text{W}$ and three values of load’s reactive power: $Q=10\text{VAR}$, $Q=100\text{VAR}$ and $Q=500\text{VAR}$. The same dependence is given in Fig. 12 for cases of combination of load’s active power of $P=1000\text{W}$ and three values of load’s reactive power: $Q=10\text{VAR}$, $Q=100\text{VAR}$ and $Q=500\text{VAR}$.

![Figure 10: Voltage waveform across EUT in case with load’s reactive power $Q=-100\text{VAR}$ and cable length of $d=100\text{m}$](image)

![Figure 11: Maximal voltages across EUT for cases of resistive-inductive load with $P=400\text{W}$ and $Q=10\text{VAR}$, $Q=100\text{VAR}$ and $Q=500\text{VAR}$](image)

![Figure 12: Maximal voltages across EUT for cases of resistive-inductive load with $P=1000\text{W}$ and $Q=10\text{VAR}$, $Q=100\text{VAR}$ and $Q=500\text{VAR}$](image)
From Fig. 11 and Fig. 12, it can be concluded that maximal voltages across EUT do not depend on value of load’s reactive power. By comparison of results given in Fig. 2 with results presented in Fig. 11 and Fig. 12 it is obvious that maximal voltages across EUT are identical for same load’s active powers, regardless of values of load’s reactive power for resistive-inductive load. This is consequence of parallel model of resistive-inductive load, in which case equivalent impedance is approximately equal to load’s resistance because inductive impedance is much higher than resistance.

**E. Resistive-capacitive load as EUT**

In case when load has resistive-capacitive character, dependence of maximal values across EUT on length of cable between SPD and EUT is given in Fig. 13, for cases of combination of load’s active power of $P=400W$ and three values of load’s reactive power: $Q=-10VAr$, $Q=-100VAr$ and $Q=-200VAr$.

![Fig. 13. Maximal voltages across EUT for cases of resistive-capacitive load with $P=400W$ and $Q=-10VAr$, $Q=-100VAr$ and $Q=-200VAr$](image)

In this case, results are almost identical as in case of purely capacitive load (Fig. 8), because of dominant effect of load’s capacitance.

**IV. DISCUSSION OF RESULTS**

Obtained results shows that performance of observed one-stage protection system evaluated through maximal voltages across EUT are not fulfilled for all analyzed cases. Namely, maximal voltages across EUT exceed selected value of impulse withstand voltage of protected equipment in many combinations of influencing parameters: type of EUT, load’s power and cable length. In other words, SPD protection distance for most of observed cases has finite value, what means that equipment connected outside of the protection distance may be exposed to danger due to appearance of voltages which maximal values exceed equipment’s impulse withstand voltage. Only exception is case with relatively high values of load’s active powers. Furthermore, for capacitive load, SPD protection distance is smaller than 1m. The same situation is observed for more realistic case i.e. for resistive-capacitive load. This is very important having in mind that most of sensitive electronic equipment have resistive-capacitive character of load due to existence of capacitive back-up filters inside power supply units. Therefore, it can be concluded that installation of only one SPD at (sub)distribution board does not provide adequate surge protection for all equipment that can be connected in circuit at different places and distances in relation to SPD.

However, previous conclusions is derived for selected protection voltage of applied SPD. Namely, by close inspection of obtained results, it can be noticed that maximal voltages across EUT reaches almost double value of SPD protection voltage. This leads to the conclusion that in case of application of SPD with protection voltage that is equal to half of the value of impulse withstand voltage of protected equipment, maximal voltages across EUT in all cases (for all types of load and values of load’s power and cable lengths) will be lower than value of impulse withstand voltage. On that way, criteria of protection performances regarding maximal voltages across EUT will be satisfied. However, this approach arises another problem, which is related to energy absorption capability of SPD. Namely, SPDs...
with lower values of protection voltages usually have lower energy absorption capability and therefore they can easily be destroyed in case of appearance of high-energy surges [13]. Another issue is survival of such SPDs in case of temporary overvoltages in the ship’s power system [14].

Since decreasing of protection voltage of SPD installed at distribution board it is not justified, adequate protection performances can be achieved only with application of additional SPDs installed throughout low-voltage power installation. Such configuration, besides criteria related to maximal voltages across EUT, has to fulfill criteria of energy coordination of installed SPDs.

V. CONCLUSION
Analysis of protection performances of protection system realized with application of only one SPD at (sub)distribution board of low-voltage power installation in ship’s electric system is given in the paper. Maximal voltages across protected equipment are used as criteria of protection performances, and they are determined for different types of protected equipment, for different values of equipment load’s power and for different lengths of cable between SPD and protected equipment. Obtained results have shown that protection performances are not fulfilled for all analyzed cases. Namely, maximal voltages across protected equipment exceed selected value of equipment’s impulse withstand voltage in many combinations of mentioned influencing parameters. In other words, SPD protection distance for most of observed cases has finite value, what means that equipment connected outside of the protection distance may be exposed to danger due to appearance of voltages which maximal values exceed equipment impulse withstand voltage. Therefore, it can be concluded that installation of only one SPD does not provide adequate surge protection for all equipment that can be connected in circuit at different places and distances in relation to SPD. Adequate protection performances can be achieved only with application of additional SPDs installed throughout low-voltage power installation, which requires special attention due to energy coordination of SPDs.

REFERENCES


Behaviour of A Barge Under Wind Conditions

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Abstract
In cases where the lines plan of a ship are missing, it needs manually to make direct measurements on the real ship and after with the help of computer software to model the ship hull up to in achieving the final shape of it. On this model are made geometric and hydrostatic calculations as well as verification of the stability criteria according to the IMO standards required by the Albanian Maritime Register. In this paper, the author will present the case study related to the stability analysis and verification of the weather stability criteria of a barge operating in the area of Durres port.

Keywords: ship stability, barge, ship hull & weather stability criteria

I. Introduction
The design of the lines plan of the ships is the basic step in order to make the hydrostatic and stabilizing calculations. Generally the ships are equipped with the line plans since their design project. In many cases in ships operating in Albania seas there aren’t these lines plan. In these cases, to design these lines plan, the direct measurements and their remodelling are needed, using the so-called reverse engineering method.

The direct measurements were made on the ship’s hull to achieve the necessary data in order to model the hull through a CAD software. In order to obtain reliable results of the ship stability, there are required other kind of data related to the ship, such as linear data, tonnage and ships classification data. Based on our experience and results using these CAD software, confirm that the results obtained using software CAD are practically reliable and can be used in other similar cases.

II. 3D Modelling of the Ship Hull
A. Methodology of the hull measuring
In order to obtain the transverse, longitudinal and waterline lines of the ship to be modelled, physical measurements on the real ship should be performed [6]. This is the most important step, because these data have a direct impact on the correct of the model shape. Then, with the help of CAD/MaxSurf software, the optimized hull model is achieved, through iterative processes. Important attention has been shown to the observance of the boundary conditions laid down on the real vessel [5].

Measuring techniques with traditional tools (such as bullet lines, tape meters, 90 degree teams, and bubble level) are used in our study, as no high level of accuracy is required and no other measurement tools have been available. The main problem that we have faced h the parallelism and verticality of the measurement directions [6].

The best methods would be those of the three-dimensional scanning of the ship hull. In practice, RE can be defined as designing a product through a digital model gained by three-dimensional measurements of a ship hull [6,8].

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The steps taken are:
1. Measurements at the keel line, in its extreme parts at the bow and stern.
2. To make it easier to build a complete hull, it is initially modelling the central hull and then the part on
   the bow and on the stern.
3. Then join them by respecting the geometric boundary conditions to achieve the full form of the hull.
4. Make the necessary verifications, the corrections, and re-measurements for reaching the final model
   of the hull.
5. Remodelling the surfaces of the hull and their smoothing for obtaining hydrostatic characteristics.
6. Finally, it comes to obtaining the 3D model of the hull.
B. Real Measurements to Build the Drawing Hull Lines that will be modelled

The measurement process is carried out in 5 physical bulkheads of the ship. The data obtained from direct measurements directly on the ship hull are presented in a table in MS Excel. The measurements are made in equidistant steps of 20 cm by z axis.

<table>
<thead>
<tr>
<th>Main Dimensions of the Barge “ALEXANDAR”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length Overall: LOA = 25.00 m</td>
</tr>
<tr>
<td>Breadth Overall: BOA = 6.20 m</td>
</tr>
<tr>
<td>Depth: D = 2.70 m</td>
</tr>
<tr>
<td>Draft: T = 1.50 m</td>
</tr>
<tr>
<td>Construction Material: Steel</td>
</tr>
<tr>
<td>Year, Place of Reconstruction: 2017, Durres</td>
</tr>
</tbody>
</table>

In order to obtain accurate measurement of the results of the semi-breadths of coordinates, also made some additional measurements in extreme slopes mainly at the bow and at the stern, although the keel line is almost right with an angle of longitudinal inclination to the x axis of 0 degrees. Having introduced the hypothesis of symmetry, points were captured only from the starboard side of the hull. Some possible errors in measurement or in entering data was reduced with further approximation process.

Using the MaxSurf software we came to an appropriate and satisfying shape of the 3D model of the ship. This process went through three phases:

1. Modelling of initial hull curves
2. Building of the hull surface
3. Smoothing of the hull surface

During the building of the model in 3D, possible errors seen with visual images in three design plans and in 3D space, was fixed, such as, putting the data, measurement errors, the introduction of coordinates and having made the necessary corrections it was made the generation of the hull as below [5]:

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**Fig. 1. GENERAL ARRANGEMENT OF THE BARGE “ALEXANDAR”**
III. Estimation of Stability of the Barge “ALEXANDAR”

Once we have done in 3-D modelling of the hull and hydrostatic calculations, it was necessary to verify the behaviour of the vessel to the meteorological effects in two extreme conditions of its loading, with full loaded conditions and the ship with 10% of cargo [1, 2].

A. Generation of Hydrostatic Curves

Hydrostatic curves are calculated with the help of Maxsurf and Hydromax Software [5, 8]. Below we will show the data of the vessel with full load, that correspond waterline DWL=1.50m.

**Table II. Hydrostatic DATA of the ship “ALEXANDAR”**

<table>
<thead>
<tr>
<th>Draft Amidsh. M</th>
<th>DWL=1.50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Displacement tonne</td>
<td>203</td>
</tr>
<tr>
<td>WL Length m</td>
<td>24.99</td>
</tr>
<tr>
<td>WL Beam m</td>
<td>6.20</td>
</tr>
<tr>
<td>Block Coeff.</td>
<td>0.861</td>
</tr>
<tr>
<td>Midship Area Coeff.</td>
<td>0.995</td>
</tr>
<tr>
<td>Waterpl. Area Coeff.</td>
<td>0.899</td>
</tr>
<tr>
<td>KB m</td>
<td>0.77</td>
</tr>
<tr>
<td>BMt m</td>
<td>2.01</td>
</tr>
</tbody>
</table>

The vertical center of gravity of the vessel in full loaded condition is calculated as KG = VCG = 1.67m.

**Table III. Weights on the vessel Case A) Full loaded condition**

<table>
<thead>
<tr>
<th>Nr</th>
<th>Weight Items</th>
<th>Weight (t)</th>
<th>VCG of weights Z1 (m)</th>
<th>Moment M XY =P-Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lightship</td>
<td>83</td>
<td>1.7</td>
<td>141.1</td>
</tr>
<tr>
<td>2</td>
<td>Cargo</td>
<td>120</td>
<td>1.65</td>
<td>198</td>
</tr>
<tr>
<td>3</td>
<td>Total Weight</td>
<td>Σ1 = 203</td>
<td>=</td>
<td>Σ2 = 339.1</td>
</tr>
</tbody>
</table>

Vertical gravity center of the vessel: \( KG = \frac{\Sigma 2}{\Sigma 1} = \frac{339.1}{203} = 1.67 \text{ m} \)
Table IV. Weights on the vessel B) Ship with 10% of cargo condition

<table>
<thead>
<tr>
<th>Nr</th>
<th>Weight Items</th>
<th>Weight (t)</th>
<th>VCG of weights Zi (m)</th>
<th>Moment MXY = P * Zi</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lightship</td>
<td>83</td>
<td>1.7</td>
<td>141.1</td>
</tr>
<tr>
<td>2</td>
<td>Cargo 10%</td>
<td>12</td>
<td>0.65</td>
<td>7.8</td>
</tr>
<tr>
<td>3</td>
<td>Total Weight</td>
<td>Σ1 = 95</td>
<td></td>
<td>Σ2 = 148.9</td>
</tr>
</tbody>
</table>

Vertical gravity center of the vessel: \( KG = \frac{\Sigma_2}{\Sigma_1} = \frac{148.9}{95} = 1.567 \, m \)

Lightship weight value is determined based on real measurement of draft. In this condition the measured draft of vessel is equal to 0.65 m. This value of draft from the hydrostatic data defines a weight value of lightship equal to 83 tonnes.

The following diagrams show the static stability curve of the ship.

![Diagram of barge stability](image)

**Fig. 3.** Diagrams of the barge stability in two loading conditions A-full loaded condition and B-10% of cargo condition

**B. Weather Criteria (Wind and Rolling Criterion)**

The ability of a ship to withstand the combined effects of beam wind and rolling shall be demonstrated, with reference to the following figure, as follows [1,4,7]:

1. the ship is subjected to a steady wind pressure acting perpendicular to the ship’s centreline which results in a steady wind heeling lever (lw1);
2. from the resultant angle of equilibrium (\( \phi_0 \)), the ship is assumed to roll owing to wave action to an angle of roll (\( \phi \)) to windward. The angle of heel under action of steady wind (\( \phi_0 \)) should not exceed 16° or 80% of the angle of deck edge immersion, whichever is less;
3. the ship is then subjected to a gust wind pressure which results in a gust wind heeling lever (lw2); and under these circumstances, area b shall be equal to or greater than area a,

\[
\frac{A_b}{A_p} > 1
\]

(1)

as indicated in the following figure below:
where the angles in this are defined as follows:

- $\phi_0$ = angle of heel under action of steady wind
- $\phi_1$ = angle of roll to windward due to wave action
- $\phi_2$ = angle of down-flooding (\(\phi_1\)) or 50° or $\phi_c$, whichever is less,
- $\phi_c$ = angle of second intercept between wind heeling lever $lw^2$ and GZ curves.

Stability data are calculated based on Hydromax Software [5]:

**Table IV. Verification of weather criteria of the barge Case A) Full loaded condition**

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Value</th>
<th>Units</th>
<th>Actual</th>
<th>Status</th>
<th>Margin %</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.749(18) Ch3 - Design criteria applicable to all vessels</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Angle of steady heel shall not be greater than</td>
<td>16.0</td>
<td>deg</td>
<td>4.0</td>
<td>Pass</td>
<td>+75.24</td>
</tr>
<tr>
<td>Angle of steady heel / Deck edge immersion angle shall not be greater than</td>
<td>80,000</td>
<td>%</td>
<td>17,219</td>
<td>Pass</td>
<td>+78.48</td>
</tr>
<tr>
<td>Area1 (b) / Area2(a) shall not be less than</td>
<td>100,000</td>
<td>%</td>
<td>224.68</td>
<td>Pass</td>
<td>+124.68</td>
</tr>
<tr>
<td>Intermediate values</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model windage area</td>
<td>m^2</td>
<td>32,916</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model windage area centroid height (from zero point)</td>
<td>m</td>
<td>2,142</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total windage area</td>
<td>m^2</td>
<td>82,916</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total windage area centroid height (from zero point)</td>
<td>m</td>
<td>4,468</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heel arm amplitude</td>
<td>m</td>
<td>0.078</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equilibrium angle with steady heel arm</td>
<td>deg</td>
<td>4.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equilibrium angle with gust heel arm</td>
<td>deg</td>
<td>5.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deck edge immersion angle</td>
<td>deg</td>
<td>23.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area1 (under GZ), from 5,9 to 50,0 deg.</td>
<td>m.deg</td>
<td>21,7587</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area1 (under HA), from 5,9 to 50,0 deg.</td>
<td>m.deg</td>
<td>5,1341</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area1(b), from 3,0 to 50,0 deg.</td>
<td>m.deg</td>
<td>26,2979</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area2 (under GZ), from -21,0 to 5,9 deg.</td>
<td>m.deg</td>
<td>4,2632</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area2 (under HA), from -21,0 to 5,9 deg.</td>
<td>m.deg</td>
<td>3,1362</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area2(a), from -21,0 to 5,9 deg.</td>
<td>m.deg</td>
<td>7,3994</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table V. Verification of weather criteria of the barge case B) Ship with 10% of cargo

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Value</th>
<th>Units</th>
<th>Actual</th>
<th>Status</th>
<th>Margin %</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.749(18) Ch3 - Design criteria applicable to all vessels</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.2.2: Severe wind and rolling</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Angle of steady heel shall not be greater than</td>
<td>16,0</td>
<td>deg</td>
<td>3.4</td>
<td>Pass</td>
<td>+78,89</td>
</tr>
<tr>
<td>Angle of steady heel / Deck edge immersion angle shall not be greater</td>
<td>80,000</td>
<td>%</td>
<td>8,310</td>
<td>Pass</td>
<td>+89,61</td>
</tr>
<tr>
<td>Area1 (b) / Area2(a) shall not be less than</td>
<td>100,000</td>
<td>%</td>
<td>148,968</td>
<td>Pass</td>
<td>+48,97</td>
</tr>
<tr>
<td>Intermediate values</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model windage area</td>
<td>m^2</td>
<td></td>
<td>51,861</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model windage area centroid height (from zero point)</td>
<td>m</td>
<td></td>
<td>1,763</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total windage area</td>
<td>m^2</td>
<td></td>
<td>101,861</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total windage area centroid height (from zero point)</td>
<td>m</td>
<td></td>
<td>3,843</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heel arm amplitude</td>
<td>m</td>
<td></td>
<td>0,190</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equilibrium angle with steady heel arm</td>
<td>deg</td>
<td></td>
<td>3,4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equilibrium angle with gust heel arm</td>
<td>deg</td>
<td></td>
<td>5,1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deck edge immersion angle</td>
<td>deg</td>
<td></td>
<td>40,6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area1 (under GZ), from 5,1 to 50,0 deg.</td>
<td>m.deg</td>
<td></td>
<td>41,2787</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area1 (under HA), from 5,1 to 50,0 deg.</td>
<td>m.deg</td>
<td></td>
<td>12,8295</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area1(b), from 5,1 to 50,0 deg.</td>
<td>m.deg</td>
<td></td>
<td>28,4492</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area2 (under GZ), from -21,6 to 5,1 deg.</td>
<td>m.deg</td>
<td></td>
<td>-11,4681</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area2 (under HA), from -21,6 to 5,1 deg.</td>
<td>m.deg</td>
<td></td>
<td>7,5293</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area2(a), from -21,6 to 5,1 deg.</td>
<td>m.deg</td>
<td></td>
<td>19,0975</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
From the verification of Weather Criteria of the Barge, the Ab/Aa ratio in Case A) Full Load Condition is exceeded by 125% of the allowed value, while in Case B) Ship with 10%, is exceeded by 49%. It results that the barge under light loadings or empty conditions has a significant loss of stability under wind actions and in this case it is needed to take balancing measures such as with liquid ballast or other ways.

IV. CONCLUSIONS

The study was carried out with the objective of completing the necessary technical documentation required by the Albanian Maritime Register for carrying out the activity of the barge "ALEXANDAR".

Here we are effectively dealt with the verification of stability under the influence of wind conditions for two loading conditions: full loaded condition and ship with 10% of cargo.

The FORMSYS computer package assisted with considerable reliability in achieving a better hull surface of the vessel.

The fulfillment of the stability criteria has been verified according to the criteria in the IMO stability code and the normative by the RINA classification societies, Bureau Veritas, Resolution MSC.267 (85).

REFERENCES


Implementing Educational Software MDSolids In the Calculations of Marine Shafting Alignment

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ABSTRACT
Marine shafting alignment calculations and their verification are nowadays essential in the design phase of a modern ship propulsion system. In general, these calculations require a specialised software. A question arises whether it is possible to perform these complex calculations by means of a very simple software, such as the educational software application MDSolids. The aim of the paper is to promote the idea that the knowledge about the actual behaviour of the mechanical system may in certain cases better suit the purpose, than a powerful numerical software. The latter does not encourage the user to understand the system behaviour, just to obtain the results. The task is to show modelling procedure by means of a simple educational program (MDSolids), the necessary pre- and postprocessing, as well as the special way to overcome the MDSolids restriction in the number of elements, replacing stepped shaft segments by an equivalent one, while keeping mechanical stiffness and loading at the same level. The final MDSolids results are compared with the specialised software results for the shafting of a bulk carrier, showing a very good agreement. It is concluded that a software program (even an educational one) may, under certain circumstances, qualify for static shafting alignment calculations. The only condition is that it allows predefined athwart movements of the radial journal bearings in the shafting model.

KEYWORDS: mechanics of materials, elastic system, static shaft line analysis, radial journal bearings & education

I. INTRODUCTION
Shafting alignment is the procedure performed in marine propulsion shafting systems of adjusting bearing reaction forces, as well as other relevant values of static response of this elastic system (such as journal slopes within the bearings, as well as bending moments and shear forces in certain sections) to meet prescribed criteria. This procedure is practically performed by shiďing (misaligning) selected bearings in athwart vertical and, in certain cases also, horizontal direction, by a predefined amount calculated during the shafting alignment design phase. This allows changing of values and/or directions of bearing reactions [1]. Misaligning of bearings can change their reaction forces, due to the fact that the elastic beam systems used to model the actual propulsion shafting are statically indeterminate systems. So, shafting alignment is practically based upon bearings misalignment (alignment means misalignment!) and this actually works, producing the proper bearings reaction forces.

Shafting alignment comprises the following phases: design of the elastic system elastic line, its verification and, finally, validation on board [1]. Any convenient modern numerical procedure (e.g. finite elements methods or similar) can be used to model the system in its design and verification phase, but it is not the practice: system modelling by means of common beams exposed to bending, shear and torsion, based upon classical Timoshenko beam theory [2] and solving them by three-moments-equation, transfer matrix methods [3] or even finite elements methods (implementing beam/girder elements [4]) are commonly used in practice. Analytical solution within the beams give in this case more informative and even better results than numerical sledge-hammer-modelling of the entire system by means of e.g. finite tetrahedral elements, being also more convenient to use.

Selection of proper software for a shafting alignment calculation within its verification phase is of utmost importance for the system designer, classification society technical specialist, or any person dealing with this in practice, or in training (even marine engineering students). These people need the software capable of solving statically indeterminate beam systems allowing the bearings to be moved in (e.g.) vertical direction upwards or downwards by a predefined amount and to calculate bearing reaction forces, shear forces, bending moments, slopes, deflections, normal stresses due to bending and/or
equivalent stresses due to thrust force, bending and torsion acting together. Any software packages allowing the bearings to be shifted athwart may qualify for this task. Nowadays, they are even available on mobile phones/tablets and their operating systems (iOS and Android), such as BeamDesign [6] and FrameDesign [7]. The latter is also available as the free online service [8]. There are also powerful commercially available software packages, dedicated for this purpose, such as SKF ShaftDesigner [9], DNV GL Nauticus Machinery (its Shaft Alignment Module) [10], ABS Shaft Alignment Software and others. Smaller IACS classification societies (such as Croatian Register of Shipping, CRS and Polish Register of Shipping, PRS) use their own in-house developed software. CRS implements Excel/VBA programs SoaMarShAl and SoaShaORJB for the purpose of propulsion shafting alignment class approval. Software packages of “broader spectra” such as RSTAB - Structural Frame & Truss Analysis Software (by Dlubal) qualify for this purpose as well, under the condition that they allow athwart movement of the bearings in the system.

This paper presents another approach: shafting alignment calculations for real shafting systems performed by marine engineering students who implement the well-known educational software MDSolids! This approach was developed by the second author within his final thesis to obtain his master’s degree in marine engineering [12]. It was essential to find a way to overcome the original MDSolids restriction to 20 beam elements only. The procedure to do this is shortly explained further on. The MDSolids calculation results have been tested for a real practical example of main propulsion shafting alignment calculation for a bulk carrier built at a local shipyard [13]. Comparison with the results with the original ones obtained by the shipyard designers, as well as the results of the CRS program SoaMarShAl shows a very good agreement in terms of the bearing reactions. This proves that a simple educational software package, such as MDSolids [14] may be found fit-for-purpose, even for complex calculations, while also enabling students to understand each step of the calculation itself.

II. ESSENTIALS OF SHAFTING ALIGNMENT

A. Shafting alignment design and verification

Shafting alignment design calculations require that the all the shaft section external and internal diameters, lengths of shaft parts, as well as axial positions of the bearings have already been defined. Shaft section diameters are determined by means of simple formulae as in IACS Unified Requirement UR M68 (all the IACS Classification Societies Rules implement this approach with no reserve) [15], that are based upon the only data available in the shafting design phase: prime mover (e.g. Diesel engine) maximal continuous rating power (MCR) at the relevant shafting speed (in rpm) and the tensile strength for the material of the shaft in question (steel). Classification Rules usually provide limit values for distances between certain shafting bearings (maximal, to avoid excessive flexural vibrations and minimal, to avoid problems with propeller whirling vibrations). These have an essential influence to the finally selected length of each shaft and positions of the shafting bearings in longitudinal direction.

![Fig. 1. Typical shafting arrangement with the essential input data for shafting alignment calculations [13]](image-url)
The initial step is to calculate bearing reactions in case of all the bearings aligned with the shaft axis, i.e. zero bearings displacements. This step is starting from the shafting structural shape, dimensions, materials and static loading of the system (self-weight of particular shafts and buoyancy in water or oil) during the alignment procedure. The necessary final results are: static elastic line for zero bearing displacements, slopes in the bearings, bending moments and shear forces.

The next step is to select the values of bearings athwart vertical movements in order to satisfy certain criteria. The most important criteria are the values of bearing reactions and the journal slopes within the bearings themselves. Bearing reactions shall not exceed the values prescribed by Classification rules, based upon the nominal bearing pressure, i.e. reaction force divided by the bearing projected area. At the same time, bearing reactions shall also remain above their minimal limit value (e.g. 20% of the weight of the shaft part between the neighbouring bearing aft and fore of the actual bearing in question). On the other hand, slopes in the bearings shall not “spend” the entire bearing clearance. Practically, only 50% of this clearance to be consumed by the journal slope is allowable.

![Fig. 2. Typical presentation of shafting alignment final results (reaction forces in bearings and shaft deflections) [13]](image)

**B. Validation of shafting alignment on-board**

Designers are also expected to prescribe the technological procedure of assembling the entire shafting system on board. They have to determine:

- The order and the sequence of assembly of particular shafts;
- Positions of possibly necessary temporary supports;
- Positions and values of particular necessary temporary forces to be applied during the shafting system assembly process;
- Values of \( \text{sag} \) and \( \text{gap} \) between separated shaft flanges in each of the assembly phases.

The validation procedure by means of on-board measurements is also to be prescribed in advance. These measurements are performed for the ship afloat, once the shafting system has been assembled. The following shall be determined:

- Actual positions at which hydraulic jacks (to apply and measure forces) and dial gauges (to measure displacements) are to be placed;
- Procedure of adjusting the actually obtained bearing reaction forces to meet the required ones;
- Additional positions in which strain-gauges shall be implemented, if they are planned as additional means of validation, together with internal forces in these sections.

**III. METHODS: EDUCATIONAL PROGRAM MDSolids**

The educational program *MDSolids* has been selected as a convenient tool for the calculation of shafting alignment owing to the fact that it enables the user to model statically indeterminate beam systems taking into account prescribed bearing athwart (vertical) offsets [14].

*MDSolids* is the software for topics taught in the Mechanics of Materials courses (also commonly called Strength of Materials or Mechanics of Deformable Solids), as a typical part of mechanical and marine engineering programs. It also features a number of modules for topics taught in the Statics course [14]. *MDSolids* consists of routines for beams and flexural members, torsional assemblies, axial assemblies,
trusses, columns, pressure vessels, section properties, Mohr’s circle analysis (including stress transformations and strain transformations), and many more topics [14]. MSolids initial display window and beam analysis module window are presented in Fig. 3 and Fig. 4.

An important advantage of MSolids is its ease-of-use. Further on, prescribed deflections and slopes for selected nodes may be input in the model and this is of utmost importance for shafting alignment analysis. The biggest drawback of MSolids is the fact that it is constrained to 20 beam elements only [Fig. 4]
depicts the data sheet for a model of 7 elements in total). Typically, shafting alignment models contain 40-50 beam elements. However, this unfortunate MDSolids constraint of 20 elements can be overcome to a certain level by means of the approach presented hereafter.

A. Combining several shaft elements: equivalent stiffness and diameter

At this point, it is to be noted that MDSolids does not take effects of shear stresses on the beam deflections into account. This may cause certain errors, especially for shorter shafting spans, exposed to shear. Several beam elements may be combined into a single element on the basis of the equivalent flexural stiffness. Defining the stiffness as ratio of force and the corresponding displacement:

\[ k = F/f \]  

(1)

Corresponding stiffness in the case of simple cantilever shaft (as presented in Fig. 5) is defined by:

\[ k_\Omega = \frac{F}{f_F} = \frac{3EI}{l^3} = \frac{3E \pi d_{ekv}^4}{64} = \frac{3\pi E d_{ekv}^4}{64 l^3} \]  

(2)

![Fig. 5. Cantilever beam with constant section and its stiffness](image)

On the other hand, a stepped cantilever shaft may be easily considered by replacing the model by a simple supported shaft, as presented in Fig. 6. Deflection in the support A may be expressed as follows:

\[ f_A = \frac{F_A}{3E} \left( \frac{l_{A1}^3}{I_{A1}} + \frac{l_{A2}^3}{I_{A2}} - \frac{l_{A1}^3}{I_{A1}} + \frac{l_{A3}^3}{I_{A3}} - \frac{l_{A2}^3}{I_{A2}} + \cdots \right) \]  

(3)

![Fig. 6. Simple supported stepped beam presented by means of the two stepped cantilever beams](image)

The stiffness of the left part of the simple supported beam (Fig. 6) amounts to:

\[ k_A = \frac{F_A}{f_F} = \frac{3E}{l_{A1}^3 + l_{A2}^3 - l_{A1}^3 + l_{A3}^3 - l_{A2}^3 + \cdots} \]  

(4)

The basic idea is to replace the stepped shaft (Fig. 6) by the shaft of equivalent diameter \( d_{ekv} \) (Fig. 5) on the basis of identical stiffness of both shafts \( k_c = k_A \) of identical length \( \ell = \ell_{A1} \). By comparing equations
(2) and (5) for identical material (Young’s modulus of elasticity, $E$) and taking into account the shaft circular section moment of inertia ($I = \pi d^4/64$) the expression for the equivalent diameter $d_{eqv}$ may be expressed as follows [12]:

$$d_{eqv} = 4 \frac{\frac{I_3}{d_3^4} + \frac{I_2}{d_2^4} + \frac{I_1}{d_1^4}}{\sqrt{\frac{I_3}{d_3^4} + \frac{I_2}{d_2^4} + \frac{I_1}{d_1^4} + \ldots}}$$

(6)

B. Combining several shaft elements: equivalent loading

Once the equivalent stiffness concept on the basis of the equivalent shaft diameter in accordance with (6) has been introduced, the next step is to combine the distributed uniform loading of several elements of the stepped shaft into distributed trapezoidal loading of the equivalent shaft. This concept of equivalent loading is based upon the static equivalence of loading for the stepped shaft and the equivalent one (Fig. 7).

![Fig. 7. Equivalent loading concept: stepped shaft with three elements](image)

The two equations based upon the identical sum of vertical forces ($\Sigma F$) and sum of moments around the system leftmost point ($\Sigma M_a$) for both shafts may be written as follows:

$$\frac{q_A + q_B}{2} L = q_A L_1 + q_A L_2 + q_A L q_3 := a \cdot L$$

(7)

$$\frac{q_A L^2}{2} + \frac{(q_B - q_A) \cdot L}{2} \cdot \frac{2L}{3} = q_1 \frac{L_1^2}{2} + q_2 L_2 \left( L_1 + L_2 \right) + q_3 L_3 \left( L_1 + L_2 + \frac{L_3}{2} \right) := b \cdot L^2$$

(8)

Solving the system (7) and (8) for the unknown trapezoidal loading values $q_A$ and $q_B$ they are obtained as follows, where the values $a$ and $b$ are defined by the right-hand sides of (7) and (8) respectively:

$$q_A = 4a - 6b$$

(9)

$$q_B = 6b - 2a$$

(10)

This means that the loading of the three stepped shaft elements may be replaced with equivalent shaft with the calculated trapezoidal loading values. MDSolids allows trapezoidal loading of the elements.
IV. RESULTS: REACTION FORCES, DEFLECTIONS, SLOPES AND INTERNAL FORCES

The actual shafting alignment calculation by means of MDSolids has been performed on an actual example of a bulk carrier vessel main propulsion shafting presented in Fig. 1. By the means of the equivalent diameter approach the number of shafting elements has been reduced from initial set of 48 elements to a total of 20 elements. The MDSolids model and the obtained reaction forces in the bearings for the actually specified offsets of the bearings are presented in Fig. 7.

Fig. 8. MDSolids model prepared upon the equivalent diameter concept with the calculated reaction forces

Diagrams for the deflections, slopes, bending moments and shear forces along the shafting system model itself are presented in Fig. 8. It has to be noted that these results are available by MDSolids in tabular form as well. However, bending stresses in general are not directly obtained as MDSolids results, but a proper postprocessor in Excel/VBA needs to be developed and implemented for this purpose.

Fig. 9. MDSolids results for deflections, slopes and internal forces of the beam model
V. DISCUSSION: REVIEW AND VERIFICATION OF MDSOLIDS RESULTS

*MDSolids* results have been compared with the ones obtained by the CRS calculation program *SaqMarShAl* (Table I). The actually calculated discrepancies of these results may be easily understood through the discrepancies maximal value of 8.7%. This is rather low and insignificant, because this value is obtained on the bearing with the lowest loading. It has be to noted that the *MDSolids* model does not take into account the influence of shear forces to the deflections (Note: in statically indeterminate systems models, calculated reaction forces are closely related with the deflections and vice versa). Consequently, calculation results (deflections and slopes) will deviate much more in the shafting parts exposed to significant shear, in this case: the crankshaft part of the system.

In addition to this the *MDSolids* calculated sum of all reactions deviates from the shipyard and CRS results only by 0.4%. This may really be considered very good, thus justifying the implementation of the presented equivalent diameter and equivalent loading approach.

<table>
<thead>
<tr>
<th>Bearing number</th>
<th>Bearing shift mm</th>
<th>Calculated reaction forces, kN</th>
<th>MDSolids</th>
<th>S04MarShAl</th>
<th>Relative difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>219.337</td>
<td>215.651</td>
<td>1.7</td>
<td></td>
</tr>
<tr>
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<td>47.157</td>
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</tr>
<tr>
<td>8</td>
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<td>668.832</td>
<td>665.964</td>
<td>0.4</td>
<td></td>
</tr>
</tbody>
</table>

VI. CONCLUSION

This paper deals with the calculation of marine propulsion shafting alignment within the design and verification phase, on the basis of pre-defined values of shaft diameters, shaft lengths and bearing axial positions (spans). The aim of this paper was to investigate whether it is possible to implement easy-to-understand educational software *MDSolids* to this rather complicated calculation for a real practical case of a local shipyard newly-built bulk carrier main propulsion shafting.

Shafting model is based upon beam elements, where their total number is limited to 20 in *MDSolids*. For this reason, in order to enable the program to be implemented to real cases of marine shafting systems, the concept of equivalent diameter and equivalent loading has been introduced and explained in detail in the paper. The equivalent diameter concept for a stepped shafting part can be obtained upon presumption of the equal stiffness of simple shaft of uniform section (i.e. constant diameter) and the stepped shaft with several varying diameters and lengths. The equivalent loading concept is based upon the calculated equivalent static distributed trapezoidal loading of this equivalent shaft, on the basis of distributed uniform loads acting on each element of the stepped shaft.

The *MDSolids* results for bearing reactions, elastic line deflections, slopes, bending moments and shear forces show a very good agreement with the ones provided by the shipyard, that were supposedly obtained by the shipyard’s commercial software, as well as the ones obtained by the Croatian Register of Shipping program *SaqMarShAl* (used by the CRS for the shafting alignment documentation approval). However, there are some differences, which are to be borne in mind, due to the simplicity of the *MDSolids* model. This justifies implementation of *MDSolids* in teaching and learning (generally speaking: education of students) even for the situations of rather complicated propulsion shafting alignment models. The ease of understanding of such concepts will certainly improve students’ knowledge and motivation to deal with this demanding topics later on, once they get acquainted with the presented concepts of equivalent stiffness and equivalent loading as presented in the paper.
REFERENCES


Measurement of Torsional Vibrations on Propeller Shafts Using Code Discs and Optical Forks

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ABSTRACT

This paper presents a method for measuring torsional vibrations on ship propeller shafts using code discs and optical forks. This method is particularly suitable for measuring torsional vibrations on shafts carrying rotating masses such as propeller on propeller shafts. With such shafts the gyroscopic effect is particularly emphasized due to the large mass of the propeller. At certain angular velocities on propeller shafts, the gusts increase significantly, and side vibrations can reach a resonant character (like with main engine where we must pass over the critical speed quickly). The angular velocity of the propeller shaft at which the described phenomena are formed, is called the critical angular velocity.

From the viewpoint of the safety and functionality of the propeller shafts, it is very important to determine critical speeds as well as other values relevant to the behaviour of the shafts, such as amplitudes and phasal movements in the critical angular velocity. This problem is particularly emphasized in the propeller shafts driven by high-speed marine engines.

By measurement of torsional oscillations on propeller shafts during the ship testing we can determine the ranges of critical angular velocities.

KEYWORDS: propeller shaft, torsional vibration, code discs, optical forks & critical angular velocity

I. INTRODUCTION

Mechanical vibrations of elastic system, such as propeller shafts, in which elastic deformations occur due to the torsional stress caused by the torque transmission, are the so-called torsional vibrations. The character of torque moment is in the function of the change of total forces on the piston mechanism (forces of gases on the piston and inertial forces on the piston mechanism). Torsional vibrations often occur on shafts that transmit variable torsional moments. In the cases where the excitation frequency is equalized to the frequency of free vibrations, resonance occurs.

Allowing an extensive operation of the system in resonant regimes or those close to the resonant ones can lead to mechanical damage on certain system elements and noise [3].

Since the marine propulsion engines operate in modes ranging from minimum to maximum number of crankshaft revolutions, propeller shafts share the same modus of speed change. It is therefore of great importance to determine the ranges of the propeller shaft revolutions in which resonance can occur, to avoid these phenomena when operating in the resonant range.

The measurement of torsional vibrations is carried out in the test run of the newly built ship or during the technical checking of the propulsion plant condition. This is mandatory in order to get certified by the classification society. The reasons for measuring torsional vibrations in real systems may vary, e.g. diagnostics and system monitoring, the development of new methods of design and manufacturing technology, defining parameters for the mathematical model of power transfer from sources of mechanical energy to consumers, and others. In order to measure torsional vibrations on the shafts, various parameters can be selected, such as torsional stress, position angle, angular velocity and angular acceleration of the shaft. Also, various sensors and electronic data processing units can be used for these kinds of measurements. The resulting parameters can be presented in different ways, such as real functions (time records), in the form of mathematical equations or graphical presentations, complex functions (spectra), and similar.
The measuring of torsional vibrations on real objects such as propeller shafts is often difficult and conditioned by various constraints such as sensor installations and data transmission to an electronic data processing unit. When code discs and optical forks are used as sensors for measuring torsional vibrations it should be noted that the torsional stresses are measured at the cross-section of the shaft where the discs are placed. In addition to torsional stress, this method can also be used for measuring the angular position as well as the frequency or the number of shaft revolutions. This is necessary to define torsional vibrations both from the aspect of their excitation and the range of the number of revolutions in which resonant torsional vibrations occur.

II. THE MATHEMATICAL MODEL OF THE MEASURING SYSTEM

Many natural processes can be described by mathematical equations or a system of mathematical equations. Equations or systems of mathematical equations that describe natural processes are called mathematical models. In this paper we are going to describe the mathematical model of the measuring system for torsional vibrations using code discs and optical forks.

The propeller shafts are loaded with a torsional moment caused by the power being transferred from the propulsion engine to the propeller by the shaft.

The torsional moment \( M_t \) on the propeller shaft can be determined by the torsional stress \( \tau_{\text{max}} \) and the polar torque \( W_\theta \) in the following way [4]:

\[
M_t = \tau_{\text{max}} \cdot W_\theta
\]  

(1)

where:
- \( M_t \) is the moment of torsion [Nm],
- \( \tau_{\text{max}} \) is the maximum torsional stress at the shaft cross-section [Nm],
- \( W_\theta \) is the polar section modulus [m²].

The torsional stress \( \tau \) changes at the cross-section so that \( \tau = 0 \) at the centre of the section, to the maximum value on the shaft edge as shown in Figure 1[5].

Fig. 1. Tangential stress distribution at the cross-section of the shaft

The polar section modulus \( W_\theta \) depends on the shape of the shaft’s cross-section; for the shaft of the circular cross-section it is determined by the equation:

\[
W_\theta = \frac{\pi D^3}{16}
\]  

(2)

and for the shafts having a ring-shaped cross section it is determined by:
where:
- $D$ is the outside shaft diameter [m],
- $d$ is the internal shaft diameter [m].

The elastic angular deformation of the shaft when loaded by a torsional moment is reflected by the angle of twist $\theta$ and the angle of shear $\gamma$ as shown in Figure 2, and the functional dependence between the torsional stress and the stated parameters is presented in the following way [5]:

$$\gamma = \frac{\tau_{\text{max}}}{G}$$

(4)

$$\theta = 2 \cdot \frac{l}{D} \cdot \gamma$$

(5)

where:
- $\theta$ is the angle of the shaft rotation [rad],
- $\gamma$ is the angle of shear [rad],
- $G$ is the shear modulus for the material the shaft is made of [N / m²],
- $l$ is the length of the shaft between the two discs [m].

If a shaft transmits the torsional moment, as in the case of transferring the torsional moment from the engine to the propeller, then the power the engine delivers to the propeller can be determined as follows:

$$P = \omega \cdot M_t$$

(5)

where:
- $\omega$ is the angular speed of the propeller shaft [rad / s].

The task of the measuring system is to determine the desired parameters based on the input data. The input data are the angle of shear for the part between the two discs and the number of shaft revolutions, as well as the shear modulus for the material the shaft is made of. With the software installed in the data processing unit, the desired parameters are presented on the display. Those are usually the
torsional stress, the number of shaft revolutions, the torsional moment and the power delivered to the propeller through the propeller shaft.

III. EQUIPMENT FOR MEASURING TORSIONAL VIBRATIONS

The choice of equipment for measuring torsional vibrations on the propeller shaft is conditioned by the type of measured parameter, the physical characteristics of the shaft and the availability or purchase of the equipment. One of the special requirements that must be fulfilled by the measuring equipment is that the measuring system does not cause changes to the propulsion system of the ship. In addition to the above, there is a set of other requirements such as frequency of measurements and resolution, measuring and storage of obtained values in real time, analogue/digital conversion of measurement signals, processing and display of measurement results, quality of shear angle sensors, simplicity in operating and control of the measuring system, and others.

The elements of the measuring system are shown in Figure 3. The basic components of the optical encoders are optical forks and code discs. The code discs are physically attached to the shaft at appropriate distance. At appropriate radiiuses on the circumference of the disc, there are slots made for the passage of a light beams. Optical forks are mounted on adequate brackets, so they do not have any physical contact with the discs and therefore not with the shaft either. The data processing unit can be positioned at any appropriate place on board the ship. The display showing the monitored values is usually placed at locations for the propulsion system monitoring and control like engine control room (ECR) [6].

![Fig. 3. Measuring system elements](image)

The measuring system can be delivered as a stand-alone installation or integrated within the ship’s monitoring and control system. As a stand-alone system, it comes with a local operating panel. The system ensures high accuracy and good long-term stability. There is also the possibility of transmitting the obtained data via the ship satellite to ashore. The system provides the ability of the ship propulsion management in order to achieve the optimum energy efficiency and reduce the emission of harmful products in the exhaust gases of marine engines.

To ensure that the system provides accurate measurement parameters, it is necessary to enter the following data into the processing unit:

- the maximum speed of the propeller shaft,
- diameter of the propeller shaft,
- inner diameter of the propeller shaft in case of the ring-shaped cross-section,
- maximum power the engine can deliver to the propeller,
- mechanical properties of the material the propeller shaft is made of.
The parameters that can be measured and displayed are:

- the number of revolutions of the propeller shaft,
- torque on the propeller shaft,
- the power the engine delivers to the propeller through the shaft.

The measuring system is completely digital. The principle of the system operation is based on the emission of light beams on the emitter section of the optical fork through the openings on the code disk. The light emitted through the openings of the discs placed at required distances on the shaft, is converted into digital electronic signals and sent to the data processing unit. The emitted light converted into digital electronic signals contains information on the speed of the propeller shaft and the relative position of one disc in relation to the other, i.e. the information on the angle of twist between the two cross-sections at which the discs are placed. Based on these two signals and other entered data, the software installed in the data processing unit determines the size of the tangential stress, i.e. the torque or power that is transmitted from the main engine through the propeller shaft to the propeller [2].

![Function block diagram of two-channel optical encoder](image)

Optical encoders can be used in all conditions of a strong magnetic field, high temperature, electrical noise and chemical corrosion, thus they are much more flexible and reliable than other classical sensors.

The most commonly used light sources are light-emitting diodes (LEDs) and laser diodes. In these, the photon emission is achieved by moving of the electron from a higher to lower energy level, or from the conduction to the valence band. In a laser, this is a stimulated emission, while in LEDs it is a spontaneous one. For this reason, the laser provides a stronger optical signal of a narrower frequency range and smaller time constant. For practical application in the sensor technology, LEDs are favoured due to their linearity, reliability and cost-efficiency. The light radiated by LEDs and lasers needs to be coherent, i.e. of a certain wavelength. LEDs often emit green, red and yellow light in the visible spectrum of 380 nm to 750 nm, and ultraviolet (UV) and infrared (IR) in the invisible part of the spectrum. The receiving section of the light converts the optical energy into electrical signals. For these purposes, photodiodes, phototransistors, photodetectors and photo-potentiometers can be used [1,3].

Two-code discs made of stainless steel are mounted on the propeller shaft. These discs are produced upon the specification for individual shafts. The distance between the code discs is defined by the external and internal shaft diameter, the maximum number of the shaft revolutions, the maximum power and the mechanical characteristics of the shaft.

The appearance of the optical fork and the method of installation in relation to the code disk are presented in Figures 5 and 6 [6].
IV. CONCLUSION

This paper aims at providing the answer to the question of whether it would be recommendable and necessary to use this kind of measuring system compared to the other existing ones. The advantages of the presented method are reflected in the following characteristics [6]:

- the possibility of continuous and high-precision measurements,
- reliable operation of the measuring system without special maintenance,
- construction which is robust, so it is good for marine environment,
- possibility of installing the equipment in the area under difficult working conditions,
- the equipment is suitable for shafts of any diameter or cross-section,
- a clear display with easy-to-read graphics and graphics visualisation,
- possibility of integrating the measuring system into the operating and monitoring system of the ship's power plant,
- possibility of measuring on shafts reaching the speeds of up to 30,000 min⁻¹,

Contrary to the above mentioned positive features, the system can be expensive if used only occasionally and exclusively for measuring torsional vibrations. Also, in case the system stays on the propeller shaft for an extensive period of time, and torsional vibrations are measured only occasionally, this could result in mechanical damage because the disks have not been mounted in a special protective box. Furthermore, working conditions are not favourable due to high vibration, high humidity, salty ambient, etc.
For all these reasons, in order to use this kind of system, it will be necessary to provide the engine crew with additional education/training, both for performing measurements and system maintenance.

REFERENCES


ABSTRACT
Multi-purpose cargo vessels are intended to carry very dissimilar cargoes (bulk, containers, steel, wood etc.). The paper analyses main parameters to be used in preliminary design of such vessels of range between 88 to 207 m in length. Diagrams and trend lines are presented in order to help designers to choose particulars to design optimum ship characteristics. These parameters include speed, length, breadth, height, draught, displacement, block coefficient, required engine power, gross tonnage and number of containers. Analysis is performed based on comprehensive database of multi-purpose cargo vessels built over the past 30 years. Preliminary design procedure, in general, is explained since this stage (the choice of main dimensions) is most important in determining ship performance.

KEYWORDS: multi–purpose cargo vessel, MPV, ship preliminary design & ship design

I. INTRODUCTION
Multi–purpose vessel (MPV) is generally defined as modern general cargo vessel (GCV) and is intended to carry different cargoes that include bulk, containers, wood, construction material, cables, pipes etc. (Fig 1). Generally, the main cargo is bulk and containers. Therefore, some MPVs have similar arrangement to bulk carriers and some to container vessels depending on which good is transported dominantly. MPV aimed primarily to carry bulk cargo can load the containers in the same hold but with additional strengthening of the double bottom structure in a way of container corners.

MPVs are typically medium sized vessels with gross tonnage between 500 and 25000. However, MPVs may have different types of loading equipment, as well as large open holds and tweendecks allowing them to accommodate various goods in the same journey, making them very adaptable while not requiring shore cargo-handling facilities (Fig 2). During the voyage, larger ones usually carry various cargoes where smaller ones are commonly used for just one type of goods. Because of numerous loading conditions MPV operate in a wide range of draughts and engine powers.

As far as propulsion specifics, MPVs have medium speed diesel engines with a gearbox and a controllable pitch propeller due to frequent change in loading and different regimes of navigation. Furthermore, most of these vessels have a generator (MEDA - main engine driven alternator) connected to the gearbox. During the standard navigation, MEDA is used as a source of electricity onboard, instead of already installed standard generators and has the same or similar power. However, when change of loading occurs during the course and the vessel needs power increase, MEDA is used as a booster engine by adding the power to the propeller shaft and therefore controllable pitch propeller. As a result, the propeller pitch would be changed to adopt additional power boost. Subsequently, a standard generator will become the source of power for MEDA.

The lack of systematic data on successful designs is a distinctive issue in an early stage of design and needs to be addressed as MPVs become more employed. The aim of the paper is to provide the preliminary design tools for estimation of main parameters of such vessels in order to obtain efficient and optimal vessel in view of ship owner’s requirements. Similar research could be found in literature [1 - 5]. Ship design spiral [1, 3] usually starts from deadweight prerequisite upon which optimum L/B, engine power, speed, energy efficiency etc. is to be calculated.
II. MPV MARKET

Although it struggled for the past several years, multipurpose sector is starting to recover with an increasing demand and more contracted newbuildings. Furthermore, it is believed that “project carriers” i.e. the vessels with cranes that can lift more than 100 t come into play. In fact, more than 70% of newbuildings in the past five years have been primarily with heavy lift capability, according to [6].

Total delivery GCS reached 65 million gross tons (GT) in 2017 as the global waterborne trade growth increased. Taking into account 23 millions GT sold for demolition, net growth of world fleet led to 42 million GT or an equivalent 3.3% annual rate. GCS newbuildings in 2017 were 1082. More than 50% were built in China making this country along with Japan the producer of over 70% of all GCS in the world [7]. According to the company data [8] Damen is one of the top MPV producers, building between 8 and 10 vessels of such type per year.

Currently, there are 640 medium size GCS (500-25000 GT) which are 0 - 4 year old (Table I), leading to the share of almost 15% of the total “medium fleet” ships, the third [9] behind offshore (22.5%) and oil/chemical tanker vessels (17.2%). Nevertheless, total number of GCS in service have almost 30% share in medium size fleet making them the largest type for that size, placing behind bulk carriers and oil tankers! In terms of medium fleet gross tonnage, GCS share of new vessels reduces to 11.3% (Table II), as other cargo vessel types (bulkbearers, oil tankers, container ships) are carrying larger deadweights for the same length. When it comes to total number of vessels in service within the whole fleet, GCS are second (18%), just behind tugs (20%), as shown in [9].

Considering deadweight share in world fleet, oil tanker dominated the market decades ago. Nowadays, bulkbearers are peaking with almost 43% of share in deadweight and 22% in monetary value, while GCS stands on 3.9% vs. 4.9%, see Fig. 3. GCS ratio in tonnage is obviously smaller taking into account that such medium sized fleet is not designed to carry large amount of cargo as in the case of some other cargo ships. However, the ratio of value to deadweight increases, despite trends in other segments of ship market, showcasing major advantage of GCS, as this ratio is far better than to “big three” (bulk carriers, oil tankers, container ships).
### TABLE I. Total number of GCS

<table>
<thead>
<tr>
<th></th>
<th>Small</th>
<th>Medium</th>
<th>Large</th>
<th>Very Large</th>
<th>Total per age</th>
</tr>
</thead>
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<tr>
<td>GT&lt;500</td>
<td>198</td>
<td>5.80%</td>
<td>640</td>
<td>14.80%</td>
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<tr>
<td>500&lt;GT&lt;10000</td>
<td>612</td>
<td>6.90%</td>
<td>3661</td>
<td>25.90%</td>
<td>84</td>
</tr>
<tr>
<td>10000&lt;GT&lt;25000</td>
<td>729</td>
<td>13.30%</td>
<td>2086</td>
<td>29.90%</td>
<td>63</td>
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<tr>
<td>+25 years</td>
<td>2758</td>
<td>17.50%</td>
<td>5304</td>
<td>38.70%</td>
<td>26</td>
</tr>
<tr>
<td>Total per size</td>
<td>4317</td>
<td>12.80%</td>
<td>11691</td>
<td>29.90%</td>
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</tr>
</tbody>
</table>

*Source: [8]*

### TABLE II. GT of GCS

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<th>Total per age</th>
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<td>GT&lt;500</td>
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<td>833</td>
<td>20.90%</td>
<td>14006</td>
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<td>Total per size</td>
<td>1456</td>
<td>16.30%</td>
<td>49182</td>
<td>21.60%</td>
<td>7790</td>
</tr>
</tbody>
</table>

*Source: [8]*

III. Database

A database of 112 multi-purpose vessels (see APPENDIX) has been created using Significant Ships [10] from 1990 until 2016 and is updated by some modern and innovative MPV vessels built in past few years. The table is presented in Appendix. Significant Ships [10] is generally regarded to contain a base of “good” and “proven” ships with trustworthy data and therefore are taken as reliable for the analysis. Apart from standard particulars, the database also includes data on speed, engine data, number of TEU container carried, number of cranes, number of cargo holds and its capacity, propeller diameter, ballast volume, tank capacities, number of poop decks, crew, boosted power by MEDA etc.

Vessels are in the range of 88m to 207.3m regarding overall length with block coefficient in between 0.62 and 0.88. Most of them have 2 to 5 cargo holds and 1 to 5 cranes. However, 35% of the vessels (39 out of 112) have no cargo handling equipment. Speeds range from 10.5kn to 22.4kn, with Froude number in between 0.15 and 0.30. Just four vessels are not intended to carry containers whereas rest of them load from 47 TEU (L<sub>oa</sub>=89.8m) to 2785 TEU (largest one – L<sub>oa</sub>=207.3m). Most of the vessels have 2
Vessel’s dimensions are typically determined upon required deadweight (or cargo capacity, TEU). Higher block coefficient is to be chosen when the same length has to provide more cargo space despite resistance increase and vice versa, which is still between 0.65 and 0.85 for most standard GCS (MPV). Breadth of the vessel is highly influenced by number of containers carried abreast on deck and in the cargo hold. The same goes for height of the vessel intended to transport containers. In addition, propulsive power can be roughly estimated using a database in order to avoid complex resistance calculations which can significantly increase early design time.

Based on the database described in Chapter III, the diagrams are formed and trend lines obtained, as shown on Fig. 4-12 and Table III. For required deadweight one can easily estimate speed, length, displacement, block coefficient, breadth, height, draught, gross tonnage and number of TEU containers.

The preliminary design procedure starts by finding a speed (Fig. 4) and length between perpendiculars (Fig. 5) of the MPV for the desired deadweight. Note that mean ratio between LPP and LOA is 0.94, acquired according to database, so both lengths are known so far. Displacement of the vessel can be obtained according to deadweight following linear dependence, as in Fig. 6. Since the speed is known, Froude number can be calculated as $F_n = \frac{v}{\sqrt{gL_{W}}}$ . In this relation speed is to be taken in m/s instead of knots, and LWL instead of LWP since the second length is unknown and the approximation is correct for the analysis. Acquired Froude number leads to block coefficient (Fig. 7). Furthermore, breadth of the vessel is selected by Fig. 8 via linear correlation. Now, draught can be calculated inversely, from block coefficient, according to relation: $T = \frac{\Delta}{\rho c g B L}$. Also, height can be chosen based on the draught of the MPV (Fig. 9). At this stage, main dimensions of the vessel are selected. Propulsive power can be estimated on the basis of Froude number and propulsive coefficient $C_D$ (Fig. 10), expressed as $C_D = \frac{1000P_B}{g\Delta\nu}$ , where $P_B$ is main engine power in kW, $g$ acceleration of gravity in m/s^2, $\Delta$ displacement in tons and $\nu$ ship speed in m/s. In addition, gross tonnage (Fig. 11) and number of TEU containers (Fig. 12) are acquired using prescribed DWT as well. Note that the same procedure can be employed even if the speed is one of the requirements, not just deadweight.

Final equations for each parameter are presented in Table III. A described procedure, using Table III, is performed to display preliminary design estimation in case of MPV that is intended to carry 20000t of deadweight (Table IV). In order to load 20000t, MPV should probably have to navigate around 17.9kn. One has to bear in mind somewhat lower reliability of the trend line employed, hence this value is a bit flexible. Length between perpendiculars would be 154.9m and length overall – 164.8m, according to their abovementioned ratio. Displacement of the vessel is expected to be 27280t. Displacement and length are supposed to be reliably predicted (high R^2). Block coefficient is roughly 0.74, whereas B, T and H are respectively 25.4m, 9.14m and 12.9m. Required engine power is calculated as $P_B = C_D g \Delta \nu / 1000$ is 12359kW and has to be used just as a very rough estimation considering that data dissipation has been quite large in this case. Vessel gross tonnage obtained is to be 15560 and while number of TEU carried - 1338. GT and TEU functions present a reliable predictability.

It has to be noted that some trend lines (speed, block coefficient and required propulsive power) have lower predictability as coefficient of determination (R^2) in such cases reaches just a bit more than 0.5, due to abovementioned diversity of vessels data caused by exploitation conditions. It causes larger data dissipation from the fitted line, so the certain bandwidth of the predicted values has to be taken into account when using such equations. On the other hand, length between perpendiculars, displacement, breadth, heights, gross tonnage and required TEU has very good matching with the trend line as R^2 reaches 0.8-0.99, making it’s estimation more reliable than in the case of the first group.
On Preliminary Design of Multi-Purpose Cargo Vessels

Fig. 4. DWT - v

Fig. 5. DWT - Lpp

Fig. 6. DWT - Δ

Fig. 7. Fc - C0

Fig. 8. Lpp - B

Fig. 9. T - H

Fig. 10. Fc - C0

Fig. 11. DWT - GT

Fig. 12. DWT - TEU
TABLE III. EQUATIONS FOR CALCULATIONS OF MAIN PARTICULARS

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<tr>
<th>Equation</th>
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<td>( v = 2.749DWT^{0.32} )</td>
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<td>( c_b = -5.751T^2 + 0.684T + 0.9 )</td>
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<td>( c_b = 0.12 e^{0.5\cdot\text{MAX}} )</td>
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<td>( GT = 0.778DWT )</td>
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<tr>
<td>( \text{TEU} = 7.441\times10^{-1}DWT^2 + 8.741\times10^{-2}DWT - 1.141E+02 )</td>
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TABLE IV. MAIN PARTICULARS FOR DWT = 20000T

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V. CONCLUSION

Multi-purpose vessels are specific type of vessels where diverse cargo transport constraint beats tonnage advantage. Due to dissimilar requirements needed for carrying bulk, containers, building material etc., MPV has to be particularly considered within the design process. This paper tries to fill in the void of lack of systematically studied data to help the issue.

A database of “reliable” multi-purpose vessels built over the past three decades is created in order to pursue guidelines for preliminary design of such vessels. The paper presents a methodology for early stage design where estimation of main particulars is of utmost importance to produce an optimal vessel for required cargo capacity. Polynomial application boundaries are primarily based on deadweight range \((2670 \text{ t} – 44569 \text{ t})\). Following presented diagrams and equations with their predictive capacity, one can estimate optimum speed, length, breadth, height, draught, block coefficient, displacement, propulsive power, gross tonnage and required TEU containers aboard.

ACKNOWLEDGMENT

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NOMENCLATURE

- GCS: General cargo ship
- GT: Gross tonnage
- MEDA: Main engine driven alternator
- MPV: Multi-purpose vessel
- TEU: Twenty-foot equivalent unit
- DWT [t]: Deadweight
- \( B \) [m]: Breadth
- \( c_b \): Block coefficient
- \( C_D \): Propulsive coefficient
- \( F_n [/]\): Froude number
- \( H \) [m]: Height
- \( L_{oa} [m]\): Length overall
- \( L_{PP} [m]\): Length between perpendicular
- \( L_{wl} [m]\): Length at waterline
- \( P_s [kW]\): Engine power
- \( \rho [t/m^3]\): Density
- \( \Delta [t]\): Displacement
REFERENCES


APPENDIX

TABLE V. MPV DATABASE

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<td>1281</td>
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<td>112</td>
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<td>2007</td>
<td>207.3</td>
<td>32.2</td>
<td>12.2</td>
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<td>49000</td>
<td>37212</td>
<td>2785</td>
<td>26270</td>
<td>33000</td>
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</tbody>
</table>
Optimal Strategy for Maintenance of Reliquefaction System on LNG Carrier

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ABSTRACT

The reliquefaction system installed onboard the LNG carriers is very significant, which due to its unavailability can cause substantial costs to the shipowner. In this paper, the cost estimation has been made to make optimal decisions about maintenance strategies. Reliability model and cost estimation are made by the Markov model, and implemented on real LNG ship scenario, based on the boil-off gas reliquefaction system. A large LNG Carrier with the direct drive slow-speed diesel engine propulsion is analyzed from the maintenance standpoint, and optimal costs are calculated, depending on chosen maintenance strategies. While choosing many states and components for inputs in the Markov model, it is shown that results don’t necessary tends to be more accurate with a complex model, compared with the simplified one.

KEYWORDS: Markov model, reliability, costs, maintenance, LNG & boil-off gas

I. INTRODUCTION

Safety and reliability are significant features for any technical system. Although both of these measures are calculated by equipment or process failure analysis, they are two different processes [1]. System reliability analysis includes studying system measurable characteristics expressed over probabilities that the system will follow its designed functions under work conditions for the determined time interval. It consists of a previous design of the logic model and system reliability analysis, and afterward over risk assessment expands to studying possible consequences caused by failures, like property damage, eventual causalities, and environmental contamination, as part of safety analysis study.

As technology develops over time, the complexity of various systems also rises. Modern technical systems usually consist of a large number of subsystems and components, related to each other to perform multiple designed tasks and functions. These systems must meet reliability and safety levels; therefore, design, manufacture, and maintenance of systems become increasingly demanding engineering task. This problem can be seen in the form of finding an optimal solution for conducting safety measures of reduced risk and accompanying costs because decisions made based on this analysis must not compromise system safety.

In this paper as the basis of the analysis is selected a typical example of liquid natural gas (LNG) reliquefaction system (RS) built-in onboard the large LNG carrier with a slow-speed diesel engine for propulsion which burns conventional fuels and is not capable of using boil-off gas as fuel. The simplified reliability model based on a time-dependent Markov approach with absorbing state is used to assess LNG RS reliability, and afterward, cost estimation is made to find optimal maintenance strategy.

The paper is structured through five sections. After the introduction, the onboard LNG RS is described in Section II from a structural and functional standpoint. In Section III is described LNG RS Markov reliability model and numerical results from the reliability analysis are presented. An LNG reliquefaction system cost analysis is presented in Section IV. The explanation is shown for differences of cases when there is no onboard maintenance and when periodic preventive inspections are planned at the end of each trip. The results obtained are compared with an example in the literature to determine the optimal maintenance strategy. Finally, some concluding remarks are given in Section V.
II. DESCRIPTION OF THE RELIQUEFICATION PLANT ONBOARD

The continuous growth of LNG marine transportation in the last decade caused a rapid increase in the capacity of LNG carriers. Unit transportation cost of these ships is affected by two significant factors: the daily boil-off rate (BOR) of the containment system and the fuel efficiency and flexibility of the propulsion system.

During the transportation of LNG by ships a most of Boil-off Gas (BOG) is generated from heat leaking into the cargo tanks from the outer environment through the cargo tank insulation. The quantity of this natural evaporated cargo is usually presented as BOR, i.e., as loss expressed as a percentage of total volume of liquid cargo per day. Typical BOR for newer LNG carrier averages 0.12 % per day [2]. The BOG produced is continuously removed to maintain the cargo tank pressure. During a ship’s voyage removed gas can be utilized as fuel, reliquefied, burned in Gas Combustion Unit (GCU) or vented to atmosphere.

In recent years, due to the increasing cost of LNG, the LNG industry has called for more efficient propulsion systems to traditional safe, but low efficient steam-turbine propulsion plant with dual-fuel boilers. A significant number of large LNG carriers built in and delivered in the last decade of this century use more efficient slow-speed diesel engines for propulsion which burn conventional fuels and are not capable of using boil-off gas as fuel. These ships are fitted with full reliquefaction systems (RS) for managing boil-off gas. In this paper, as the basis of the analysis is selected LNG RS used in [3] with capacity that is suitable for installation on large LNG carrier with the cargo capacity of 200,000 fitted with direct drive slow-speed diesel engine propulsion system. The diesel engine can burn only heavy fuel oil or marine gas oil. An LNG RS is illustrated by a simplified functional diagram shown in Fig. 1.

![Diagram of Liquid Natural Gas Reliquefaction System](image.png)

Fig. 1. Liquid natural gas reliquefaction system function diagram.

It consists of two main parts: a BOG circuit and nitrogen (N$_2$) circuit. The BOG circuit is an independent loop which comprises BOG preparation, BOG compression, and BOG liquefaction. It consists of a pre-heater, plate-fin cryogenic heat exchanger, separator, two BOG compressors (duty & standby) and two LNG return pumps (duty & standby). The plate-fin cryogenic heat exchanger and the separator are assembled into one enclosed unit called the cold box system. Boil-off gas is removed from the LNG tanks using a three-stage centrifugal low duty BOG compressor. To provide the stable temperature at the inlet to the BOG compressor, a pre-heater is installed upstream of the BOG compressor. The BOG is compressed and cooled by fresh water after each stage of compression, so the temperature is around 41 °C when the BOG enters the cryogenic plate-fin heat exchanger. The condensate leaves the heat exchanger at a temperature of about -160°C. Incondensable gases (if any) are separated in the separator and routed to the GCU or returned to the cargo tank. After separation, the liquefied gas is returned to the cargo tank due to the pressure differential between the separator pressure and tank pressure or via LNG return pump.
The purpose of the N2 circuit is to provide the required refrigeration capacity to liquefy BOG. The main components of the nitrogen loop are two N2 companders (duty & standby), expander, N2 water coolers, cold box, and N2 supply system (nitrogen reservoir, two drier, two N2 booster compressor and two oil separator systems). Nitrogen gas at a pressure of around 1000 kPa is compressed to 4200 kPa in N2 compander which is a three-stage integrally geared centrifugal compressor with one expander stage. The expander gives direct work to the gearbox, which reduces the work required by the primary driver of the N2 compander. The nitrogen is cooled by fresh water after each stage of compression. After the final compression and after cooling, the nitrogen is split into two streams. One is led to the “warm” section at the top of the cryogenic heat exchanger in which the nitrogen is cooled in two steps, first to -50°C and then to -110°C. The second is routed to the pre-heater to heat the BOG and is then returned to the plate fin heat exchanger at a temperature of -50°C.

The redundancy of some components is requested by the International Code of the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code). A detailed description of the reliquefaction process can be found in [4, 5].

### III. MARKOV MODEL OF LNG RELIQUEFACTION SYSTEM

On the receiving terminal LNG is sold depending on its energy content. A failure of the LNG RS leads to not properly controlled pressure in cargo tanks. This may result in both, loss of LNG and venting of gas to the atmosphere or flaring the gas in GCU. The decision on the choice of an appropriate method depends on many; primary safety, economic and legal factors. LNG RS failures lead to the cost of LNG losses and the costs of corrective maintenance. Also, it may pose a severe risk both to the LNG carrier and to the environment [3].

Standard classification rules are mainly prescriptive nature and constitute the reactive framework around which the maritime domain operates. The rules did not arise from an analysis of ship systems, an analysis which was performed to identify problems and solutions before they occur. To move from a reactive to a proactive approach of safety, the International Maritime Organization (IMO) in 2002 introduced a frame-work of the Formal Safety Assessment (FSA) as a method for accessing the risk related to maritime safety and the protection of the marine environment.

The proactive approach in the FSA is reached through the probabilistic modeling of failures and development of accident scenarios [6]. This can be achieved by the use of suitable methods for evaluating the probabilities of failure. It is essential to get a model that meets the FSA and the data obtained used in deciding the maintenance strategy. At the same time, it should not compromise the safety of the technical system.

Since the LNG RS is a system consisting of a large number of components, each one dependent on one, Markovian method is particularly suitable for modeling multi-components system failures. With Markov reliability model the multi-component system can be described at any time by specifying its possible states, the transition between states and transition rates. An excellent introduction to Markov chains theory and their application in reliability engineering can be found in [7, 8].

As in the reliability model [3], the simplified Markov reliability model in the paper includes only redundant key components of LNG RS. These components are two BOG compressor system (duty & standby) and two N2 compander system (duty & standby). This provides a comparison of the obtained results for both models.

On Fig. 2 simplified LNG RS Markov reliability model state diagram is shown. The model consists of a four (4) possible states, a transition between states and transition time rates.
The LNG RS Markov model reliability model states are listed and named in Table II.

<table>
<thead>
<tr>
<th>State</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>All components of LNG RS are in function</td>
</tr>
<tr>
<td>DBOG</td>
<td>Failed duty BOG compressor system</td>
</tr>
<tr>
<td>DN2</td>
<td>Failed duty N2 compander system</td>
</tr>
<tr>
<td>A</td>
<td>No supply fuel gas and liquefaction (absorbing state)</td>
</tr>
</tbody>
</table>

From Fig. 2. is apparent that only the corrective maintenance strategy applies to the model. In state 0 all components are in function, and the system is operating as designed. As shown in Fig. 2., from that state system can jump into three states: DBOG, DN2, and A. The state DBOG refers to a failure of duty BOG compressor system with transition (failure) rate $\lambda_{BOG}$. Upon a failure, the standby BOG compressor system is started immediately. The same applies to state DN2 which refers to a failure N2 duty compander system with transition (failure) rate is $\lambda_{N2}$. In both states LNG RS is still at work, meaning that system is functioning.

From states DBOG or DN2 system can jump in state A. In that state LNG RS is in a failed state because both BOG compressor systems or both N2 compander system are failed. Finally, upon a failure of the cold box system and/or LNG return pump, etc., the Markov model can jump directly from state 0 to state A with transition (failure) rate $\lambda_{BOG} + \lambda_{CN}$. This means that BOG cannot be removed from the tanks in order to maintain the cargo tank pressure or liquefy. So, the BOG must be burned in GCU or vented to the atmosphere. Therefore, state A is absorbing state in which, over any state transition the system cannot jump into any other state, i.e., it stays in A until the system is repaired. In addition to corrective maintenance costs, this state leads to the lost BOG/LNG.

This state and reduced complexity make the basis of the difference between the model in the paper and model in [3]. It is important to mention that because of periodic inspections analyzed in the paper, repair rates $\mu_{BOG}$ and $\mu_{N2}$ are adopted if the failed component is found during periodic preventive inspections planned at the end of each trip.

A. Reliability model assumptions and Input reliability data

Reliability analysis is performed using the following assumptions:
- The LNG RS is a coherent system.
- All the components in the LNG RS reliability model are assumed to be statistically independent.
- Failure and repair rates are constant (time independent).
- Failure and repair rates are assumed to be exponentially distributed.
After repair, the component is good as new.
Switching operation of redundant components are 100% reliable and do not influence the reliability of the system.

The transition rates as reliability data are presented in Table III. This data is estimated according to [3].

<table>
<thead>
<tr>
<th>Transition rate (per hour)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\lambda_{\text{BOG}}=1.7 \times 10^{-4}$</td>
<td>Failure rate of BOG compressor system (compressor &amp; driver)</td>
</tr>
<tr>
<td>$\lambda_{\text{N2}}=2.85 \times 10^{-4}$</td>
<td>Failure rate of N2 compander system (compressor &amp; expander &amp; driver)</td>
</tr>
<tr>
<td>$\lambda_{\text{CB}}=5.5 \times 10^{-5}$</td>
<td>Failure rate of cold box system (plate-fin cryogenic heat exchanger &amp; separator)</td>
</tr>
<tr>
<td>$\lambda_{\text{P}}=7.5 \times 10^{-5}$</td>
<td>Failure rate of LNG return pump</td>
</tr>
<tr>
<td>$\mu_{\text{BOG}}=8 \times 10^{-3}$</td>
<td>Repair rate of BOG compressor system (compressor &amp; driver)</td>
</tr>
<tr>
<td>$\mu_{\text{N2}}=8 \times 10^{-3}$</td>
<td>Repair rate of N2 compander system (compressor &amp; expander &amp; driver)</td>
</tr>
</tbody>
</table>

B. Numerical result

The Markov analysis and the system reliability calculations have been performed by a custom-made program in Matlab® software. Solving LNG RS Markov reliability model using the set of differential equations as described in [7], probability distributions of states $P(t)$ and system reliability function $R(t)$ through determined time interval with onboard repairs are presented by plots in the diagram on Fig. 3.

As seen on Fig. 3, Markov reliability model is based on a time interval of 8.064 hours. It is an assumed time that ship is on the seagoing through one year. The system reliability function $R(t)$ is defined as the sum of states DBOG and DN2. The Markov process starts from state 0 at $t=0$, where all components are in functioning states as described before. In state diagram on Fig 2., that means that reliability at $t=0$ is $R(t=0)=1$. As time forwards, the reliability function $R(t)$ decreases and the probability of states failures increases. By simplifying the model compared to [3], the system will much faster arrive into fault, which means that more extensive and more complex model does not necessary tends to be a better model.

According to previously stated maintenance strategies, in the next section the LNG RS cost analysis will be performed, to find an optimal solution. A primary focus will be on costs caused by unavailability to perform reliquefaction. As stated before, it refers to the absorbing state A that indicates unreliability of the system. This state creates unexpected BOG/LNG costs which can be reduced by choosing an optimal maintenance strategy.
IV. Maintenance Cost Analysis

Maintenance costs, as a significant aspect of any technical system in exploitation, should be minimized to make the system economically efficient. At the same time, it is necessary to maintain an adequate level of its availability and safety. To find optimal maintenance costs, it is important to find a balance between replacement costs after failure or corrective maintenance, and some of the preventive strategies as age replacement, block replacement, periodic replacement with minimal repair and similar [7,8].

Two strategies have been considered. These are, as previously stated, no onboard maintenance of the BOG compressor system and the N2 compander system as shown in Fig. 2, and scenario when periodic preventive inspections are planned at the end of each trip. The first means that no repair actions are carried out on the ship and all maintenance actions have to be carried out to repair the failures at the loading or receiving terminal. If the failure implies that the reliquefaction system is not functioning, the BOG will be flared or vented to the atmosphere. The latest maintenance strategy means that a preventive inspection is carried out at the loading terminal to detect and repair failures before a new trip.

In the maintenance cost model of LNG RS in this paper, a finite period of 8.064 hours is observed. It is an assumed time that ship is on the seagoing through one year [3]. As BOG loss causes reduced delivered energy content, the quantity of BOG loss is significant part while determining techno-economic parameters. The amount of evaporated cargo can be expressed over the total amount of LNG loss through one day, or Boil-Off Rate (BOR). Adopted data is mainly based on inputs in [3].

<table>
<thead>
<tr>
<th>TABLE III. Basic Input Data for LNG RS Maintenance Costs Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voyage per year-336 days</td>
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<tr>
<td>Cargo tank volume:</td>
</tr>
<tr>
<td>Maximum loading cargo tanks in %</td>
</tr>
<tr>
<td>Average BOG mass per hour at BOR 12%-mABOG</td>
</tr>
<tr>
<td>Average value of BOG [3]</td>
</tr>
</tbody>
</table>

One of the methods for determining total expected costs is finding all states in the Markov model that causes costs and, based on sojourn time that system stays in these states, assign appropriate costs per time unit. According to the model from Fig. 2, the state which causes BOG cost is state A due unavailability to perform reliquefaction. For this case according to [9], total expected BOG costs for the time interval of a round trip or 672 hours [3] are modeled and calculated according to:

\[ C_{BOG}(A, t_0) = \int_0^T c_0(A(t_0)) \, dt \]  

where:

- \( C_{BOG}(A, t_0) \) – expected total BOG cost for system age time \( t_0 \) for state A, USD per unit time;
- \( c_0(A(t_0)) \) – cost related to state \( A(t_0) \), USD per unit time.

Over round trip, sojourn time for state A has been calculated based on an algorithm from [9] according to the Markov model shown on Fig. 2. For the given cost \( c_0 \) regarding the state A, the total expected cost \( C_{BOG} \) is calculated for the case of no onboard repair, and a case of periodic inspections as mentioned before. Results are shown in Table V. As stated in [3] round trip of 28 days or 672 hours is defined, and flare costs are given as 117,000,00 USD per round trip, in case of no onboard repair. When compared with the simplified model as shown of Fig.2 and using cost analysis according to [9], expected sojourn time for state A is calculated in the amount of 345 hours. That means according to the cost model that BOG loss will generate costs for 345 hours with average BOG value of 811,40 USD/h from Table IV. Multiplying BOG value per hour with the expected number of hours spent in a state that causes costs, total expected flare costs can be calculated for the round trip as presented in Table V.
According to Table V that would generate flare costs of 279.795 USD/trip. If that is expanded for one year, total expected costs are 3.357.540 USD/year. Markov model from [3] have onboard repairs and spare parts available, so there is no absorbing state like in simplified model from Fig.2., but there are annual maintenance costs in the amount of 145.000,00 USD/year, along with the costs of spare parts for failed components. A simplified model is maintained in a corrective way, which means that all repairs are conducted in a harbor. The latest maintenance strategy means that a periodic preventive inspection is carried out at the loading terminal to detect and repair failures before a new trip. That would mean for the model from Fig.2 that system will have repair rates $\mu_{BOG}$ and $\mu_{N2}$ from states DBOG and DN2 to state 0 accordingly. For that case, expected sojourn time for state A is calculated in the amount of 115 hours. That means according to the cost model that BOG loss will generate costs for 115 hours with average BOG value of 811,40 USD/h from Table IV. Multiplying BOG value per hour with the expected number of hours spent in a state that causes costs, total expected flare costs are 93.311 USD/trip. If that is expanded for one year, total expected costs are 1.119.732 USD/year. The difference between costs for the simplified model without periodic inspections and the one with them is that the latter has an additional annual investment of 145.000 USD/year for eventual repairs. With the simplified model in mind, it can be concluded that the costs are relatively similar, but model complexity is fairly reduced. By comparing results of the simplified model and [3], it can be concluded that optimal maintenance strategy would be to have onboard repair as option 2 from [3], with periodic preventive inspections at the end of one trip at the loading terminal.

### TABLE IV. COSTS COMPARISON

<table>
<thead>
<tr>
<th>Description</th>
<th>Model [5]</th>
<th>Simplified model with no onboard maintenance</th>
<th>Simplified model with periodic preventive inspections</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expected BOG flare</td>
<td>15%</td>
<td>30%</td>
<td>9%</td>
</tr>
<tr>
<td>Sojourn time for state A</td>
<td>N/A</td>
<td>345 h</td>
<td>115 h</td>
</tr>
<tr>
<td>Average BOG value per hour – $C_0$</td>
<td>811,40 USD/h</td>
<td>811,40 USD/h</td>
<td>811,40 USD/h</td>
</tr>
<tr>
<td>Costs of BOG loss over round trip (%)</td>
<td>117,000,00 USD/trip</td>
<td>279,795,00 USD/trip</td>
<td>93,311,00 USD/trip</td>
</tr>
<tr>
<td>Annual investment – preventive maintenance costs</td>
<td>145,000,00 USD/year</td>
<td>0</td>
<td>145,000,00 USD/year</td>
</tr>
<tr>
<td>Costs of BOG loss over one year</td>
<td>1,500,000,00 USD/year</td>
<td>3,357,540,00 USD/year</td>
<td>1,119,732,00 USD/year</td>
</tr>
<tr>
<td>Total costs</td>
<td>1,645,000,00 USD/year</td>
<td>3,357,540,00 USD/year</td>
<td>1,358,043,00 USD/year</td>
</tr>
</tbody>
</table>

As a model from [3] has repair rates, LNG RS reliability is very high. That means that there should be a sufficient amount of spare parts onboard, which can be replaced very fast if needed, without stopping the reliquefaction process. That maintenance strategy is desirable, but it is necessary to distinguish if that strategy is cost-effective, and how many redundant components should be installed to satisfy the required level of system safety. By comparing costs in Table V. and system reliability function $R(t)$ from Fig.3. with a model in [3], the simplified model in this paper is on a safer side from an engineering standpoint because it is more probable that system will fail compared with a model in [3], and the costs are relatively similar.

As a follow-up to this paper, the Markov model will be expanded to other LNG RS components, which will be used to find optimum maintenance interval and total mean cost time per unit. Also, an alternate propulsion system with gas-fuelled engines will be analyzed, and a dynamic model of BOG evaporation will be calculated.

### V. CONCLUSION

In this paper onboard LNG reliquefaction system is analyzed because failures of this plant can lead to the BOG/LNG loss costs, the costs of corrective maintenance and also may pose a serious risk both to the LNG carrier and to the environment. Compared to literature, a simplified model of the LNG reliquefaction system is shown, and the reliability function is calculated. It is shown that even with this model, compared to the model from literature, the system is still on a safer side from the engineering aspect. Cost analysis has been made different from literature, and when compared with cost results, they were
relatively similar. By simplifying the Markov model, the system is reaching fault faster. As much as a complex system is, relatively simple Markov model can be constructed because its complexity does not guarantee a better model. When a model in the paper is compared with a model in literature, it can be seen that optimal maintenance strategy would be to have onboard maintenance, with periodic preventive inspections at the end of one trip at the loading terminal.

REFERENCES


Potential to Reduce Environmental Pollution from Ships Through the Modular Concept Approach

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ABSTRACT

In the current practice, ship design is generally approached with the aim of keeping building-cost at the minimum, often forcing low-cost designs and low value-added market solutions. This is particularly true for small-size passenger vessels designed for short-sea shipping which are usually built by small shipyards which cannot sustain high costs of innovation and investments in education and research. In addition, unlike other transport modes, vessels are generally produced in small series and the investment cost has a strong impact on the initial vessel cost. Therefore, ships are often based on previous concepts and designs with essentially no modernization, thus leading to poor energy efficiency improvements, high vessel life-cycle costs and significant environmental impact.

The new regulations in shipping sector demand energy efficiency improvements, but the stakeholders lack in providing support in achieving these requirements. In order to increase competitiveness, changes are required not only in individual stages of a shipbuilding process, but integrally throughout the production process. Conventional design and production paradigm can be changed by developing a modular concept in ship design. The aim of this paper is to determine the potential to reduce environmental pollution from ships and thereby the externalities by applying modular concept for small passenger ships in the Mediterranean. This new concept for a high-efficiency passenger vessel class can facilitate the design process, reduce the initial cost of more technologically advanced vessels by allocating innovation costs to units in a much larger series, and thus prove as a viable and sustainable alternative.

KEYWORDS: small passenger ship, modular concept, energy efficiency, environmental pollution & costs

I. INTRODUCTION

The majority of the cargo worldwide is transported by ships. The reason for this is that shipping is generally considered as the most efficient way to transport goods. This efficiency refers to the fuel oil consumption for a given economic output, where the economic output (sometimes called benefit for the society) is defined in tons and nautical miles of cargo transported. Cargo ships are powered by slow-speed super-long-stroke diesel engines with very low specific fuel oil consumption (SFOC). Also, the capacity of ships is very large, especially when compared with road vehicles or even trains. This leads to very low values of the fuel oil consumption and economic output ratios and very low cost of the transportation. On the other hand, any investment in innovative energy efficient technologies is perceived as a huge capital cost. Even more, since the shipping is considered as very efficient there is a very low awareness that any improvements are necessary at all. Hence, in the current practice, ship design is generally approached with the aim of keeping building-cost at the minimum, while the ship operation is approached with the aim of keeping fuel oil consumption at the minimum. These two aims are mostly opposed, so the most economic solutions are sought. On one side, low-cost designs and low value-added market solutions based on previous concepts and designs are often forced. On the other, the use of cheapest fuel oil and cheapest crew in the ship operation is forced.

This is particularly true for small-size ships. Usually, small-size passenger vessels designed for short-sea shipping are built by small shipyards. In addition, unlike other transport modes, vessels are generally produced in small series. As a consequence, the investment cost has a strong impact on the initial vessel cost. Therefore, high costs of innovation and investments in education and research is unsustainable from the economic point of view. Ships are often based on previous concepts and designs with only slight modifications required by the ship-owner with essentially no modernization. This leads to poor energy efficiency improvements, high vessel life-cycle costs and significant environmental impact. The aim of this paper is to propose a change in the paradigm of the ship design through introduction of modular approach. In the next section the main characteristics of modular approach are outlined. After that,
the environmental impact of such approach is estimated as well as the potential to achieve sustainability is discussed. The conclusion section provides the main findings of the paper including the guidelines for further research in the application of modular approach in small ships design.

II. MODULAR APPROACH

Modular approach is well known in many industries, with broad application in automotive industry. The idea is to offer customers a range of products with different user characteristics, but with the similar basic design. This allows customers to make certain modification to the design, i.e. to personalize the product, but with the majority of the design left intact. Modular approach is a sort of a compromise between mass production and tailor production. In mass production all the products are identical. This reduces the price of the product, but does not allow for any changes thus making the product less attractive to customers. In tailor production the product is completely defined according to customer wishes, but then the price is significantly higher. When modular approach is used, the main components of a product are mass produced, while the final assembly is then according to customer needs. In fact, if all components are defined in advance, it is possible to mass produce every component (which is usually the case) which limits the final selection, but further reduces the price of the product.

Similar approach could be applied in shipbuilding industry (Fig. 1). In a sense, it is already applied, although at a very low level. For example in ship power systems it is already possible to combine different components available in the market (such as engine, generators, gearboxes, shafts, bearings etc.) to build the power system. Some companies offer “a complete solution” for which they guarantee the optimum performance. But these “complete” solutions are complete within themselves and not within the entire power system. The interaction of different components in the entire system is usually not tested (before the ship trials), so in order to make the correct combination, specific knowledge and experience is required. For larger ships and bigger shipyards with many employees this does not provide a serious issue. But for smaller vessels built in small shipyards this can present a challenge. Hence, small shipyards are restricted to the production of ships for which they have positive feedback in a hope these ships will remain attractive for the market in the future. Also, they hope any future modifications will not affect the ship exploitation characteristics negatively. The idea behind this paper is to develop a series of small passenger vessels based on the modular approach which would present a true innovation in the market.

Fig. 1. Modular ferries as offered by Damen Shipyard

A. Ship modules

The idea is that the ship will be made of three basic modules: ship hull, ship superstructure and ship power system. Ship hull would further be made of bow section, middle section and stern section. Depending on ship exploitation characteristics, i.e. ship speed and main particulars several options would be proposed. Ship superstructure would be developed with the aim of increasing the passenger’s comfort, i.e. based on the habitability level required by the ship-owner. Ship power system would be defined based on two main parameters: the total power required and the maximum emission levels allowed. The modules will be developed based on the market needs which can be identified by analysing passenger ships built and sold on the market.
For this purpose, Review of Maritime Transport studies issued by UNCTAD are used. According to the UNCTAD Review of Maritime transport 2018 [1] passenger ships and ferries represent 0.3% of the world fleet deadweight tonnage, but 11.8% of the world fleet dollar value as it can be seen from the Fig. 2.

Fig. 2. World fleet by principal vessel type, 2018 (percentage) [1]

Fig. 3 shows passenger fleet size in the last 20 years in the capacity in DWT, as well as the increase in the percentage. These data are based on the UNCTAD reports. These reports are issued annually and provide data for that year and, as a reference, data for the past year. A notable increase can be observed throughout that period, apart from 2013. Until 2012 UNCTAD data were based on Lloyd’s Register of ships database, while from 2013 data are obtained by Clarkson Research Service without a clear description on which ships are taken into account. The difference in the ships observed is a probable reason for this discrepancy. Nonetheless, the figure shows that the market is continuously growing and that any improvements in that segment of shipping will have positive impact on the overall energy efficiency performance. Also, UNCTAD studies contain many other data which are useful for the modular approach implementation. For example, it is interesting to observe that the average time passenger ships spend in port is relatively short, but the number of calls is of an order of magnitude higher compared to other ship types.

Fig. 3. Size of the world passenger ship fleet in thousands of tons of DWT per year
B. Ship power system module

Ship power system is conventionally divided into main power system (producing mechanical power for the propulsion system) and auxiliary power system (producing electrical and heating power to assist the main power system and for crew and passengers). Recently, the integrated and hybrid power systems have been developed and applied for ships, particularly passenger vessels [2]. Integrated power systems are characterized by the centralized production of the power required on-board, while hybrid ones are characterized by the use of different types of power sources. Their main characteristic is higher energy efficiency and lower gas emissions. The energy efficiency has become a requirement for larger vessels. Even though the implementation of this regulation is not mandatory for small ships, improvements in energy efficiency can have many benefits: lower costs due to lower fuel oil consumption and higher sailing range. Lower gas emissions contribute to the sustainability of the vessel, which can have positive impact not only for the environment, but also for the ship-owners in branding their ships as eco-friendly and thus attracting more passengers to choose their vessel.

III. Achieving sustainability through modular approach

Sustainability implies three interrelated dimensions: ecological, economic, and social. Short-sea shipping presents great economic and social opportunity as it is labour-intensive, involves a wide variety of professions throughout entire maritime industry, from shipbuilding to shipping, insurance, brokerage and freight forwarding sectors, contributes to tourism, development of island agriculture accessibility of mainland market and services for islanders, and also for green innovation [χ].

Green innovation here implies among others the product design. The practice of designing products and the processes for making those products in environmentally responsible ways is known as Design for the Environment [ψ]. Its practice focuses on reducing the use of hazardous substances, minimizing consumption of energy and resources, reducing waste and expanding the lifecycle of products through recycling and reuse.

System thinkers may design components that can easily be separated and disassembled and the parts recycled. Furthermore, products can have longer lives when they are repairable, designed for easy replacement and designed so that broken parts can be reused or recycled. That is where the concept of modularity, a fundamental idea in the field of product design, presents its advantages. Modularity is not only good for business because of streamlining production processes, reducing the amount of inventory or making products easy to upgrade without needing to scrap large numbers of obsolete parts and thus providing economies of scale. Modularity is also the DFE and design for reuse because such equipment, in this case ships, are upgradeable.

In other words, developing a concept of modular ship hull, ship superstructure and ship power system is compliant with the principles of circular economy, industrial ecology, life-cycle design, eco-efficiency [5], dematerialization, product longevity, design for reuse and design for disassembly. In that respect appropriate environmental standards should be further developed by regulators and green public procurement promoted [6].

IV. Conclusion and recommendations

In this paper the potential to reduce the environmental pollution from ships and thereby the externalities by applying modular concept for small passenger ships in the Mediterranean are determined. As concluded from the UNCTAD reports, passenger ships fleet is continuously growing. Although its share in tons of deadweight is very low, the value of these ships is significant and therefore there is potential to implement new concepts such as modular approach. This new concept for a high-efficiency passenger vessel class can facilitate the design process, reduce the initial cost of more technologically advanced vessels by allocating innovation costs to units in a much larger series, and thus prove as a viable and sustainable alternative. Further research is required to define precisely technical characteristics of each module in order to achieve maximum benefit both for the ship-owners and for the environment.
ACKNOWLEDGMENT
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REFERENCES


Reduction of Particulate Matter Emission from Marine Diesel Engines

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ABSTRACT

Although some medical studies estimate that emissions of particulate matter from the marine diesel engines may be directly responsible for a large number of deaths worldwide, the direct rules that limiting this emission by the IMO are not defined as opposed to the automotive industry where this emission was regulated since 1992. In this paper, ship management strategies as well as commercially effective technologies for reducing the emission of particulate matter from marine diesel engines have been analysed in order to demonstrate the ability to reduce this harmful emission. With the application of available strategies aimed at reducing the fuel consumption and the simultaneous use of the scrubber system, this emission could be to a large extent limited. The negative consequences of this emission on human health and climate point to the need to define the direct rules by IMO, in order to control this emission, which will also initiate an additional incentive for the development of new technologies to solve this issue.

KEYWORDS: diesel particulate matter, exhaust gas cleaning system, scrubbers & diesel particulate filter

I. INTRODUCTION

International maritime transport is a very important element of world trade since almost 90% of the products of this exchange are transported by the vessels and at present there are no other transport possibilities for a significant percentage of this trade [12]. Transport of the goods by the merchant vessels in view of the used energy per ton and mile is the most energy efficient way of transport [1]. In order to ensure competitiveness in a dynamic maritime transport market, maritime companies use poor quality fuels, which has a direct consequence of emitting harmful pollutants from exhaust gases. The analysis of the layout of the waterways determined that 70% of all international waterways are within 400km of the coastline [1] [3]. This data points to the fact that harmful emissions of exhaust gases can have an impact on the quality of human health in these areas and also affect climate.

The global fleet includes over 104,000 merchant ships, and their contribution over the period from 2007 to 2012 on the total global world emissions was 13% for SOx and 15% for NOx [13]. Some studies show that shipping contribution to the global black carbon emission is 1.3% and that approximately 60% of black carbon emission on a global level is generated from energy sources, while 40% is generated by wildfires [16].

According to data from 2017 mentioned by European Environmental Agency, international navigation is very important element of the overall harmful emissions in EU. The data show that 16% of NOx emissions, 4% of PM10 emissions, 7% of PM2.5 emissions, and 16% of SOx emissions are produced by international maritime navigation [3].

It is a worrying fact that the emission of particulate matter particles in the EU at the local level from the ships is between 20-30% of PM2.5 emissions, while the participation of international maritime operations in European waters of PM2.5 is 15-25% [3].

A. A brief insight into particulate matter

The combustion process of fuel inside the engine cylinder is never complete. Particulate matter in exhaust gases is generated as a consequence of incomplete burning, pyrolysis and existence of parts of non-combustible fuel. One of the basic steps necessary to understand the problems associated with limiting emission of particulate matter is to get familiar with the structure of the particular matter of the marine engines themselves and the mechanism of their formation.

During the engine operation, particulate emissions are generated by two processes [5]:

- Accumulation process: During this stage particles are formed by agglomeration of the carbon and other solid elements in the engine cylinder during the combustion, forming the "Black Carbon", where the gases are additionally absorbed onto the surface of these particles.
- The nuclei process: During this part the particles are formed when the temperature in the exhaust duct is lowered and after contact with the atmosphere what leads to the formation of condensed hydrocarbons and sulphates.

The base parts of diesel particle matter are [10]:

1. **SOF (solid fraction)**, a solid part that consist carbon and ash. The carbon part is known as soot or black carbon.
2. **SOL (soluble organic fraction)** is a soluble part which includes organic material derived from the lubricating oil and organic material originating from the fuel.
3. **SO₄**, it consisting sulfuric acid and water, this part is called sulphate particles.

An example of the usual structure of diesel particulate PM is shown in Fig. 1.

![Fig. 1. Diesel PM particles and its structure [10]](image)

The PM particles are influenced by many factors and will greatly depend from the engine technology and the engine load, while the sulphate part will depend primary from the content of sulphur in used marine fuel. IMO (2009) has emphasized that sulphate fraction and sulphur particles have the highest percentage of particulate matter mass which is 80% and 78% of the total harmful emissions [1].

In order to show the effect on the particle matter structure in relation to the composition of the used fuel and engine stroke, an example is shown in Fig. 2.

![Fig. 2. Example of the PM particle structure [4]](image)

With respect to their diameter, PM particles can be classified into the following groups [10]:

1. Large particles, with a diameter greater than 10μm
2. Coarse particles, with a diameter ranges from 2.5-10μm, also known as PM10 particles
3. Fine particles, with a diameter ranges from 0.1 to 2.5μm, known as PM2.5 particles
4. Ultra-fine particles, 50-100nm (0.1μm), also known as PM0.1 particles
5. Nano particles with diameter size less than 50nm

### B. Marine engines

Currently, being the widest propulsion devices applied on board, the ships have diesel engines powered by different marine fuels. At present, the most powerful commercially available marine engine is two
stroke single action engine with cross head with power of 80 MW [9]. Owing to the low cost of HFO fuels, this medium is the most commonly used marine fuel.

**Table I. The ISO Characteristics of the Used Marine Diesel Engines [9]**

<table>
<thead>
<tr>
<th>Characteristics as per ISO 8217</th>
<th>Limit</th>
<th>HFO</th>
<th>MDO</th>
<th>MGO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kinematic viscosity at 50 °C (mm²/s)</td>
<td>Max</td>
<td>10-700</td>
<td>11.0</td>
<td>6.0</td>
</tr>
<tr>
<td>Density at 15°C (kg/m³)</td>
<td>Max</td>
<td>920-1010</td>
<td>900</td>
<td>890</td>
</tr>
<tr>
<td>Cetane number</td>
<td>Min</td>
<td>n.d.</td>
<td>35</td>
<td>40</td>
</tr>
<tr>
<td>CCAI</td>
<td>Max</td>
<td>850-870</td>
<td>n.d.</td>
<td>n.d.</td>
</tr>
<tr>
<td>Flash point (°C)</td>
<td>Min</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Acid number (mg KOH/g fuel)</td>
<td>Max</td>
<td>2.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Carbon residue micro method (%m/m)</td>
<td>Max</td>
<td>2.5-20</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Water (%)</td>
<td>Max</td>
<td>0.3-0.5</td>
<td>0.3</td>
<td>n.d.</td>
</tr>
<tr>
<td>Ash (% m/m)</td>
<td>Max</td>
<td>0.04-0.15</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Vanadium(mg/kg)</td>
<td>Max</td>
<td>50-450</td>
<td>n.d.</td>
<td>n.d.</td>
</tr>
<tr>
<td>Sodium (mg/kg)</td>
<td>Max</td>
<td>50-100</td>
<td>n.d.</td>
<td>n.d.</td>
</tr>
<tr>
<td>Aluminum plus silicon (mg/kg)</td>
<td>Max</td>
<td>25-60</td>
<td>n.d.</td>
<td>n.d.</td>
</tr>
</tbody>
</table>

The used marine fuel composition and the additives in the fuel itself, have an impact on the emission of PM particles. The following figure shows the origin of the constituent elements of PM particles.

C. Marine Fuels

Marine fuels are obtained by refining of crude oil and therefore belong to a group of fossil fuels. Marine fuels produced during refining are residual parts and these residuals can be classified as HFO and distillates. The distillates can be further classified as MDO and MGO. HFO is the cheapest product of crude oil, which has a decisive influence on its wider application, while the distillates themselves have a significantly higher price and their use will greatly affect the reduction of the profits of shipping companies [9]. In Table II, the characteristics of marine fuels are shown as per ISO 8217 standard.
The sulphur content of fuel (FSC) has an impact on particulate matter emissions from marine engines. The sulphur content of the fuel will affect only the sulphate part of the particulate matter meaning that the lower sulphur content will result in a lower emission of the sulphate part of the particulate matter. When using the same fuel, the measurements results show that lower particulate emissions have two-stroke engines compared to four-stroke engines. With the use of MGO fuels with increasing engine load, the emission of PM particles increases, while the measurements with HFO fuels show the opposite.

The sulphur content of the fuel will not affect the emission of the black carbon particles, and this part of the particles is considered the most harmful for human health [1].

D. Impact on human health
The harmfulness of the exhaust gases emissions from diesel engines was also recognized by the World Health Organization, so in 2012 it changed its classification from "probably carcinogenic to humans" to "carcinogenic for humans" [9]. There are studies also referred to by the European Environmental Agency, which estimates that the emission of particulate matter from marine diesel engines could be responsible for 60,000 deaths from lung and heart disease [3]. In the emission of particles from marine diesel engines there is a large number of very small particles with a diameter smaller than 10 nm. The impact of particles on the health will depend on the size of the particles and their chemical composition. Researches studies show that the greatest influence is by the smallest particles because they can enter deeper into human lungs [9].

II. Regulations of particulate emissions from marine diesel engines
The first rules for controlling the emission of PM particles in the EU from diesel cars entered into force in 1992 under the EURO I standard, while the latest rules were adopted in 2014 to further limit this emission (Euro 6 standard) and the limit is set to 0.01g/kWh [European Commission 2011] [9].

Unlike automotive industry, there are no rules in marine industry that directly limit the emissions of particulate matter in order to prevent or mitigate their detrimental effect. In 2008, IMO adopted Regulation 14 within the Marpol Convention and its Annex VI entitled as "Sulphur oxides (SOx) and particulate matter". Although the title of the regulation refers to particulate matters, the regulation itself does not limit the emission of particulate matter. The basic idea of IMO when adopting this regulation was to try to limit sulphur content indirectly by limiting the sulphur content of the fuel. Limitations of sulphur content are prescribed for the global level and for special areas known as Emission Control Area (ECA areas). Currently defined ECA areas are the Baltic Sea with the North Sea and the English Channel, the coastal area around USA, Canada and Caribbean.

Table III shows the allowed sulphur content of fuel at the global level and in controlled areas.

Presently, the global limit of sulphur content is 3.5% m/m, while from 2020 this limit will be reduced to 0.5% m/m, and in SECA it will be 0.1% m/m.

In addition, EU legislation (2005/33 EC) limits the sulphur content of fuels used in EU ports to 0.1% m/m from 1 January 2010. It was believed that the use of the low sulphur fuel will reduce the emission of PM2.5 for 80% from 2000 to 2020 [European Environmental agency] [9].
III. ANALYSIS OF CONTROL MEASURES FOR REDUCTION OF PARTICULATE MATTER EMISSION

Reducing the emissions of this issue from the vessels in order to control their harmful effects can be done in several ways by:

1. Reducing the fuel consumption of the marine diesel engine
2. Using enhanced quality fuel oils
3. Using an exhaust gas cleaning system

A. Reducing the fuel consumption of the marine diesel engine

This method is based on the simple fact - less fuel consumption causes less emissions and it is very easy to apply it by reducing the ship speed and therefore harmful emissions of gases [1]. The application of this method implies conducting of efficient ship operations. The massive application of this method commenced during the global economic crisis in 2009 with the aim not to reduce emissions but to reduce fuel costs. In its reports, the European Environmental Agency states that by 2011, 93% of the ships reduced vessel speed for 20% on the route between Europe and Far East and in that way 3 billion dollars of fuel was saved per year on a global level [3]. The application of this method provides immediate results and thanks to the economic benefits of its application, affects the popularity of its application. Also an improvement of the speed by reducing fuel consumption can be also achieved by choosing most convenient sea routes based on weather condition. The following table shows the effect of reducing the fuel consumption on the emission of PM particles.

<table>
<thead>
<tr>
<th>Energy efficient operation</th>
<th>%PM reduction</th>
<th>%PM₁ reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slow steaming</td>
<td>15-40</td>
<td>15-40</td>
</tr>
<tr>
<td>Weather routing</td>
<td>20-30</td>
<td>20-30</td>
</tr>
<tr>
<td>Advanced routing</td>
<td>2-4</td>
<td>2-4</td>
</tr>
</tbody>
</table>

PM₁-particle size with diameter less than 1μm

Reducing the fuel consumption can also be achieved by improving the vessel design – the same speed can be achieved with lower fuel consumption. In design, improvements can be done by improvement of the design of the hull structure with propeller and by the use of alternative propulsion engines. Optimization of the design can be achieved by optimizing the design of the propeller, optimizing the design of the hull, reducing the weight of the ship, cleaning the hull and applying better quality hull protection. All of the above methods require docking of the ship and a longer delay of the ship operations. The following table shows the potential options for reducing particulate matter emissions by optimizing the design of the ship.
### Table V. Influence of Design on Emission PM Particles [1]

<table>
<thead>
<tr>
<th>PM reduction by design improvements</th>
<th>%PM</th>
<th>%PM₁</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ballast water and trim operation</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Plant design</td>
<td>1.4</td>
<td>1.4</td>
</tr>
<tr>
<td>Propeller upgrade (nozzle and tip winglets)</td>
<td>0.5-3</td>
<td>0.5-3</td>
</tr>
<tr>
<td>Propeller boss cap with fins</td>
<td>1-3</td>
<td>1-3</td>
</tr>
<tr>
<td>Complete propeller-rudder replacement</td>
<td>2-6</td>
<td>2-6</td>
</tr>
<tr>
<td>Weight reduction</td>
<td>&lt;5</td>
<td>&lt;5</td>
</tr>
<tr>
<td>Hull coating</td>
<td>0.5-9</td>
<td>0.5-9</td>
</tr>
<tr>
<td>Hull cleaning</td>
<td>1-10</td>
<td>1-10</td>
</tr>
<tr>
<td>Optimal hull design</td>
<td>5-20</td>
<td>5-20</td>
</tr>
<tr>
<td>Advanced autopilot</td>
<td>0.5-3</td>
<td>0.5-3</td>
</tr>
<tr>
<td>Pumps and fan speed control</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Solar energy</td>
<td>2-10</td>
<td>2-10</td>
</tr>
<tr>
<td>Wind assistance (sails)</td>
<td>2-32</td>
<td>2-32</td>
</tr>
<tr>
<td>Wind assistance (Flettner rotors)</td>
<td>3.5-12</td>
<td>3.5-12</td>
</tr>
<tr>
<td>Hybrid battery and diesel electric main propulsion</td>
<td>&lt;30</td>
<td>&lt;30</td>
</tr>
</tbody>
</table>

PM₁ - particle size with diameter less than 1μm

### B. Use of enhanced quality fuel oils

The basic strategy that the IMO with its Regulation 14 of Annex VI wanted to implement was the use of low-sulphur fuel in order to indirectly limit the emission of PM particles, and primarily reducing SOX emissions. However, the use of fuels with less sulphur content only reduces the sulphate part of particulate matter, while the black carbon part emission remains intact, being the most toxic part of particle matter [1]. Tests carried out on ship diesel engines using HFO (1.6% S) and MGO / Ultra low sulphur of 0.03% S showed that specific carbon emissions are higher for HFO than for MGO, while for the content of the smallest particles of 0.3-0.4μm diameter emissions for MGO was greater than for HFO[1].

One of the possible solutions to mitigate harmful diesel emission is the usage of biofuels and biofuel blends [17]. Researches with marine diesel engines show that biofuels and its blends generate lower NOx, SOx and CO emission even when using blend biofuels made from wasted frying oil [13]. Measurement are showing that biodiesel fuel produces lower particulate matter emission compared to diesel as a consequence of lower aromatic and sulphur content in biodiesel fuel, and for the blended fuel this reduction will become smaller with smaller biodiesel proportion [17].

LNG is considered as one of the solutions regarding the problem of the overall emissions of diesel engines, and its use would significantly reduce the emissions of SOx, NOx, and PM. The CO emission would increase but additional exhaust gas treatment (exhaust gas recirculation) would also limit this CO emissions.

In December 2018, the passenger company AIDA took over the first ship “AIDAnova” powered only by LNG fuel [15]. The use of LNG requires a modification of marine engines, ship construction, additional safety measures and additional crew training. Currently, the major limiting factor in the use of this fuel is the lack of adequate port infrastructures around the world to enable the supply of fuels [1].

The strategy developed by some engine manufacturers is developing dual fuel engine which allows the use of liquid and gaseous fuels. The usual way of applying this technique is to inject the gas into the suction chamber collector and then mix it into the cylinder of the engine in order to fire the mixture. The usual practice is to start these engines with diesel and then switch over to gas [1].

### C. Exhausts gas cleaning system

During the last decades, various technologies have been developed in order to try to reduce the emission of PM particles from exhaust gases of diesel engines. Unfortunately, the efficiency of the application of these technologies with marine diesel engines are significantly less successful compared to shore
systems. The efficiency of these developed technologies for solving this problem has been evaluated by using the TRL (Technological Readiness Level) parameter. Based on this parameter, technological readiness of the application of individual systems can be seen [1] [European Commission].

**Table VI. Efficiency of Exhaust Gas Technologies [1]**

<table>
<thead>
<tr>
<th>Exhaust gas cleaning system</th>
<th>%PM₁ reduction</th>
<th>%PM₁ reduction</th>
<th>TRL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selective catalist reduction</td>
<td>n.a.</td>
<td>Negligible</td>
<td>9</td>
</tr>
<tr>
<td>Wet scrubbers</td>
<td>&lt;85</td>
<td>n.a.</td>
<td>9</td>
</tr>
<tr>
<td>Venturi scrubbers</td>
<td>&gt;90</td>
<td>&lt;50</td>
<td>9</td>
</tr>
<tr>
<td>Fabric filters</td>
<td>&gt;90</td>
<td>&gt;90</td>
<td>5</td>
</tr>
<tr>
<td>Diesel particulate filter</td>
<td>&lt;95</td>
<td>&lt;95</td>
<td>5-6</td>
</tr>
<tr>
<td>Diesel oxidation catalyst</td>
<td>&lt;95</td>
<td>&lt;95</td>
<td>5</td>
</tr>
<tr>
<td>Electrostatic precipitators</td>
<td>&gt;90</td>
<td>60-80</td>
<td>5</td>
</tr>
<tr>
<td>Particle agglomerators</td>
<td>n.a.</td>
<td>90</td>
<td>4-5</td>
</tr>
<tr>
<td>Wet ESP</td>
<td>n.a.</td>
<td>n.a.</td>
<td>5</td>
</tr>
<tr>
<td>Wet electrostatic scrubbers</td>
<td>&lt;85</td>
<td>&gt;90</td>
<td>5</td>
</tr>
<tr>
<td>Heterogenic condensation assisted scrubbers</td>
<td>n.a.</td>
<td>n.a.</td>
<td>3-4</td>
</tr>
<tr>
<td>Bubble towers</td>
<td>&gt;90</td>
<td>&gt;90</td>
<td>3-4</td>
</tr>
</tbody>
</table>

PM₁-particle size with diameter less than 1μm

According to EU rules TRL parameter is determined according to the scale in Table VII.

**Table VII. TRL parameter [6]**

<table>
<thead>
<tr>
<th>TRL No:</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRL 1</td>
<td>Basic principles observed</td>
</tr>
<tr>
<td>TRL 2</td>
<td>Technology concept formulated</td>
</tr>
<tr>
<td>TRL 3</td>
<td>Experimental proof of concept</td>
</tr>
<tr>
<td>TRL 4</td>
<td>Technology validated in lab</td>
</tr>
<tr>
<td>TRL 5</td>
<td>Technology validated in relevant environment</td>
</tr>
<tr>
<td>TRL 6</td>
<td>Technology demonstrated in relevant environment</td>
</tr>
<tr>
<td>TRL 7</td>
<td>System prototype demonstration in operational environment</td>
</tr>
<tr>
<td>TRL 8</td>
<td>System complete and qualified</td>
</tr>
<tr>
<td>TRL 9</td>
<td>Actual system proven in operational environment</td>
</tr>
</tbody>
</table>

Current PM reduction techniques are insufficiently developed for marine use [11]. As can be seen from the Table 6 commercially available efficient systems for the treatment of exhaust gases from diesel engines are scrubbers, as practically proven for marine applications with 85% of the particle removal efficiency [1].

**D. Scrubbers**

This device is primarily developed to reduce SOx emissions from marine diesel engines in order to allow the use of high sulphur cheap fuels, however, an additional feature of this system is particle matter removal function from the exhaust gases. This device performs cleaning of exhaust gases by using either seawater or chemical treated fresh water or dry elements to remove SOx and PM particles from exhaust gases. The device itself is installed on the exhaust system in the ship's funnel area. SOx gases are soluble in water and when dissolved from strong acids that react with water alkalinity, they form soluble sodium sulphate salt (Na₂SO₄) which is natural salt in the sea water. In addition, particulate matter will tie up for the water droplets and particles will be removed from exhaust gases as an addition to the sludge at the bottom of the scrubber.
SOx is removed by chemical reaction with wash water while the PM particles are removed by impact, diffusion, interception or particle absorption mechanism with water droplets.

The efficiency of cleaning PM particles from exhaust gases will depend on the particle size, efficiency decreases with smaller particles and vice versa.

The complete cleaning system itself consists of the four basic components [8]:

1. Exhaust gas cleaning scrubber unit (EEC);
2. The wastewater treatment system which allows that water can be released into the sea;
3. The sludge treatment system for processing the sludge produced during cleaning process;
4. Control system.

The process of washing the exhaust gases in the scrubber unit includes three basic steps [8]:

**Step 1** Generating droplets of water in the size of 100μm to 1000μm;
**Step 2** Getting a contact between water and gas droplets containing PM particles;
**Step 3** Removing water from the gas stream and drying the cooled and purified exhaust gas.

Removal of particles in the device itself is carried out through three known mechanisms [8] (Figure 5):

1. Direct collision of PM particles and water known as impact;
2. Contact intercepts of particles that did not experience a direct collision;
3. Diffusion of particles by drops of water.

The basic idea of this process is to achieve the best possible contact between particles and water droplets. Precision nozzles are used to form precisely defined size of water droplets. The basic nozzle design uses gas turbulence to break the flow of water and form water droplets while some other systems use either ultrasonic energy or compressed air energy. After the cleaning process, water droplets must be removed from the exhaust gas. All versions of wet scrubbers have a part designed to reduce the exhaust gas temperature known as the "quench section" in the first stage of the treatment of gases. This
part is constructed as a nozzle in which about 60% SOx and part of PM particles are removed. Thanks to the large difference velocities between gas and water in this part, favourable conditions for the removal of PM particles through collisions are created. In this section, the gas stream is cooled to 60 °C using 20% of the total amount of water. If the flow of water is low, the exhaust gas after it will remain hot, which will cause the water to evaporate before contacting with SOx and PM particles. With the cooling of the exhaust gas its volume decreases, which has an impact on the optimal dimensions of the scrubber in order to be placed in a restricted area of the ship funnel [8]. The Quench section is shown in Fig. 6.

After this part where the exhaust gas is cooled down and partly cleaned, the scrubber must have at least one more stage in which the remaining flushing of the exhaust gas is carried out. The overall efficiency of the scrubber will depend on the quality of the contact between the drops of water and gas, the water temperature and water saturation with the removed elements from the exhaust gas stream. An efficient scrubber design will achieve 85 to 90% removal of PM particles, and is currently the most efficient system for solving this problem of marine engines [1]. In Figure 7, “Spray tower” scrubber and its inner section is shown.

All scrubber systems (open, closed, hybrid) use the same cleaning principles for PM removal.

In addition to wet scraper, systems known as dry scrubbers were developed, these systems use Ca (OH)₂ instead of alkaline water to reduce SOx emissions. Some manufacturers have developed these systems, but apart from the effectiveness of removal of SOx gases, data on the efficiency of removing PM particles haven been revealed [1].

E. Diesel Particulate Filter (DPF)

The use of these filters for new cars equipped with diesel engines in the EU is mandatory since 2009 as part of the EURO V standard. The filter physically removes most of the PM particles using a variety of filtration mechanisms: diffuse sedimentation, inertial deposition and interruption. As these mechanisms overlap, these systems with automotive engines achieve a high degree of efficiency [10]. The use of these systems with marine diesel engines with HFOs or distillates is highly inefficient due to the rapid clogging of the filters themselves as a result of large PM particles that are characteristics of the marine diesel engine operation [1].

In 2012, MOL installed first self-cleaning particulate filter on a 9MW diesel generator engine powered with a HFO [14]. The installed DPF consisted of four parallel cylindrical filters with silicon carbide elements. The reported efficiency was 80% [14], which is very low compared to the results achieved on automobile diesel engines.

The system included automatic and active regeneration performed in that way that one filter unit was in regeneration mode while the other three were in cleaning function. The principle of regeneration through an internal heating system was not revealed. According to the available data, the system was maintenance free.
The basic problem and the challenge of using these systems with HFO fuels is high ash content in the fuel that cannot be oxidized during regeneration [1]. System has been tested for 1 year but no further results were published.

Fig. 8. DPF installed on MOL ferry vessel [14]

IV. CONCLUSION

In this study, the strategies that need to be applied in order to limit the emissions of particulate matter from marine diesel engines were analysed. The results of this analysis indicate the following conclusions:

- The Marpol Convention, with its Regulation 14 of Annex VI did not successfully manage to solve this problem. The main reason for this is prescribed to failure of convention as it tried indirectly to limit particulate matter emissions by defining the permissible content of sulphur in fuel, limiting only the sulphate part of particulate matter, while the content of sulphur in the fuel does not affect the black carbon part as the most dangerous part of these particles. All research data regarding particulate matter influence on humans suggest that there is a need to lay down direct regulations to control emission from marine diesel engines.
- The technologies for reducing the emissions of particulate matter from marine diesel engines have not been developed successfully.
- Scrubber systems are presently only commercially available efficient systems for the treatment of exhaust gases from diesel engines as practically proven for marine applications with 85% particulate removal efficiency.
- Efficient ship operations can be achieved with reduction of fuel consumption with simultaneous use of scrubber cleaning systems and this could significantly limit the emission of particulate matter from marine diesel engines.
- The use of LNG fuel for diesel engine operation could to a great extent solve the issue of this emissions but, unfortunately, apart from required modification of the ship’s systems for use of these fuels, the major problem is the lack of supply infrastructures around the world in order to provide a safe supply system for these fuels.
- By prescribing MARPOL direct rules in accordance with the available technological readiness level, additional technological development aimed at solving or mitigating problem of this emission might be achieved.
REFERENCES


[8] EGCSA - Exhaust gas cleaning system association, A practical guide to exhaust gas cleaning systems for the maritime industry, EGSA handbook 2012


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Spare Parts Optimization Using A Planned Maintenance System

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ABSTRACT
A certain amount of spare parts is required for any maintenance operation. The organization and the implementa-
tion of proper maintenance requires appropriate amount of spare parts. Safety and reliability of the ship depends
upon proper maintenance, requiring appropriate amount of spare parts as well. The ship is a vehicle that is in con-
stant motion with a limited amount of useful space in general, this fact is also applied to spare parts storage. Spare
parts in stock represent not only “dead capital”, but also a significant annual cost. Therefore, more attention should
give to optimization of spare parts. Determination of the optimal amount of spare parts can be presented as
a compromise that should meet the requirements for proper and timely maintenance, as well as decrease of the
costs for spare parts. The Planned Maintenance System is used for planning, documentation and implementation
of surveys and maintenance, as well as for monitoring of spare parts stock and consumption. Systematically and
continuously collected data from a computerized Planned Maintenance System can be used for the optimization
of spare parts.

This paper shows how to implement the optimization of spare parts on board using analysis of the data obtained
from the ship’s computerized Planned Maintenance System.

KEYWORDS: optimization, planned maintenance system, spare parts & data analysis

I. INTRODUCTION
During construction phase of any technical system, the basic requirement is to fulfil its purpose through-
out whole useful life. In order to achieve that requirement, it is necessary to have proper and timely
maintenance for all parts of that system. Basic prerequisites for organizing and carrying out good
maintenance are the appropriate quantity and availability of spare parts (Figure 1) [1]. Determining the
required amount of spare parts, their procurement and deliveries, and timing when they are going to be
used, is a complex and demanding task [2].

![Planning framework for maintenance](image)

Ship is a vehicle, in constant motion, making procurement and delivery of spare parts limited. Due to
this reason, organization of proper maintenance requires spare parts to be kept on board, on ship’s
stock. Several factors influence this requirement: limited capacity of the useful storage size and the
costs of purchasing and storing of spares. According to [3], "stocking cost are in conflict with the overall
maintenance aim of minimal costs. The resulting trade-off between low inventory costs and short machine downtime is addressed by spare parts and maintenance planning”.

Previous researches have been endeavoring throughout different approaches to achieve spare parts optimization, respectively proper spare parts planning. Proper planning of spare parts is conditioned by failure prediction for some system, i.e. it depends on maintenance type applied and condition of the machinery [4].

This paper describes a case study, how optimization of spare parts on board can be achieved using data analysis from Planned Maintenance System (PMS) records created over period several years. Required amount of spare parts can be anticipated by gaining insight about spare parts stock on board, analysis of the prior maintenance and failures, as well as inspection of the scheduled maintenance for the future. Thus, it is important that planned maintenance and spare parts stock are observed together, so that necessary spare parts are available for achieving timely maintenance actions [5]. In this paper provision refrigeration compressor parts management was analyzed. Compressor manufacturer is SABROE Company, whereas ship is equipped with two compressors type SBO 43. Using data from planned maintenance system, following data are analyzed:

- Previous maintenance data;
- Planned maintenance data;
- Current spare parts stock data.

A. Non-disclosure condition

As shipping company allowed access to their data strictly under non-disclosure condition, all details leading to identification of the ship and the company are removed from the article.

II. MAINTENANCE

Planned maintenance system contains following planned jobs, which are written according to manufacturer’s recommendations [6]:

- Check – it is carried out every 3 months, during which visual and acoustic check is performed in order to determine possible leakage or unusual noise and vibrations while machine is working. On top of this, working parameters like oil and cooling media quantity are checked.
- Inspection – is carried out every 5000 working hours. Heating rod, driving belts, safety automatics and return oil system are checked. Oil and water-cooling systems are checked for possible deposits and clogging.
- Overhaul – is carried out every 10000 (minor) or 20000 (major) working hours. During overhaul compressor is dismantled in order to examine parts for wear or defect. In case of normal wear and no defects detected, compressor is assembled and returned for operation. Suction filter is cleaned during every overhaul, together with lubricating oil and belts. Parts that are examined during minor and major overhaul are similar, only difference is that oil pump, drive and valves are checked only during major overhaul.

B. Performed Maintenance

Maintenance data about installed equipment is taken from planned maintenance system database (Table I. and II.). Inspection of data shows that in the past three years there were no failures.

<table>
<thead>
<tr>
<th>TABLE I.</th>
<th>MAINTENANCE RECORDS OF COMPRESSOR NO.1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Compressor No.1</strong></td>
<td>Date done</td>
</tr>
<tr>
<td></td>
<td>12.5.2015</td>
</tr>
<tr>
<td></td>
<td>11.8.2015</td>
</tr>
<tr>
<td></td>
<td>13.11.2015</td>
</tr>
<tr>
<td></td>
<td>13.2.2016</td>
</tr>
<tr>
<td></td>
<td>13.5.2016</td>
</tr>
<tr>
<td></td>
<td>13.8.2016</td>
</tr>
<tr>
<td></td>
<td>11.11.2016</td>
</tr>
<tr>
<td></td>
<td>12.2.2017</td>
</tr>
</tbody>
</table>
Also, inspection and overhaul were carried out on both compressors in the past three years. Measurement of parts during overhaul determined that there was a normal wear on all examined parts on both compressors. In addition, no defects or need for replacement arose during examinations. Considering that maintenance actions were completed according to manufacturer’s instructions it is deemed that original operational capability is restored to the machine.

C. Future maintenance

All planned jobs except checks depend on the number of running hours that the PMS calculates based on the average running hours (Table III).

<table>
<thead>
<tr>
<th>Counter</th>
<th>Date Read</th>
<th>Current value</th>
<th>Start date</th>
<th>Daily average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hours</td>
<td>16.08.2018</td>
<td>15:203</td>
<td>5.01.2009</td>
<td>4.2</td>
</tr>
<tr>
<td>Hours</td>
<td>15.09.2018</td>
<td>14:996</td>
<td>5.01.2009</td>
<td>4.04</td>
</tr>
</tbody>
</table>

Planned jobs for refrigeration compressors are shown in Table IV and V, where can be noticed that during 2019 no overhaul jobs are planned, i.e. there should be no spare parts consumption, only several compressor checks.

<table>
<thead>
<tr>
<th>Title*</th>
<th>Last done</th>
<th>Frequency</th>
<th>Due</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressor check</td>
<td>09.08.2018</td>
<td>3 months</td>
<td>9.11.2018</td>
</tr>
<tr>
<td>Compressor inspection</td>
<td>28.04.2017</td>
<td>5000 hours</td>
<td>5.01.2020</td>
</tr>
<tr>
<td>Compressor major overhaul</td>
<td>N/A</td>
<td>20000 hours</td>
<td>27.08.2021</td>
</tr>
<tr>
<td>Compressor minor overhaul</td>
<td>28.04.2017</td>
<td>10000 hours</td>
<td>5.03.2023</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Title*</th>
<th>Last done</th>
<th>Frequency</th>
<th>Due</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressor check</td>
<td>02.09.2018</td>
<td>3 months</td>
<td>2.12.2018</td>
</tr>
<tr>
<td>Compressor inspection</td>
<td>09.01.2018</td>
<td>5000 hours</td>
<td>24.02.2021</td>
</tr>
<tr>
<td>Compressor major overhaul</td>
<td>N/A</td>
<td>20000 hours</td>
<td>10.12.2021</td>
</tr>
<tr>
<td>Compressor minor overhaul</td>
<td>09.01.2018</td>
<td>10000 hours</td>
<td>24.5.2024</td>
</tr>
</tbody>
</table>

D. Spare parts and prices

In Table VI, spare parts stock for provision compressors is shown. Since, spare parts were supplied by different suppliers and not at the same time, for this paper three offers were requested and provided by three different suppliers.
TABLE VI. SPARE PARTS AND SHIP’S SUPPLIERS QUOTATIONS (IN US $)

<table>
<thead>
<tr>
<th>Description</th>
<th>Maker’s Reference</th>
<th>In Stock</th>
<th>Price 1</th>
<th>Total 1</th>
<th>Price 2</th>
<th>Total 2</th>
<th>Price 3</th>
<th>Total 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Magnetic plug for oil filter</td>
<td>1.991.414</td>
<td>1</td>
<td>7.61</td>
<td>7.63</td>
<td>8.57</td>
<td>8.57</td>
<td>7.78</td>
<td>7.78</td>
</tr>
<tr>
<td>2. Gasket for oil filter</td>
<td>1.991.415</td>
<td>2</td>
<td>7.61</td>
<td>15.26</td>
<td>7.71</td>
<td>15.43</td>
<td>7.78</td>
<td>15.57</td>
</tr>
<tr>
<td>3. Thrust spring for oil strainer</td>
<td>1.991.416</td>
<td>1</td>
<td>7.61</td>
<td>7.63</td>
<td>8.57</td>
<td>8.57</td>
<td>7.78</td>
<td>7.78</td>
</tr>
<tr>
<td>4. Oil strainer</td>
<td>1.991.417</td>
<td>1</td>
<td>7.61</td>
<td>7.63</td>
<td>8.57</td>
<td>8.57</td>
<td>7.78</td>
<td>7.78</td>
</tr>
<tr>
<td>5. Bearing bush (motor side)</td>
<td>1.991.450</td>
<td>1</td>
<td>27.64</td>
<td>27.64</td>
<td>30.99</td>
<td>30.99</td>
<td>28.17</td>
<td>28.17</td>
</tr>
<tr>
<td>6. Bearing bush (crank. side)</td>
<td>1.991.451</td>
<td>1</td>
<td>27.64</td>
<td>27.64</td>
<td>27.90</td>
<td>27.90</td>
<td>28.17</td>
<td>28.17</td>
</tr>
<tr>
<td>7. Connecting rod with piston</td>
<td>1.991.455</td>
<td>4</td>
<td>236.76</td>
<td>947.04</td>
<td>235.59</td>
<td>942.36</td>
<td>241.27</td>
<td>857.08</td>
</tr>
<tr>
<td>8. Suction strainer</td>
<td>1.991.461</td>
<td>2</td>
<td>7.61</td>
<td>15.26</td>
<td>8.57</td>
<td>17.14</td>
<td>7.78</td>
<td>15.57</td>
</tr>
<tr>
<td>9. Gasket for suction valve</td>
<td>1.991.462</td>
<td>4</td>
<td>7.61</td>
<td>30.52</td>
<td>8.57</td>
<td>34.28</td>
<td>7.78</td>
<td>31.13</td>
</tr>
<tr>
<td>10. Suction stop valve</td>
<td>1.991.463</td>
<td>2</td>
<td>198.57</td>
<td>397.14</td>
<td>200.42</td>
<td>400.84</td>
<td>202.35</td>
<td>404.71</td>
</tr>
<tr>
<td>11. Discharge stop valve</td>
<td>1.991.464</td>
<td>2</td>
<td>183.30</td>
<td>366.60</td>
<td>185.01</td>
<td>370.02</td>
<td>186.79</td>
<td>373.58</td>
</tr>
<tr>
<td>14. Valve plate complete</td>
<td>1991.474</td>
<td>4</td>
<td>197.05</td>
<td>788.2</td>
<td>198.88</td>
<td>795.52</td>
<td>200.8</td>
<td>803.2</td>
</tr>
<tr>
<td>15. Lower valve plate gasket</td>
<td>1991.476</td>
<td>5</td>
<td>7.61</td>
<td>38.15</td>
<td>8.57</td>
<td>42.85</td>
<td>7.78</td>
<td>38.91</td>
</tr>
<tr>
<td>16. Upper valve plate gasket</td>
<td>1991.477</td>
<td>5</td>
<td>7.61</td>
<td>38.15</td>
<td>8.57</td>
<td>42.85</td>
<td>7.78</td>
<td>38.91</td>
</tr>
<tr>
<td>17. Cylinder head, air-cooled</td>
<td>1991.478</td>
<td>2</td>
<td>89.26</td>
<td>178.52</td>
<td>111.62</td>
<td>232.24</td>
<td>112.70</td>
<td>225.4</td>
</tr>
<tr>
<td>18. Shaft seal complete</td>
<td>1991.479</td>
<td>2</td>
<td>357.44</td>
<td>714.88</td>
<td>360.78</td>
<td>721.56</td>
<td>728.48</td>
<td>1456.96</td>
</tr>
<tr>
<td>19. Gasket for shaft seal cover</td>
<td>1991.481</td>
<td>1</td>
<td>7.61</td>
<td>7.63</td>
<td>8.57</td>
<td>8.57</td>
<td>7.78</td>
<td>7.78</td>
</tr>
<tr>
<td>20. Compressor pulley</td>
<td>1991.482</td>
<td>2</td>
<td>222.76</td>
<td>445.52</td>
<td>277.52</td>
<td>555.04</td>
<td>168.11</td>
<td>336.22</td>
</tr>
<tr>
<td>21. Set of gasket</td>
<td>1991.484</td>
<td>1</td>
<td>157.33</td>
<td>157.33</td>
<td>158.79</td>
<td>158.79</td>
<td>160.33</td>
<td>160.33</td>
</tr>
<tr>
<td>22. V belt (OPTIBELT)</td>
<td>DIN 7753 Super X power</td>
<td>4</td>
<td>24.15</td>
<td>96.60</td>
<td>37.33</td>
<td>149.32</td>
<td>23.12</td>
<td>92.48</td>
</tr>
<tr>
<td>23. Filter element 15-20, 150 micron</td>
<td>Part No. 148H3124</td>
<td>1</td>
<td>57.92</td>
<td>57.92</td>
<td>96.60</td>
<td>96.60</td>
<td>43.24</td>
<td>43.24</td>
</tr>
</tbody>
</table>

Total: 4403.41 4693.29 5011.89

Mean value of spare parts on stock is used in this paper for calculations, it is calculated as arithmetic mean of prices offered by three suppliers:

$$\bar{V} = \frac{V_1 + V_2 + V_3}{3} \quad [\text{US} \$] \quad (1)$$

where:

$\bar{V}$ - mean value of spare parts,

$V_1, V_2, V_3$ – price of spare parts gained from each supplier.

III. FAILURE SIGNIFICANCE ANALYSIS, RISK INDEX

Significance analysis [7], [8] aims to determine criticality categories for effects of failure i.e. consequences. With respect to the failure effects, the analysis of the significance distinguishes safety and working aspect according to the classification of failures (Table VII). Effect that failure can have on the equipment or environment is expressed by significance index – SI. Significance index indicates loss magnitude which is attached to one undesired event [7].

TABLE VII. SIGNIFICANCE INDEX (FAILURE EFFECTS GRADATION) [8]

<table>
<thead>
<tr>
<th>Class</th>
<th>Size</th>
<th>SI</th>
<th>Possible failure effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety - $SI_{io}$</td>
<td>1</td>
<td>Critical</td>
<td>Ship loss, environment catastrophe</td>
</tr>
<tr>
<td></td>
<td>0.1</td>
<td>Strong</td>
<td>Critical damage, major ship breakdown</td>
</tr>
<tr>
<td></td>
<td>0.01</td>
<td>Marginal</td>
<td>Minor breakdown, secondary damage</td>
</tr>
<tr>
<td></td>
<td>&lt;0.0001</td>
<td>Negligible</td>
<td>No breakdown, no damage to the ship or environment</td>
</tr>
<tr>
<td></td>
<td>Not available</td>
<td>0.01</td>
<td>Ship is not available for operation for days</td>
</tr>
<tr>
<td></td>
<td>Partially available</td>
<td>0.001</td>
<td>Ship is not available for operation hours</td>
</tr>
<tr>
<td></td>
<td>Reduced performance</td>
<td>0.0001</td>
<td>Ship works with reduced performance</td>
</tr>
<tr>
<td></td>
<td>Available</td>
<td>&lt;0.00001</td>
<td>Ship is completely operational</td>
</tr>
</tbody>
</table>

392
Using significance analysis, significance indices for provision system are:

\[ S_{I(a)} = < 0.001 \quad S_{I(\infty)} = < 0.00001 \]

According to the Table VII failure of provision system will have negligible significance on safety and operation of the ship, significance could increase during a period of time in form of disruption of crew’s life conditions. Also, according to significance class classification [8], this system is classified as secondary function in working segment.

Risk index is a product of significance index, failure frequency in previous working time and probability that reserve machinery will fail during failure of the working machine. Since, in observed time there were no failures on the system, in this paper for calculation of failure frequency in previous working time failure rate data are taken from generic reliability database [9], [10]:

\[ \lambda = 107.7057 \cdot 10^{-6} \quad [h^{-1}] \]  

(2)

As significance indices are very negligible, as well as probability that reserve machine will break down during failure of working machine, risk index does not need to be calculated because obtained value will be negligible.

IV. DISCUSSION (PRO ET CONTRA)

A. Argument Pro 1

Ship owner’s SMS can be cited as an argument for procurement and storage of spare parts for refrigeration provision system. In part referring to ISM code and spares on board SMS states [11]:

"The means used to promote the reliability of the equipment and technical systems identified in paragraph (j) are:

- To order spare parts,
- To have enough spare parts available,..."

Equipment list in paragraph (j) does not specify provision system, but states:

"...and all other equipment that may be deemed appropriate”.

If this argument is accepted as decisive, question about amount of spare parts on stock arises. Authors of the article have defined list of spare parts that might be required when performing some future overhaul based on their experience. In Table VI cited spare parts are bolded. Mean procurement value for mentioned parts per amount of one piece each would be 867.07 dollars (Equation 1).

B. Argument Pro 2

Additional argument for procurement and storage of spare parts can be found in IACS recommendations, as it applies for all compressors. According to IACS [12], there is no requirement for spare parts, yet recommendations given as a list of minimum recommended spare parts for essential auxiliary machinery of ships for unrestricted service. Recommended spare parts amount for compressors and their mean value is shown in Table VIII. Total mean value of recommended spare parts amount according to IACS would be 635.7 dollars (Equation 1).

<table>
<thead>
<tr>
<th>Spare parts</th>
<th>Recommended</th>
<th>Mean value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Suction and delivery valves complete of each size fitted in one unit</td>
<td>½ set</td>
<td>397.82</td>
</tr>
<tr>
<td>2. Piston rings of each type and size fitted for one piston</td>
<td>1 set</td>
<td>237.87</td>
</tr>
</tbody>
</table>
C. Arguments Contra
Considering previous maintenance analysis, as well as failure significance analysis and risk index it can be assumed that there is no reason for storage of provision system spare parts, especially knowing that during inspections no indications for potential failure were found. In addition, overhauls of the system are not planned for next 12 month period [13]. All listed point that possession of spare parts on board for this system is not needed.

V. CONCLUSION

By analyzing spare parts stock on board, previous and planned maintenance data, for refrigeration provision system, optimization of spare parts amount is possible, i.e. cost reduction.

The discussion shows that amount of spare parts on stock does not match significance of the system, failures occurred in the past as well as planned spare part consumption in near future.

- If claim that no spare parts on board are necessary, which is based on the importance of the system, its configuration and the planned consumption of spare parts, is presumed valid, it is followed with the fact that there is 4702.86 dollars of unnecessary spare parts on board.
- If claim that certain amount of spare parts on board is needed, based on company’s SMS (see E), then there is still 3835.79 dollars of unnecessary spare parts on board.
- If minimum amount of spare parts is calculated according to IACS (see F), then there is 4067.16 dollars of unnecessary spare parts on board.

In all these cases significant amount of spare parts on board is present which is not necessary and will not be consumed for long time. The analysis shows that there are at least 3835.79 dollars of spare parts that will not be used in the near future. This amount represents the value of parts, without any passive costs such as procurement or deterioration of spare parts on stock.

Due to ship’s self-sufficiency, it contains a great number of systems as well as various system types, therefore provision system do not represent isolated case concerning systems with low failure significance. Air condition system, superstructure ventilation system, fresh water production system, waste water draining system, etc., can be mentioned as similar failure significance systems. If it is possible to save up to 4000 dollars by applying mentioned optimization and using data analysis for only one system, then by applying integrated maintenance and spare parts analysis on systems with similar failure significance optimization would result in even major savings.

REFERENCES


The Preliminary Risk Analysis of The Subsystems of The Auxiliary Engine

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ABSTRACT
The failures of individual ship systems and subsystems can cause material damage, environmental pollution, delays in operation or the loss of human lives. Through the application of risk analysis, this paper analyses historical data on the failures of the marine auxiliary engine in exploitation. The risk levels of all auxiliary engine subsystems are assessed based on the application of the approved Preliminary Risk Analysis methods and the use of historical data on the failures observed. The failures were analysed based on their frequency and the degree of their consequences during the exploitation period of three years. Based on these assessments, the paper identifies a high-risk subsystem of the auxiliary engine and proposes the measures of risk reduction.

KEYWORDS: auxiliary engine, auxiliary engine subsystem, preliminary risk analysis & level of risk

I. INTRODUCTION
A ship can be defined as a very complex technical system because it represents a set of technical components that are interconnected in a single unit and capable of performing certain functions (cargo and passenger transportation, storage, protecting drives, propulsion etc.). The ship as a complex technical system can be classified into several subsystems: hull, machine complex, equipment and superstructure. The machine complex consists of machines and devices that provide energy, both, for the propulsion of the ship and for all other operations on the ship (cargo handling, fuel, lubrication, steering, electricity production, etc.). [1]

Recognizing the importance of different influences that may negatively affect the exploitation of ships, the International Maritime Organization (IMO) has acknowledged the need to identify risk and perform risk analysis, assessment and management. Therefore, through the SOLAS Convention, the ISM Code was introduced, along with the “Guidelines for Formal Safety Assessment for use in the IMO Rule-Making Process”, as part of MSC Circ.1023 and MEPC Circ. 392, 5 April 2002. [2].

One of the first and the simplest risk-rating tools, which has been efficient since the very beginning of the risk analysis until today, is a risk matrix, that is, a "probability and consequence matrix". The matrix is a very effective and useful tool for risk assessment. Although there are many standard matrices in different contexts (ISO, IMO, NASA, etc.), individual projects and organizations should create their own matrix or adapt the existing ones. [3,4]

The autonomy of a ship as a technical system, which usually performs its functions at sea, far from the shore, requires a high level of reliability of all subsystems. In that sense, the auxiliary engine is one of the most important ship systems, which provides the source of electricity for the power supply of almost all other subsystems of the ship. Therefore, this paper identifies and analyzes the most frequent failures of the auxiliary engine subsystems using the appropriate empirical database for the types and number of failures of ten vital subsystems of the auxiliary engine for a three-year exploitation period. The research was carried out on the auxiliary engine "Yanmar 8EY26L" of the container ship "ALS JUVENTUS" of Asiatic Lloyd - Singapore between 2016 and 2018.

II. PRELIMINARY RISK ANALYSIS - PRA
PRA initially categorizes the consequences that can cause system failures (Table I.), and then their probability (Table II.). The categorization of consequences is determined on the basis of the scope of the risk factors such as: the system tendency to cause an error, the operating conditions of the system, the
possibility of escalation of a small error into a bigger one, and the safety of the crew in the area of observation. The category of failure probability determined by the factors that can affect the failure of the system. Each of the factors has its own weight and their combination represents the of a possible failure. The factors that affect the frequency of failures are: the potential failure of the mechanism, the concrete condition of the equipment, the nature of the process, the project design of the equipment, as well as the basic maintenance and lubrication, cleaning and checking. [5]

<table>
<thead>
<tr>
<th>TABLE I. CLASSIFICATION OF FAILURE CONSEQUENCES [5]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consequence Categories</td>
</tr>
<tr>
<td>------------------------</td>
</tr>
<tr>
<td>I – Catastrophic (4)</td>
</tr>
<tr>
<td>II – Critical (3)</td>
</tr>
<tr>
<td>III- Marginal (2)</td>
</tr>
<tr>
<td>IV- Negligible (1)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TABLE II. CLASSIFICATION OF FAILURE PROBABILITIES [1]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency Categories</td>
</tr>
<tr>
<td>------------------------</td>
</tr>
<tr>
<td>A- Incredible (1)</td>
</tr>
<tr>
<td>B- Unlikely (2)</td>
</tr>
<tr>
<td>C- Likely (3)</td>
</tr>
<tr>
<td>D- Often (4)</td>
</tr>
</tbody>
</table>

When defining the categorization of the consequences and the frequency of the failures of the system, the factors are combined and the 4x4 risk matrix is obtained. The matrix determines the level of risk (Table III.). The objective of this analysis can be presented as follows: monitoring and observing the system in operation in order to detect the area of high risk and identify the risk level of each part of the system, based on a consistent methodology. [5]

<table>
<thead>
<tr>
<th>TABLE III. RISK MATRIX [5]</th>
</tr>
</thead>
<tbody>
<tr>
<td>PROBABILITY CATEGORY</td>
</tr>
<tr>
<td>CONSEQUENCE CATEGORY</td>
</tr>
<tr>
<td>A</td>
</tr>
<tr>
<td>I</td>
</tr>
<tr>
<td>II</td>
</tr>
<tr>
<td>III</td>
</tr>
<tr>
<td>IV</td>
</tr>
</tbody>
</table>

When the results of the categorization of the consequences and the frequency of failures are entered in the risk matrix, the risk level of the system can be obtained. PRA analysis determines the level of risk (that can be high, medium and small) for each part of the system. Based on the results of the risk level, the maintenance of the system parts can be classified into three groups:

- The parts of the system with a high level of risk (risk between 12 and 16 in Table 3). These parts of the system will be a part of further analysis based on project design, engineering, risk and maintenance.
- The parts of the system with a medium level of risk (risk between 4 and 9 in Table 3): the parts of the system with a medium level of risk will be analyzed on the basis of the RCM - Reliability Centered Maintenance.
- The parts of low-risk systems (risk between 1 and 4 in Table 3): these parts of the system belong to the areas of acceptable risk and they are maintained by the use of traditional methods. [5]
III. THE SUBJECT OF RESEARCH

As a subject of the research was taken the auxiliary engine by the Japanese company "Yanmar 8EY6L" on the ship "ALS JUVENTUS" - Asiatic Lloyd - Singapore. It is a four-stroke diesel engine with eight cylinders, the maximum power of 2450 kW at the speed of 720 min⁻¹. The subsystems of this auxiliary engine are listed in Table 4, while Fig. 1 shows all subsystems except the engine reference system.

<table>
<thead>
<tr>
<th>Subsystem designation</th>
<th>Auxiliary engine „Yanmar 8EY26L“</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Cylinder head</td>
<td></td>
</tr>
<tr>
<td>2. Cylinder block and liner</td>
<td></td>
</tr>
<tr>
<td>3. Piston and connecting rod</td>
<td></td>
</tr>
<tr>
<td>4. Timing gear, camshaft and intake/exhaust swing arm</td>
<td></td>
</tr>
<tr>
<td>5. Aircooler and exhaust manifold</td>
<td></td>
</tr>
<tr>
<td>6. Lubricating oil subsystem</td>
<td></td>
</tr>
<tr>
<td>7. Cooling water subsystem</td>
<td></td>
</tr>
<tr>
<td>8. Fuel oil subsystem</td>
<td></td>
</tr>
<tr>
<td>9. Main bearing and crankshaft</td>
<td></td>
</tr>
<tr>
<td>10. Starting air system and airmotor</td>
<td></td>
</tr>
</tbody>
</table>

IV. METHODOLOGY OF THE RESEARCH

The research methodology consists of several steps. The first is the unification of the detected ship's auxiliary engine ratings based on the historical data recorded in ship records. Then the failures recorded were processed in accordance with the degree of their consequences and frequency. By recording the degree of consequences and the failure frequency, a risk matrix is formed for each individual subsystem of the auxiliary engine.

On board "ALS JUVENTUS", the third engineer has the task of ensuring a reliable and safe operation of the auxiliary engines. This is achieved by proper maintenance based on the instruction book in which the number of working hours for each subsystem of the auxiliary engine is prescribed along with the maintenance procedure in case of a sudden failure of one of the subsystems. All maintenance data is recorded by the third engineer in the "Excel" program on a daily basis, in order to keep a record of all maintenance done on the four auxiliary engines on the boat "ALS JUVENTUS". Analyzing the data recorded on the failures in the period from between 2016 and 2018, the first author of this paper collected the data on the auxiliary engine number two on the ship mentioned. Based on the data collected, a review of the failures for the period observed was drafted and summarized for each subsystem considered, as shown in Fig. 2.
In order to apply the method of Preliminary Risk Analysis, it was necessary to define the failures on the basis of the degree of their consequence. The types of failures in accordance with the degree of the consequence are, therefore, listed in Table 5.

<table>
<thead>
<tr>
<th>The subsystems of auxiliary motor</th>
<th>The types of failures by year</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The burnout of three exhaust valves; (I) Two cases of blocked rotocaps; (I)</td>
<td>The burnout of one exhaust valve; (I)</td>
<td>One case of the leakage of the fuel injection gasket; (I)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>There was no failure; (-)</td>
<td>Three cases of worn out liners; (I)</td>
<td>Two cases of worn out liner; (I)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>One case of the leakage of the piston rings; (I)</td>
<td>One case of the leakage of the piston rings; (I)</td>
<td>Four cases of the leakage of the piston rings; (I)</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>There was no failure; (-)</td>
<td>The wear out of a cam of the camshaft; (II)</td>
<td>There was no failure; (-)</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Four cases of the burnout of the expansion joint; (I)</td>
<td>Three cases of the burnout of the expansion joint; (I) Two cases of the burnout of the seal between the cylinder head and the exhaust manifold; (II)</td>
<td>One case of the burnout of the expansion joint; (I)</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>One case of the clogging of the pipeline of the high-pressure fuel pumps (III)</td>
<td>Two cases of the contamination of oil with fuel; (II)</td>
<td>One case of the oil pump failure; (II)</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>One case of the leakage of the seal on the water cooler; (III)</td>
<td>There was no failure; (-)</td>
<td>One case of the failure of the cooling water thermostat; (II)</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Three cases of the faulty operation of the fuel injector; (II) One block in the operation of the high-pressure fuel pumps; (II)</td>
<td>Four cases of faulty operation of the fuel injector; (II) Two blocks in the operation of the high-pressure fuel pumps; (II)</td>
<td>Four faulty operations of the fuel injector; (II) One block in the operation of the high-pressure fuel pumps; (II)</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>There was no failure; (-)</td>
<td>There was no failure; (-)</td>
<td>There was no failure; (-)</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>One case of clogging of the suction filter preceding the air motor; (IV)</td>
<td>There was no failure; (-)</td>
<td>The air motor failure; (IV)</td>
<td></td>
</tr>
</tbody>
</table>

NOTE: (I, II, III and IV are the categories of failure in Table 1)
Preliminary Risk Analysis. Risk matrices for each subsystem in Table 4 were created for the years of 2016, 2017 and 2018 based on the failure analysis presented in Chapter 4.

In order to enhance this research, Fig. 3 shows only one risk matrix for the year of 2016 for the subsystem number one, known as "cylinder head". On the example of the subsystem 1 - "cylinder head" - five failures for the year of 2016 were analyzed and the failure frequency rate obtained is 5/365 = 0.014. This frequency corresponds to category C-likely (10-1 to 10-2). The category of consequences falls into I-catastrophic consequences category, based on failure types given in Table 5.

The application of Preliminary Risk Analysis (Fig. 3) on the subsystem 1 - "cylinder head" - indicates C-I position i.e. position 12, which corresponds to a high-risk failure according to the risk matrix.

![Fig. 3. Risk Matrix "cylinder head" for 2016](image)

**V.V. DISCUSSION**

The data presented in Table 6 were obtained through the application of the methodology previously defined i.e. the application of the PRA method to the other nine subsystems of the auxiliary engines for the years of 2016, 2017 and 2018. The table presents the risk levels (high, medium, small) per year for each subsystem considered.

<table>
<thead>
<tr>
<th>TABLE VI.</th>
<th>THE FINAL RESULTS OF RISK MATRICES OF ALL SUBSYSTEMS PER YEAR</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Risk levels per year</th>
<th>The subsystems of the auxiliary engine</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12</td>
<td>8</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>-</td>
<td>8</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>8</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>-</td>
<td>6</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>12</td>
<td>12</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>6</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>4</td>
<td>-</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>2</td>
<td>-</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

Table VI. leads to the following conclusions:

1. The "Aircooler and exhaust manifold" subsystem has the highest level of risk in the period of three years. The largest number of failures of this system was related to the burnout of the expansion joint, which required special attention in order to successfully reduce the risk level of this subsystem in 2018.

2. The "Cylinder block and liner" subsystem had a medium risk level in 2017 and 2018, while in 2016 there was no failure. This subsystem, in case of a failure, leads to catastrophic
consequences. In order to reduce the level of risk, it is necessary to reduce the frequency of the failures of the subsystem considered.

3. The "Starting air system and airmotor" subsystem had a low level of risk in 2016 and 2018, while in 2017 there was no failure. This subsystem in case of failure leads to negligible consequences and is very reliable in terms of failure frequency.

4. The "Fuel oil subsystem" had a medium level of risk in the period of three years. Failures of this subsystem in the period of three years led to critical consequences. As can be seen from Figure 2, the frequency of these failures has slightly changed, and therefore the risk level is the same for the three years.

5. The "Piston and connecting rod" subsystem had a medium level of risk in 2016 and 2017, while in 2018 the risk was high. This subsystem in case of failure leads to catastrophic consequences. In order to reduce the level of risk, it is necessary to reduce the frequency of failures of the subsystem, as seen in 2016 and 2017.

6. The "Cylinder head" subsystem had a high level of risk in 2016, while in 2017 and 2018 it the risk level was medium high. The failures of this subsystem mentioned in Table 4 lead to catastrophic consequences. Figure 2 indicates that the largest number of failures was in 2016, which implies the greatest failure frequency (Table 2) and the risk level.

7. The "Timing gear, camshaft and intake/exhaust swing arm" subsystem had a medium level of risk for in 2017, while in 2016 and 2018 there was no failure. This subsystem in case of failure leads to critical consequences and is very reliable in terms of failure frequency.

8. The "Lubricating oil subsystem" had a low level of risk in 2016, while in 2017 and 2018 there was a medium risk. The failure of this subsystem in 2016 could have marginal consequences while the failures in 2017 and 2018 of (Table 2) could have critical consequences.

9. The "Main bearing and crankshaft" subsystem did not have a failure in the period investigated.

10. The subsystem "Cooling water subsystem" had a medium level of risk for in 2018, while in 2016 and 2017 there were no failures. This subsystem in case of failure leads to critical consequences.

VI. CONCLUSION

The analysis of the ten vital subsystems of the Yamar 8EY26L engine (Table 6) shows that the subsystem "Aircooler and exhaust manifold" has a critical risk level. Considering the failures of this subsystem, as shown in Table 5, it can be concluded that the failures are mostly caused by expansion joint burnout. This failure represents a disadvantage of the auxiliary engines "Yanmar 8EY26L". Therefore, the failures should represent the subject of further analysis when it comes to engine design. It can also be concluded that the subsystems: "cylinder head" and "piston and piston rod" had a high level of risk during one of the years of observation. This signals the need of taking preventive maintenance measures and monitoring these subsystems. Other subsystems belong to the medium-level risk group and will be analyzed by various maintenance methods, in order to reduce the frequency of their failures and, hence, their risk level.

The methodology used and the research could be extended to a greater number of engines and a longer period of time in order to obtain historical data on critical subsystems and define a new maintenance practice. In that way the number of failures would be reduced while the reliability of the ship systems would increase.

REFERENCES


The Risk Assessment of The Dynamic Positioning System Based on Historical Data

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ABSTRACT
A large number of incidents in the offshore oil and gas industry have created a negative image of this industry. The numerous incidents resulted in many fatalities, injuries, massive pollution and economic losses. Many offshore vessels are equipped with the dynamic positioning system, a complex navigation system, in order to enable the most complicated operations in the offshore industry. In this paper, the risk assessment of the dynamical positioning system has been done based on historical data recorded over the period of nine years by the IMCA organization. In order to discover the weak points of the overall dynamic positioning system the risk analysis was conducted for four subsystems of this system, which are responsible for more than 72% of the total number of incidents.

KEYWORDS: dynamic positioning system, risk assessment, offshore incidents & international marine contractors association

I. INTRODUCTION
Offshore industry has been marked as a high-risk industry since its beginning due to the large number of incidents. Between 1981 and 2001, 376 people died in offshore incidents [1]. With the aim of risk control and in order to reduce the number of potential incidents, this industry very often relies on the experience from nuclear and other high-risk industries. From 2009 to 2015, 619 incidents were recorded in relation to the functioning of the dynamic positioning system in offshore industry [2].

The application of the ship dynamic positioning system enabled the exploration of oil basins at the great depths of seawater. The existence of these basins was previously known, but the technology was not developed for their exploration. The current record of oil drilling at the sea depth of 3400 meters has been achieved in 2016 by the Maersk drill ship [3]. By applying the dynamic positioning system, it is possible to perform the most complicated and risky operations in the offshore industry. The system is also applied within cruise industry, one of the largest cruise ships, m/v Oasis of The Sea, has recently been equipped with the dynamic positioning system class 2 [11]. Also, in 2017, the Wartsila company successfully tested a remote-controlled ship equipped with the dynamic positioning system in the North Sea, where the operator was located 8000 km away, in California [4].

II. DYNAMIC POSITIONING SYSTEM (DP SYSTEM)
Dynamic positioning system is a computer-controlled navigation system designed to automatically maintain the position and azimuth of the vessel within very strict tolerances using the propellers and the rudders [12]. A ship at sea is exposed to the effects of external forces that have the effect of changing the position of the ship [5]. The ship at the sea has 6 degrees of freedom of movement as shown in Fig. 1.

Fig. 1. Six degrees of freedom of ship motion [5]
The dynamic positioning system has the possibility to control only: surge, sway and yaw motion of the vessel. The dynamic positioning system components can be classified into 6 following groups [6]:

- Position reference system
- Environment reference system
- Heading reference system
- Propulsion system
- Power system
- Control system

The control system is processing the input sensors signals, a signal of a desired ship position set by the operator and by use of the mathematical model of ship motion control system is generating the control signals to the system of propellers in order to eliminate the ship position error.

![Fig. 2. Dynamic positioning system control system schematic [7]](image)

A. The IMO classification of the DP ships
The IMO organization defines 3 classes of the DP ships, in regard single failure influence to ships station keeping capability [8]:

- **IMO equipment class 1**, known also as DP1 system, in case of a single fault on one of the components of the system, the system will not be able to maintain the position of the ship.
- **IMO equipment class 2**, known also as DP2 system, in case of a single fault on one of the components of the system, the system will be able to maintain the position of the ship.
- **IMO equipment class 3**, known also as DP3 system, in addition to DP2 requirements for this system, it is also required that the parallel components of the system are placed in separate waterproof and fireproof compartments.

For each of the above-mentioned DP systems, IMO prescribes the requirements for related installed ship equipment, its configuration, testing and the system response in case of single fault in the system [8]. Classification societies also prescribe the rules related to the ships dynamic positioning system.

B. IMCA –International Maritime Contactor Association
The first IMO rules were adopted in 1994 and were in effect for twenty-three years [8] [13] while the technology and the industry safety requirements during that period were significantly changed and left plenty of non-regulated areas. During the above-mentioned period, IMCA emerged as an organization that prescribes standards in the field of the dynamic positioning systems. IMCA is a consultative IMO member and its primary goal is to collect data and standardize the processes of the industry, whose membership includes over nine hundred companies [9].

C. Testing of the ship DP system
For the dynamic positioning systems class 2 and 3, IMO requires an obligatory risk analysis by means of the DP FMEA (Dynamic Positioning Failure Mode Effect Analysis) method and a practical test of the results of this method through initial, annual, five-year and extraordinary surveys. IMCA defines the standards and methodology for the conducting of the FMEA method and its verifications by ship proof trials [10].
D. DP FMEA (Dynamic Positioning Failure Mode Effect Analysis) analysis

DP FMEA is an engineering analysis of the ship systems and its components, to a level of detail which can identify all potential failure modes and their influence on ship station keeping capabilities [8]. The analyses were conducted to check the redundancy of the ship systems and to confirm that the ship was constructed on that way that a single fault will not cause loss of ship’s position [8]. Basically, this method performs a risk analysis for each single failure mode where the risk is calculated as:

\[ \text{Risk} = \text{Frequency of the failure} \times \text{Severity (consequence) of the failure} \]

Example of IMCA risk matrix is shown in Fig. 3.

![IMCA risk matrix](image)

Severities of the failure mode as per IMCA regarding the DP system station keeping capabilities are calculated using the bellow table in Fig. 4.

![Failure mode severity table](image)

III. IMCA INCIDENTS REPORTS

As noted above, the basic objective of checking the dynamic positioning system of a ship by using DP FMEA and its proof tests is to establish that the ship is designed on that way that in the event of a single fault vessel will be able to keep its position. Based on an analysis of the IMCA DP incident reports between 2007 and 2015 it was found that 619 incidents occurred on the ships in DP mode [2]. The structure of DP incidents classified according to main cause and the year of occurrence is presented in Table I.
The DP incidents recorded by the IMCA organization are defined as dangerous situations with a potential to cause economic consequences, serious injury, fatality, a significant damage to the property, environment and the economic consequences [10].

A DP ship may lose the position in the following two scenarios: drive-off and drift-off. The drift-off occurs in case of insufficient thrust capacity, while the drive-off situation happens if the DP control system faultly detect that the ship is off the position and the system will give the command in order to change vessel position by using thrusters. [10]

The analysis of the annual trend shows that the number of incidents is relatively constant, while a slight increase is detected in the number of failures of the propulsion system (Fig. 5.).

![Trend of IMCA DP incidents](image)

**Fig. 5.** Trend of IMCA DP incidents over the period 2007-2015

By the analysis of the structure of the incidents, it was revealed that 82.4% of the incidents are caused through the fault of: computer system, human error, power system and position reference system (Figure 6).
IV. RISK ANALYSIS

In the further risk analyses of the dynamic positioning systems, only the faults of computer, propulsion, power, and references systems will be analysed as they constitute 72% of the total faults. Human errors will not be analysed due to the incomplete research data available.

A. Research method

The analysis was based on 619 ships, where the DP incidents were recorded by IMCA organization during the nine years or 3286 days of observation. The incidents were not classified according to the class of DP because IMCA in its annual reports doesn’t provide the information on the DP class, although the DP class is the most important factor regarding vessel station keeping possibility.

Preliminary analysis settings are:

- Risk is calculated as: Risk = The frequency of a failure X The severity of a failure
- One recorded DP incident is seen as one day.
- All DP incidents are classified into two following categories:
  - LOP: Loss of the ship position incidents (drive-offs and drift-offs)
  - PLP: potential loss of the ship position incidents (include reports not categorised as LOP)
- The severity of DP incidents is determined by the use of IMCA proposed pattern shown in Figure 4.
- The frequency of the incidents is determined by calculating the percentage of fault occurrence over the 3286 days of observation (9 years). On the basis of the percentage of fault occurrence calculated for 100 days, the frequency is evaluated by using the matrix shown in Table II.

<table>
<thead>
<tr>
<th>TABLE II. FREQUENCY MATRIX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>1</td>
</tr>
</tbody>
</table>

- As per proposed IMCA severity matrix (Figure 3) all LOP incidents will be classified as the severity class 5, while PLP incidents will be seen as the severity class 4.

B. Propulsion system risk analysis

As per IMCA description, propulsion system includes the following elements: main propellers and/or thrusters with drives, accompanying hydraulic systems, lubrication systems, emergency stops, steering gear, gearboxes, cooling system, control loops, manual, joystick and the DP interfaces [10].
After sorting and reviewing the data, it was found that the total number of the incidents was 116, including 17 drive-offs, 7 drift-offs and 92 other incidents [2]. After additional sorting of the data, the incidents are categorised into two groups as shown in Table III.

<table>
<thead>
<tr>
<th>Propulsion system incidents</th>
<th>LOP</th>
<th>PLP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of incidents</td>
<td>24</td>
<td>92</td>
</tr>
<tr>
<td>% of 619 incidents</td>
<td>3.87</td>
<td>14.86</td>
</tr>
<tr>
<td>% of incidents days (3286 days)</td>
<td>0.73</td>
<td>2.79</td>
</tr>
</tbody>
</table>

The risk of propulsion incidents is evaluated as per Table IV. by using the IMCA consequence pattern (Fig. 3.) and the frequency pattern adopted (Table II.).

<table>
<thead>
<tr>
<th>Risk Matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
</tr>
<tr>
<td>Frequent</td>
</tr>
<tr>
<td>Probable</td>
</tr>
<tr>
<td>Occasional</td>
</tr>
<tr>
<td>Remote</td>
</tr>
<tr>
<td>Improbable</td>
</tr>
<tr>
<td>Risk Frequency</td>
</tr>
<tr>
<td>X Consequence</td>
</tr>
</tbody>
</table>

C. Power system risk analysis

According to IMCA, the power system consists of the following elements: generators, voltage regulators, governors, generator, bus bar protection systems, power distribution (high, medium, and low voltage AC distribution systems), emergency systems configuration and distribution, the UPS systems, low voltage DC distribution systems and control power supplies, bus tiebreakers and breaker interlocks [3].

After the data processing, it was found that the total number of the incidents associated with the power system was 83 [2]. By additional data sorting, the incidents are classified as per Table V.

<table>
<thead>
<tr>
<th>Power system incidents</th>
<th>LOP</th>
<th>PLP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of incidents</td>
<td>24</td>
<td>59</td>
</tr>
<tr>
<td>% of 619 incidents</td>
<td>3.87</td>
<td>9.53</td>
</tr>
<tr>
<td>% of incidents days (3286 days)</td>
<td>0.73</td>
<td>1.79</td>
</tr>
</tbody>
</table>

The risk for the power system is evaluated as in Table VI using the previously adopted patterns to determine the consequence and frequency of a fault.

<table>
<thead>
<tr>
<th>Risk Matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
</tr>
<tr>
<td>Frequent</td>
</tr>
<tr>
<td>Probable</td>
</tr>
<tr>
<td>Occasional</td>
</tr>
<tr>
<td>Remote</td>
</tr>
<tr>
<td>Improbable</td>
</tr>
<tr>
<td>Risk Frequency</td>
</tr>
<tr>
<td>X Consequence</td>
</tr>
</tbody>
</table>
D. Computer system risk analysis
By organizing the data related to the computer system, it was found that the total number of the incidents was 96 [2]. By additional data sorting, the incidents are classified as per Table VII.

<table>
<thead>
<tr>
<th>Computer system incidents</th>
<th>LOP</th>
<th>PLP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of incidents</td>
<td>24</td>
<td>72</td>
</tr>
<tr>
<td>% of 619 incidents</td>
<td>3.87</td>
<td>11.63</td>
</tr>
<tr>
<td>% of incidents days (3286 days)</td>
<td>0.73</td>
<td>2.19</td>
</tr>
</tbody>
</table>

Based on previously defined patterns, the computer system has been evaluated as indicated in Table VIII.

<table>
<thead>
<tr>
<th>Reference system incidents</th>
<th>LOP</th>
<th>PLP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of incidents</td>
<td>23</td>
<td>76</td>
</tr>
<tr>
<td>% of 619 incidents</td>
<td>3.71</td>
<td>12.27</td>
</tr>
<tr>
<td>% of incidents days (3286 days)</td>
<td>0.69</td>
<td>2.31</td>
</tr>
</tbody>
</table>

E. Reference position system
The function of the reference system is to precisely, globally and relatively, determine the vessel position at sea. By sorting the data, it was found that the total fault number related to this system was 99 [2]. Table IX. is presented upon the final sorting of the consequences of the incidents.

<table>
<thead>
<tr>
<th>Reference system incidents</th>
<th>LOP</th>
<th>PLP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of incidents</td>
<td>23</td>
<td>76</td>
</tr>
<tr>
<td>% of 619 incidents</td>
<td>3.71</td>
<td>12.27</td>
</tr>
<tr>
<td>% of incidents days (3286 days)</td>
<td>0.69</td>
<td>2.31</td>
</tr>
</tbody>
</table>

The reference system has been evaluated as indicated in Table X.

V. Discussion
By evaluating the risk of the propulsion system, it can be seen that this system has a high risk for potential incidents while the actual position incidents belong to the medium risk group.

Regarding the power system, by analysis it was found that potential incidents have also a high risk but slightly lower comparing to propulsion system. As the function of the power system is the production
and distribution of electric energy, which is the crucial element of the functioning of other ship systems, calculated risk in Table 6 should be observed with attention.

For the computer system, a particularly high risk has been detected with potential incidents. As this system is a part of the DP control system [10], the high risk of the computer component is increasing the overall risk of the complete DP control system as the heart of the DP system.

After the risk analysis, it was determined that the reference system is operating in the area between high risks for potential incidents towards medium risk for actual incidents. As the reference system is providing important inputs for the DP control system, the reference system is influencing the reliability of the entire DP control system.

It is obvious that for the four systems screened, the risk of actual position loss is identical and belongs to the group of medium risk.

VI. CONCLUSION

By analysing the risk of the four ship systems it was found that the risk of the potential loss of the position of the propulsion and computer systems are identical and higher than the risks of the reference and power system. The reference and power system are identical in terms of risk group.

The high risk of the propulsion system can be explained by the fact that this system is the most complex system in terms of the number of its physical components, which besides actuators (propellers), involves drive motors, associated pipelines systems, and a variety of other equipment related. The increased number of components increases the possibility of the potential failure of each component, and therefore the overall risk.

Generally, the problems of the computer system are common for all computers and these problems include hardware and software ones. As the software includes a huge number of algorithms, mathematical models, software filters, etc. it is obvious that every single line of the program software could cause a problem related to the functioning of the computer system. The high risk can be explained as a consequence of the huge number of points where the software issues and hardware components issues may possibly arise and these possible failures are almost uncountable.

The reference system shows a lower risk compared to the previous two systems, which can be easily explained as a consequence of the high-level redundancy as well as the existence of the different types of sensors, in case of a sensor failure another sensor assumes the function of determining vessel position.

The power system even though the complex system but with much less consisting components than propulsion system also shows a lower level of risk in relation to the power and computer system and in this case it could be explained as a direct consequence of a properly designed system based on a good quality conducted DP FMEA analysis.

Theoretically, DP FMEA analysis with accompanying research should eliminate the occurrence of these faults. The occurrence of the incidents is a result of the low quality of the DP FMEA analysis conducted. The number of position loss failures could be reduced or mitigated by the application of a high-quality DP FMEA analysis. A good quality FMEA would emphasize the implementation of the necessary technical measures for the elimination consequence of DP system failures in case they occur. Based on the number of recorded DP incidents, it can be claimed that the definition of the stricter standards for conducting DP FMEA analysis, in accordance with IMCA, would additionally reduce the risk associated with the ship systems, especially with the propulsion and computer system.

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Use of PMS Continuous Improvement Scheme for Maintenance Adjustments in Shipping Industry

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ABSTRACT
Computerized Planned Maintenance Systems have been in use for more than thirty years in shipping industry. They are used for organizing and planning of the maintenance process as well as for recording of performed maintenance actions. Maintenance is carried out according to the maintenance plan that is inserted into the computerized Planned Maintenance System and should be modified over time, according user’s experience, i.e. user’s feedback. One of the forms of user’s feedback are records of the performed maintenance in the Planned Maintenance System. Those records, after comprehensive analysis, should be used as a source for maintenance modification. The Continuous Improvement Scheme is the functionality that every Computerized Planned Maintenance Systems must have. This scheme is one of the items that is monitored during annual survey of the System. The Scheme is designed to allow systematic reporting of detected shortcomings within the System as well as for suggesting different improvements. All changes within the Computerized Planned Maintenance Systems should be proposed through a Continuous Improvement Scheme. This includes the changes that are proposed by monitoring and analysing maintenance records. All changes within the Planned Maintenance System over time should be visible through this Scheme.

Authors of the article reviewed the Continuous Improvement Scheme in two shipping companies through computerized Planned Maintenance System. This paper presents the results of the review and the analysis of the usage and quality of the requests sent through the Scheme.

KEYWORDS: planned maintenance system, database, continuous improvement & maintenance interval adjustment

I. INTRODUCTION
There is a multitude of different Computerized Planned Maintenance Programs used in shipping industry today. Initially these programs were used only for organizing and planning of the maintenance process, while today they are used to manage a variety of tasks in the shipping industry [1]. Still, Planned Maintenance segment of the program remained core of the system. According to the ISM Code [2], every Computerized Planned Maintenance System (PMS) must have a Continuous Improvement Scheme, a functionality designed to allow systematic reporting of detected shortcomings or non-conformities [3] within the System as well as for suggesting various improvements (Fig.1.). The scheme also must have a control mechanism [4], which will alert in case of neglecting of the scheme.

There are several possible types of the Continuous Improvement Suggestions in the Continuous Improvement Scheme, seen in Fig.1. Those types (Groups) are:

1. Rectifying the mistakes entered in the beginning of usage of the PMS [5],
2. Inserting missing equipment, spares or work procedures,
3. Rectifying discovered bugs and/or glitches in the system,
4. Modifying Maintenance plan according user’s experience.
The first two groups of the Continuous Improvement Suggestions occur at the beginning of the usage of the program and are caused by shortcomings of the development of the database. Third type is linked to the program and is present during all time of program usage. Last type of the Continuous Improvement Suggestion should be linked to the analysis of the Computerized Planned Maintenance Program data after certain amount of the time.

The investigation into usage of the Continuous Improvement Scheme has been performed in two shipping companies. To obtain better results following criteria was selected for the shipping companies:

- Shipping companies are from different countries,
- Crews are from different countries,
- Different computerized Planned Maintenance Program is used,

This paper describes the process of the investigation into the usage of the Continuous Improvement Suggestions, showing all obtained results, especially regarding the last type of the Suggestion, modifications of the maintenance plan according user’s experience.

Although shipping industry is known for its conservatism and tradition [6], and crew often looks for a mode to simplify their daily work, discovered facts during this research were the surprise for all persons involved.

As both shipping companies allowed access to their data strictly under no disclosure condition, all details leading to identification of the ship and the company are removed from the article. Instead of their real names, companies will be named A and B.

II. COMPANY A CONTINUOUS IMPROVEMENT SCHEME

Company A allowed access to limited number of the ships in their database, sample of eleven ship’s PMS databases were rechecked during research of the use of the Continuous Improvement Scheme. SMS manual of the company A is determining that every six months at least one Continuous Improvement Suggestion for the PMS must be issued.

In Table I. Continuous Improvement Suggestions are divided according to the types of the Suggestion. Last column in the table is named “useless”, that word is describing quality of those proposals. Majority of that group in the proposal text has following:

- Nothing to propose,
- All in order,
- Done,
- Good.
### TABLE I. Usage of the Continuous Improvement Scheme (COMPANY A)

<table>
<thead>
<tr>
<th>Ship</th>
<th>Ship’s age</th>
<th>Continuous Improvement Suggestions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Total</td>
</tr>
<tr>
<td>1</td>
<td>18</td>
<td>41</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>18</td>
</tr>
<tr>
<td>3</td>
<td>11</td>
<td>39</td>
</tr>
<tr>
<td>4</td>
<td>12</td>
<td>26</td>
</tr>
<tr>
<td>5</td>
<td>17</td>
<td>38</td>
</tr>
<tr>
<td>6</td>
<td>4</td>
<td>21</td>
</tr>
<tr>
<td>7</td>
<td>19</td>
<td>56</td>
</tr>
<tr>
<td>8</td>
<td>6</td>
<td>28</td>
</tr>
<tr>
<td>9</td>
<td>14</td>
<td>36</td>
</tr>
<tr>
<td>10</td>
<td>11</td>
<td>31</td>
</tr>
<tr>
<td>11</td>
<td>7</td>
<td>53</td>
</tr>
<tr>
<td></td>
<td></td>
<td>387</td>
</tr>
</tbody>
</table>

Overall usage of the Continuous Improvement Suggestions of the Company A is shown in Fig. 2. The largest part (almost 60%) of all Suggestions are in the Useless group, extremely small amount of suggestions (0, 52%) belongs to the Group 4.

---

**III. COMPANY B CONTINUOUS IMPROVEMENT SCHEME**

According to obtained PMS database from Company B, six ships were analyzed for using Continuous Improvement Scheme. Reason for research in Company B is to determine how often Continuous Improvement Suggestions in PMS are used in new-build ships (average ship’s age = 4 years), unlike ships in Company A. Continuous Improvement Suggestions for Company B are systemized in Table 2. due to type of suggestion.
### TABLE II. Usage of the Continuous Improvement Scheme (Company B)

<table>
<thead>
<tr>
<th>Ship</th>
<th>Ship’s age</th>
<th>Continuous Improvement Suggestions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Total</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>13</td>
</tr>
<tr>
<td>5</td>
<td>7</td>
<td>24</td>
</tr>
<tr>
<td>6</td>
<td>7</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td></td>
<td>83</td>
</tr>
</tbody>
</table>

Overall suggestion usage for Company B is shown in Fig. 2. Continuous Improvement Suggestions percentage are similar to Company A, where majority of suggestion are in Useless group (67.47%) due to lack of explanation and useful information of suggestions. Maintenance plan suggestions according to user’s experience are in Group 4 with only 2 suggestions from total of 83.

![Continuous Improvement Suggestion usage (Company B)](image)

**Fig. 3.** Continuous Improvement Suggestion usage (Company B)

### IV. Results and Discussion

Overall suggestion results from A and B Company are shown in Fig. 4. From total of 470 suggestions, 285 belongs in Useless group, 104 in Group 1, 71 in Group 2, 6 in Group 3 and 4 in Group 4. First group with 104 suggestions (22, 13%) are mistakes entered in the beginning of usage of the PMS. Missing equipment or spare parts (for example: ME lubricating oil separator, ME injection valve, bearings for steering gear pump etc.) and also work procedures (commented such as: Analysed all corrective work, pump tested – working properly etc.) are in group 2 with share of 15.11 % (71 suggestion). Small number of discovered bugs and glitches (6 suggestions) are in group 3. Maintenance modifications according to user’s experience are in group 4 with only 4 suggestions (0, 85%) to modify or improve maintenance plan.
A. Improvements of the Company A Maintenance plan

There are only two suggestions for the improvement of the Maintenance process in all analysed databases. Both suggestions are incomplete, missing supporting data. The first suggestion is the extension of the air compressor system maintenance period, suggestion submitted by the vessel Chief Engineer. In the records there are no traces of the analysis or calculations prior to submitting the suggestion. Reasons for the suggestion remained unknown. The second suggestion issued by 3rd Engineer and endorsed by Chief Engineer, the request to decrease period of cleaning of diesel generator fuel filters, is also missing vital data. It is not clear why the suggestion was issued and what should be the new period and duration of changed maintenance plan.

B. Improvements of the Company B Maintenance plan

In analysed databases of Company B there are two suggestions for modifying Maintenance plan. According to user’s feedback, first suggestion is that some jobs are not applicable for these ships such as main engine integrated balancer, lubricating oil cooler and fresh water cooler, suggesting that rejection of this jobs for maintenance is better solution. However, this suggestion is missing explanation and data to verify this statement. Second suggestion is to replace ball bearing on auxiliary engine supply fuel pump which will decrease periodical preventive jobs. Reasons for decreasing preventive jobs are unknown and there are no vital data necessary for this suggestion.

V. Conclusion

Adequate managing and maintaining of marine machinery require use of the appropriate Planned Maintenance Program with segment of Continuous improvement scheme. Purpose of this scheme is to detect shortcoming in system and to suggest necessary improvements. Research results have shown that in two companies only four suggestions were found requiring the modification of the maintenance plan. Considering the amount of examined data, that quantity is extremely small. However, these suggestions are missing data and explanations to verify their suggestions and are mostly unprepared. As suggestions were issued by experienced and knowledgeable crew members in the engine department, it was expected that suggestions should be well founded and reasonable, as well explained.

Overall results show that usage of the Continuous improvement system in the Planned Maintenance System is mostly limited to rectifying the mistakes in the PMS and inserting missing equipment, spares or work procedures. Usage of the system for rectifying discovered bugs and/or glitches in the system is...
minor (as analysed PMS programs are in use for a significant period, most of the bugs in the system are already rectified), and usage for modification of the maintenance plan according user’s experience is heavily neglected.

This research shows that use of PMS Continuous improvement scheme for maintenance adjustments in shipping industry is either neglected or the safety and economic potential is not recognized. Analysis of the PMS data and resulting maintenance plan improvements can significantly decrease costs of maintenance and expand life cycle of all systems on board, as well as improve safety of the ship in general. To enable cost reduction, it is necessary to emphasise to the crew the importance of proper usage of this scheme and the data inside PMS, and what are the benefits of this scheme.

REFERENCES


Application of AIS Data for Qualitative and Quantitative Analysis of Ship Traffic Flows

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ABSTRACT
The article presents the idea of method of processing AIS data into information useful for qualitative and quantitative analysis of ship traffic flows. In the introduction the manner of exchanging and storing data in AIS was generally characterised. An original programme for creating maps of ship traffic intensity and tabular ship profiles was described in the main part. The last part presents analysis of ship traffic flows in the Gdańsk Bay in the year 2017, conducted with the use of the original software.

KEYWORDS: Automatic Identification System, qualitative and quantitative analysis & processing AIS data

I. INTRODUCTION
Safety in the sea is determined by the state of environmental conditions, objects in motion and organisation and realisation of human activity, which does not cause danger to the traffic of water drafts, human life and environment.

Safety conditions in a particular reservoir can be evaluated on the basis of depiction of ship traffic. Information regarding the traffic, depending on situation of the reservoir, can be obtained by applying different methods of observation, including AIS.

The static and dynamic AIS data describing depiction of ship traffic, after adequate processing can be very useful for executing qualitative and quantitative analysis.

AIS – Automatic Identification System is a system operating in the VHF sequence, working automatically and providing information in interfaces: ship-to-ship, ship-to-airborne SAR unit and ship-to-coast station, also including coastal base station.

According to the SOLAS Convention, AIS should automatically provide adequately equipped coastal stations, other ships and planes with information concerning identity of ships, type, position, course, speed, navigational status and other information that increases safety. It should also automatically receive such information from ships similarly equipped with this system, monitor, keep track of ships and exchange data with apparatus of coastal stations.

Information conveyed through AIS contain data regarding number of ships in a particular area, including their identity, type, length, width, immersion, cargo type, position, course and speed in relation to sea bed.

AIS also allows for displaying of ship traffic on an electronic map and a radar, supplying information to VTS centres, monitoring of obligatory and recommended routes, calculating of required surface of water lane and a ship’s width, and plenty of other information which can be collected, archived and aimed for statistic purposes. Analysing AIS data one can:

• obtain information about number and size of different types of ships employing various shipping routes;
• improve safety of shopping through broadening of knowledge on the subject of requirements for navigational support systems and ship traffic;
• improve effectiveness and efficiency of planning, managing and maintaining of shipping routes, including support for navigation and ship traffic control;
• provide data for risk analysis;
provide data for long-term planning;
provide data for investigation of maritime accidents.

AIS data can also be collected from local, regional, state and international network systems of base stations and can be applied for further improvement in quality of services provided in maritime transportation.

II. GATHERING AND PROCESSING OF AIS DATA

For the purpose of conducting research we used the AIS data set from the area of the Gdańsk Bay stored in the year 2017 in a state data base of the Polish system AIS-PL (which was made available by Maritime Office in Gdynia for research purposes) [5]. This set is composed of daily files with „raw” AIS announcements with collective volume of approx. 8.6 GB [2][3]. On its basis we prepared:

- a quantitative profile – based on the layout of traffic intensity. A GRID-type file with mesh resolution 2" was used for its development,
- qualitative profiles – based on tabular files, utilised in the programme Microsoft Excel for building statistics with breakdown by type, immersion and ship length.

These profiles constituted a result source of information prepared for execution of qualitative and quantitative analysis.

GRID-type files have a form of regular grid of squares. Each of the squares was matched with a value referring to a number of ships „dwelling” in it in a given time period, determined as a result of analyses of relative positions of subsequent segments along which the water drafts cruise and segments limiting particular meshes in the GRID network (Figure no. 1).

![Geometrical interpretation of the method of establishing value for a mesh in the GRID network](image)

Figure no. 1 presents a fragment of a GRID network (its four meshes) and two trajectories of ship movement, which were established on the basis of coordinates of ship positions. The ships were tracked in the AIS system. Inside of each mesh (square) there is a knot that is matched with a value determined as a result of analysis of relative positions of subsequent segments along which the water draft cruises and segments limiting particular meshes in the GRID network. Value of the knot is increased by one, if the segment along which the water draft cruises is crossed by one of the segments forming sides of the square limiting the mesh of the knot. The water draft which Has caused the increase of the value in a
knot can cause another increase by one only when another segment of its trajectory of movement crosses one of the segments forming sides of a square limiting another mesh. Due to this, one can avoid a multiple reaction of the same water draft with the same knot. It has a special significance in case of announcements with position coordinates (no. 1·3·18), which can be transmitted with high frequency (even every 2 seconds) – depending on the navigational status, speed of the ship and its manner of manoeuvring [2]. Below we present the dependents used for determining of coordinates (X, Y) of the point of crossing of straight lines going through points A(x₁, y₁) and B(x₂, y₂), forming another segment of trajectory of ships’ movement and straight lines crossing the sides of the square of the mesh for each knot in the GRID network:

\[ Y = \frac{y_2 - y_1}{x_2 - x_1} (Gi - x_1) + y_1 \]  

\[ X = \frac{x_2 - x_1}{y_2 - y_1} (Gj - y_1) + x_1 \]

Calculated coordinates of the point should be located on the analysed line of the side of the square, which means that the water draft has entered the mesh zone and that the knot value should be increased by one.

Below we present the format of the GRID result network saved in an output file [4].

```
ncols    10
nrows    10
xllcorner 18.00000000
yllcorner 54.00000000
cellsize  0.00027778
NODATA_value  0
0 0 0 0 2 0 0 0 0 0
0 0 0 0 0 1 0 0 0 0
0 0 0 1 0 0 0 1 0 0
0 0 0 0 0 0 2 0 0 0
0 0 0 0 0 3 0 0 0 0
0 0 0 2 0 0 1 0 0 0
0 0 0 2 0 0 1 0 0 0
0 0 2 0 0 1 0 0 0 0
0 0 2 0 0 0 0 0 1 0
2 2 0 0 0 0 0 1 0
0 0 0 0 0 0 0 0 1 0
```

This file can be imported by applications of GIS type (Geographic Information Systems), such as: MapInfo, ArcGIS and subsequently used in those programmes for creating maps with layouts of ship traffic intensity with cartographical basis (e.g. in cartographic modelling of Merkator).

In turn, output tabular files can be imported by applications with functionality of a spreadsheet e.g. Microsoft Excel and subsequently utilised for creating statistics of qualitative ship movements.

This file is produced as a result of appropriate processing of announcements with static information about a ship, i.e. no. 5 and 24 to a text format [2]. It contains a numerical tally of ships with breakdown by type compliant with ITU-R M.1371-5 (Tab. No. 1), immersion, length and class of used AIS transponder and class of used AIS transponder.

Table no. 1 Breakdown of ships by type applied in AIS [2, p. 114].
<table>
<thead>
<tr>
<th>Identifier No.</th>
<th>Ship Type</th>
<th>Special craft</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>Pilot vessel</td>
<td></td>
</tr>
<tr>
<td>51</td>
<td>Search and rescue vessels</td>
<td></td>
</tr>
<tr>
<td>52</td>
<td>Tugs</td>
<td></td>
</tr>
<tr>
<td>53</td>
<td>Port tenders</td>
<td></td>
</tr>
<tr>
<td>54</td>
<td>Vessels with anti-pollution facilities or equipment</td>
<td></td>
</tr>
<tr>
<td>55</td>
<td>Law enforcement vessels</td>
<td></td>
</tr>
<tr>
<td>56</td>
<td>Spare – for assignments to local vessels</td>
<td></td>
</tr>
<tr>
<td>57</td>
<td>Spare – for assignments to local vessels</td>
<td></td>
</tr>
<tr>
<td>58</td>
<td>Medical transports (as defined in the 1949 Geneva Conventions and Additional Protocols)</td>
<td></td>
</tr>
<tr>
<td>59</td>
<td>Ships and aircraft of States not parties to an armed conflict</td>
<td></td>
</tr>
</tbody>
</table>

**Other ships**

<table>
<thead>
<tr>
<th>First digit(^{(1)})</th>
<th>Second digit(^{(1)})</th>
<th>First digit(^{(1)})</th>
<th>Second digit(^{(1)})</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 – Reserved for future use</td>
<td>0 – All ships of this type</td>
<td>–</td>
<td>0 – Fishing</td>
</tr>
<tr>
<td>2 – WIG</td>
<td>1 – Carrying DG, HS, or MP, IMO hazard or pollutant category X(^{(2)})</td>
<td>–</td>
<td>1 – Towing</td>
</tr>
<tr>
<td>3 – See right column</td>
<td>2 – Carrying DG, HS, or MP, IMO hazard or pollutant category Y(^{(3)})</td>
<td>3 – Vessel</td>
<td>2 – Towing and length of the tow exceeds 200 m or breadth exceeds 25 m</td>
</tr>
<tr>
<td>4 – HSC</td>
<td>3 – Carrying DG, HS, or MP, IMO hazard or pollutant category Z(^{(2)})</td>
<td>–</td>
<td>3 – Engaged in dredging or underwater operations</td>
</tr>
<tr>
<td>5 – See above</td>
<td>4 – Carrying DG, HS, or MP, IMO hazard or pollutant category OS(^{(2)})</td>
<td>–</td>
<td>4 – Engaged in diving operations</td>
</tr>
<tr>
<td>6 – Passenger ships</td>
<td>5 – Reserved for future use</td>
<td>–</td>
<td>5 – Engaged in military operations</td>
</tr>
<tr>
<td>7 – Cargo ships</td>
<td>6 – Reserved for future use</td>
<td>–</td>
<td>6 – Sailing</td>
</tr>
<tr>
<td>8 – Tanker(s)</td>
<td>7 – Reserved for future use</td>
<td>–</td>
<td>7 – Pleasure craft</td>
</tr>
<tr>
<td>9 – Other types of ship</td>
<td>8 – Reserved for future use</td>
<td>–</td>
<td>8 – Reserved for future use</td>
</tr>
<tr>
<td></td>
<td>9 – No additional information</td>
<td>–</td>
<td>9 – Reserved for future use</td>
</tr>
</tbody>
</table>

DG: dangerous goods  
HS: harmful substances  
MP: marine pollutants  
\(^{(1)}\) The identifier should be constructed by selecting the appropriate first and second digits.
Identifiers to be used by ships to report their type

(2) NOTE 1 – The digits 1, 2, 3 and 4 reflecting categories X, Y, Z and OS formerly were categories A, B, C and D.

Figure no. 2 presents the main window of the original programme application for creating of the described GRID type files and tabular files.

This application was prepared in the integrated environment of application development C++ Builder 10.2.3. It is compatible with the operating system Windows 10 [1].
III. OBTAINED RESULTS

A. Quantitative profile

![Image: Layout of ship traffic intensity in the Gdańsk Bay in the year 2017](image)

Fig. 3. Layout of ship traffic intensity in the Gdańsk Bay in the year 2017

B. Qualitative profile

Overall, 3168 ships were registered, of which 2660 (84.0%) had AIS transponders of class A and 508 (16.0%) transponders of class B.

<table>
<thead>
<tr>
<th>Ship type</th>
<th>Number of ships</th>
<th>Percentage</th>
<th>Number of ships / Number of ships in total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vessel - fishing [30]</td>
<td>176</td>
<td>5.6%</td>
<td>176/3168</td>
</tr>
<tr>
<td>Vessel - towing [31]</td>
<td>7</td>
<td>0.2%</td>
<td>7/3168</td>
</tr>
<tr>
<td>Vessel - towing and length of the tow exceeds 200 m or breadth exceeds 25 m [32]</td>
<td>19</td>
<td>0.6%</td>
<td>19/3168</td>
</tr>
<tr>
<td>Vessel - engaged in dredging or underwater operations [33]</td>
<td>25</td>
<td>0.8%</td>
<td>25/3168</td>
</tr>
<tr>
<td>Vessel - engaged in diving operations [34]</td>
<td>9</td>
<td>0.3%</td>
<td>9/3168</td>
</tr>
<tr>
<td>Vessel - engaged in military operations [35]</td>
<td>56</td>
<td>1.8%</td>
<td>56/3168</td>
</tr>
<tr>
<td>Vessel - sailing [36]</td>
<td>105</td>
<td>3.3%</td>
<td>105/3168</td>
</tr>
<tr>
<td>Vessel - pleasure craft [37]</td>
<td>35</td>
<td>1.1%</td>
<td>35/3168</td>
</tr>
<tr>
<td>Vessel - reserved for future use [38]</td>
<td>2</td>
<td>0.1%</td>
<td>2/3168</td>
</tr>
<tr>
<td>Vessel - reserved for future use [39]</td>
<td>2</td>
<td>0.1%</td>
<td>2/3168</td>
</tr>
<tr>
<td>High-speed craft (HSC) [40]</td>
<td>10</td>
<td>0.3%</td>
<td>10/3168</td>
</tr>
<tr>
<td>High-speed craft (HSC) - carrying DG, HS, or MP, IMO hazard or pollutant category X [41]</td>
<td>3</td>
<td>0.1%</td>
<td>3/3168</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td>---</td>
<td>-----</td>
<td>-------</td>
</tr>
<tr>
<td>High-speed craft (HSC) - carrying DG, HS, or MP, IMO hazard or pollutant category OS [44]</td>
<td>16</td>
<td>0.5%</td>
<td>16/3168</td>
</tr>
<tr>
<td>High-speed craft (HSC) - reserved for future use [45]</td>
<td>8</td>
<td>0.3%</td>
<td>8/3168</td>
</tr>
<tr>
<td>High-speed craft (HSC) - reserved for future use [48]</td>
<td>17</td>
<td>0.5%</td>
<td>17/3168</td>
</tr>
<tr>
<td>High-speed craft (HSC) - no additional information [49]</td>
<td>5</td>
<td>0.2%</td>
<td>5/3168</td>
</tr>
<tr>
<td>Pilot vessel [50]</td>
<td>3</td>
<td>0.1%</td>
<td>3/3168</td>
</tr>
<tr>
<td>Search and rescue vessels [51]</td>
<td>8</td>
<td>0.3%</td>
<td>8/3168</td>
</tr>
<tr>
<td>Tugs [52]</td>
<td>100</td>
<td>3.2%</td>
<td>100/3168</td>
</tr>
<tr>
<td>Port tenders [53]</td>
<td>4</td>
<td>0.1%</td>
<td>4/3168</td>
</tr>
<tr>
<td>Vessels with anti-pollution facilities or equipment [54]</td>
<td>3</td>
<td>0.1%</td>
<td>3/3168</td>
</tr>
<tr>
<td>Law enforcement vessels [55]</td>
<td>7</td>
<td>0.2%</td>
<td>7/3168</td>
</tr>
<tr>
<td>Spare – for assignments to local vessels [56]</td>
<td>5</td>
<td>0.2%</td>
<td>5/3168</td>
</tr>
<tr>
<td>Spare – for assignments to local vessels [57]</td>
<td>1</td>
<td>0.0%</td>
<td>1/3168</td>
</tr>
<tr>
<td>Passenger ships - all ships of this type [60]</td>
<td>45</td>
<td>1.4%</td>
<td>45/3168</td>
</tr>
<tr>
<td>Passenger ships - carrying DG, HS, or MP, IMO hazard or pollutant category X [61]</td>
<td>7</td>
<td>0.2%</td>
<td>7/3168</td>
</tr>
<tr>
<td>Passenger ships - carrying DG, HS, or MP, IMO hazard or pollutant category Y [62]</td>
<td>1</td>
<td>0.0%</td>
<td>1/3168</td>
</tr>
<tr>
<td>Passenger ships - carrying DG, HS, or MP, IMO hazard or pollutant category Z [63]</td>
<td>1</td>
<td>0.0%</td>
<td>1/3168</td>
</tr>
<tr>
<td>Passenger ships - carrying DG, HS, or MP, IMO hazard or pollutant category OS [64]</td>
<td>16</td>
<td>0.5%</td>
<td>16/3168</td>
</tr>
<tr>
<td>Passenger ships - reserved for future use [65]</td>
<td>4</td>
<td>0.1%</td>
<td>4/3168</td>
</tr>
<tr>
<td>Passenger ships - no additional information [69]</td>
<td>39</td>
<td>1.2%</td>
<td>39/3168</td>
</tr>
<tr>
<td>Cargo ships - all ships of this type [70]</td>
<td>1233</td>
<td>38.9%</td>
<td>1233/3168</td>
</tr>
<tr>
<td>Cargo ships - carrying DG, HS, or MP, IMO hazard or pollutant category X [71]</td>
<td>106</td>
<td>3.3%</td>
<td>106/3168</td>
</tr>
<tr>
<td>Cargo ships - carrying DG, HS, or MP, IMO hazard or pollutant category Y [72]</td>
<td>14</td>
<td>0.4%</td>
<td>14/3168</td>
</tr>
<tr>
<td>Cargo ships - carrying DG, HS, or MP, IMO hazard or pollutant category Z [73]</td>
<td>9</td>
<td>0.3%</td>
<td>9/3168</td>
</tr>
<tr>
<td>Cargo ships - carrying DG, HS, or MP, IMO hazard or pollutant category OS [74]</td>
<td>13</td>
<td>0.4%</td>
<td>13/3168</td>
</tr>
<tr>
<td>Cargo ships - reserved for future use [75]</td>
<td>5</td>
<td>0.2%</td>
<td>5/3168</td>
</tr>
<tr>
<td>Cargo ships - reserved for future use [76]</td>
<td>14</td>
<td>0.4%</td>
<td>14/3168</td>
</tr>
<tr>
<td>Cargo ships - reserved for future use [77]</td>
<td>15</td>
<td>0.5%</td>
<td>15/3168</td>
</tr>
<tr>
<td>Cargo ships - reserved for future use [78]</td>
<td>12</td>
<td>0.4%</td>
<td>12/3168</td>
</tr>
<tr>
<td>Cargo ships - no additional information [79]</td>
<td>260</td>
<td>8.2%</td>
<td>260/3168</td>
</tr>
<tr>
<td>Tanker(s) - all ships of this type [80]</td>
<td>213</td>
<td>6.7%</td>
<td>213/3168</td>
</tr>
<tr>
<td>Tanker(s) - carrying DG, HS, or MP, IMO hazard or pollutant category X [81]</td>
<td>40</td>
<td>1.3%</td>
<td>40/3168</td>
</tr>
<tr>
<td>Tanker(s) - carrying DG, HS, or MP, IMO hazard or pollutant category Y [82]</td>
<td>33</td>
<td>1.0%</td>
<td>33/3168</td>
</tr>
<tr>
<td>Tanker(s) - carrying DG, HS, or MP, IMO hazard or pollutant category Z [83]</td>
<td>17</td>
<td>0.5%</td>
<td>17/3168</td>
</tr>
<tr>
<td>Tanker(s) - carrying DG, HS, or MP, IMO hazard or pollutant category OS [84]</td>
<td>11</td>
<td>0.3%</td>
<td>11/3168</td>
</tr>
<tr>
<td>Tanker(s) - reserved for future use [85]</td>
<td>4</td>
<td>0.1%</td>
<td>4/3168</td>
</tr>
<tr>
<td>Type of Ship</td>
<td>Number</td>
<td>Percentage</td>
<td>Total</td>
</tr>
<tr>
<td>-----------------------------------------------------------------------------</td>
<td>--------</td>
<td>------------</td>
<td>-------</td>
</tr>
<tr>
<td>Tanker(s) - reserved for future use [88]</td>
<td>5</td>
<td>0.2%</td>
<td>5/3168</td>
</tr>
<tr>
<td>Tanker(s) - all ships of this type [89]</td>
<td>124</td>
<td>3.9%</td>
<td>124/3168</td>
</tr>
<tr>
<td>Other types of ship [90]</td>
<td>49</td>
<td>1.5%</td>
<td>49/3168</td>
</tr>
<tr>
<td>Other types of ship - carrying DG, HS, or MP, IMO hazard or pollutant category Y [92]</td>
<td>14</td>
<td>0.4%</td>
<td>14/3168</td>
</tr>
<tr>
<td>Other types of ship - carrying DG, HS, or MP, IMO hazard or pollutant category Z [93]</td>
<td>2</td>
<td>0.1%</td>
<td>2/3168</td>
</tr>
<tr>
<td>Other types of ship - reserved for future use [96]</td>
<td>4</td>
<td>0.1%</td>
<td>4/3168</td>
</tr>
<tr>
<td>Other types of ship - reserved for future use [97]</td>
<td>2</td>
<td>0.1%</td>
<td>2/3168</td>
</tr>
<tr>
<td>Other types of ship - carrying DG, HS, or MP, IMO hazard or pollutant category Y [99]</td>
<td>25</td>
<td>0.8%</td>
<td>25/3168</td>
</tr>
<tr>
<td>Other types of ship - no additional information [99]</td>
<td>156</td>
<td>4.9%</td>
<td>156/3168</td>
</tr>
<tr>
<td>Undefined [0]</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

**Fig. 4.** Percentage breakdown of ships by immersion

**Fig. 5.** Numerical breakdown of ships by length
IV. CONCLUSIONS

The presented method of processing AIS data could automate the process of examining the state of environmental conditions, objects in motion, organization and realization of human activity in the sea.

Obtained results in the form of:

- map of layout of ship traffic intensity allow for determining of the number of ships cruising through the area in shape of an ellipsoidal trapezium with a given side length (in the research the length of 2" was adopted) in a particular period of time (in the research the period of 1 year was adopted),
- numerical tallies of ships with breakdown by type of transponder and a ship, immersion and length,

constitute useful information about quantitative and qualitative profiles of ship traffic. On their basis one can evaluate the safety conditions of shipping in a maritime reservoir. However, it should be remembered that this evaluation should be executed in connection with analysis of many other coefficients describing e.g.: reservoir, water drafts, positioning systems, hydro-meteorological conditions, navigational infrastructure, systems of control and traffic surveillance, which could also cause danger for water drafts, human life and natural environment.

REFERENCES


Streamlining Logistics Services Via Collaboration Platforms

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ABSTRACT
Logistics operators, who are actively included in numerous logistics processes, cooperate with various stakeholders in logistics chain. Such complex cooperation with a large number of stakeholders needs unobstructed information flows resulting in up-to-date, accurate and timely information. The communication between stakeholders could be improved via the implementation of collaboration platforms. In this paper, trends in providing of logistics services will be identified, some challenges that arise in switching to collaboration platforms will be researched, and the potential benefits of collaboration platform implementation will be presented.

KEYWORDS: collaboration platforms, logistics operators & information flows

I. INTRODUCTION
The increased necessity of collaboration in the supply chain requires the adaptation and digitalization of logistics services. In the adaptation process, the need for optimization of information flows between all logistic operators is especially emphasized. Although the adaptation is inevitable, a large number of logistics operators still provide their services by using phones, emails, fax machines, and paper documents [1]. Logistics operators need to adapt their business models with the final aim to streamline logistics services. Demanding customers expect logistics services to be completely in accordance with their requirements. Although logistics operators are aware of the need to adapt, most of them have not changed their business models. This gap between old and new business models could be overcome by the implementation of collaboration platforms. There are three characteristics of collaboration: sharing of real time information, alignment of interest of individuals and organizations and standardization of processes [2]. Collaboration based business models not only facilitate costs and improved customer service through shared information/assets and better coordination of collaborative network activities, but they also generate synergistic benefits that companies cannot achieve individually [3]. Logistic service providers are resorting to collaboration in order to consolidate or improve their market position [4]. The business goal of the digital supply chain is to deliver the right product into the customer’s hands as quickly as possible — but also to do so responsively and reliably, while increasing efficiency and cutting costs through automation. This goal cannot be achieved unless the supply chain is fully integrated, seamlessly connecting suppliers, manufacturing, logistics, warehousing, and customers, and driven through a central cloud-based command center [5]. The potential of collaboration platforms is not sufficiently recognized and valorized while at the same time logistics operators are striving to improve information flows. Collaboration platforms possess great potential to streamline logistics services.

II. COLLABORATIVE LOGISTICS SERVICES
The evolution of logistics services driven by digitalization will create changes in logistics operators’ business model. Emerging digital technologies are fundamentally transforming the supply chain landscape. To stay one step ahead, business leaders in this field need to grasp the opportunities digitalization presents – both to evolve the existing business model but also to fundamentally rethink logistics operations in order to remain competitive in the digital age [6]. The key to providing these changes are collaborative organizational structures, processes and mechanisms including new business models and customer access or involvement [7].
According to the survey “The Evolving Freight Forwarding Market 2017,” conducted by the Logistics Trends&Insights, participants were asked which improvement would they utilize the most over the course of the next five years. Survey respondents stated as follows: 58% of shippers said “digitization,” while 92% of participants said “digitization adds value.”

The survey of business performance of 20 leading forwarders conducted by booking platform Freightos showed the following results: 15 forwarders use online forms and 9 forwarders provide instant quoting or ad-hoc request of quotation form. The survey results also identified a lack of customer friendly online features and focus mostly on classical model of communication e.g. mails, phone calls etc. The survey results pointed out the necessity to implement collaboration platforms.

As logistics services become more complex with very demanding customers’ requirements (price, quality, availability, visibility, delivery service...etc.), it is necessary to increase connectivity and harmonization by merging stakeholders and processes. Inadequate information flows can present a great obstacle, because logistics services should be reliable, accurate, non-time-consuming, transparent, effective and sustainable. Information storage and retrieval should be centralized: located in one place and accessible by all stakeholders, which could be achieved via the implementation of collaboration platforms.

A collaborative platform is a user interface that enables different parties from the entire supply chain to enter, view, and use data where it is most relevant to their actions in the logistics process. This sort of technology has only become viable with recent advances in cloud computing that allows users from anywhere in the world to access and work off the same databases from any mobile device. The huge advantage of a collaborative platform over EDI is that platforms allow for strict process controls throughout the entire supply chain when entering and using data - from warehouses to truckers, ocean carriers, forwarders, etc. These controls create data standards in an industry inundated with so many varying processes and vendors.

There are some main reasons for implementation of collaboration platforms to streamline logistics services:

- Increasingly demanding consumers: logistics operators need a system which is capable of responding instantly to customers’ needs, and is able to adapt to continuously demanding customers who demand fast and reliable services.
- The arrival of newcomers on the market: companies must compete with online services, enabling direct contact in a real time via electronic platforms. Traditional service models are no longer viable.
- Proliferation of stakeholders: logistics service process is complex, including numerous stakeholders (suppliers, distributors, carriers, etc.) who work to fulfil customers’ requirements.

Leading logistics operators started to adapt and to transform business models, and the full implementation of collaboration platforms should follow. Deloitte conducted the analysis of the global trends which will affect seaport industry, and among other aspects has determined that one of the leading trends is the digitalization of logistics. The increasing need to digitize the information streams and data exchange will become the comparative advantage of seaports. PricewaterhouseCoopers devised a study to attempt to analyze the main issues of the future of logistics industry. The study determined that customers’ expectations for faster, flexible, more transparent shipments would increase rapidly. In addition, collaboration will be the key to achieve more efficiency.

Although the collaboration platforms present significant potential, they are not yet recognized as a driving force for transformation of logistics services. Digitalization process, demanding customers and companies that recognize the collaboration platforms potential will surely prompt the implementation of collaboration platforms.
III. IMPLEMENTATION CHALLENGES—SWITCHING TO COLLABORATIVE MODE

Streamlining logistics services via collaboration platforms implies the transformation of business models: the upgrade and modification of existing models or the creation of new models. Regardless of the transformation mode, it is necessary to implement collaboration platforms which are simple to use and able to adjust to customers’ requirements.

The implementation of collaboration platforms does not follow a “prescribed” model, there are issues and challenges to be examined and solved in order to create an efficient collaboration platform. The complexity of transformation faces the logistics operators with a demanding task, they must be ready to find an adequate response to challenges, which could be summarized as follows (Figure 1) [14]:

1. Customer experience: fulfilling customers’ expectations is the trigger for a transformation of the current business model. The key is the collaboration between all parties involved and the implementation of collaboration platforms, which are able to provide "tailor made" services which customers require. Once the collaboration platforms are implemented, it is necessary to continuously analyse customers' behaviour and needs by using big data analysis to improve collaboration platforms performance.

2. Digital operations: to be able to transform business models, logistics operators must adapt their digital culture, processes, operations and relations in their business networks. Authors believe that this challenge can be the most difficult because it takes time to change the established patterns and to adapt the necessary procedures, standards, legal issues and similar.

3. Technology: collaboration platforms must be suitable for all users and based on latest technology solutions such as cloud computing. Platforms should provide more information about existing services in all shipping modes and give users the access to real-time information about the delivery of goods. Furthermore, collaboration platforms should optimize the management of shipping processes by presenting real-time information about delays, incidents, etc. in order to create an up-to-date and responsive system. Finally, collaboration platforms should enable the completely paperless administration.

Fig. 1. Logistics services transformation challenges

4. Digital practices: this challenge is linked with digital operations but more focused to personnel than procedures. The main task is to change the personnel mindset, accentuating the teamwork. Operators must invest in training personnel on how to use the collaboration platforms. Sharing and distributing knowledge becomes important as well as the establishment of long-term cooperation between network members. Logistics operators who lack own resources can engage experts (IT experts, HR experts or other necessary) to solve this challenge and to overcome the gap between the old and the new business.

Solving the determined challenges varies in time and efforts. Detecting customers’ requirements takes the least time, but when it comes to digital operations and the change of established patterns, time and complexity increases. Technology is a challenge that can be quite easy to overcome. Digital practices can appear to be a time-consuming challenge, but also an opportunity to learn from another operators’ experience. Regardless of intensity of each challenge, logistics operators should take time to solve them in order to implement appropriate collaboration platforms.

IV. COLLABORATION PLATFORM MODELS

Digitalization is omnipresent in the logistic sector, but is especially present in freight forwarding as a subsector in which logistics operators act on behalf of many stakeholders: importers, exporters or other companies, in order to organize the safe, efficient and cost-effective transportation of goods. Operators consequently become "communication and information intermediaries".

A wide range of logistics operator’s tasks can be summarized as follows: selection of transport modes and routes, arranging of payments, fulfilling international shipping requirements and providing all necessary documentation [15]. While managing all these tasks, logistics operators are presented with various challenges regarding data including [16]:

- Transmitting data accurately from the exporter to the forwarder,
- Receiving information in a compatible format from the forwarder to populate shipment transactions,
- Minimizing errors and miscommunications between the exporter and the forwarder,
- Ensuring the forwarder is performing all contracted services.

Operators are communicating with all stakeholders involved, and are transferring information between them. Collaboration platforms present a unique service which has a great potential to achieve completely unobstructed information flows.

According to the survey conducted by Technavio [17], global freight forwarding services market is estimated to grow 4.8% from 2017 to 2021. Another survey was conducted by Freightos [18], in which 70 forwarders participated (including the leading such as DHL, Schenker and Kuehne+Nagel), which stated:

- 74% of forwarders predict that by 2021 freight will be highly automated, with human interventions only by exception,
- 70% of forwarders claim that the majority of funds will be invested in new services and in attracting new customers,
- Enhanced operational efficiency, on time delivery and improved satisfaction could yield up to 12% potential savings for forwarders,
- Shippers will not be predominantly price driven.

Another Freightos [9] survey (20 leading forwarders participated) has shown that five forwarders use full manual rate techniques with average of 57 hours to respond to quote requests. Furthermore, the survey detected that 72% of the surveyed forwarders failed to quote at all. Errors, as expected with a manual process, were prevalent.
The above stated surveys confirm the need to transform existing business models and the necessity of collaboration platforms implementation. Logistics operators therefore must reallocate their resources to be able to provide competitive services in the changing logistics market [19].

Before researching the examples of concrete collaboration platforms, it is necessary to refer to the two basic variants of business models: traditional logistics operators and “digitalized” forwarders.

The first group consists of traditional logistics operators: the leading companies with a large market share, long-term business relationships and contracts. Some of leading companies (e.g. Maersk, DHL, Schenker, Kuehne+Nagel, UPS) have definitely shifted towards the digitalization of their services, but generally their “digital” progress is slower than the second group of “digitalized” forwarders. New “digitalized” entrants (e.g. Flexport, iContainers, FreightHub, Kontainers, Freightos) are transforming traditional information flows by using the possibilities of big data, cloud and connected platform technologies to provide customers with the ease of access, price transparency, and real time integrated services [20]. New “digitalized” operators have stimulated the “traditional” companies to change their business models and to implement collaboration platforms, e.g. Damco implemented a startup ”Twill” - customer collaboration platform; DB Schenker introduced ”uShip”: an online platform to connect with trucking subcontractors, etc. Figure 2. shows the functionality of the Twill collaboration platform [21].

![Diagram of Twill collaboration platform functionality](https://www.twill.net/what-is-twill/ (Accessed 07 January 2019))

The process starts with the selection of the date and trade line (shipment from source to destination). Then the platform offers a list of the most appropriate supplier, from which a customer selects one. After choosing a supplier, the customer selects a container, checks booking details and then confirms the booking. The customer can check the status of shipment and add documents regarding the shipment. Twill creates a centralized database of documents, notifications, conversations etc., to provide all relevant information about each shipment in real time [22].

Before the implementation of Twill platform customers contacted numerous freight forwarders, constantly following shipment details via emails, phone calls, involving paper administration. Unpredicted situations caused even more communication resulting in higher costs and delays. Twill system allows placing a booking instantly – 80% of bookings are completed within 3 minutes, and 30% within 1 minute [23].
FreightHub as a new “digitalized” operator implemented a collaboration portal that enables all supply chain partners and customers to collaborate, share documents and provide payment. Any special instructions such as handling and/or storage, required customs documents, the packing list and other documents can be uploaded, shared and emailed to third parties. The portal enables customers to get rate quotes with just a couple of clicks instead of up to 2 weeks on average to book their freight [24].

The base technologies behind collaboration platforms should be cloud computing and big data analysis. It is important to implement collaboration platforms that are upgradable for future needs. Collaboration platforms must enable easy access, easy data input, easy processing and real time exchange of data in order to provide fast and reliable service.

V. BENEFITS OF COLLABORATION PLATFORMS

Undoubtedly, collaboration platforms possess a large potential to streamline logistics services. Collaboration platforms can provide benefits for all stakeholders involved in logistics services. The potential benefits of collaboration platforms can be determined as follows (Figure 3).

- Business model transformation,
- Customers and logistics operators experience,
- Processes and administration improvement,
- Sustainability.

Business model transformation: implementation of collaboration platforms changes the core of existing business models, but also creates new models and possibilities for operators enabling them to stand out. For example, freight forwarders can differentiate from others by profiling as a “Logistic Platform Player”, combining the customer-oriented collaboration platforms with the role of matchmaker by developing an online platform for many-to-many buyer-seller relationship. In addition, freight forwarders can differentiate from others as “Logistics Execution Specialists”, by focusing physical transport activities on online platforms combined with smart assets (containers, ships etc...) to provide IoT services [20]. Logistics services overlap with other connected sector services and activities; therefore the implementation of collaboration platforms will induce better connectivity between sectors and common activities, as well as influence other sectors to improve their business models.

Fig. 3. Benefits of collaboration platforms. Source: Authors
Customers and logistics operators’ experience: from the aspect of logistics operators, unified processes, simplified synchronization and collaboration with both customers and business partners, elimination of various different systems will enable simpler and easier service. In addition, logistics operators can create reports to follow up on customers’ behavior. Customers can benefit from simplified "one point" service platform to submit their requests, which will be visible in any moment. There will be no more waiting for the response and the delay in business procedures. Both customers and logistics operators will be able to connect to the platforms from anywhere because collaboration platforms exploit the cloud and IoT functionalities. The iContainers digital freight forwarder conducted a survey to examine what shippers think about the digitalization of ocean freight services. 46% participants consider the possibility to manage documents online as the most valuable service offered by a digital freight forwarder, as opposed to 23% participants who chose the instant quote features, 17% who chose quality to price ratio and 14% who chose wider range of routes and rates of service [25].

Business processes and administration: without collaboration platforms, information flows between customers and operators imply numerous phone calls, e-mails, paper documents, miscommunications, mistakes, lack of awareness and fast reaction to unpredictable situations, delays, etc. When relevant data is shared with the right counterpart in a timely manner, it becomes actionable and useful information. Being able to acquire information from the other parties and automatically detect the position and status of parcels or containers increases the situational control, predictability of delivery, and quality of service as perceived by end-customers [26]. Collaboration platforms implementation simplifies business processes, and reduces paper administration.

Sustainability: Implementation of collaboration platforms can improve sustainability in the following aspects:

- Economic aspect: transformation of the classical logistics service model and implementation of common platform, elimination of unnecessary processes, procedures and delays, increased responsiveness etc. can generate significant savings for users and for logistics operators. For example, the survey conducted by Technavio determined that when the operators adopt technologies such as data analytics, e-freight, web portals, and cloud-based systems to provide a high quality of services to their customers, potential savings of up to 12% can be achieved [17].

- Environmental aspect: inadequate logistics services during the transport of goods and all connected activities cause a lot of unnecessary movements of goods. The consequence is the increased amount of gas consumption, increased amount of CO₂ emissions (and other polluters). Furthermore, paper administration causes too much natural resources exploitation. The implementation of collaboration platforms will reduce polluters’ emissions and save natural resources. It is estimated that logistics holds a share of 13% in all emissions [29]. The implementation of digital solutions such as collaboration platforms has the potential to reduce logistics emissions from 10% to 12% by 2025 [28]. Furthermore, 50% of the trucks are returning empty after delivery, producing more unnecessary movements, which can be harmful for the environment [27].

- Social aspect: collaboration platforms provide equal opportunities for all involved, as well as standardization. In addition, collaboration platforms can eliminate the necessity for different types of education for various systems. Furthermore, the process of development and implementation of collaboration platforms requires the engagement of various IT experts, human resources experts etc. That is especially applicable in the case of new market entrance and new companies, which can generate new employment.

All potential benefits additionally highlight the importance of collaboration platforms implementation. Collaboration platforms generate long-term benefits reflecting in all segments of logistics operators’ business.
VI. CONCLUSION

Logistics services are moving to a new collaborative and customer-centric level. Logistics operators should adapt their existing business models to collaboration-based business models. The reasons to implement collaboration platforms are increasingly demanding customers who require fast and reliable services, newcomers on the market who accelerate the use of online services and numerous stakeholders involved in providing logistic services. The implementation of collaboration platforms possesses a significant potential to transform the existing business models. Logistics operators who act on behalf of many other stakeholders in order to organize transportation of goods have recognized the potential of collaboration platforms to streamline their services. The two main groups of logistics operators are traditional logistics operators and “digitalized” operators. The traditional logistics operators are still dominant on the market, taking the advantage of their well-established business networks. The other group, “digitalized” logistics operators are new entrants on the market, who base their growth on advanced online solutions to provide services to their customers. Traditional operators slowly started to switch to collaborative approach to customers, e.g. Damco implemented the “Twill” platform which enables customers to book almost instantly. The implementation of collaboration platforms is a challenging process for logistics operators. The first challenge is to identify requirements of demanding customers in order to implement collaboration platforms that enable customers to receive the requested services easily. In addition, it is necessary to create platforms which are able to analyze customer’s behaviour in order to upgrade the collaboration platforms. After the detection of customers’ requirements, it is necessary to meet the prerequisites for transformation of business models: to adapt digital culture, processes, operations and relations in business networks. The implementation of collaboration platforms should be based on cloud and big data technologies to provide easy access to real-time information to customers. Furthermore, logistic operators need to change their personnel mindset and provide adequate education for the use of collaboration platforms.

The implementation of collaboration platforms transforms entire business models, generates many benefits for customers and operators, but also for other stakeholders and connected sectors, supporting the overall sustainability. The creation of new or adaptation of existing models will enable logistic operators to stay competitive but will also enable them to become “Logistics Platform Players” and “Logistics Execution Specialists”. Without collaboration platforms, the information flow between customers and logistics operators implies numerous telephone calls, e-mails and paper administration. Collaboration platforms enable customers to submit their requests at “one point” and follow their shipments at any moment. Logistics operators will have the possibility to unify their processes, which will enable simpler and easier service, minimizing possible delays. Collaboration platforms are gathering stakeholders in one place to exchange information, enabling them predictability of delivery, reduction of delays and lowering the costs of unpredicted situations. Collaboration platforms can also improve the overall sustainability. From the economic aspect of sustainability collaboration platforms can contribute to savings by eliminating of unnecessary processes and procedures, minimizing delays etc. The collaboration platforms can decrease pollution emissions as well as the exploitation of natural resources, by minimizing empty transport. In addition, social aspect of sustainability can be improved through the necessity of employing various experts during the implementation process, and elimination of unnecessary heterogeneous education for different systems.

REFERENCES


Streamlining Logistics Services Via Collaboration Platforms


Verification of The Evaluation Methodology for Ship’s Planned Maintenance System Database

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ABSTRACT
The Evaluation methodology for a ship’s Planned Maintenance System is a method developed to test the data in the Planned Maintenance System database and indicate where the database and the maintenance plan should be improved. It has been developed in 2017 and it was tested in practice after development. Testing of the Evaluation methodology was performed on five ship’s databases belonging to two different companies. Results of the testing were published in 2017 studies. Additional evaluation of several ship’s Planned Maintenance System databases was performed in order to re-examine functioning of the Evaluation methodology and the questionnaire, to verify the results of the testing of the Methodology. Additional evaluation and analysis of the results was conducted using same methods used during initial testing.

This paper is describing process of the additional evaluation and listing obtained results. That is followed by the analysis of the results and finally with comparison of results of both evaluations which is giving the answer to the question: “Are the results of the evaluation performed for the verification purpose similar to testing results?”

KEYWORDS: planned maintenance system, database, evaluation methodology & questionnaire

I. INTRODUCTION
The Evaluation methodology for a ship’s Planned Maintenance System (hereinafter: the Methodology) has been developed with intention to create a tool for evaluation of the data in the Planned Maintenance System databases, applicable for all Computerized Planned Maintenance Systems. It was developed with the intention to be used during development of the computerized ship’s Planned Maintenance database and to evaluate existing databases in everyday use. The Methodology is based on DQA (Data Quality Assessment) principle [1], and for that purpose the questionnaire (Table I.) with thirty questions has been developed. Each question should be answered with a grade 1 to 5. Questions evaluated with grades 4 and 5 are considered satisfactory and DB changes are not needed. When question is graded 1, 2 or 3, database should be improved.

Testing of the Methodology (hereinafter: the Testing) was performed on five ship’s databases with intention to check the functionality and operability [2]. Results of the testing process of the Methodology and analysis of testing results were published in 2017 [3]. The conclusion of the Testing was that the methodology is useful for evaluation of newly created databases as well as for databases in long time use, i.e. “useful tool for evaluation of data in PMS DB and as help for all persons involved in DB construction and construction process”, and that “use of questionnaire is proved to be simple and received results are reliable” [3].

Database evaluation process performed in four shipping companies, with intention of verification of the testing results (hereinafter: the Verification), is described in this paper. During this process twenty-five computerized databases were evaluated. Several conditions had to be fulfilled to render verification results valid [4]. Those conditions are that evaluation procedure, the questionnaire (Table I) and the analysis methods used for the Verification, as well as personnel profile, must be the same as for the Testing. Additional condition is that evaluator qualifications must be similar to qualifications of evaluators during the Testing. Results of the analysis are brought in several tables. Conclusion of the research, if the above-mentioned conclusions are valid, is obtained by comparison of the evaluation results of the Testing and the Verification.
<table>
<thead>
<tr>
<th>Area</th>
<th>No.</th>
<th>Question</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machinery and equipment</td>
<td>01</td>
<td>Is all machinery and equipment included in the database?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>02</td>
<td>Is all included equipment marked properly and uniquely, according to their shipboard location and markings?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>03</td>
<td>Is all necessary machinery divided to subcomponents (to smaller subsystems) in logical manner?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>04</td>
<td>Does machinery or equipment have larger number of subcomponents then necessary?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>05</td>
<td>Is there equipment or machinery listed in the database more than once, or do they have same markings or names?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>06</td>
<td>Is the data about the manufacturer, the type and the serial number entered to all relevant items?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>07</td>
<td>Do all equipment and machinery entries have the same style, abbreviations, and markings?</td>
<td></td>
</tr>
<tr>
<td>Jobs inside DB</td>
<td>08</td>
<td>Do all devices in the DB have linked maintenance plan according to manufacturer’s recommendation?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>09</td>
<td>Are manufacturer’s recommendations grouped according to devices, periods and company maintenance rules?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>Are all jobs required by company policy included in the DB? (e.g. SSM – Safety Management System)?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>Are all jobs based on manufacturer’s recommendation changed due to the company policy (if exists)?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>Are all jobs required by flag state rules and regulations included in the DB?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>Are all jobs required by class society included in the DB?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>Is there a number of smaller jobs which can be grouped together?</td>
<td></td>
</tr>
<tr>
<td>Special jobs and rules - DB jobs general</td>
<td>15</td>
<td>Is fire detection sensor list inserted into the DB together with the testing plan?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>Is the alarm system and its testing program entered in the DB?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>Is PMS self-improvement program inserted into the DB, and is there control mechanism for PMS DB self-improvement program?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>Is critical equipment marked according to company SMS?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>Are job descriptions written clearly and straightforward?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>Are jobs created and grouped according to multiplier principle?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>21</td>
<td>Are all the same type jobs, coming from different sources, synchronized?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>Are all the same jobs, resulting from different requirements (sources), merged?</td>
<td></td>
</tr>
<tr>
<td>Spare parts</td>
<td>23</td>
<td>Are all required spare parts included in the database?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>Are spare parts distributed to proper equipment and machinery?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>Are all spare parts properly marked, do they have sufficient data for ordering?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>26</td>
<td>Is company critical spare parts list inserted in the DB?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>27</td>
<td>Do all spare parts have the same style, abbreviations, markings, etc.?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>28</td>
<td>Are there spare parts entered several times?</td>
<td></td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>29</td>
<td>Are all users inserted in the DB, and are all access rights defined in order?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>Is there any other deficiency noted in computerized PMS database?</td>
<td></td>
</tr>
</tbody>
</table>

*Questions in red are most important in the questionnaire, they have a great impact on maintenance quality. Questions in red yellow have less importance for database quality, mostly affecting the user’s workload. Green-colored questions do not affect the quality of maintenance, they are dealing with arrangement of data in the database.

**Non-disclosure condition**

All four shipping companies allowed access to their databases and their confidential data strictly under no disclosure condition. According to their request, all data leading to identification of the ship or the company is removed from this article.

Instead of the real names, companies in the paper will be named A, B, C and D.
Veriﬁca on of The Evalua on Methodology for Ship’s Planned Maintenance System Database

2019

8th

II.RESULTS OF THE EVALUATION FOR THE VERIFICATION
Shipping companies A, C and D databases were evaluated by the company employees familiar with company SMS (Safety Management System) and with computerized PMS program. Company B databases
were evaluated by one of authors of the paper, who is not familiar with the company SMS. Therefore,
those evalua on grades might have certain amount of subjec vity. Evalua on results of all three companies is given in Table II.
TABLE II.

RESULTS OF THE EVALUATION OF DATABASES FOR THE VERIFICATION
Database

Ques on

A-

A-

A-

B-

B-

B-

B-

B-

C-

C-

C-

C-

C-

C-

C-

C-

D-

D-

D-

D-

D-

D-

D-

D-

D-

III.ANALYSIS AND COMPARISON OF RESULTS
A. Summa on of grades and average grade value
Summa on of grades and average grade value of the Veriﬁca on is shown in Table III. To facilitate comparison, results of the Tes ng are shown in the Table IV.
TABLE III.
DB

A- A- A-

SUMMATION OF GRADES AND AVERAGE GRADE VALUES OF THE VERIFICATION DATABAS ES
B-

B-

B-

B-

B-

C-

C-

C-

C-

C-

C-

C-

C-

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D- D-

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Aver.

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This analysis shows different behaviour of databases within companies. Databases belonging to companies B and D have high uniformity of grades, and very high average grade of all their databases. Uniformity of grades of Company C databases is also present, although less pronounced, with one database as exception. Company A database have high variation in their grades going from average 3.97 up to 4.73.

Comparison of summation of grades and average grade values of both evaluations show similarity of exceptions. Company A database have high variation in their grades going from average χ.ύϋ up to ψ.ϋχ.

Resemblance analysis of evaluation grades was made according to Equation υ [χ] as the next step of the analysis:

\[ S = 100 - \frac{100}{nQ} \sum |R_{ij} - R_{kj}| \times \frac{1}{nG-1} \% \]  

Where:

- \( S \) – resemblance of grades of two databases
- \( nQ \) – total number of questions,
- \( R_i \) – answer on \( i^{th} \) question (\( i = 1, 2 \ldots n \))
- \( b_j \) – \( j^{th} \) evaluated database,
- \( bk \) – \( k^{th} \) evaluated database; (\( j, k = 1, 2 \ldots m, j \neq k \)),
- \( nG \) – total number of grades.

Results of the resemblance analysis of grades the Verification databases is shown in Table V.

### Table IV. Summation of grades and average grade values of the testing databases[3]

<table>
<thead>
<tr>
<th>Database</th>
<th>Sum. of grades</th>
<th>DB-1</th>
<th>DB-2</th>
<th>DB-3</th>
<th>DB-4</th>
<th>DB-5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Av. grade value</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A1</td>
<td>122</td>
<td>122</td>
<td>118</td>
<td>119</td>
<td>122</td>
<td></td>
</tr>
<tr>
<td>A2</td>
<td>8.07</td>
<td>4.00</td>
<td>3.93</td>
<td>3.97</td>
<td>4.07</td>
<td></td>
</tr>
</tbody>
</table>

### Table V. Resemblance analysis of evaluation grades of the verification databases

<table>
<thead>
<tr>
<th>A1</th>
<th>A2</th>
<th>B1</th>
<th>B2</th>
<th>B3</th>
<th>B4</th>
<th>B5</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>C6</th>
<th>C7</th>
<th>C8</th>
<th>D1</th>
<th>D2</th>
<th>D3</th>
<th>D4</th>
<th>D5</th>
<th>D6</th>
<th>D7</th>
<th>D8</th>
<th>D9</th>
<th>DB-ψ</th>
<th>DB-υ</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>80.8</td>
<td>80.8</td>
<td>80.8</td>
<td>80.8</td>
<td>80.8</td>
<td>80.8</td>
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</tbody>
</table>

1 Green squares represent resemblance analysis of evaluation grades within each company.
To facilitate comparison, results of the resemblance analysis of the Testing databases are shown in the Table VI.

<table>
<thead>
<tr>
<th></th>
<th>DB 1</th>
<th>DB 2</th>
<th>DB 3</th>
<th>DB 4</th>
<th>DB 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>DB 1</td>
<td>100</td>
<td>98.33%</td>
<td>96.66%</td>
<td>97.50%</td>
<td>90.00%</td>
</tr>
<tr>
<td>DB 2</td>
<td>98.3</td>
<td>100</td>
<td>95.00%</td>
<td>95.83%</td>
<td>90.83%</td>
</tr>
<tr>
<td>DB 3</td>
<td>96.7</td>
<td>95.0</td>
<td>100</td>
<td>99.17%</td>
<td>86.66%</td>
</tr>
<tr>
<td>DB 4</td>
<td>97.5</td>
<td>95.8</td>
<td>99.17%</td>
<td>100</td>
<td>87.50%</td>
</tr>
<tr>
<td>DB 5</td>
<td>90.0</td>
<td>90.8</td>
<td>86.66%</td>
<td>87.50%</td>
<td>100</td>
</tr>
</tbody>
</table>

Resemblance analysis of both evaluations show similar pattern, values are consistent for both evaluations. No discrepancies between two evaluations were found during this analysis.

IV. CONCLUSION

Evaluation of twenty-five computerized databases (Table II) in four different shipping company and analysis of the evaluation results confirmed the claim which was presented during the Testing that the Methodology is “useful tool for evaluation of data in PMS DB and as help for all persons involved in DB contraction and construction process”. During the evaluation for the Verification, four different evaluators (Chapter II) used the Methodology and confirmed another part of the claim presented during the Testing, that “the use of questionnaire is proved to be simple”.

The analysis of the Verification results and comparison with analysis of the Testing results showed that that the results were similar to both evaluations and that there were no major deviations. This confirms the final part of the assertion that “the received results are reliable”.

As all claims from the Testing are one by one confirmed during this research, all assertions stipulated in the Testing, and above in Conclusion as well, are valid.

REFERENCE


Determinants of Kinetoses and Techniques of Prevention

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2 – Psychologist, Psychotherapeutic practice, nadjadijanovic@hotmail.com

ABSTRACT
Kinetosis (seasickness, motion sickness) is a condition or syndrome of poor adaptation of the organism to movement. The cause of such a state is the nonconstructivity of the perceived motion and vestibular system. One sense says we sit or stand, and the other one is to move. This creates a conflict of senses. Kinetosis is a relatively normal disorder that can be of different intensity and occurs in all people, except those without a functional vestibular apparatus. Symptoms of kinetosis are: nausea, restlessness, anxiety and tension, dizziness, weakness and difficult movement of the head. The origin of the disorder is somewhat psychological and reminiscent of the state of anxiety. There are many symptoms that coincide with both conditions, so we focused on the degree of correlation between these two variables. There is a significant correlation of neuroticism, as a personality trait and kinetosis. The research shows that there is a correlation between them. There is statistically strong association in women at the level of τ.τυ, while in men it is at the level of τ.τω. There are a lot of techniques that are used to prevent and overcome this condition, depending on the individual characteristics of an individual.

KEYWORDS: kinetosis, neuroticism & techniques of prevention

I. INTRODUCTION
In the second half of the 19th century, the origin of the disease was significantly polemic. In Anglo-Saxon countries, Irvin suggested the use of that term. Many theorists have tried to explain the etiology of the disease. The simplest parameter, the stomach, in which some of the symptoms of kinetosis occur, presents the majority of theories. They were mainly based on disorders in the mechanical part of the bowel, bowel irritation and impaired liver function. Later, these theories were rejected, because other theoretical considerations did not take into account other relevant factors. The term "kinetosis" appears in the Romans' peoples, only then, when the importance of the vestibular apparatus in the human organism was realized. At that time, it was justified that the etiology of the disease was in it [υτ].

II. KINETOSIS (DISEASE OF MOVEMENT)
Vestibular apparatus is a system that provides a sense of balance in the body. This way we get information about the position of our body. This provides a compensation movement, such as feedback on self-induced and other generated external forces. This system is a mediator between the perception of the environment and our position in relation to it. It has a very complex task because it aims to present an objective state to our organism, which is sometimes an impossible goal, waiting for a healthy system. What is logical is that the damaged system cannot yet maintain the proper state of the organism. A special part of the vestibular apparatus is urticulus and sakulus, which detect information on vertical gravity and define our linear motion. So we have clear sensory messages about movement, balance and orientation in space [2].

If someone often feels upset or tired while traveling, it’s probably symptoms of kinetosis. This is caused when there is incongruency in our visually perceived movement and in our sense of balance in the vestibular sense. Imagine you sit and your body does not move. Furthermore, the perception system sends information to your brain, then the brain to the body. But our senses also see that we are moving and sending this information further. This conflict, in fact, causes unclearness in the body.

More than 50% of passengers, whatever means of transport, suffer from this disease or condition. This condition is treated as uncompromising, because it is what sets the majority conditions. The problem of such travelers is that there is one sole aim to get out of this situation. This refers to the fact that every form of travel, in people suffering from kinetosis, is reduced to thinking about going and coming on the
road, because it is stress for the psyche and body. These types of travel do not have the same quality as people who do not have a problem of disease.

The most important symptoms of the disease are: restlessness, anxiety, nausea, dizziness, headache and general weakness [6].

III. THEORETICAL APPROACHES TO DISEASE

One of the most common hypotheses for explaining the cause of the disease is that it functions as a normal way to protect the body from toxins through the help of neurological centers in the brain. The confusion of visual sense and balancing sensations usually leads to problems of the whole body and this is usually solved by induction of vomiting.

Through the feeling of movement, for example, on a ship without windows, the inner ear and eyes have a different experience. As a result of mismatch, the brain will come to the conclusion that one of them does not tell the truth and further concludes that hallucination is a consequence of swallowing poison [3].

The second is the theory of the Sherrington law that describes reciprocal prevention between agonistic and antagonistic muscle pairs, and the implication of stretching the extra-ocular muscle. Thus, the approach, the critical presence of the exit to Vagus nerves, proved to be the direct cause of muscle stretching. Therefore, as a cause of nausea in motion, the stimulation of the nerve due to stretching of the muscle of the eye is proposed. This theory is supported by the fact that people without maze (inner ear) are immune to the disease of movement and why symptoms occur when they pass through different acceleration of the body / head; why the combination of voluntary and reflexive eye movements can cause the proper functioning of Sherrington’s law; and why many drugs that suppress eye movements also serve to suppress the symptoms of nausea [7].

The third theory says that kinetosis is associated with different types of personality and physical vestibular functioning of men and women. More specifically, kinetosis has a statistically significant gender difference, as well as a significant relationship with neuroticism, as a significant personality trait.

Neuroticism is the inability to organize and quality directional personality potentials to solve problems that occur in attempts to achieve some personal aspirations. An increased level of neuroticism suggests a greater possibility of various anxiety disorders, depressive episodes and more frequent feelings of unpleasant emotions such as anger and guilt [5].

IV. METHODOLOGY AND RESULTS

Our work was especially focused on the third theory, more specifically on the relationship between kinetosis and neuroticism, as a special personality trait in both sexes. The study was conducted on a suitable sample of 100 respondents (47 females and 53 males). Considering that it is difficult to find, in one place, a larger number of women who have sailed, the sample was focused on a female target group which at least once had a long navigation of 8h. The questionnaires were filled out online by women who had this experience. The male part of the sample was exclusively students from the Kotor Maritime Faculty who had the same experience.

The scientific goal was to determine how neuroticism is related to kinetosis in both sexes. And the practical goal is to prevent kinetosis through practice and to make the right choices when choosing a sailor. The dependent variable is kinetosis (at least 3 symptoms), the independent variable is half, and intervening is neuroticism (a test of general neuroticism).

The following statistical procedures were used in the processing of data from this study: frequencies and percentages; measures of central tendency (mean); measure differences between segments of crossed variables (Pirson Hi square); Measures showing the degree of connection between variables (C - coefficient of contingency). Data processing was done through the SPSS Windows 17 program.
The results show that there is statistical significance between kinetosis and neuroticism, both in men and in women.

**TABLE I. LINKAGE OF KINETOSIS AND GENERAL NEUROTICISM**

<table>
<thead>
<tr>
<th>Pirson Hi square</th>
<th>Degrees of freedom</th>
<th>C - coefficient</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\chi^2 = 10.857$</td>
<td>df = 4</td>
<td>$c = 0.236$</td>
<td>$p = 0.032$</td>
</tr>
</tbody>
</table>

From Table 1, it can be seen that there is a statistical significance at the level of 0.05, which implies that respondents who are neurotic are potential candidates for kinetosis, if they do not already have.

**TABLE II. RELATIONSHIP BETWEEN KINETOSIS AND SEX**

<table>
<thead>
<tr>
<th>Sex</th>
<th>Pirson Hi square</th>
<th>Degrees of freedom</th>
<th>C - coefficient</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men</td>
<td>$\chi^2 = 9.365$</td>
<td>df = 4</td>
<td>$c = 0.221$</td>
<td>$p = 0.045$</td>
</tr>
<tr>
<td>Women</td>
<td>$\chi^2 = 11.362$</td>
<td>df = 2</td>
<td>$c = 0.301$</td>
<td>$p = 0.010$</td>
</tr>
</tbody>
</table>

From Table 2 it can be seen that also there is a statistical significance at the level of 0.05 and 0.01. In relation to sex, women are statistically significantly correlated with kinetosis, at the level of 0.01, while men at the level of 0.05. This means that women are more susceptible to kinetics, but are more neurotic.

Now, if we ask the question of whether our psyche affects our movement, the conclusion would be affected. We just do not know exactly how many percent. The results of the research can be important indicators, but the shortcomings of the screening must also be presented. Women who were respondents may have had only one trip experience, which could have elements of the kinetosis, and that the cause was the second factor. It is well known that the first journey in itself as a trial trip, or, more precisely, it is the time for which the organism has not yet assimilated the whole idea that it is normal to travel and in a field that is not firm.

However, previous research shows similar results, so this is a significant determinant for further research. Also, it should be dealt with in more detail the elements of neuroticism, which is a particular general entity of psychic life and should explore the individual elements that make up it.

Women are culturally, in this region, more susceptible to neuroticism because they are still represented as a weaker sex, and can not be fully realized in a large percentage. No matter how the password "Woman is for a house, and a man for a job," elements of rudimentary understanding still have a trace in the Balkans.

Furthermore, it would be important to examine how the vestibular apparatus works in neurotic and non-neurotic.

**V. TECHNIQUES OF KINETOSIS PREVENTION**

Some useful psychological and practical techniques can be applied to any type of trip that brings unpleasant experiences.

First, the brain processes information more easily if viewed in front of itself, i.e. not looking from the side. This is especially true for journeys by means of vehicles with windows. An example of driving a car is perhaps the simplest. Sitting in the front seat (for ages older than 12 years), looking ahead is necessary, because the amount and speed at which information is processed, if viewed on the sidelines, is complex for the already existing conflict (kinetosis) that the brain processes. Always sitting in the direction of moving the vehicle.
- It’s a good idea to learn breathing techniques. Primarily, breathe on the mouth, because breathing on the nose stimulates the receptors of the senses of smell that cause nausea. This applies to journeys where there is warm or stagnant air. Fresh air is the best solution [4].

- Also, positive thinking is a key element in life, even during the journey. The brain directly sends information to the body, and the stomach immediately. Because of this, an unpleasant thought creates a picture in the head that the body experiences very really, irritating as if it really happened. So, pleasant thoughts send pleasant feelings that calm the stomach and body to a certain extent.

- It does not look in the floor or it does not read during the ride.

- In the night, or on a boat without windows, it’s useful to simply close your eyes and relax your thoughts. With body relaxation techniques, you adjust the body to the situation you are in at the moment. This means that deep breathing, with inhalation through the nose and double longer breathing on the mouth, is an important factor to fill each oxygen cell with oxygen.

- Kinetosis is not a true disease, but a higher state, to which the organism enters when the journey begins. This condition should not be disputed but accepted with the conviction that it is not dangerous, as tension and panic can produce more negative consequences than the symptoms of kinetosis itself.

- A trip to a hungry stomach is avoided. It is necessary to moderate the intake of mild food before the journey. Sweets are avoided, as are angry and too spicy foods. The intake of the liquid should also be moderate.

- It is important to note that a person can get kinetosis as a result of neurotic disorders, and kinetosis may also disappear through psychotherapeutic treatment of neurosis. An example is the resistance of the body to the individual being pushed by the sea and starting a new lifestyle, and in a strong pathological symbiosis with one of the parents. At that point, the body is beginning to be alarmingly inaccurate because the problem can only be solved by psychological treatment. Then, people who have close proximity with other people have the feeling that the enclosed space suffers and presses and then the panic attack mixes with the kinetosis [9].

- From natural preparations, ginger is used as an effective prevention of nausea or raw gum or capsules based on dumbbell have an anti-emetic effect.

- Accupuncture has started to be used significantly lately. Using finger pressure, it can prevent and alleviate the illness of movement. Pericardium 6 or Nei Kuan pressure point is fairly easy to locate. These are the points on our inner joints, about three fingers wide. Exactly at the point where the pulse is measured. Third, the third and fourth fingers press the joint from the inside, and below, the outside of the joint fits with your thumb and little finger. In this part, a slight glow should be felt, which is an indicator that the requested center has been found [1].

Other treatments for diseases of the disease relies on drugs. McClose is the most well-known and most widely used antihistamine, in the form of Dramamine, Bonina, Antivert. Each type of drug may be helpful, but may have contraindications, so be careful with their use. Children up to 5 years of age should avoid taking this type of drug [8].

VI. Conclusion

Kinetosis or disease of movement is in more than 50% of the condition that only occurs once or occurs during travel. Symptoms should not be ignored, but should not be understood as a potential danger. What’s important is that people do not need to limit travel because of the symptoms that kinetosis brings with them, before trying out the techniques they can help. As the psychological factor is a significant aspect of this condition, one should deal with the personal etiology of this problem.
Also, given the results obtained in the research, this field should be explored in several directions because the subject is actual and could bring significant practical progress in the field of disease, psychological sphere and science in general.

REFERENCES


The Importance of Highlighting Factors That Affect the Psychosomatic Health of Seafarers

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ABSTRACT

It is undeniable that maritime sector is one of the most effective economic activities in the world and that maritime transport brings relatively high profits. In modern times, salaries are the biggest motivation for people to qualify for a seafarer’s title. It is not unusual that, apart from information about earnings, future seafarers do not pay much attention to other aspects of this vocation, which greatly concern their overall health. Lack of awareness and insufficient emphasis on the significance of the psychosomatic health of the future seafarers create superficially trained, mentally unprepared and unsuitable personnel who plan to deal with maritime navigation. There are many factors that determine the psychosomatic health condition of a seafarer and in this paper each of them will be considered. By pointing to this aspect of maritime engagement, potential maritime personnel are able to observe more accurately and re-examine the choice for a future profession. The aim of this paper is to understand the importance of informing future candidates for the title of seafarer and point to factors that have an adverse effect on the overall mental health of the seafarer.

KEYWORDS: seafarer, ship, health, psychosomatic & education

I. INTRODUCTION

The conditions of life and work of seafarers, socially isolated working environment, interpersonal relations and all other impediments are in general a complex factor in determining the total quantity and variety of pressures and burdens that seafarers experience. Of course, all these factors greatly affect the psychosomatic health of an individual engaged in this activity. It is not a rare case that when choosing a seafaring vocation most candidates are not familiar with the challenges that this profession includes and which greatly affects their health. “The protection of seafarers is crucial not only to provide quality shipping services, but also to ensure the quality health of seafarers, and thus protecting their human rights.” [5]

The aim of this paper is to point to future seafarers to factors that contribute to physical and psychological imbalances. By highlighting these factors, we prepare seafarers for unusual life and working conditions that can be encountered. It is also important for candidates to recognize them on time, which will contribute to minimizing the effects of these factors and act preventively in order to ensure a better and healthier working environment.

First of all, the specificity of maritime vocation will be pointed out, i.e. what distinguishes it from other professions on land, as well as the motivation of candidates for the future title of seafarer. Each of the factors that affect the psychosomatic health of the seafarer will be listed and individually considered. It is crucial for each future seafarer to become aware of these factors that may impair their overall health integrity. When, in addition to theoretical and practical professional training, the candidate learns to manage these factors by actively participating in the contribution of a more pleasant working environment, he/she will be able to perform professional duties more effectively and with working satisfaction.

II. SEAFARER’S VOCATION

“A seafarer is defined in the Regulations as any person, including a master, who is employed or engaged or who works in any capacity on board a (seagoing) ship, whose normal place of work is on a ship.” [6]

“Seafarers are, inter alia, persons who have been employed by a ship-owner to do ship service on board a ship at sea, i.e. work performed by persons taking part in the ship’s operation and maintenance as well as the provisioning of those on board. Furthermore, seafarers can be persons who perform repair and maintenance work on ships, special ship personnel who have been engaged to work at sea on board a
ship. The seafarer’s vocation is determined by particular features of their lives on board which have psychosomatic implications for their health. The characteristics and specific features of seafaring profession are not sufficiently examined and therefore seafarers are exposed to many risks. Although maritime industry does take steps in making working and living conditions at sea more comfortable for seafarers, they are still not compatible enough with one’s physical and emotional needs.

III. CANDIDATE’S MOTIVATION FOR CHOOSING SEAFARER PROFESSION
According to a research, reasons why candidates choose sailing as their future profession (sorted by most frequent), are:

- Better earnings,
- They are not able to professionally engage on land,
- They want to gain new experiences by travelling around the world,
- Primarily possess a motivation for this profession (in a very low percentage).

Therefore, the maritime profession will bring a lot of risks to the psychosomatic health of seafarers because the primary factor for choosing this profession is not originally motivated by personal interest and professional satisfaction.

From an educational point of view, candidates are relatively quickly trained in maritime courses. Courses that give candidate a professional certificate lead to negative professional fluctuations, the cause of which is the lack of quality and the impossibility of adaptability in relation to the professional marine environment. With this educational system, the sailor quickly gets the professional certificate. And in the maritime labour market, insufficiently educated professional staff is formed in a relatively short time.

Of course, in the given concept, neither does the candidate benefits, nor the shipping company. The candidate spends time looking for professional engagement without previously coordinated information and practical factors with the psychosomatic integrity of an individual.

IV. FACTORS AFFECTING THE PSYCHOSOMATIC HEALTH OF THE SEAFARER
When trying to define factors that reflect the psychosomatic situation of a seafarer as an individual, it is clear that they are different for each seafarer and consequently have a different impact on the individual. As human nature is complex, it is impossible to fully identify all the factors and every aspect of the impact they have on employees in the maritime industry. Therefore, the following are the four most commonly distributed factors:

- Ship as a specific working environment,
- Separation from family and home,
- Multiculturalism and interpersonal relationships on board and,
- Limitations satisfying human needs.

A. Ship as a specific working environment
Ships, as the most popular freight transporting vessels, have contributed to the creation of the world market because they are the cheapest and most ecological mode of transport. We are witnesses of technical and technological advancement in the design and construction of ships, making it more and more suitable for their use. However, with all the technological improvements, it is impossible to eliminate ship’s components that have an impact on the health of seafarers. Motors, turbines, propellers and other elements of the engine machine create strong noise and vibrations that have a detrimental effect on all the employees on board, and most of them employed in the engine room. However, a much stronger impact on the inconvenience caused by the launch of the ship has the sea. Adverse weather conditions affect the movement and rolling of the ship. In addition to the expected physical health problems of which the most common types of occupations are, these movements of the ship create a high
level of stress among seafarers. Table I shows the level of stress that seafarers experience in certain situations that are inevitable when working on board. This is something that every individual who wants to be a seafarer must be aware of. Awareness of the certainty of these situations in the workplace is crucial so that the seafarer can physically and mentally prepare for them.

### TABLE I  SHIPS IMPACT ON STRESS LEVELS [2]

<table>
<thead>
<tr>
<th>Description</th>
<th>Sample 1</th>
<th>Sample 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stress level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>none</td>
<td>66</td>
<td>20</td>
</tr>
<tr>
<td>slight</td>
<td>77</td>
<td>20</td>
</tr>
<tr>
<td>moderate</td>
<td>83</td>
<td>28</td>
</tr>
<tr>
<td>High</td>
<td>138</td>
<td>30,61</td>
</tr>
<tr>
<td>Noise and vibration on board</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number</td>
<td>18,13</td>
<td>21,16</td>
</tr>
<tr>
<td>Percent</td>
<td>22,8</td>
<td>28,57</td>
</tr>
<tr>
<td>Rolling of the ship</td>
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<td></td>
</tr>
<tr>
<td>Number</td>
<td>67</td>
<td>25</td>
</tr>
<tr>
<td>Percent</td>
<td>9,89</td>
<td>16</td>
</tr>
<tr>
<td>Ship averages and maritime accidents</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number</td>
<td>46</td>
<td>21</td>
</tr>
<tr>
<td>Percent</td>
<td>15,93</td>
<td>14,29</td>
</tr>
<tr>
<td>Bad weather conditions (storms, winds, waves and hurricanes)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number</td>
<td>37</td>
<td>18</td>
</tr>
<tr>
<td>Percent</td>
<td>15,67</td>
<td>15,31</td>
</tr>
</tbody>
</table>

B. Separation from family and home

Professional engagement on board involves giving up, adjusting and, of course, separated family life. Since internet era, a seafarer is able to have more frequent contact with family and friends. Another important factor which defines the conscious and unconscious behaviour of a sailor is his relationship with his family.

### TABLE II  HOW SEAFARING CAREER AFFECTS FAMILY RELATIONSHIPS [2]

<table>
<thead>
<tr>
<th>Description</th>
<th>Marriage and family</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sample 1</td>
</tr>
<tr>
<td>Divorce caused by working on a ship</td>
<td></td>
</tr>
<tr>
<td>yes</td>
<td>217</td>
</tr>
<tr>
<td>no</td>
<td>132</td>
</tr>
<tr>
<td>maybe</td>
<td>15</td>
</tr>
<tr>
<td>Increased need for family during day</td>
<td></td>
</tr>
<tr>
<td>entire day</td>
<td>100</td>
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<tr>
<td>afternoon</td>
<td>30</td>
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<td>night</td>
<td>52</td>
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<tr>
<td>free time</td>
<td>182</td>
</tr>
<tr>
<td>Thinking about family</td>
<td></td>
</tr>
<tr>
<td>at work</td>
<td>25</td>
</tr>
<tr>
<td>after work</td>
<td>190</td>
</tr>
<tr>
<td>on holidays</td>
<td>149</td>
</tr>
</tbody>
</table>
As shown in Table II based on a survey carried out on a sample of 364, i.e. 98 long-sailing seafarers, cer-
tain conditions in the family and the marriage of the seafarers contributed to the employment on board. Sample 1 gives us information that almost 60% of divorces are cause by working on ship while sample 2 shows almost 40%. Basically, half of divorces are caused by separated life due to professional engage-
ment. According to the survey, seafarer’s most increased thoughts and need for family is during night and after work. That is exactly the time a seafarer should be resting and preparing for work.

C. Multiculturalism and interpersonal relationships on board
Comparing to former selection process of ship crews, changes are evident in relation to seafarer’s na-
tionalities. According to research, the main source of maritime crew is no longer brought from tradi-
tional maritime regions, but is now moving to the whole world.

The social environment on board is unique in relation to the social environment on land. Multicultural-
ism is certainly reflected on seafarers as individuals, and therefore also on the maritime industry. It af-
flicts safety, efficiency and effectiveness of communication, work satisfaction, group cohesion, maritime
accidents, etc. Therefore, it is necessary to make constant efforts in building up the organizational and corporate culture, which are the basis for safe navigation in every sense.

When the aspects of organizational and corporate culture are clearly identified and applied successfully, multicultural crews become more efficient than those that are not. Their benefits are reflected in:

- Different approaches to problem solving and decision making,
- More competent crew,
- More work experience,
- Different types of education,
- Adaptation success.

D. Limitations on satisfying human needs
When talking about human needs, we must primarily define the motives that drive these needs. The
motif is the desire to initiate the activity of an organism, while the need is the lack of certain substances in the organism that is necessary for its normal functioning. This need is called a physiological need. In additional to physiological, there is also a psychological need that is similar to concepts such as desire and aspiration. Because of the above mentioned characteristics of work on the ship, the seafarer is not always able to satisfy these needs. This leads to various organism function disorders, which every candidate has to be aware of in order to eliminate or, at least, minimize them.

V. Highlighting the factors
The seafarer is the most significant link for a successful maritime sector process. Sailing, in this case, freight and passenger transport by sea is the primary branch of maritime affairs. As maritime sector is a global economic activity, its impact is also reflected on the global level. Thus, a high level of theoretical, practical and psychological education creates a high-quality personnel. High-quality staff influences not only the company’s success, but also global economic and ecological situation. Highlighting the factors affecting the seafarers’ psycho-physical state is one of the first steps in introducing seafarers with their future profession. Raising awareness of the specifics of the maritime vocation, which is the primary goal of this work, creates selection of candidates interested in professional navigation. Through further education, which must include mental preparedness, the selection process of candidates will be clearly de-
ined. As a product of quality education, highly trained personnel will be created, who will, first of all, on their own professional satisfaction, successfully perform their working duties.
VI. CONCLUSION

First of all, the employee, in this case the seafarer, should primarily be motivated by personal interest in this vocation. His professional choice must be his satisfaction. In this way, the seafarer will be able to successfully perform professional duties. After the individual has consciously and responsibly opted for this invitation, educational institutions, according to international standards, theoretically and practically train the candidate for navigation. In addition, in accordance with international standards, applicants attend applied courses related to crew relationships, team work, work environment adaptation, etc. Considering the current educational matrix compared to the previous ones, there are some improvements in taking care of the psychosomatic health of the seafarer. However, they need to be constantly updated and adapted in line with market changes, technological developments, environmental standards and the unique needs of the seafarer. The importance of highlighting these factors is evidently necessary both for seafarers as individuals, and for all maritime subsystems as a specific economic branch. Each educational institution, shipping company and HR manager must make efforts to provide seafarers with a comfortable working environment. Personnel processes must be in the immediate function of achieving the goals of the shipping company together with the goals of the individual in order to achieve employee identification with the goals of the company and build a work environment that meets the psycho-physical integrity of the seafarer and the goals of the maritime enterprise. Finally, it is concluded that emphasizing these factors, in addition to practical and theoretical training, candidates need to be mentally prepared for the specificity of their future occupation. By the synthesis of these three types of training, high-quality marine personnel develop their professional engagement with personal and global benefits, while not endangering the overall psychophysical integrity.

REFERENCES


What Does A Doctor of Medicine Do at The Faculty of Maritime Studies?

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ABSTRACT
First Aid and Medicine for seafarers are compulsory subjects at the Faculty of Maritime Studies in Split. Course contents are envisaged by the STCW Convention. No crew member can be signed on board of the vessel without having attended first aid and without Dυυ certificate. Deck Officers and Chief Engineer, in addition to Dυυ, should have a Dφτ certificate. Its content is foreseen in the subject Medicine for seafarers. Subjects The First Aid and Medicine for Seafarers at the Faculty of Maritime Studies in Split are trained by a Doctor of Medicine, specialist doctor of public health, who is in full-time employment. According to our knowledge, other faculties of maritime studies employ Doctors of Medicine of various specializations as external associates. Judging by many years of experience, students are reluctant to listen to these subjects, probably from the belief that these contents will not be needed in the future. The experience gained in working with older students, who worked on shore, shows that they have a different attitude towards the mentioned courses and are actively participating in them.

KEYWORDS: Doctor of Medicine, first aid, medical care & seafarers

I. INTRODUCTION
Seafaring is, by its nature, international activity. This means that national laws and recommendations alone can do little to ensure health and safety on the seas of the world. There is now a framework of international conventions as basis for common global standards of safety and, to an extent, for maritime healthcare provision. Health and safety at sea are challenges in an industry where ships may be owned in one country, trading between other ones, and managed by the crewmembers that have different cultures and only a limited command of a common language [υ, φ, χ].

Seafaring has always been considered a dangerous profession with a higher morbidity and mortality than in most professions ashore. Merchant ship crews are exposed to extreme conditions of weather, hazards connected with the operation of mechanical equipment, toxic cargoes and toxic substances used aboard. Their health is affected by noise, vibration, smoke inhalation, fatigue, overwork, and other exposures. Travelling to the tropics can result in exposure to exotic diseases such as malaria and other infectious diseases [ψ].

Maritime medicine is not adequately established, nor a properly defined discipline within the medical world. There is no speciality in the field, and the establishment of academic degrees has just started. Tentatively, a definition of maritime medicine could be “any medical activity related to questions concerning the employment, working conditions, living conditions, health and safety of workers at sea”. This type of definition includes various types of maritime professions, including the employees in the commercial fleet, the navy, the fishing fleet, sea piloting, offshore installations, and leisure boats [1]. Maritime medicine has important shared interest areas and competencies with occupational medicine, primary health care, emergency medicine, public health, tropical medicine, and travel medicine [1, 4].

In case of sudden illness or an accident and injury during the ship’s voyage, the chances of receiving proper and effective treatment are limited for seafarers in regard to ordinary employees on shore as for the lack of direct and prompt access to qualified medical assistance. Due to the aforementioned, seafarer’s health education and training in order to provide basic medical services on board are mandatory [4].
II. MOST COMMON SEAFARERS HEALTH PROBLEMS

There is no systematic, continuous monitoring of the seafarers health status, mainly as for the majority of medical health care services are requested in the different ports of the world, without the coordination of diverse health systems. With the technological and social development much has improved in the seafarers’ lifetime. Injuries are still among the seafarers leading causes of working inability. However, other health problems have not disappeared, only the causes and health issues have changed. Previously, in terms of seafarers’ diseases, the first associations were infectious diseases \[\omega\]. HIV / AIDS infection is one of the most important public health issues in the world today and it is usually introduced by seafarers in their living community \[\iota\]. Today, the main causes of seafarers’ morbidity are chronic illnesses related to their lifestyle, primarily cardiovascular diseases but there are also various malignant diseases as a result of occupational exposure \[\upsilon, \omega\]. With the technological improvement in ship technologies, many activities previously operated by seafarers are now managed automatically by machines. Even if there is an exercise room or a gym on board ship, taking into account the limited space on the ship, the question arises if the seafarers have the enough exercising habits to spend the excessive intake of calories.

Many duties on a modern vessel have become sedentary and inactive or they require only moderate level of energy expenditure, so the extent of physical inactivity is alarmingly high. The nutrition quality on ship is often limited \[\upsilon\] and there is frequently lack of professional cooks resulting in unsatisfied and overweight crewmembers \[\psi\].

III. MEDICAL ASSISTANCE AT SEA

With fact that on board merchant ships there are no professional medical doctors, a sick seafarer is confronted with unfavourable conditions, vulnerable in the open seas, hundreds of miles distant from the closest doctor. The future seafarers comprehend the basic knowledge of first aid and medical care in their education process in various institutions and schools which only partially mitigates the problem, as the level of knowledge acquired is rarely refreshed, while the extent of medical aid which should be administered by ship’s officers often extends beyond their professional abilities.

Due to the current relations, there has been a need for seafarers to establish a fast contact with a doctor in order to consult the personnel authorized to provide the medical services on board about the setting of diagnosis, treatment and care of the diseased persons. The establishment of radio and tele-medical assistance on board ship and increase in range of marine radio stations enabled the efficient communication between the professional medical staff on shore and crew in provision of medical assistance onboard.

IV. SEAFARERS HEALTHCARE ON BOARD SHIP

The provision of the proper professional healthcare is not often disposable for an ill or injured seafarer at sea \[\phi\]. Ships without a medical doctor on board are required to have either at least one seafarer who is in charge of medical care and administering medicine as part of his regular duties. The crewmembers in charge of medical care on board who are not medical doctors are obligated to have satisfactorily completed training in medical care. Hence, there must be medical equipment available, a person trained to use it and ready access to information on the prevention, diagnosis and treatment of a disease. Normally, these instructions are found in the form of a manual which are supported by international arrangements for access to radio medical advice all over the world \[\upsilon \iota\].

Considerable effort has been done to improve seafarers living and working conditions on the global scale. The Maritime Labour Convention requires all ships to carry a medical chest and medical equipment, while the International Maritime Organization’s (IMO) International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) addresses medical competences required for seafarers on board. The aim of the Convention is to ensure that, in emergencies, ship based medical care is similar to that found ashore. The STCW Convention from 1978 is of particular importance from the maritime health professional’s point of view. Despite being very general in its approach, the
The STCW Convention regulates the pre-sea medical and periodic examinations of seafarers, but also defines the standards for emergency medical training requirements for different groups of personnel on board [2, 3].

Medical emergency procedures training and medical care are other very important issue areas for the STCW Convention. The training requirements differ according to the professions and ranks on board. The first or the lowest level of training requirements on ship is “Personal survival techniques”. These competencies are obligatory for anyone signing on to a ship, as well as for the next step of “Elementary first aid” requirements. The next level of competences and requirements is “Medical first aid” course, whose obligation and application depend on the certain positions on board, usually delegated to the master and deck and engine departments. The highest level is “Medical care”. This course aims at training dedicated personnel to carry out medical care on board and is obligatory for all nautical personnel. While the responsibility for medical care is always on ship’s master, it is usually the 1st officer delegated to handle all practical cases.

The seafarers’ knowledge and skills on board ship, regarding the medical competencies, are covered by the STCW Convention requirements for training level of nautical personnel which is a necessity in acquisition of mandatory medical certificates.

According to international conventions and regulations, seafarers must be covered by adequate measures for the protection of their health and have access to prompt and adequate medical care, including the proper dental care, whilst working on board. Health protection and care should be provided at no cost to the seafarer, in accordance with national law and practice. Ship-owners are obligated to provide the right to visit a qualified medical doctor or dentist without any delay in ports of call, where practicable to seafarers [2, 10]. All ships should have adequate and sufficient medical chest and equipment which are complementary to the type of activity they are engaged in. The medical chest and equipment must be maintained in good order, including for example, properly labelled and stored medicines where the expiration date has not yet passed and maintaining the equipment functionality. Ships must also carry medical guides. Medical chest contents guidance information can be found in the International Medical Guide for Ships [2, 3, 10].

If the ship is engaged in carrying dangerous or hazardous goods, the medical chest should contain the equipment necessary for treating personnel who may come into contact with cargo. Information on these requirements can be found in the Medical First Aid Guide for Use in Accidents Involving Dangerous Goods. Verification that the necessary information on the nature of the substances, the risks involved, the necessary personal protective devices, the relevant medical procedures and specific antidotes should be available to the seafarers on ships carrying dangerous cargoes. Therefore, specific antidotes and personal protective devices should be on board whenever dangerous goods are carried.

V. SEAFARERS EDUCATION IN CROATIA WITH REGARD TO MEDICAL FIRST AID AND MEDICAL CARE COURSES

The education of seafarers’ in Croatia with regard to acquiring the Medical First Aid and Medical Care courses is performed by secondary maritime schools, maritime faculties and private maritime schools. These courses are performed in accordance with international requirements and conventions. Maritime Medicine is a compulsory course in secondary maritime schools as well as for students of all four undergraduate university study programmes at the Faculty of Maritime Studies in Split. After completing the required classes and meeting the prescribed conditions for acquiring the certificate at the faculty, students are eligible to receive a certificate D19 (Medical First Aid) upon completing their education. In addition to Medical First Aid course, Medical Care is also compulsory course solely at Nautical Studies programme, where students, after completing the classes and the required conditions for obtaining the certificate, receive a certificate D20 (Medical Care) upon completing their education. It should be emphasized that Medical Care is also an elective course in undergraduate university studies in Marine Engineering and Marine Electrical Engineering and Information Technologies.
It is seen that some of the institutions of higher education in Croatia have established a diverse study programme of Medical First Aid and Medical Care courses. The syllabus is, as a rule, created and organized in form that only students of undergraduate study programme of Nautical Studies have Medical Care course while the Medical First Aid course is excluded from the regular classes. In such conditions, future seafarers are compelled to invest in education by attending the courses of education or lifelong learning in various training centres, which are organized in secondary maritime schools, private schools or at faculties. It should not to be forgotten that all crew members are obligated to poses a Medical First Aid (Dυυ) certificate on board ship and if this course is not included in regular study programme, after the completion of their education on faculty, seafarers are ought to attend and compensate the course at the various training centres which is linked to additional obligations and costs.

VI. CONCLUSIONS

Despite the modern ship technologies, high-quality crew accommodation components and exceptional ship communications, the absence of a doctor on board most merchant vessels represents an issue in terms of the timely, adequate and efficient response to acute health disorders and life-threatening injuries. All crew members engaged in merchant navy ships should be qualified to provide first aid assistance, while officers should manage to provide also the medical care assistance. The quality of the level of knowledge is often questionable. Improvement recommendations are related to the programme equalization of courses “Medical First Aid” and „Medical Care” courses and implementation of “Medical First Aid” as a mandatory course in syllabuses on all higher maritime education institutions. Finally, it is suggested the inclusion of health promotion and rise in seafarers awareness of responsibility for their own health condition.

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Creation of Montenegrin Maritime Safety System through the Prism of Legal Solutions

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ABSTRACT
Securing the safety of maritime navigation is one of the strategic objectives of the International Maritime Organization (IMO), which regulates this area through the adoption of numerous international conventions. EU also pays particular attention to this issue through the adoption of numerous directives. To this effect, and bearing in mind the obligation of their application, each country creates a maritime safety system through establishment of an institutional framework on the one hand and on the other hand through creation of its national legislation. This issue is of particular importance since there are realistic expectations for Montenegro, as an associate member of the Paris Memorandum of Understanding on Port State Control (Paris MoU), to became its full member and a potential member of the European Union in the near future. In her paper, the author talks about the creation of Montenegrin national maritime safety system through the implementation of institutional and legislative reforms. The author pays particular attention to harmonization of maritime legislation related to PSC with the Paris MOU and Directive No. 2009/16/EC on Port State Control, as a necessary condition for entry of Montenegro in the Paris MoU and for obtaining the status of a full member.

KEYWORDS: safety, maritime navigation, maritime safety system & the legislative framework

I. INTRODUCTION
Maritime safety cannot not be viewed in isolation from the international framework. Still, the role of each state individually is invaluable. UN, IMO and ILO adopted numerous international pieces of legislation in order to improve maritime safety. As a result, nowadays, there is a comprehensive legal system which, by means of numerous conventions, guidelines, codes and other legal instruments, governs almost all aspects of maritime safety (ship safety, cargo safety, labour safety and navigation safety). Nevertheless, their existence and adoption in itself, although being the imperative of maritime navigation, is not sufficient to ensure a safe navigation. As a matter of fact, legal instruments can accomplish their purpose and be effective only when they are implemented and strictly enforced by the state.

Ensurance and improvement of maritime transport safety is the primary task set by Montenegro [9] and so is, in this context, keeping the pace with regional maritime trends toward becoming a member of the Paris Memorandum of Understanding on Port State Control (Paris MoU) - as one of nine regional Agreements on PSC. Montenegro, as a flag state and as a port state, endeavours to fulfil its commitments from numerous international instruments. On one hand, this is reflected in a responsible relation to the ships flying the flag of Montenegro in terms of jurisdiction and supervision. On the other hand, this is reflected in the observance of procedure of inspection and control of foreign ships calling at the ports or anchorages of Montenegro. A starting point for a responsible conduct is the establishment of an adequate institutional system which will be capable of ensuring the fulfilment and observance of requirements of international conventions, ratification of all necessary international conventions on maritime safety, and establishment of effective mechanisms which are necessary in order to ensure implementation and enforcement of international conventions through adoption of national pieces of legislation which are compliant with requirements contained in international regulations.

This work devotes particular attention to the above commitments from the perspective of ensuring a full membership of Montenegro in the Paris Memorandum. The first part of the work provides a brief overview of the maritime institutional framework in Montenegro, with particular reference to port state control officers (PSC officers) as the pillar of port state control. The work also provides an overview of ratified international conventions in the field of maritime safety and shows how they are incorporated into the national legislation. The next part of the work has been devoted to the activities undertaken by Montenegro toward putting in place legal reforms and harmonisation of national legislation with the Paris Memorandum in order to become its full member. Finally, the work provides final considerations.
II. MARITIME ADMINISTRATION OF MONTENEGRO

The maritime administration of Montenegro has been set up using as a model the structure which existed in the former state. The Ministry of Transport and Maritime Affairs is the overarching institution in Montenegro in charge of maritime transport. Within the Ministry, there is the Directorate for Maritime Transport under which Harbour Master’s Offices\(^1\) and Maritime Safety Department\(^2\) fall.

The Ministry of Transport and Maritime Affairs performs activities related to: maritime transport, safety and security of maritime navigation, security protection of merchant ships and ports for international transport, prevention and taking of emergency measures in case of sea pollution from vessels etc. The Maritime Safety Department is in charge of activities related to: navigation safety in the coastal sea of Montenegro, issuance of certain documents and certificates to Montenegrin ships, organisation and performance of maritime search and rescue action, protection of sea against pollution from waterborne and floating crafts etc. Harbour Master’s Offices are in charge of: keeping register books, acquisition of competences by the crew members, inspection of ships and other vessels in terms of their seaworthiness, the condition of their plants, devices, instruments, apparatuses and equipment etc.

In the context of this work, particularly important are inspections of foreign ships and crew calling at the ports or anchorages of Montenegro, which fall under the field of competences of the Harbour Master’s Office Bar and Harbour Master’s Office Kotor\(^4\) i.e. Montenegrin Port State Control Officers (PSCOs). These officers have been granted a special authorisation by the port authorities in Montenegro. Since they are the pillar of inspection of foreign ships, the speed of accession of Montenegro to the Paris MoU highly depends on them. To be able to perform inspection activities, the officers must meet certain requirements in compliance with Annex 6 to the Paris MoU entitled “Minimum Criteria for Port State Control Officers” and, in connection with this, Section 3 Item 3.3. of the Paris MoU and Article 22 of the DIRECTIVE 2009/16/EC on port State control. These are general and specific requirements which have to be met. Such requirements have been incorporated in the Montenegrin legislation by adoption of the Law on Maritime Navigation Safety\(^3\) and the Rulebook on Special Conditions to be Met by Maritime Navigation Safety Inspectors and on Inspection Procedure from 2015\(^6\) which ceased to be valid by the adoption of the new Rulebook on the Procedure of Ship Inspection and the Design of Identity Cards of Inspectors\(^7\) which entered into force on 1 January 2019.

In addition to the fulfilment of necessary requirements, a special attention has been focused on allocation of certain funds for training and professional development of Montenegrin inspectors. The aim of this is to perform a safe and efficient inspection of foreign ships. In this sense, particularly important is the active participation of inspectors in numerous seminars and workshops organised by IMO, EMSA and other organisations aimed at training and professional development of PSCOs.\(^4\)

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\(^1\) In Montenegro, there are two Harbour Master’s Offices: Harbour Master’s Office Bar and Harbour Master’s Office Kotor, with Harbour Branch Offices in Ulcinj, Budva, Virpazar, Tivat, Zelenika and Herceg Novi.

\(^2\) Maritime Safety Department comprises the following organisational units: Technical Inspectorate for Vessels Division, Division for the Prevention of Sea Pollution from Vessels, Marine Telecommunications Division, Maritime Search and Rescue Division, Aids to Navigation Division, Register of Yachts Division, and Administration, Finance and Technical Maintenance Division.

\(^3\) Hereinafter referred to as: LMNS.

III. INTERNATIONAL LEGISLATION

In respect of international legislation, Montenegro adopted numerous international conventions which, in compliance with the Article 9 of the Constitution of Montenegro from 2007 [1] “... shall make an integral part of the internal legal order of Montenegro, shall have the supremacy over the national legislation and shall apply directly when they regulate relations differently than the national legislation”. As a member of IMO - a specialised agency of the United Nations with its basic task to improve maritime safety and security and prevent vessel-generated pollution of the sea – Montenegro is a party to the most important international conventions in the field of maritime safety. Further, as a member of ILO, which plays an important role in respect of maritime safety and in particular occupation safety, Montenegro is a party to numerous conventions adopted by ILO in the field of maritime affairs and in respect of working conditions of mariners on ships. The adoption of the Maritime Labour Convention from 2006 was particularly important. By ratifying the Convention, Montenegro ensured the fulfilment of minimum requirements in terms of working and living conditions of mariners sailing on the ships which fly the flag of Montenegro [8].


IV. NATIONAL LEGISLATION

Reforms in the maritime legislation of Montenegro cannot be viewed in isolation from the strategic commitment of Montenegro to become an EU member-state and, in this regard, a member-state of the Paris MoU [3]. In order to accomplish these priorities, Montenegro is fully devoted to the fulfilment of required conditions. As a result, following its accession, Montenegro could function within the system of inspection of foreign ships in its ports i.e. the pre-determined rules of EU. One of conditions to be fulfilled by Montenegro is to harmonise its maritime legislation with the ratified Paris MoU and EU legislation, primarily the Directive 2009/16/EC on port State control (Directive on PSC). The Directive on PSC contains almost all main provisions of the Paris MoU and, where necessary, regulates specific issues in more detail. In terms of enforcement of PSC, this Directive is a legal commitment for EU member-states.

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5 Given that EU member-states were not consistent in terms of implementation of the Paris Mou, the need arose for EU to intervene toward adoption of its own legislation on PSC. On 19 June 1995, EU adopted the Directive 95/21/EC on port State control, which was subject to several amendments (Council Directive 98/25 EC, Commission Directive 98/42 EC, Commission Directive 1999/97 EC, Directive 2001/106 EC, Directive 2002/84 EC) and repealed by the Directive 2009/16/EC.
(therefore, not for all members of the Paris MoU) and establishes the control system within the already existing system. By its adoption, the European Union ensured that all EU member-states implement the Paris MoU consistently and fully, with appreciation of specificities of maritime policy of EU. Such EU support makes the Paris MoU more efficient than other similar regional Agreements which do not have such legally binding legislative support.

Montenegro adopted a number of laws and by-laws in order to ensure a better implementation and practical enforcement of international Conventions, the Directive and the Paris MoU itself. The above Law on Maritime Navigation Safety [4] and Rulebook on the Procedure of Ship Inspection and the Design of Identity Cards of Inspectors [7] are particularly important. They were adopted, among the other things, in order to harmonise the maritime law of Montenegro with international Conventions and EU acquis, to keep pace with the development of new standards in the field of navigation safety, and to harmonise the provisions on inspection with provisions of the Paris MoU.

A. LMNS and provisions on PSC

The Law on Maritime Navigation Safety shall regulate the conditions for maritime crafts, crew and waterborne crafts that navigate in the inland waters and in the territorial sea of Montenegro for safety of maritime navigation and other issues which ensure safety of maritime navigation (Article 1 of LMNS). The Rationale of the LMNS specifies that the Law incorporates all relevant and binding international conventions (including their Protocols) and numerous regulations (Directives) of the European Union. Directive 2009/16/EC on port State control [2] has been partly appreciated i.e. several of its provisions have been incorporated into the Law. However, the full transposition of provisions was expected to happen by the adoption of a by-law on PSC.

Section XIV (Inspection) of the LMNS of Montenegro regulates inspection in Articles 183 to 198. Inspection of foreign ships calling at the ports of Montenegro is a part of inspection of navigation safety. The legal basis for performance of inspection of foreign ships is provided in Article 186 of LMNS. This Article clearly specifies that inspectors are bound to inspect foreign ships calling at the ports or anchorages of Montenegro. During inspection, inspectors check whether the crew manning and total condition of the ship (including engine room, premises for the accommodation of crew members and hygiene conditions on board) are in compliance with the rules and standards stipulated in relevant international Conventions. These are “relevant instruments” of the Paris MoU: SOLAS Convention, LL Convention, MARPOL Convention, STCW Convention, Merchant Shipping (Minimum Standards) Convention, COLREG, CLC Convention, TONNAGE Convention, BUNKER Convention, MLC Convention, International Convention on the Control of Harmful Anti-Fouling Systems on Ships, 2001, Athens Convention relating to the Carriage of Passengers and their Luggage by Sea, 1974, amended by Protocol of 2001.6 Where inspection is performed over a ship flying a flag of a state which is not bound by the above Conventions, the Montenegrin legislator, in compliance with the Paris MoU and EU Directive, also starts from the principle “no more favourable treatment”. 7 In such case, the inspector shall check whether the ship meets certain safety requirements in terms of structure, equipment, crew members, cargo (type, quantity and stowage), number of passengers and total load, in order to be able to safely continue its scheduled voyage. When inspecting the safety of navigation of ships, the inspector shall primarily, but not exclusively, take into consideration the contents of the above Conventions.8

In terms of inspection of foreign ships, Articles 187 and 188 of the LMNS are important since they entitle inspectors to undertake certain measures in case that, during inspection, it becomes ascertained or there is a reasonable doubt that there are certain deficiencies (which are an obvious threat to safety, health and environment). Although LMNS does not expressly specify the measures, it could be concluded based on the formulation of these Articles that an inspector shall be entitled to prohibit a ship to leave the port of Montenegro, prohibit performance of certain operations on board, as well as prohibit a

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6 Article 186 paragraph 1 of LMNS.
7 Section 2 item 2.4 of the Paris MoU and Article 3 item 3 of the EU Directive.
8 Article 186 paragraphs 2 and 3 of LMNS.
ship to enter the port of Montenegro. LMNS does not provide the definition of terms “prohibition of navigation”, “refusal of access”, “prohibition of operations”, whereas it clearly specifies the cases where these measures are undertaken. This is understandable to a certain extent because the by-law i.e. Rulebook from 2015 was expected to regulate more closely the procedure of inspection performance.

A foreign ship shall be prohibited from leaving the port of Montenegro in case of identification of some of the following deficiencies:

- the ship has no valid documents which are required under the above international Conventions;
- the position of load line or free board does not comply with the data contained in such documents;
- the ship has not been loaded in accordance with approved load line, or freeboard;
- the cargo was not properly arranged;  
- if the inspector establishes that the vessel has embarked more persons than permitted (Article 187 of LMNS).

The measure of prohibition of operations shall be imposed on a ship if it has been established that a foreign ship holds no valid document demonstrating the proper working order of ship equipment used for cargo loading and unloading, or if it has been established that the condition of such devices is not in compliance with the data on such document. In this case, the loading and unloading of cargo using the ship equipment shall be prohibited.

In addition to deficiencies which lead to prohibition of foreign ships from leaving the ports, LMNS envisages the measure of prohibition of leaving the port if there is reasonable doubt that:

- the condition of a ship does not materially conform to the data stated in the documents under the requirements of international Conventions;
- a foreign ship has embarked more passengers than allowed;
- there is no minimum number of properly qualified crew members on board for safe operations and the ship in such condition would not be fit to continue the voyage without putting in danger the life on board.

Prohibition of navigation may be imposed on a ship in case any deficiency is detected on the ship during inspection activities regarding the seaworthiness of a ship. According to Article 189 of LMNS, during inspection activities regarding the seaworthiness of a foreign ship, an inspector checks:

- if the ship holds valid prescribed ship documents and ship books;
- whether there have been material changes on the ship since the date of issuance or endorsement of documents (certificates) due to which the ship is obviously not fit for navigation without danger to persons, the cargo carried on board and the environment;
- if the ship meets the conditions in terms of technical supervision;
- if there is a marking of load line, or freeboard, on either side of the ship;

These prohibitions are in force as until a ship is fit to continue the voyage without putting in danger the life on board.

According to Article 194, if it has been determined that a crew member does not hold a certificate for performing specific duties on board or has no valid embarkation permit, the inspector shall give order to the master to disembark such crew member if such identified non-conformity is not remedied within a specified period.

Article 188 of LMNS.

In performing an inspection, the inspector may request from the recognised organisation or administrative body to inspect the documentation for certification of the ship which is subject to such inspection (Article 190 paragraph 5 of LMNS). If it has been determined that there is a reasonable doubt that the actual condition on board does not comply with the issued ship documents and books, or that the ship is not scheduled to enter the ports of Montenegro before the expiry of ship documents and books, inspection of seaworthiness may be conducted out of the inland seawaters and territorial sea of Montenegro (Article 190 paragraph 4 of LMNS).

Article 52 of LMNS contains provisions on technical supervision.
• drills of the crew members in handling life-boats and other life-saving appliances and devices for detection, prevention and fire-fighting;
• whether the vessel holds a valid register of cargo gear and whether the condition of the cargo loading/unloading gear complies with the data referred to in the cargo gear register.

If a deficiency is identified, the master shall be given order to rectify the identified deficiencies within specified period (Article 190 paragraph 1 of LMNS). However, if the identified deficiencies are not rectified by the master or of identified deficiencies are of such nature that they endanger the safety of ship, persons and cargo on board and the environment, or if its waste water tanks are full, the ship shall be prohibited from further voyage and its certificate on seaworthiness shall be withdrawn (Article 190 paragraph 2 of LMNS).

Additionally, LMNS envisages the obligation of removal of a ship which represents or may represent immediate danger for ports, waterways, navigation, exploitation of marine resources or environment. The inspector shall, by means of the Decision, order the ship-owner to undertake measures for removal of such ship within reasonable time, under the supervision of the Harbour Master’s Office (Article 190 paragraph 7 of LMNS). If the ship-owner fails to act under the Decision of inspector, the Harbour Master’s Office shall organise the removal of such ship by means of legal entity or natural person who perform such activities, at the cost and risk the ship-owner.

LMNS stipulates the obligation to prepare the Decision on undertaken measures as well as to provide notification of competent authorities. The inspector shall prepare the Decision on undertaken measures. The appeal against this Decision may be filed to the Ministry of Transport and Maritime Affairs. The appeal shall not delay the execution of the Decision (Article 198 of LMNS). The competent authority whose flag the ship flies and International Maritime Organization shall be informed about the state of facts determined during inspection, undertaken measures and prepared Decision, through diplomatic or consular bodies (Article 187 paragraph 3 of LMNS).

B. Rulebook from 2018

The Rulebook on the Procedure of Ship Inspection and the Design of Identity Cards of Inspectors was adopted in 2018 and entered into force on 1 January 2019, thus repealing the Rulebook on Special Conditions to be Met by Maritime Navigation Safety Inspectors and on Inspection Procedure from 2015. The main reason for adoption of the new Rulebook should be sought in the fact that the Rulebook from 2015 failed to meet expectations in terms of inspection procedure in the ports of Montenegro. In fact, the inspection procedure in the ports of Montenegro was not compliant with provisions of the Paris MoU and Directive 2009/16/EC on port State control. This resulted in performance of inspection in the manner which was not compliant with inspection procedure performed on the territory covered by the Paris MoU, which slowed down the process of accession of Montenegro to the Paris MoU.

The new Rulebook is compliant with the Paris MoU and Directive 2009/16/EC on port State control. The Rulebook regulates the manner, procedure and frequency of inspection of foreign ships calling at ports.
and anchorages of Montenegro as well as the ships of Montenegrin nationality, criteria and procedures for selection of ships for inspection, measures undertaken by maritime safety inspectors following the performance of inspection, acting in case of appeal against the Decision in compliance with the Paris MoU, and the design of identity cards of inspectors.

Provisions of Article 6 of the Rulebook envisage the obligation to perform inspection on an annual basis. Article 7 of the Rulebook envisages the possibility to delay or not to perform inspection. Article 9 stipulates the flow (procedure) of inspection performance and selection of ships calling at the ports or anchorages of Montenegro which undergo inspection. Article 8 of the Rulebook stipulates the periods between inspections and comprehensiveness of inspections. In accordance with this Article, the ships calling at the ports or anchorages of Montenegro can undergo a periodical or additional inspection. Articles 10, 11 and 12 of the Rulebook stipulate a basic, in-depth and extended inspection, respectively. Following the performed inspection, an inspector may undertake certain measures envisaged in Articles 14, 15 and 16. The Rulebook also contains provisions on submission of inspection reports (Art.18), dislocation of detained ship and ship under the prohibition of operations (Art.19), prohibition of leaving the port or operations on board (Art.20), acting in case of an appeal (Art.21), and provisions on complaints of mariners under the Maritime Labour Convention.

V. CONCLUSION

Accession of Montenegro to the port state control system within the Paris MoU region is particularly important for improvement of maritime safety at both regional and national level. Although a regional approach to port state control proved to be positive, the role of each state individually in this system is invaluable. Since 2011, when Montenegro became an associate member of the Paris MoU, the changes within the national maritime safety system became obvious. The changes developed in two directions: toward establishment of adequate institutional framework, on one hand, and toward establishment of adequate legal framework, on the other.

A well-organised and professional maritime administration is certainly one of major prerequisites for accession of Montenegro to the Paris MoU. The existence of trained port state control officers as the pillars of inspection is of primary importance. Presently, there is an adequate institutional framework for performance of PSC in Montenegro. Montenegrin PSCOs play a dominant role in this framework. Still, this does not mean that the process is finished. Due to continuous improvement of standards for performance of PSC, it is necessary that Montenegrin inspectors undergo a continuous training in compliance with Paris MoU and that they are supplied with adequate equipment to perform inspection.

Given that the Montenegrin legal framework on PSC was the main obstacle to obtaining the status of the full member of the Paris MoU, and since the performance of inspections in the ports of Montenegro was not compliant with provisions of the Paris MoU, certain measures have been undertaken in this regard. Particularly important was the adoption of the new Rulebook in 2018, whose provisions were made compliant with the Paris MoU and which entered into force on 1 January 2019. Given its recent entry into force and its compliance with the Paris MoU and Directive 2009/16/EC on port State control, the inspection of foreign ships in the ports and anchorages of Montenegro is expected to be performed in the same manner as in the other member-states of the Paris MoU region, which will make Montenegro significantly closer to the full membership in the Paris MoU.

REFERENCES


Compliant with Annex 8 to the Paris MoU and Article 11 of the Directive on PSC.


Inspection in Coastal Liner Shipping

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ABSTRACT
Public transport in costal liner shipping is the transport of passengers, cargo and vehicles in the internal marine waters and territorial sea of the Republic of Croatia performed on pre-established lines in compliance with the published terms and conditions of the sailing schedule and services pricelist. Public transport service in costal liner shipping is provided by shipping companies under a public service contract which is concluded as a concession contract for profitable lines, respectively a public transport service contract for non-profitable lines. Shipping companies perform transport by ships specially built for transport of passengers and vehicles, by high-speed passenger craft services, respectively passenger ships. The occupation of public transport service in coastal liner shipping is subject to inspection. Inspection includes in particular the inspection of shipping companies in performing their public transport services in accordance with a public service contract, the inspection of preferential transport, the inspection of international public transport, public coastal liner shipping without public service obligation and occasional transport. In addition inspection includes mandatory surveys for the safe operation of ro-ro passenger ships and high-speed passenger craft services operating on domestic and international voyages. Provisions on inspection are contained in a basic regulation governing the public transport service in costal liner shipping – Law on Coastal Liner Shipping and Occasional Costal Maritime Transport. However other administrative provisions also regulate inspection in costal liner shipping. These activities are also regulated by the Law on Harbourmaster’s Offices and the Ordinance on Inspection of Navigation Safety. The work gives full and systematic analysis of provisions on carrying out inspections in costal liner shipping.

KEYWORDS: inspection, coastal liner shipping, inspector & navigation safety

I. INTRODUCTION
Public transport1 in coastal liner shipping is an important factor in the field of maritime navigation, considering that it provides permanent and regular services between the mainland and the islands, without which there would be no sustainable development of inhabited islands in internal waters and territorial sea of the Republic of Croatia. This sector provides regular sailing route between 73 island and 22 mainland ports to a total of 56 state routes. [6]

Maritime Code of the Republic of Croatia as the basic rule of the maritime law, in Title 9, part 3, analyses the content of the inspection. Inspection surveillance of the implementation of the provisions of the Maritime Code and regulations in maritime safety are carried out by the navigation safety inspectors of the Ministry responsible for maritime affairs (hereinafter: the Ministry of Maritime Affairs) and Harbourmaster’s Offices, as well as professional employees of the Ministry of Maritime Affairs and Harbour Master’s Offices and authorized officials of the service for monitoring and management of maritime transport with special authorization granted by the Minister of Maritime Affairs. Inspections relating to supervision of implementation of the provisions of the Maritime Code of the navigation safety also include inspection of Croatian maritime facilities in terms of their ability to sail or use, or transport passengers and goods in terms of protection of human life and property.

In addition to the provisions contained in the Maritime Code [3], the provisions on inspection are also contained in the basic regulation about public transport in coastal liner shipping - Act on Transport in Liner Shipping and Occasional Costal Maritime Transport [9] and other regulations, which also gives the competence of performing inspection control in coastal liner shipping. These regulations are the Law on Harbourmaster’s Offices and the Ordinance on Inspection of Navigation Safety [4].

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1 Public transport is transport of persons and things which, under the same conditions, are available to everyone and are carried out on the basis of transport contract. [3]
II. Inspection Surveillance According to the Act on Transport in Liner Shipping and Occasional Costal Maritime Transport

Act on Transport in Liner Shipping and Occasional Costal Maritime Transport was adopted in 2006, and determines conditions and arrangements of services of public transport of general economic interest with the public service obligation, regular public transport services without public service obligation, information system of public transport, preferential transport of passengers and vehicles of islanders, organized public transport, identification, alignment and publication of timetable, providing funds for continuous, regularly and free public transport. This Act establishes the scope of international maritime liner shipping, the conditions which are to be met by the ship and the carrier, the alignment of the timetable in international liner shipping, and the occasional passenger transport. (Art 1) The Act in Part IV contains provisions on inspection in public coastal liner shipping. These provisions in the text of the Act have been included in the Amendments to the Act of 2016. Inspection supervision is regulated by articles 59 - 59.d. Supervision of the implementation of this Act and the regulations issued by the Ministry of Maritime Affairs shall be carried out by the Inspection for Navigation Safety. Inspection tasks are also performed by other civil servants of the Ministry of Maritime Affairs under a special authority issued by the Minister of Maritime Affairs. (Art 59, para 2-3)

Maritime Safety inspection supervises directly the implementation of the Act and regulations adopted pursuant to it, and monitors: shipping companies in carrying out public transport in accordance with the public service contract; the implementation of preferential transfer; and the performance of international public transport, public liner shipping without public service obligation and occasional service. (Art 59a)

Shipping companies in regular public transport perform shipping on the state, county, inter-county and local lines. On these lines, there are public service obligations. Public service obligations are defined in Art.2, pt. 4 and Art.4, pt. 2 of Regulation (EEC) No.3577/92 applying the principle of freedom in providing services to maritime transport within Member States (maritime cabotage) [7]. The shipping companies that provide transport services on these lines conclude contracts for public service. A public service contract is an agreement between the grantor / public contracting authorities and shipping companies in order to provide appropriate services, which is concluded as a concession contract for public service or as a contract for public transport (Art 4, para 1, pt.12).

Passenger and vehicle categories that are entitled to preferential transport with discounts in public transport are set out in Art.47, para. 2 of the Act, while the categories of passengers and vehicles entitled to free transport in public transport are specified in Art 47, para 3 of the Act. The manner and procedure of exercising

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2 Public service concession contract is a contract identical to the contract of public services for public transport operation, in which the selected concessionaire shall pay a concession fee in accordance with the Law on Concessions. [9]

3 Public service contract represents public supply contract which subject is transport waterway service concluded with the meaning of Annex II B, Law on public contracts. [9]

4 According to the quoted provision, the right to preferential discount transport in public transport have:
- Croatian and foreign citizens residing in the islands or Pelješac peninsula and the citizens of the Member States of the European Area and their family members regardless of their nationality, who have a registered temporary residence and that at least 183 days in a year stay in the islands or the peninsula Pelješac,
- children older than three and up to twelve years of age,
- vehicles of natural persons and foreign citizens referred to in point 1, leasing company vehicle with residence on an island registered in the competent administrative body in the Republic of Croatia,
- legal person vehicles or vehicles registered in craft, family farm, freelance activity, and the lessee users with vehicles registered on the island, and in the competent administrative body in the Republic of Croatia,
- healthcare workers and other public service employees (police, armed forces, fire fighters, port authority) whose permanent work is on the island and their official vehicles are used on the island,
- healthcare workers and their official vehicles when performing regular transport of patients from the islands to the mainland and vice versa,
- other persons who acquire the right to special regulations.

5 According to the quoted provision, the right to free transport in public transport have:
- scholars and students with residence on the island who travel each day to school or higher education institution outside the island,
- scholars and students who during schooling temporarily reside outside the island, and go on islands on weekends,
the right to preferential transport are prescribed by the Ordinance on conditions and manner of exercising the right to preferential transport on public maritime transport lines.

International maritime liner transport includes passenger ro-ro and high-speed passenger craft lines that connect Croatia with foreign ports (Art 2, para 2)

Lines in the public transport without public service obligations are not considered regular public transport. (Art. 55a, para.1) The conditions under which the public transport can perform regular services without public service obligations as well as the payment of transfer fees are regulated by Art.55a and 55b of the Act. Occasional transport of passengers in coastal liner shipping is transport that does not have fixed schedule and is not considered as public transport. (Art 56, para 1) Occasional transport of passengers is considered to be transport as an integral part of tourist offer (part of the excursion program, tourist arrangements, passenger transports), taxi service, transport of legal and natural persons for their needs. (Art 56, para 4)

During inspection, inspectors are authorized: to remedy irregularities and determine the period within which the irregularities must be eliminated; seize the objects or island card and vignettes; prohibit the provision of public transport that is done without its contract; issue a penalty charge notice; file an indictment to initiate misdemeanour procedure; submit the records of the irregularities to the (concession) grantor or the contracting authority; and take other measures and actions that are authorized by the Law, regulations adopted in accordance with the Misdemeanour Act [8]. Confiscated island cards for travellers, vehicles and a vignette for vehicles due to abuse shall be declared invalid for the period up to six months by the inspector, and in case of repeated use of specified invalid island cards they will be temporarily taken away for up to six months for each repeated case of identified abuse. (Art 59 b)

Before starting the inspection, the inspector is obliged to inform the responsible person of the legal person, unless he/she considers that such information would reduce the effectiveness of the inspection. Legal and natural persons that are engaged in public transport in accordance with the contract of public service, and implement preferential and international public transport, public liner transport without public service obligation and occasional transport are obliged to allow the inspector to carry out the inspection. An inspection record will be prepared by inspector. (Art 59 c)

If the inspector, while performing his task, determines that the shipping company is operating without contracts, carrying out such a transport will be prohibited. Because of this offense, the court shall impose a shipping company a protective measure to prohibit total or partial acquisition of concession rights according to the Misdemeanour Act. If a shipping company carries out a public transport contrary to the provisions of a public service contract, the inspector is obliged to compile a record of detected irregularities and to notify the grantor or the public contracting authority within three days. If the vessel used for public transport does not meet technical and safety requirements, the inspector will set a deadline for deficiency removal and inform the grantor or the contracting authority. Depending on the nature of the deficiency, the performance of this transport might be temporarily prohibited. (Art 59 d)

III. Inspection Surveillance According to the Law on Harbourmaster’s Offices

Ministry of Maritime Affairs has prepared the text, and referred new Law on Harbourmaster’s Offices to the procedure which adoption and coming into force is expected in the near future. Territorial structure and organization of work of harbourmaster’s offices, navigation safety and surveillance of maritime domain, organizing of

- children who attend compulsory preschool program outside the island which is their place of residence, as well as pupils and students who are studying on the island of their residence and the children who attend preschool programme on the island of their residence, for activities outside the island of their residence,
- children of one to three years of life,
- pensioners and persons older than 65 years who reside on the island,
- healthcare workers and their official vehicles when performing medical transport of patients from the islands to the mainland and vice versa,
- police officers and their official vehicles when performing duties on the islands,
- employees of other public services (police, armed forces, fire fighters, Harbourmaster’s Office and the Mountain Rescue Service) and their official vehicles in cases of disaster and in cases of emergencies and search and rescue operations, with the agreement of the Agency for coastal shipping.
their performance, rights, duties and responsibilities of employees in performing their tasks, the legal status, inspection and other issues important for operation of harbourmaster’s offices will be arranged by this Law.

Art. 4, no. 1 draft of the Law on Harbourmaster’s Offices defines the tasks of navigation safety and the point 9 expressly provides that the inspection of coastal liner shipping is the duty of navigation safety. In this way, inspectors are directly performing the task of inspection conducting in coastal shipping. It will be carried out in accordance with the Act on Liner Shipping and Seasonal Coastal Maritime Transport by inspectors of harbourmaster’s office.

IV. INSPECTION SURVEILLANCE ACCORDING TO THE ORDINANCE ON INSPECTION OF NAVIGATION SAFETY

The manner and procedures for carrying out inspection of the navigation safety, protection of the marine environment, living and working conditions of crew members on ships, security of ships and ports; the amount and obligations of reimbursement of the costs of re-inspection, the conditions to be met by the inspectors for the navigation safety, the forms and manners of issuing the identity cards and badges of the inspectors for the navigation safety, the authority to perform certain inspection tasks are determined by Ordinance on Inspection of Navigation Safety. In addition, mandatory inspections will be set up to enable safer navigation of ro-ro passenger ships and high-speed passenger crafts on regular routes that enter or leave the port in the Republic of Croatia. [1]

Art. 107 - 121 of the Ordinance on Inspection of Navigation Safety have prescribed mandatory reviews for the safe sailing of ro-ro passenger ships and high-speed passenger crafts, in particular for those on international and domestic voyages. These provisions shall apply to all ro-ro passenger ships and high-speed passenger crafts which are sailing on domestic or international routes regardless of their nationality. [2]

A. Mandatory inspections for safe sailing of ro-ro passenger ships and high-speed passenger crafts on international voyages

Prior to the commencement of a regular voyage of ro-ro passenger ships and, if applicable, a high-speed passenger craft, before the expiration of a 12-month period, the inspector must determine whether the ship holds a valid certificate issued by the flag state or recognized organization on behalf of the flag state; whether it is being reviewed for the purpose of issuing the certificates in accordance with the relevant procedures prescribed by the International Maritime Organization A.746(18) in connection with a harmonized system of survey and certification; whether the ship complies with the standards for classification under the rules of the recognized organization, or by rules accepted as equally valid by the flag state in terms of construction and maintenance of the hull, machinery, electrical and control devices; whether the ship is equipped with a voyage data recorder (VDR / S-VDR) to provide data in the event of maritime accident investigations; and whether it meets the specific stability requirements, in accordance with the provisions of the Regulation for statutory certificates of ships, when sailing in the area covered by national legislation. After the initial inspection has been carried out, the inspector makes a record on which basis Harbourmaster’s office issues a certificate of initial inspection of the ro-ro passenger ship and high-speed passenger craft. (Art 108)

Before establishment of a regular route for a ro-ro passenger ship or a high-speed passenger craft, the inspector shall check whether a company which operates or intends to operate ro-ro passenger ships or high-speed passenger craft applies special requirements set out in Annex XIX of the Regulation and complies with the

6 The quoted attachment lists specific requirements for the company. It stipulates that the inspector, when conducting the initial check on the company, the initial special inspection, the regular special inspection and other examinations, shall check the following requirements which the company is required to provide on its ro-ro passenger ships and high-speed passenger crafts:

– whether the commander is properly informed of the availability of navigation systems and other information schemes that assist him/her in the safe conduct of a ship on a voyage before a ro-ro passenger ship or a high-speed passenger craft leaves the port and to use established charts to provide navigation instructions and information;
– whether the relevant provisions of Articles 2 to 6 of the MSC / Circular 699 are applied, with changes to the Guidelines on Passenger Safety Instructions;
provisions prescribed by the initial inspection of the ro-ro passenger ship and high-speed passenger craft, and accepts in advance that the harbourmaster’s office and the state representatives of the countries which port the vessel enters, as well as other really interested Member States of the European Union, may lead, participate fully or cooperate in each investigation related to the maritime accident or incident, to allow them access to data from a VDR / S-VDR passenger ro-ro ship or high-speed passenger craft involved in an accident or incident. After the initial inspection in connection with the company, the inspector makes a record on which basis the harbourmaster’s office issues a certificate of initial inspection of the company.

Prior to establishing a regular voyage for a ro-ro passenger ship and a high-speed passenger crafts, the inspector must perform a special inspection in accordance with Appendices XIX and XX of the Regulation to ensure that the ship meets the required requirements for safe sailing on a regular basis. (Art 110)

On the basis of satisfactory results of the initial inspection and the initial special inspection, the harbourmaster’s office shall issue the approval for regular voyage navigation in accordance with the Act on Transport in Liner Shipping and Occasional Coastal Maritime Transport.

- whether the working time schedule is set up at a visible place on board, whether it contains a work schedule at sea and in port, and the highest number of working hours or the minimum number of hours of rest for crew members keeping the watch;
- that the commander does not have any decision-making obstacles which, according to his professional judgment, are necessary for safe sailing and ship operation, especially in poor weather conditions and sea state;
- whether the commander keeps records of navigational activities and incidents that are important to the safety of navigation;
- whether there is any damage or permanent door distortion of the shell plate, as well as the plates itself, which may affect the integrity of the ro-ro passenger ship or passenger high speed craft, and damage to the equipment for fixing such doors, immediately reported to the flag State and to the host State; repaired;
- whether there is an updated passage plan on board before departure of a ro-ro passenger ship or passenger high speed craft; IMO Resolution A.893 (21) must be taken into account when making a passage plan;
- whether passengers on board have information on services and assistance available to the elderly and the disabled, and whether they are available in a form suitable for persons with visual impairment.

7 Appendix XIX of the Act cited in the note No 6

8 The quoted attachment lists procedures for conducting special examinations. It stipulates that a special inspection has the purpose of ensuring that statutory requirements, in particular those relating to construction, reconstruction and stability, machinery and electrical installations, boarding, stability, firefighting equipment, maximum permissible number of passengers, rescue and transportation of dangerous materials, radio communications and navigation are fully met, and such a review shall, where applicable, cover at least the following: starting the emergency generator; emergency lighting overview; an overview of emergency power supplies for radio installations; fire exercise, including demonstration of the use of appropriate equipment; an inspection of the emergency fire pump operation with two fire extinguishers connected to the main fire line; remote control of fuel supply for boilers, main and auxiliary machinery and ventilation shutdown; control of remote and local control of fire damper; fire detection and fire alarm systems testing; proper closing of fire doors testing; work of bilge pumps; closing of watertight bulkheads, locally and remotely; to determine whether the key persons on board are familiar with the Damage Control Plan; the landing of at least one boat and a rescue boat in the sea, referring and testing the engine and the steering system, and the return of the boats to their place on board; checking the inventory status of all lifeboats and collecting boats; and testing the ship’s steering gear and auxiliary steering gear. The special inspection must include a check on the planned maintenance system on board. The special review must focus on the familiarization of crew members and their effectiveness in carrying out security procedures, emergency procedures, maintenance, work procedures, passenger safety, navigating bridge procedures, and cargo and vehicle related procedures. It is necessary to check the data in the logbook relating to the ability of seafarers to understand and, where necessary, issue orders and instructions and to provide feedback in a common working language. Check for the existence of documented evidence that crew members have successfully passed special courses, in particular with regard to mass management, familiarity, safety training for staff directly assisting travellers in passenger areas, especially elderly and helpless persons in case of sudden situations, crisis management situations and course on human behaviour. The special inspection shall include an assessment of whether the compilation of the passenger list causes unnecessary disturbance to particular crew members who keep the watch. Certificates of crew member qualifications issued by third countries will be recognized only when they comply with Rule I / 10 amended by the STCW 78 International Convention.
Ro-ro passenger ship and high-speed passenger craft shall be subjected to a special inspection, once in 12 months, in accordance with Annex XX⁹ of the Act, and to inspection during regular voyage, which aims to cover as many areas as indicated in appendices XIX¹⁰, XX¹¹ and XXI¹² of the Act in order to confirm that the ship meets all the necessary requirements for safe navigation.

A special inspection shall be carried out in accordance with the Annex XX¹³ of the Act in cases where a ro-ro passenger ship or high-speed passenger craft carries out major repairs, modifications or changes, or when changing the company or flag of affiliation or the classification society. However, when changing company, the vessel shall be relieved from a special inspection, if harbourmaster’s office determinates that the safe navigation of the ship is not endangered by these changes.

The inspector will prohibit ro-ro passenger ships or high-speed passenger crafts from operating on a regular basis in cases where:

- they do not comply with the provisions of the Ordinance on initial inspection on ro-ro passenger ships and high-speed passenger crafts and initial inspection related to company and flag states;
- deficiencies are identified in accordance with the initial and regular special inspection and other examinations which pose an imminent threat to human lives, the ship, its crew and the passengers;
- there are identified deficiencies that are contrary to the requirements regulating the reporting of dangerous and polluting substances, the minimum requirements for seafarers’ training, the ISM Code, which pose an imminent threat to human lives, the ship, its crew and passengers;
- no consultations by the flag state concerning the provisions of a special regulation governing exemptions and the issuance of a license for high-speed craft operations;
- ship does not have permission to sail on a regular basis.

The prohibition of the task will last until the possible danger has been removed and the requirements of the Act are met.

When a ro-ro passenger ship or a high-speed passenger craft is already sailing on a regular basis and deficiencies are detected, the inspector shall order their removal within a specified period, provided that the identified defects do not present an immediate danger to the safety of the ship, its crew and passengers. When the deficiencies have been removed, the inspector will check it. On the contrary, the operations will be prohibited.

When performing inspection, the inspector must cooperate with the appropriate services of the host state. Special inspections must be carried out by teams of qualified inspectors, and inspectors from other host states may also be involved in the team. The inspector submits his/her record to the Ministry of Maritime Affairs and Ministry to the flag state, if that state is not a host state but is included in the inspection of the ship. The inspector can inspect the vessel on a regular basis at the request of the other host state. At the request of the company, the inspector must invite representatives of the flag state (which is not one of the host states) to be present at a special inspection in accordance with the provisions of the Act. The inspector makes a record based on the findings of the initial and regular surveillance.

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⁹ Appendix XX of the Act cited in the note No 8
¹⁰ Appendix XIX of the Act cited in the note No 6
¹¹ Appendix XX of the Act cited in the note No 8
¹² The quoted attachment provides guidelines for inspectors in carrying out unannounced inspections during regular shipping on a ship. It provides guidance on: passenger information, loading and stability information, sailing conditions, safety notices, log entries, dangerous goods, cargo attachments, watertight doors closing, firefighting, communication in emergency situations (distress), working language among crew members, safety equipment, navigation and radio equipment, additional emergency lighting, emergency exits, procedures books, engine room cleanliness, garbage disposal, scheduled maintenance and navigation.
¹³ Appendix XX of the Act cited in the note No 8
B. Mandatory inspections for safe sailing of ro-ro passenger ships and high-speed passenger crafts on domestic regular voyage

Prior to the commencement of a regular voyage of ro-ro passenger ship or high-speed passenger craft, or before the expiration of a 12-month period for a ship that is already on the regular voyage, the inspector must check whether the company managing or intending to operate the ro-ro passenger ship or a high-speed passenger craft on a regular basis applies special requirements set out in the Annex XIX of the Act. In addition, prior to the establishment of a regular voyage for a ro-ro passenger ship and high-speed passenger craft, or before the expiry of a 12-month period for a ship that is already sailing on a regular voyage, the inspector must perform a special inspection in accordance with appendices XIX and XX of the Act, to ensure that the ship meets the requirements for safe sailing on a regular basis. According to the satisfactory results of the inspection of the company and the special inspection, the harbourmaster’s office issues the approval for navigation on a regular basis in accordance with Act on Transport in Liner Shipping and Occasional Coastal Maritime Transport. (Art 118)

Ro-ro passenger ship and high-speed passenger craft shall be subjected to a special inspection, once in 12 months, in accordance with Annex XX of the Act and the inspection during regular voyage, which aims to cover as many areas as mentioned in Appendices XIX, XX and XXI of the Act for the purpose of confirming that the ship meets all the necessary requirements for safe navigation. A special inspection shall be carried out in accordance with Annex XX of the Act in cases where a ro-ro passenger ship or high-speed passenger craft has major repairs, overhauls or when it changes a company. However, when changing company, the vessel shall be relieved from a special inspection, if harbourmaster’s office determinates that the safe navigation of the ship is not endangered by these changes. In the event of a special inspection during the regular voyage, the inspector gives due consideration to the requirements in terms of navigation and maintenance of the ship. On the findings of a special inspection, the inspector makes a record. (Art 119)

The inspector will prohibit ro-ro passenger ships or high-speed passenger craft from operating on a regular basis in cases where:

- the ship does not have a permit to sail on a regular line in national navigation;
- deficiencies are identified in accordance with a special inspection and inspection during a regular voyage which pose an imminent threat to human lives, the ship, its crew and passengers, and environment;
- there are identified deficiencies that are in conflict with the requirements regulating the reporting of dangerous and polluting substances, the minimum requirements for seafarers’ training, the ISM Code, which pose an imminent threat to human lives, ship, its crew and passengers, and environment.

The prohibition of the operation will last until it is established that the immediate danger has been removed and that the requirements of the Act are met. In the event of prohibition, the inspector must also notify the company, and state all the reasons for prohibiting the operation. (Art 120)

Upon completion of the inspection, detailed, extended, initial, regular or special one as well as other examinations, the inspector shall make a record. The record contains the results of the inspection with all deficiencies.

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14 Appendix XIX of the Act cited in the note No 6
15 Appendix XIX of the Act cited in the note No 6
16 Appendix XX of the Act cited in the note No 8
17 Appendix XX of the Act cited in the note No 8
18 Appendix XIX of the Act cited in the note No 6
19 Appendix XX of the Act cited in the note No 8
20 Appendix XXI of the Act cited in the note No 12
21 Appendix XX of the Act cited in the note No 8
The inspector is obliged to acquaint the commander of the ship with the contents of the record, as well as all obligations arising from it (for the commander of the ship, owner or other authorized person). If there are deficiencies, for which a measure of prohibition on a regular voyage is imposed, the inspector will prohibit further operations. A copy of the record and a decision on the prohibition of operations are to be handed over to the commander, the shipping company and the Ministry without delay. The Ministry informs the competent authorities of the flag state, or other interested parties as soon as possible, within 24 hours at the latest. (Art 120a)

According to the data\textsuperscript{22} on the inspection of ro-ro passenger ships and high-speed passenger crafts on domestic regular voyage in 2018, a total of 70 inspections of ro-ro passenger ships and 44 of high-speed passenger crafts were performed. There were 39 ro-ro passenger ships under inspection; irregularities were detected on a single ship. This represents only 1\% of the irregularity of all examinations performed. On the other hand, 18 high-speed passenger crafts were subjected to 44 inspections and irregularities were found in only one vessel. This represents 2\% of irregularities from all examinations performed.

V. CONCLUSION

Inspection surveillance in coastal liner shipping is carried out on the basis of several regulations. It is performed by authorized inspectors of the Ministry of Maritime Affairs or the competent Harbourmaster’s offices. Inspecting the implementation of the provisions of the Act on Transport in Liner Shipping and Occasional Coastal Maritime Transport refers in particular to inspection of ships performing public transport pursuant to a public service contract, preferential transport and international public transport, public liner transport without public service obligation and occasional transport. Inspection in accordance with the Act on Transport in Liner Shipping and Occasional Coastal Maritime Transport shall be subject to the provisions of the Law on Harbourmaster’s Offices and are in direct competence of the harbourmaster’s offices.

In addition to the aforementioned types of inspection, in the aspect of maritime navigation safety, the inspection in accordance with the Ordinance on Inspection of Navigation Safety is of particular importance. This inspection includes mandatory inspections for the safe sailing of ro-ro passenger ships and high-speed passenger crafts, particularly those on international and domestic voyage. These provisions shall apply to all ro-ro passenger ships and high-speed passenger crafts, irrespective of their nationality whether they are on domestic or international routes. In practice, inspections are usually carried out before the tourist season, after a regular annual overhaul on the vessel. Then all ships on each line are subjected to surveillance. If there is a rotation of ships on certain lines, no reviews are made and previous surveys are also taken into account. By reviewing available data about the inspection of ro-ro passenger ships and high-speed passenger crafts in 2018, it can be concluded that the number of deficiencies identified in these inspections is minimal and there is a satisfactory level of navigation safety of these types of vessels.

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Legal Framework for Marine Environmental Governance

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ABSTRACT
Marine environmental governance covers rules, institutions, processes, agreements, arrangements and activities
carried out to manage the use of the sea. The paper elaborates the stakeholders’ impact on the law of the sea re-

gime, those under the auspices of the United Nations and the European Union, and those other specific regimes
focused on marine environmental governance. The analysis is focused on good governance as the process whereby
public institutions conduct public affairs, manage public resources and guarantee the realization of human rights
with due regard to the rule of law. The result of the evaluation is that many important impacts in the reality of ma-
rine protection are disregarded such as increasing importance of cross-border private and subnational state cooper-
aƟon. The author advocates for a more polycentric approach to be achieved by stakeholders in environmental law
and policy within the law of the sea scheme for the benefit of the improved implementation of good governance in
marine environment.

KEYWORDS: legal framework, governance, marine environment & environmental law

I. INTRODUCTION
The intense use of the coastal sea, in combination of climate changes, place additional pressure on the
protecƟon of marine environment and seek management and governance response of with proacƟve
approach of regulatory bodies and stakeholders.

Management in organizaƟons is broadly defined as the function that coordinates the efforts of people to
accomplish goals and objectives using available resources efficiently and effectively, while governance is
the establishment of policies and strategies, and continuous monitoring of their proper implementaƟon,
by the members of the governing body of an organization.

The paper evaluates the evolution of the concept of marine environmental governance, with the analy-

sis of major institutional frameworks. It is focused on marine protection challenges and the active role of
stakeholders in environmental law and policies to improve good governance in coastal areas.

II. THE EVOLUTION OF MARINE ENVIRONMENTAL GOVERNANCE
Spatial planning is the methods used largely by the public sector to influence the future distribuƟon of
activities in space. Focusing on coastal area, marine spatial planning (hereinafter: MSP) is a multidiscipli-
nary instrument for easier enforcement of ecosystem approaches in order to obtain rational use of ma-
rine resources, streamlining current activities, minimizing the overall impact on the marine environ-
ment, and ensuring the resilience of coastal and marine areas to climate change.

Integrated coastal zone management (hereinafter: ICZM) aims for the coordinated application of the dif-
ferent policies affecting the coastal zone and related to activities such as nature protection, aquaculture,
fisheries, agriculture, industry, off shore wind energy, shipping, tourism, development of infrastructure
and mitigation and adaptation to climate change. It will contribute to sustainable development of
coastal zones by the application of an approach that respects the limits of natural resources and eco-
systems, the so-called ecosystem-based approach. Integrated coastal management covers full cycle of
informaƟon collection, planning, decision-making, management and monitoring implementaƟon. It is
important to involve all stakeholders across the different sectors to support broad implementaƟon of
management strategies.

Governance as the action or manner of governing the state or authorities within the state includes es-

tablishment of policies, and continuous monitoring of their proper implementaƟon, by the members of
the governing body of an organization. Good governance characteristics are participation, rule of law,
transparency, responsiveness, consensus orientation, equity, effectiveness and efficiency, accountability and strategic vision.

Environmental governance can be defined as formal and informal arrangements, institutions and mores which determine how resources, or an environment are utilized how problems and opportunities are evaluated and analysed, what behaviour is deemed acceptable or forbidden and what rules and sanctions are applied to affect the pattern and resources and environmental use [1].

Governance is a general term used to describe methods and institutions that guide human behaviour [2]. Approaches to governance in marine environments are often less developed than in terrestrial environments. Implementation of natural source management in marine ecosystems is more difficult than terrestrial ecosystems due to lack of visible boundaries between marine ecosystems and the vast area of waters.

Environmental governance is defined as interventions aiming at changes in environmental-related incentives, knowledge, institutions, decision making and behaviours and a set of regulatory processes, mechanisms and organizations through which political actors influence environmental actions and outcomes [3].

Global environmental governance refers to the sum of organizations, policy instruments, financing mechanisms, rules, procedures and norms that regulate global environmental protection. The end goal of global environmental governance is to improve the state of the environment and to eventually lead to the broader goal of sustainable development [4].

III. MAJOR MARINE INSTITUTIONAL FRAMEWORKS

The United Nations Convention on Law of the Sea (UNCLOS) 1982 is a comprehensive global and legal instrument that can be regarded as an overarching framework for multiple uses of sea. It also provides legal basis to allocate activities and obligations to protect the marine environment. According to UNCLOS there are several marine areas in which coastal states can exercise jurisdiction regarding the marine spatial planning such as internal waters, territorial seas, archipelagic waters, contiguous zones, continental shelves, exclusive economic zones and fishery zones [5].

The Convention on Biological Diversity (CBD) 1992 stipulates a commitment to introduce environmental impact assessments procedures for proposed activities that may have adverse effects on biological diversity, including public participation [6].

United Nations Conference on Environment and Development, Rio de Janeiro, Brazil, 3 to 14 June 1992 in its Chapter 17 sets out framework program of action for achieving protection and sustainable development of the marine environment and its resources. The program areas include, among others, marine environmental protection and integrated management and sustainable development of coastal areas [7].

At the regional level, there is no single policy or set of policies to manage the marine environment. Instead, there are overlapping policies that leave significant problems unaddressed, although there is a need for a more optimal sustainable development by better integration of the different marine-related activities. A more coherent maritime policy should be created among marine-oriented policy areas, such as fishery, transport, environment, energy, industry, defence and science policies.

Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive)] pursues the ecosystem based approach in the sense that the adoption of decisions can no more be based on sectorial approach only, but must reflect major transboundary marine ecosystems that should be preserved in order to maintain the basic resource for all maritime activities. Governance based on ecosystems constitutes an integrated approach and differs from approaches to date which are usually focused on species, sectors, activities or problems, and considers cumulative effect of various
sector. Ecosystem services among others include provisioning services (food, raw materials, fresh water, medicinal resources), regulating services (local climate and air quality, carbon sequestration and storage, moderation of extreme events, waste-water treatment, erosion prevention and maintenance of soil fertility, pollination, biological control), habitat or supporting services (habitats for species, maintenance of genetic diversity, soil formation, photosynthesis, primary production, nutrient recycling, i.e. services needed to maintain other services), and cultural services (recreation and mental and physical health, tourism, aesthetic values, spiritual, religious values and the sense of place). Human dimension of MSP can be simplified in most cases to listing and mapping activities (e.g. oil and gas, fisheries, shipping) [8].

Directive 2014/89/EU of the European Parliament and the Council of 23 July 2014 establishing a framework for maritime spatial planning creates a framework for maritime spatial planning aimed at promoting the sustainable growth of maritime economies, the sustainable development of marine areas and the sustainable use of marine resources. When establishing and implementing maritime spatial planning, States shall consider economic, social and environmental aspects to support sustainable development and growth in the maritime sector, applying an ecosystem-based approach, and to promote the coexistence of relevant activities and uses. Through their maritime spatial plans States shall aim to contribute to the sustainable development of energy sectors at sea, of maritime transport, and of the fisheries and aquaculture sectors, and to the preservation, protection and improvement of the environment, including resilience to climate change impacts. In addition, States may pursue other objectives such as the promotion of sustainable tourism and the sustainable extraction of raw materials [9].

Recommendation of the European Parliament and of the Council of 30 May 2002 concerning the implementation of Integrated Coastal Zone Management in Europe although not making a reference to MSP, provides a basis for doing so, as a part of requirements of States to develop national ICZM strategies. It lists principles defining the essential characteristics of ICZM. The Recommendation outlines integration across sectors and levels of governance, as well as a participatory and knowledge-based approach. It provides frameworks steps which the States should take to develop national strategies for ICZM. Given the cross-border nature of many coastal processes, coordination and cooperation with neighbouring countries and in a regional sea context are also encouraged [10].

According to the Constitution of the Republic of Croatia it is a constitutional category that the sea, seashore, islands, waters, air space, mineral resources, and other natural assets, as well as land, forests, flora and fauna, other components of the natural environment, real estate and items of particular cultural, historical, economic or ecological significance which are specified by law are of interest to the Republic of Croatia and shall enjoy its special protection [11].

The Law on Maritime Domain and Seaports prescribes that the maritime domain is constituted by the internal sea waters and the territorial sea, their bed and subsoil and part of the land which is by its nature intended for public maritime use or has been declared as such, and everything connected with this part of the land on the surface or below it. The following are considered to constitute maritime domain: the coast, the ports, the breakwaters, the levees, the shoals, the reefs, the estuaries flowing into the sea, the canals connected with the sea and in the sea and maritime subsoil all animate and inanimate natural resources. The boundary of the maritime domain is determined on the basis of the existing natural and man-made legally constructed obstacles. Demarcating the maritime domain provides the legal grounds for the registration of the maritime domain in the land registry books [12].

IV. ENVIRONMENTAL CHALLENGES

Coastal zones are the hinge between maritime and terrestrial development. From its beginning the concept and the approach to spatial planning on land has undergone some significant transformations from development from a project- or permit-based approach to a more comprehensive approach to resource use planning based on distinct areas. In the second phase it developed from a pure means of physically organizing space to an increasingly communicative activity which needs to rely on co-operation between
different scales of decision-making, sectors and stakeholders. More recently, linkage to the concept of coastal governance, where the focus is as much on the process of planning as on its actual output.

MSP operates within three dimensions, addressing activities on the sea bed, in the water column and on the surface. In the mentioned there are some private ownership rights although the sea is generally a public and not private resource. Time should also be considered as a fourth dimension. MSP is innovative in the sense that it enables the recognition that the oceans are no longer being a free for all commons, but rather a space where human interests and responsibilities (established and emerging) and ecosystems interact [13].

The boundaries of coastal zone management have been limited in most countries to a narrow strip of coastline within a kilometre or two from the shoreline. Only rarely have the inland boundaries of coastal management included coastal watersheds or catchment areas. Even more rarely does coastal management extend into the territorial sea and beyond to the exclusive economic zone.

In many ways MSP is like ICZM. For example, both are integrated, strategic, and participatory – and both aim to maximize compatibilities among human activities and reduce conflicts both among human uses and between human uses and nature. MPS and ICZM strategies need to be mutually coordinated, ensure effective cross-border co-operation between States and between national bodies and stakeholders in relevant sectoral policies and identify the cross-border effects of marine spatial plans and integrated coastal zone management strategies on seawater and coastal areas.

Spatial planning is also being linked to the concept of coastal governance, where the focus is as much on the process of planning as on its actual output. Present planning in marine environment is much similar with land planning of the sixties. Much can be learned from the existing systems of land use planning, but at planning it is also necessary to take account of the differences. First, marine area is tri-dimensional and dynamic in its character, so that each site will have multiple uses, simultaneously or during various periods or seasons, as opposed to the constancy of use at land.

The Republic of Croatia has an extensive spatial planning system, but an ICZM strategy has not yet been developed and there is no specific MPS regulation in Croatia. The 300 m marine belt, which is protected under the Physical Planning Act could be considered an exception [14]. Land-based activities have relevance for MSP - urbanism has direct impact on the area of impervious surfaces, pollution and intensity of storm runoff and pollution of the sea.

The most recent spatial plans of various Croatian counties indicate that very little has been done regarding MSP, save for standard aspects such as berths, submarine cables and pipelines, ports, etc., comprehensive plan would require the availability of much more data, especially the knowledge of situation concerning marine ecosystems.

In the end, international laws and organizations do not guarantee good governance but can only provide a basis for responsible and effective governance by individual states. In this context of utmost importance are nongovernmental or civil society organizations, which are organized on a local, national or international level to address issues in support of the public good.

V. STAKEHOLDERS IN GOVERNANCE

The most obvious shortcoming of international organizations and national authorities is the fragmentation and lack of coordination between different programmes and institutions.

International and national marine environmental governance needs well-functioning organizations and legal frameworks as a basis for action and in support of responsible and effective marine and maritime management by individual countries.

At a national level, most countries still lack a coherent integrated policy for marine and maritime affairs. In most governments, there is a strong sector-oriented division among the different ministries.
In deciding on the appropriate balance between environmental and development goals, marine and maritime managers need knowledge from many disciplines, such as sociology, engineering, political science, law, economics and ecology. It is essential in order to understand management constraints and provide a nuanced description of the factors that contribute to the outcomes in these systems, for instance, regarding the sustainable use of marine area [15].

Governance capacity failure include lack of motivation or political will, mismatch of governance framework and governance capacity, lack of knowledge and experience, lack of human and financial resources, lack of skills to deal with governance challenges and lack of compliance capacity and mechanism [16].

The World Bank has on the one hand increased its lending for positive environmental projects, and even proven willing to incorporate at least some environmental cost-benefit assessments in the screening of traditional projects. But the World Bank has been far less effective in moving beyond the traditional project-based mentality of development to a more environmentally sound, holistic approach to promoting sustainable livelihoods and the satisfaction of basic human needs [17].

The role in good governance of nongovernmental or civil society organizations as not-for-profit groups, principally independent from government, which are organized on a local, national or international level to address issues in support of the public good are of utmost importance. Among the many different types of environmental NGOs involved in both global and regional marine issues the World Wildlife Fund (WWF), Greenpeace, Oceana, Birdlife International and Seas at Risk can be mentioned.

Forthcoming marine governance needs even greater emphasis on international cooperation through well-functioning multilateral organizations. In our opinion it requires relevant mandates by national governments to take on board global or regional processes, expert roles and normative frameworks supported by all stakeholders.

VI. Conclusion

Coastal area is extremely vulnerable due to predatory investors practice and insufficient material and human resource capacity of international bodies, state administration bodies, local self-government units, companies and other stakeholders’ deficiencies. The result is that many important impacts in the reality of marine protection are disregarded such as increasing importance of cross-border private and subnational state cooperation.

A legal framework consists of the aggregation of laws enacted over time by the legislative authorities of a state and customary law, which have been accumulated through judicial or traditional practice. The institutional framework is the systems of institutions referring to all public and civil society organizations contributing to the implementation of a certain policy objective and responsible for managing, conserving, using public goods and services provided by the resources concerned.

It should be emphasized that MSP and ICZM strategies need to be mutually coordinated, must ensure effective cross-border co-operation between States national bodies and stakeholders in relevant sectoral policies and identify cross-border effects of marine spatial plans and integrated coastal zone management strategies on seawater and coastal areas. In the implementation of marine spatial planning, active stakeholder participation, process development, as well as monitoring and evaluation of project implementation are proposed.

Marine governance and MSP should be developed in a transparent manner and should advocate public interest in order to optimize the use of the sea, reduce the cost of information, regulation, planning and decision-making. Good governance is seen as the process whereby public institutions conduct public affairs, manage public resources and guarantee the realization of human rights with due regard to the rule of law.
In the enforcement of governance and MSP, active stakeholder participation, process development, as well as monitoring and evaluation of project implementation are proposed.

In author’s opinion it is important the stakeholders’ impact on the law of the sea regime, those under the auspices of the United Nations and the European Union, and those other specific national regimes focus on marine environmental governance in accordance with good governance principles.

In the Republic of Croatia maritime domain constituted by sea and seashore is a common good governed by public authority that must care for it, maintain it and is responsible for it. Although there are some private ownership rights in coastal zone, the sea is generally a public and not private resource.

Conclusively the author advocates for a more polycentric approach to be achieved by stakeholders in environmental law and policy within the law of the sea scheme for the benefit of the improved implementation of good governance in marine environment.

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The Treatment and Role of Islands in Maritime Boundary Delimitation

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ABSTRACT
One of the most controversial issues in maritime boundary delimitation is the status and role of islands. This issue often appears as one of the more complex issues in maritime boundary delimitation. There are serious disagreements in the literature in relation to the treatment of islands in judicial decisions concerning maritime delimitation as well as in delimitation agreements. The jurisprudence concerning maritime boundary delimitation is very diverse. In this paper, the author will discuss the rights of islands as regards maritime boundary delimitation and the position of islands in international conventions on the Law of the Sea. A review of some verdicts on maritime boundary delimitation will also be presented, with an emphasis on the treatment of islands.

According to the Convention on the Law of the Sea, islands are granted equal status and equal rights to the continental shelf as well as to all other areas of extended jurisdiction. Island states can be defined as states whose borders are maritime boundaries so that the phrase “island state” does not have any special meaning in international law, since these are states like all other states. All islands have shores and at least some of these shores face areas that need to be delimited. The issue of treatment of islands in maritime boundary delimitation deserves special attention, which will be discussed in more detail in the paper itself.

KEYWORDS: island, sea, maritime boundary delimitation & jurisprudence

I. INTRODUCTION
One of the most controversial issues in the delimitation of maritime boundaries is that of the status of islands in the Law of the Sea. In the literature, there are disagreements over the issue of the treatment of islands in judicial delimitations as well as in delimitations by agreement between states. The jurisprudence on the issue is very diverse. All multilateral international agreements and judgments before the International Court of Justice and the Arbitral Tribunals recognizes the same principled status and rights to all coasts including islands.

The status of islands is defined by international agreements. Article 121 (2) of the Convention on the Law of the Sea recognizes that islands enjoy the same status and equal rights to the continental shelf and to all other maritime jurisdiction zones as any other territory. According to paragraph 1 of Article 121 of the Convention on the Law of the Sea: “An island is a naturally formed area of land, surrounded by water, which is above water at high tide”, while paragraph 3 defines rocks “which cannot sustain human habitation or economic life of their own” and therefore “have no exclusive economic zone or continental shelf” [1]. One of the controversial issues about which little has been said in the literature, but not in practice, is the question of the role of islands in maritime boundary delimitation.

For more than half a century, international law has tried to develop an equitable delimitation of maritime boundaries. This effort is primarily reflected through two key groups of multilateral treaties – The Geneva Convention of 1958 and the 1982 Convention on the Law of the Sea. As succinctly summarized by Petrinović, Mandić, and Siriščević in their paper on the Importance of Maritime Law in Seafarer Training pursuant to Amendments to the STCW Convention [2], the seventeen parts of the UNCLOS cover all institutes of the International Law of the Sea, i.e., the territorial sea and the contiguous zone, the straits used in international navigation, archipelagic states, the exclusive economic zone, the continental shelf, high seas, the regime of islands, enclosed or semi-enclosed seas, the right of access of landlocked states to and from the sea and freedom of transit, the Area, the protection and preservation of the marine environment, marine scientific research, the development and transfer of marine technology.

The jurisprudence of the International Court of Justice (ICJ) has covered a wide range of issues in the area of the Law of the Sea over a long period of time. A large number of agreements have been signed that define delimitation lines separating specific types of jurisdiction or more comprehensive maritime boundaries that separate all maritime jurisdictions between two states [3]. Maritime delimitation is an operation performed between two or more states with an aim to divide the overlapping areas where
there is a conflict between coastal states as regards exercising their rights over the area and each state claims spatial jurisdiction over the same maritime area [4]. This fact emphasizes one of the key characteristics of maritime delimitation – its international character.

The delimitation of maritime zones and jurisdictions, thus, relates to the separation of the spatial jurisdiction of island states, as well. In spite of the great significance of customary law in maritime boundary delimitation between states, the principles of customary law developed until WWII have been largely ignored in the theory of the International Law of the Sea [5]. Nevertheless, customary law is still an important source of maritime delimitation as is recognized in the UN Convention on the Law of the Sea [6].

The Law of the Sea is, probably, the area of international law that is most influenced by case law [7],[8]. The jurisprudence of international courts in this area is of far greater importance than just a subsidiary source, and it can be said without much exaggeration that it has also quite an unusual role of a direct source of law. There are a large number of judgements of ad hoc tribunals, whose nature emphasizes the rules of arbitration agreements, whereby the decision of the arbitrators is to be based on the principles of international law, as opposed to the ICJ whose statute requires the application of the legal rules listed in paragraph 1 of article χό [ύ],[υτ].

Islands as sovereign nations are states under international law. Island states are defined as countries whose borders are maritime, while the term itself does not bear special significance in international law because an island state is a state like all other states. Since the Truman proclamation, island states have profited most through a vast expansion of maritime territory and jurisdiction. One of the essential components, in this respect, is the political status of islands, which, as a relevant circumstance, is not clearly defined in case law. The impact of the political status of an island on delimitation did not appear to have been legally grounded.

II. EXAMPLES FROM JURISPRUDENCE

According to the Convention on the Law of the Sea, more precisely, according to a broader interpretation of Article 3 [1] the term rock refers to uninhabited and inaccessible small islands and formations of islands. The interpretation of this article would mean limiting its application only to geological formations that are truly rocks, more precisely to rock formations that emerge from the sea and have no soil on them [11]. This broader interpretation of rocks as synonymous with all small uninhabited islands is supported by a large number of theorists. The practice of states favors the position that even the smallest deserted island can generate maritime zones, and in reality, maritime powers declared the continental shelves of practically all their islets. States declare exclusive economic zones and shelves of seemingly uninhabited rocks. In 1977, France declared the exclusive economic zone around the island of Clipperton, a low coral reef less than 3 miles in diameter which was the subject of the well-known arbitration by King Victor Emmanuel III of Italy. The islands in the Indian Ocean: Juan de Nova, Glorieuses, Europa and Bassas da India, around which France declared the exclusive economic zone are neither bigger nor more significant than Clipperton.

The verdicts of the ICJ do not indicate that there is a clear rule by which islands are disregarded and have no rights, but all circumstances must be carefully considered before their presence is ignored in a delimitation. A large number of bilateral agreements on delimitation deals with situations in which islands, rocks and low-tide elevations are in the delimitation area, whereby the smaller an island, the less important its role in delimitation becomes.

In court and arbitration judgments, authorative and unequivocal views were repeatedly reiterated that islands had the same rights as any other land territory. In practice, there is no clear judicial statement based on which it could be concluded that rights of islands as such were diminished or qualified as lesser, or where islands were treated as special circumstances. There are not many explicit views in court judgments as regards the question of which coasts of an island are considered when calculating proportionality. According to the Law of the Sea, the part of the coast facing the delimitation area must be taken into consideration. The problem with islands is that they have a coastline projecting towards several directions.

D. Karl’s is one of the most elaborated attempts to classify the rights of an island in relation to maritime zones and establish these rights in relation to their position. According to him, the measure of an island
size for the purpose of delimitation should be the length of its coastline so that a portion of the coast bordering the delimitation area should be taken into account. It also specifies that the maximum appropriate length should be the total length of the island [12].

In the first court case in which islands appeared – the Anglo-French Arbitration, the Arbitral Tribunal started from the view that the islands had full rights to the continental shelf [13]. The principles of customary international law governing the delimitation of the continental shelf were confirmed by this judgment. The disagreement was about the delimitation in two areas. In its submissions to the Arbitral Tribunal, France argued that the Geneva Convention on the Continental Shelf was not in force between the parties because of the country’s standing reservations made at the time of accession to the Convention and the subsequent standing objections of Great Britain to those French reservations. Great Britain took the view that the Geneva Convention was fully in force between the parties. On the other hand, France took the view that the Court did not have jurisdiction to deal with any zones that were part of the French territorial sea and that the Court was competent to perform the delimitation of the continental shelf. Great Britain advocated the application of the principle of equity. In this case, the particular importance is attached to the attempt of the Court to combine the rules of customary law with article 6 of the Geneva Convention and the practice of the States. This view supports the theory that international law dealing with the delimitation of maritime boundaries is based on a continuum of law, which, despite the fact that it originated from various sources rests on the foundations of equity. The verdict in this case has contributed to further progress of delimitation rules particularly regarding the criteria for determining the presence of the British Isles near the French mainland coast. The Arbitral Tribunal found that the islands that are “are clearly territorial and political units which have their own separate existence, and which are of a certain importance in their own right separately from the United Kingdom” [14]. In this case, it was about changing geography and treating islands as a special circumstance and France was awarded a 12-mile enclave from the islands to the mid-Channel. If these had been independent states and not parts of Great Britain, they could themselves claim the rights to the belt.

The Eritrea/Yemen Arbitration [15] concerned the establishment of territorial sovereignty over a number of islands in the Red Sea.

The decision of the Maritime Delimitation Tribunal was based on geographical factors and as such was consistent with the existing practice of the ICJ. Since the time of the North Sea judgment where the ICJ set the basis for further development of the law on maritime delimitation, through various adjustments of its practice, the Court either strengthened or subtly diminished the significance of certain factors important for maritime delimitation [16]. In this case, the Court’s decision is important because of the explicit consideration of the interests of third countries. The Court took into account the straight baselines that were then first presented before it, and which had been previously published on scale maps that confirmed their position. The Court diminished the role of proportionality of the length of the coasts, but indicated a possible use of the test of proportionality of the surfaces of waters belonging to the parties, which is one of the novelties introduced with this case.

The proportionality of the length of the coast was introduced with the case of the North Sea. In this case, the tribunal strictly applied Article 121 of the Convention on the Law of the Sea. The Court's decision is significant because it further strengthened the relationship between the jurisprudence of the ICJ and the arbitral tribunals with regard to the application and development of the modern law of maritime delimitation.

The Court’s treatment of individual islands, islets and degrees confirms that their rights depend more on the degree to which they distort the line of equidistance and on some other factors than on their legal status as such [17]. In this case, one factor particularly attracted the attention of the arbitrators, and this is the presence of an island chain whose delimitation had to be done. The presence of islands caused a double difficulty. The first difficulty was related to the group of islands near the coast. The question was raised on whether they should be involved in drawing the baselines. The other difficulty was related to the islands located near the Red Sea between the two countries. The issue, in this regard was to what extent the median line of delimitation should be shifted so as to not deprive these islands of the sovereign rights to the maritime areas they would otherwise have been entitled to. In the first phase of the proceedings in which it was decided on the sovereignty over islands, the Court refused to
recognize the sovereignty of either of the two states over the islands on both sides of the median line, thus avoiding the difficulties that would arise from this in the maritime delimitation phase [17].

As regards the role of islands, the Eritrea/Yemen case is by far the most significant precedent after the Anglo-French Arbitration which (as was the case with Jan Mayen) concerned an island’s right to generate maritime zones and to be one of the main parties to a delimitation.

The judgment of the Court of Arbitration in the dispute concerning the maritime delimitation between Canada and France on the island of St. Pierre and Miquelon (the arbitration judgment was adopted in 1992) [18] partially applies to issues relating to the delimitation of territorial seas. In 1989, Canada and France requested that the Court of Arbitration establish a single delimitation which would govern all the rights and jurisdiction which the parties were able to exercise in terms of international law. The task of the Court of Arbitration was to complete the delimitation lines in the south (towards the open ocean) and towards the east [19], [20], [21]. The cause of the dispute over the maritime border between Canada and France were the islands of St. Pierre and Miquelon. Canada argued that the islands St. Pierre and Miquelon were entitled only to 12 miles of territorial sea, while on the other hand, France argued that they had the right to the continental shelf and the Exclusive Economic Zone, and that the delimitation should be performed using the median line. What the two countries managed to agree upon in negotiation was only the delimitation in the territorial sea in the narrow area between Newfoundland and the island of St. Pierre and Miquelon, while the delimitation of the other maritime areas was, because of the impossibility of agreement, submitted to an ad hoc court of arbitration for decision. In 1989, Canada and France concluded an agreement which set up the Court of Arbitration. The Court of Arbitration was asked to establish a single maritime boundary which would delineate all of the sea areas in which the coastal states had the right to exercise jurisdiction [22]. To be specific, the statement that the extension of the sea projection of the land depends in each case on the geographic circumstances has even greater significance for the territorial sea. The Court pointed out that any specific coastline, no matter how short it is, may have a sea projection of up to 200 miles.

One of the interesting disputes, in this respect, is that between Denmark and Norway concerning the delimitation of fishery zones and the continental shelf that lies between the small island of Jan Mayen (which belongs to Norway) and Greenland, the world’s largest non-continental island, belonging to Denmark. In this case, Denmark’s position was that the island should be recognized as having a partial effect. The ICJ, however, held that, small as Jan Mayen is, its size cannot affect its rights under international law in relation to the rights and principles of non-interference; since Jan Mayen is recognized as an island, it is entitled to all the elements that are normally associated with a foreign territory. One of the judges in this case held that the island itself did not represent a special circumstance with limited possibilities of the coastal projection towards the sea [23].

III. CONCLUSION ON THE ROLE OF ISLANDS IN MARITIME BOUNDARY DELIMITATION

Articles 74 and 83 of the Convention on the Law of the Sea emphasize the aim of equitable delimitation on the basis of international law [1]. In terms of the practice of states and consensual delimitation, it should be noted that although the agreements often do not contain much evidence as regards the reasoning and motives of the parties, this practice is generally in agreement with the views presented in the jurisprudence of courts and tribunals. The agreements on maritime boundary delimitation rarely establish norms of international law. The presence of islands and rocks is often a factor that may complicate a delimitation. The most that can be done, in terms of theory, is to point out some examples of practice, and within those cases, some tendencies in the practice of the states. The solutions in the agreements are different. In no case was an island that would be comparable in size to a land territory of similar size treated differently. The role of islands in the delimitation of maritime zones depends on the general geographical correspondence and the political context. The judgments may also lead to a somewhat different conclusion that the proclaimed equality of islands with the land is primarily of a formal nature. Coastal states have the same ability as any other land territory and any other coast to project towards the sea, and this ability is no greater or smaller just due to the fact that it is a coastal island.

It is concluded that the rights of the islands are, to a significant extent, directly proportional to the length of their coasts. As a rule, islands are the same as any other land territory, but are always treated with much more caution and attention than other land territories.
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Unmanned and Remotely Operated Vessels - How Should the Rules On General Average And Salvage Be Updated?

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ABSTRACT
The Rules on General Average and Salvage were first established by the Rhodians and Rhodian Law 900 BC. General Average was an important part of the law because it gave a certain protection for the cargo-owners if the vessel and the cargo were about to face an accident at sea. The point of the general average law was and still is to give protection in accidents where something extraordinary has to be done in order to save the vessel and/or its cargo from destruction. Rules on salvage were first created to encourage the divers to earn a reward on the basis of the how deep the salvaged objects were and on the basis of their value. The legislation and rules have been developed on the basis of these principles of ancient origin. How can decisions or acts in necessity be made if there is no-one on board to do it, or the vessel is controlled from a great distance without a good perspective of the situation. The act needs technical solutions but also development in rules and legislation. In this article, I am handling different kinds of legally problematic occurrences that may appear with unmanned vessels, which are not easy to answer on the basis of existing rules and legislation. The legislative history envisages that the rules need to encourage to commit salvage and General average acts. The flexibility of the existing rules is clearly not enough for autonomous vessels. They need revision or we need new rules just for autonomous vessels. Will the old principles of law like Common Safety, Common Benefit or No Cure No Pay- principle and encouragement to Salvage Reward, be still applicable and useful as basis for the new legislation? The article will weight, if these principles have any possibilities to survive or do we need new thinking from another perspective.

KEYWORDS: maritime salvage, general average, maritime law & autonomous shipping

I. INTRODUCTION
Technological development in shipping is fast even though the industry is often accused of being old fashioned. Legal rules are developed slowly when you compare them to technological development. Rules of law on General Average and salvage originate from ancient times. It is difficult to predict how fast the unmanned and remotely operated vessels will dominate the seas. The average lifetime of vessels is long so in any case the traditional vessels with crew onboard will still be used for decades. The rules of law need therefore to be applied to both manned and unmanned vessels for long time. In any case there will always be vessels which need to have crew on board.

The rules of law need to be adjusted to the reality. IMO conventions are already considered and under review of the Maritime Safety Committee and Legal Committee. Salvage Convention will need updating in order to be applied if there will not be a new convention for unmanned or remotely operated vessels. Updating Salvage Convention even in smaller details has been problematic issue. The relevant changes required by the industry have often been made by the contractual market driven solutions like LOF and SCOPIC.

The Law of General Average has been based on Rules made by industry representatives for already more than 150 years. The approval for these York-Antwerp Rules from all parties of the maritime industry is also a slow process, but it is generally much faster than revising a Convention which needs approval of from the majority of countries represented in IMO. The clear benefit of the YAR rules is that there are several alternative versions where the shipowners can choose from. At the moment YAR 1974, 1994 and 2016 are all alternatives in use.

The drafters of Rules and legislation are clearly in situation where the need to adjust themselves in a situation where technology is developing faster than the new rules and legislation can be enacted and
small changes to existing rules do not meet the needs of the maritime industry. This is clearly visible with the Law General Average and Salvage where the Principles of law have historical roots.

II. HISTORY OF THE RULES

The Rules on General Average and Salvage were first established by the Rhodians and Rhodian Law 900 BC. General Average was an important part of the law because it gave a certain protection for the cargo-owners if the vessel and the cargo were about to face an accident at sea. [1] The point of the general average law was and still is to give protection in accidents where something extraordinary has to be done in order to save the vessel and/or its cargo from destruction. The first known General Average Acts was to jettison part of the cargo to save the ship and rest of the cargo and divide the loss between those whose property was thereby saved and distribute these contributions to the less fortunate whose cargo was thrown overboard. In turn, Rules on salvage were first created to encourage the divers to earn a reward on the basis of the how deep the salvaged objects were and on the basis of their value. [2] The legislation and rules have been developed on the basis of these principles of ancient origin. They have been flexible enough for 3000 years and have been continuously rewritten to meet the demands of the maritime profession and industry.

The rules have been encouraging the different interests and participants to do their utmost for the safety and security for both ship and cargo as well as the persons onboard. Decisions and acts have been based on the rules and usually they have been made at sea.

III. RISE OF UNMANNED OR AUTONOMOUS SEAFARING

How can this kind of decisions or acts - described in previous chapter - be made if there is no-one on board to do it, or the vessel is controlled from a great distance without a good perspective of the situation. The acts need technical solutions, but also development in rules and legislation. In this article, we are handling different kinds of legally problematic occurrences that may appear with unmanned vessels, which are not easy to answer on the basis of existing rules and legislation.

It is clear, that new development in technology, like unmanned or even autonomous vessels, creates new demands and need for development of salvage industry as well as investment. This applies on General Average as well as the act must be made possible also autonomously or from distance.

When discussing with the persons representing the industry which develops the technology, it seems that many technological issues already have been developed or are at least under consideration. This applies also GA and salvage situations. Therefore, it has been obvious for some time already, that these companies are recruiting Masters and Chief engineers who have experience at sea. Some of them are interested in Master studies at the University and the legal complexities are then combined to technology in many of their thesis when they combine their Master studies to the working life. Therefore even legal professionals and professors are involved and technology and law need to meet the others expectations.

Definition of unmanned or autonomous ship needs to be clarified before moving further to the problems of legislation development on these highly specified areas of law. Comité Maritime International (later CMI) International Working Group has defined the concepts in their paper in a following way. First unmanned but remote-controlled vessel is described as those which are capable of controlled movement on the water in the absence of any onboard crew:

“Instead, control is performed in essentially two ways. It can be performed by remote-control, whereby a shore based remote controller uses a laptop computer and joystick to control the unmanned ship’s movement and signalling using radio and satellite communications. In doing so the controller is aided by the streaming of the ship’s vicinity effected by cameras and aural sensors fitted to the ship’s hull / chassis.

The definition of the IWG concludes that unmanned vessel can also be autonomous and “...may be controlled” autonomously. This involves the ship being pre-programmed before deployment (or before
setting sail), and, thereafter, performs a predetermined nautical course without any human interaction whatsoever.” This definition of CMI IWG made the division quite roughly in two.

The work in the IMO will clear the differences on determining the different levels of autonomy even closer to 4 different stages. The work of IMO is currently on its way in Maritime Safety Committee and Legal Committee: [8]

“To facilitate the progress of the regulatory scoping exercise, the degrees of autonomy are organized (non-hierarchically) as follows (it was noted that MASS could be operating at one or more degrees of autonomy for the duration of a single voyage):

1) Ship with automated processes and decision support: Seafarers are on board to operate and control shipboard systems and functions. Some operations may be automated. 2) Remotely controlled ship with seafarers on board: The ship is controlled and operated from another location, but seafarers are on board. 3) Remotely controlled ship without seafarers on board: The ship is controlled and operated from another location. There are no seafarers on board. 4) Fully autonomous ship: The operating system of the ship is able to make decisions and determine actions by itself”[8]

The progress of the levels of autonomy of vessels is difficult to predict and there are very different opinions how fast the vessels autonomy in the maritime industry will grow. As stated in World Maritime University’s report: “Given the agenda of Maritime Autonomous Surface Ships (MASS) Working and Correspondence groups at IMO, international regulations for autonomous ships are expected to be in place before 2035. But for specific operations in national waters, inland or near-coastal waters, it is anticipated that autonomous ships may be navigating the waters by 2028.” [7]

At this stage in this article we will concentrate on the unmanned, remote controlled vessels for the reason that the law of salvage and law of general average concentrates on someone making the decision on the General Average act or act on salvage. If we consider the liability issues, taking into consideration what has been said above, the liability of persons on behalf of the shipowner or cargo-owner making the decisions and the liability of the software developer are very different. If we consider the technological solutions for example the rules on General average such as jettison of cargo (Rule I) or Voluntary Stranding (Rule V), it is very difficult to predict when a Vessel can make these decision autonomously without remote controller, who in turn already now can make the decisions and implement the order through technological means if the risks have been evaluated when the vessel has been built as autonomous and remote controlled.

As CMI IWG states in page 19: “The role of a remote-controller of an unmanned ship is in a sense similar to that of a master in that both assume real-time command of the movement and signalling etc. of the relevant ship. A pre-programmer of an autonomous unmanned ship, by contrast, enjoys a role unparalleled in the traditional maritime domain. He is potentially the last human input into the ship’s navigational course but unlike a master, he does not exercise real time decision-making influence”.

Also, according to World Maritime University’s report, autonomous ships under human command are likely to reach 11 to 17 per cent by 2040 and these ships would operate in national and following regional jurisdictions and specialized trades. [7] When discussing with persons working in the companies developing the technology, this prognosis seems rather modest in their view.

The legislative history envisages that the rules need to encourage to commit salvage and General Average acts. The flexibility of the existing rules is clearly not enough for unmanned or autonomous vessels. They need revision - Or we need new rules just for autonomous vessels.
IV. DEVELOPMENT OF THE RULES

A. Law of General Average

The History of General Average goes far to time immemorial: “What is given, or sacrificed, in time of danger, for the sake of all, is to be replaced by a general contribution on the part of all who have been thereby brought to safety. This a rule which from the oldest recorded times has been universal amongst seafaring men, no matter to what country they belonged, being obviously founded upon the necessities of their position.” [1] The Rules on general Average have survived, and they have been needed for at least 3000 years. But will they be needed when there are no more seafaring men as the sentence above describes, but vessels will be first unmanned and remote controlled and in the end autonomously taking care of themselves as pre-programmed units of collected cargo?

Knut Selmer states: “Few legal institutions have been so ardently attacked and so faithfully defended as the equitable distribution of common salvage expenses at sea.” [4] This statement of his was made 1958 but still applies. The writer of this article has been involved with Salvage and General Average rules since 1993 and the discussion on abolishment of General Average as an institution has been going on this period until 2016 and creation of 2016 York-Antwerp Rules when the consensus between the industry stakeholders was reached after 4 years of work. Will the Rules be under yet another attack in the future when shipping will be automated?

The Rules on General Average have been updated on a voluntary basis by the industry several times since 1864 and are expressed in carriage contracts as York-Antwerp Rules. Since the Roman times the Law on General Average was fragmented and had developed into different directions in common law and continental jurisdictions. York-Antwerp Rules were created as private law instrument to harmonise what needed to be inserted into carriage contracts to make the maritime law and liability of the participants to the common venture work in reality to meet their commercial interests. It has served the industry and been updated 1890, 1924, 1950, 1974, 1994, 2004 and 2016.

The new version is YAR 2016, which still does not take into consideration of unmanned vessels. The writer of this article was a member of the International Working Group that developed the rules 2012-2016. The undersigned took up the problem with the unmanned vessels but the International Working Group considered it premature in its informal discussions still spring 2016 in Istanbul.

What mechanism for updating or creating the new legislation for General Average situations would be suitable and fulfil the needs for safety and security for unmanned vessels in distress? The creation of the rules for General Average is an example of voluntary basis creation of law by the markets and the industry. General average belongs to the maritime law and operates within it. The law of the sea may be compared to a human body: it consists of a great number of organisms, all with different functions. [4]

Even though autonomous shipping seems to differ from traditional, it needs to work in the same environment as the traditional one and the rules will mostly be the same as previously. According to CMI IWG There is no reason in principle why the owner of an unmanned ship ought not to be given the benefit of the general right of limitation of liability currently enjoyed by manned shipowners. [6]

The IWG continues that “one of the most powerful arguments in favour of unmanned ships being regarded as “ships” and for their integration into the existing legal framework is that their operation would involve many of the same risks of collision and pollution as their manned counterparts.” [6] Therefore, General average will be part of the autonomous shipping as well in the future. There will be need for general average sacrifices like jettison of cargo, extinguishing fire on shipboard, cutting away wreck, voluntary stranding, damage to machinery and boilers, expenses lightening a ship when ashore and consequent damage, expenses at port of refugee and salvage remuneration, which is again often part of GA according to the new 2016 AYR and distributed as GA expense.
B. Law of Salvage

There is evidence that almost three thousand years ago under the Rhodian maritime code, which was applied not only in ancient Greece but also in other parts of the Mediterranean, volunteer salvors were held entitled to be rewarded for their services. The principle was later adopted in Roman law. Based on Roman law influence the rules on salvage were adopted first in medieval collections of law and later they found their way in continental and common law jurisdictions which by the modern times had received national influence and were not unilateral. At latest by the time of the Motor vessels the Law of Salvage needed harmonised rules.

According to Brice, The first attempt at some general unification of the relevant principles of the law of salvage occurred at a meeting of the International Maritime Committees (established in 1897) in 1905, which led to the conclusion of the Brussels Convention on Salvage 1910. The inadequacy of that Convention to meet modern circumstances led to the preparation of a Draft Convention by the Comite Maritime International (CMI) in Montreal in May 1981. Thereafter, at meetings in London of the Legal Committee of the International Maritime Organisation (IMO) the draft was discussed in detail. Finally at a Diplomatic Conference in London on April 28 the New London salvage Convention was accepted.

However, the convention did not meet all the necessary solutions and it needed to be supplemented by industry soon after 1996 after it came to force.

Updates to Salvage convention were considered last 2012 by CMI but they were then buried by the IWG and international sub-committee in Beijing Conference of CMI. The unmanned vessels were not then discussed at all. Taking up the salvage law will be an issue in the future and it might be necessitated by the unmanned vessels and encouraged by the salvage industry. It was a topic already at table in the industry supported conferences and in the IMO Legal Committee. The IMO Legal Committee will start to review the need for updating the conventions under its auspices.

CMI IWG on its spreadsheet of Conventions has made some preliminary consideration of the needs of clauses that are in need of reform, but it needs to be considered if it has any possibilities to survive with the rules of ancient origin, or does it need new thinking from another perspective. Salvage is industry highly based on encouragement principle and remuneration – Nowadays remuneration not just for skills and efforts of the salver but also investment in salvage tugs and equipment. If the encouragement in investing in salving autonomous vessels or investing in autonomous salvage vessels is seen by the salvage arbitrators something in which the industry needs to be encouraged, then maybe the need for change of rules is not so important after all and the old principle from B.C. still can be considered as workable solution.

V. RISE OF AUTONOMOUS SEAFARING AND LAW — SOME CONSIDERATIONS FOR THE FUTURE

Development of technology is fast – So fast that it is hard to predict. Development of legislation is usually slow and what comes to creating international law, that is usually even slower process. We will try to analyse and predict the future below when it comes to development of technology in relation to legislation.

A. Rewriting of Conventions

The IMO conventions do not take into account the autonomous vessels at all as they have not been created before any of has been considered reality. IMO has decided to start a scoping exercise to identify current provisions in an agreed list of IMO instruments and assess how they may or may not be applicable to ships with varying degrees of autonomy and/or whether they may preclude MASS operations and after that, an analysis will be conducted to determine the most appropriate way of addressing MASS operations, taking into account, inter alia, the human element, technology and operational factors.

The list of instruments to be covered in the MSC’s scoping exercise for MASS includes those covering safety (SOLAS); collision regulations (COLREG); loading and stability (Load Lines); training of seafarers...
and fishers (STCW, STCW-F); search and rescue (SAR); tonnage measurement (Tonnage Convention); and special trade passenger ship instruments (SPACE STP, STP). [8] The Liability Convention and conventions like Salvage Convention however belong to the auspices of the IMO Legal Committee, which will make its own scoping exercise.

Comite Maritime International IWG states: "Unmanned ships and especially autonomous navigation has the potential to alter the way in which liability is distributed in respect of accidents or incidents at sea. The careful navigation of a ship has traditionally been entrusted to trained seafarers whose competence the relevant shipowner can ensure based on codified standards. Navigation in an unmanned context will be the task either of a shore-based remote controller or alternatively, the developers and pre-programmers of software technology seeking to perform this task, or both. In other words, new liability players are introduced and even those retained arguably assume very different responsibilities." [6]

Making changes to different IMO instrument is a task of which magnitude is difficult to estimate in its entirety. Briefly stated, the process of changing SOLAS and MARPOL compared to liability conventions and Salvage Convention is difficult to estimate as the structure of the Conventions and the process of making changes in it is different.

When this article deals with only Salvage Convention, we just need to look back to the review of Salvage convention after the 1978 Amoco Cadiz incident. It took 11 year to reach a consensus in London Diplomat conference in 1989 to reach a final Convention text of the 1989 London Salvage Convention. It took even until 1996 when it came to force and replaced the Bryssel salvage convention from 1910. Even though it’s wording was not precise, and it had to be supplemented with private law instrument called SCOPIC (special Compensation P & I Clause) created together with ISU and International Group of P&I Clubs. Even though CMI has analysed the needs of changes to Salvage convention as fairly modest in CMI Spreadsheet on Conventions [5], the need for taking into account more complex situations is obvious.

In reality the updating of the Salvage Convention would probably also take up some other issues in addition to autonomous shipping and it would create a new version of the instrument which could create a third alternative instrument among Salvage Conventions when not all jurisdictions would be interested in joining it.

B. An Own Convention for autonomous seafaring

IMO has made an estimation that relevant legislation and Conventions will be in place for international vessel traffic by 2035. This resembles the time period for achieving an IMO instrument and having that internationally accepted in relevant jurisdictions. Very much depends on economic considerations – If the autonomous vessels create economical changes then the legislation could be achieved also as soon as the economic realities insist creating the environment for such a solution. For example, we have a good example - After 2001 the ISPS code was created and put into action with utmost speed. Importing to US would have become impossible and therefore the changes were needed by the industry and enforced rapidly. Due to obvious time constraints which the changes in different IMO instrument will create, there has been several opinions that autonomous shipping should receive an instrument or convention of its own. It is still difficult to envisage how many changes this kind of convention would demand from other Conventions – If any.

The most important issue which needs to be established and seems to be rather difficult to establish without a specific convention for the autonomous shipping, is the liability of owners or operators of autonomous vessels or their manufacturers. For example some risks vary strongly from the traditional vessels – Cybercrime of autonomous vessel can be considered as very different kind of risk from traditional vessels. Liability conventions need to limit the risk to a certain extent so that the risk is insurable for the insurance industry or P & I Clubs.
C. Formation of Rules on Voluntary bases by the Market

Both Salvage and GA have are examples where industry market has created law by creating its own instruments. York-Antwerp Rules can be considered as one of those instruments and Lloyds Open Form of salvage agreement and SCOPIC alike. Even though the IMO would come to a conclusion that the London Salvage Convention needs to be updated, it is hard to believe that salvage industry would survive without any new solutions for autonomous vessels by the industry. At least standardisation of salvaged vessels would be needed as there is no crew on board to assist the salvor. Law of salvage might be a hydrid in a way that it can continue on the basis of Convention, either in a changed form, but it will definitely need also rules made by the market/industry.

General average has survived on the basis of York-Antwerp Rules for long even through national legislation exists in some countries. In most however, it has ben developed on the basis of YAR. In any case it seems clear that GA will continue as a market driven exercise. It seems that the industry developing the autonomous vessels has already considered the technological solutions needed for GA acts and therefore need for change is not great and it can be made by supplementing the existing rules for example by GA rules/guidelines for autonomous vessels to be accepted as part of the cargo solution or carriage contract and approved by the IUMI as representative of the Marine Insurers.

VI. Conclusions

The Law of Salvage and GA have been developed for more than 3000 years. They have complex history but they have survived and seen threats and possibilities. Vessels and cargo still needs to be salvaged from marine peril and common perils still encounter the vessels at sea - Even when vessels sail without crew. Cases like “Pergo” have been salved before - Where abandoned vessels have been salved after they have continued their journey on automatic steering after the vessel had been abandoned by her crew.

It is therefore no precedent that an “autonomous” vessel is salved and salvage remuneration is paid for the salvors without whom the vessel with or without cargo would have been

Referring to the industry’s history since 1970 after large oil spills, the market has created solutions like LOF 1980, TOVALOP, CRISTAL, SCOPIC etc. when it has seen it economically important and necessary. IMO will probably develop a solution for a convention(s) by the 2035, but if the industry seems it economically important and the autonomous vessel are sooner reality, it will create its own solutions meanwhile before that. In general, what comes to IMO instruments, it seems possible to “mend” or amend existing conventions enough as long as the vessels are remotely controlled, but it seems that when the vessels are truly independent and machine intelligence decides the acts of the vessel on the basis of predetermined software then there should be own convention for liability of the autonomous vessels as the liability regime differs strongly from the one that exists today. Therefore it seems that in the end when vessels are truly independent, all the solutions of law presented are needed to cover the area of autonomous shipping combined with the traditional seafaring.

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Yacht Charter Party Agreement According to Croatian Law

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Abstract

Amendments to the Maritime Code of 2018 regulate, among other things, certain issues in the field of nautical tourism, and thus create conditions for sustainable development and greater legal certainty by facilitating the business activities of the yacht chartering companies, whilst ensuring a fair balance between the contract parties. The paper gives an interpretation of the new statutory provisions regulating the yacht charter party agreement. This is the first time that yacht charter agreement is regulated as a nominate contract under Croatian law. Yacht charter party agreement is a contract by which the owner undertakes to deliver a yacht or boat to the charterer for the purpose of recreational navigation, and in return, the charterer is obliged to pay hire. The contract is concluded for a specific period. Yacht charter party agreement frequently includes accommodation of persons on the chartered vessel. Vessel can be chartered with or without crew. The authors discuss the legal definition and essential elements of the contract, rights and obligations of the contract parties, their contractual liability and termination of the contract. The analysis leads to a conclusion that the statutory regulation of the yacht charter party agreement is a step forward that should contribute to the predictability of legal protection of the parties involved, a uniform judicial interpretation of these contracts, and to the improvement of yacht charterers’ business practices.

Keywords: Amendments to the Maritime Code of 2018, yacht charter party agreement, contract parties & contractual liability

I. Introduction

Nautical tourism is the navigation and stay of tourists (navigators or passengers) on vessels (yachts, recreational craft and boats) for personal or commercial activities, as well as their stay in nautical tourism ports and ports open for public transport, for the purpose of rest, recreation and cruising. The development of chartering activities begins together with the development of nautical tourism. In the world economy charter activities began to develop in the mid-20th century (Cote d’Azur), while in Croatia commercial charter activities developed parallel to the construction of marinas within the former ACY group, but its full expansion was reached at the beginning of the new millennium. Charter activities include the charter of vessels (yachts and boats) or the provision of accommodation on vessels in the internal waters and the territorial sea of the Republic of Croatia in compliance with the Ordinance on the conditions for conducting the activity of chartering of vessels with or without crew and the provision of guest accommodation services on vessels. According to the Ordinance, a vessel is a waterborne craft, defined in the Maritime Code as a boat or a yacht and used for charter activities (Article 2, p. 1) Chartering of a vessel means providing a vessel to an end user for the purpose of recreation, with or without crew, without guest accommodation service, for an appropriate fee which is pre-established and publicly available, while provision of accommodation service means providing a vessel to an end user (with or without crew), for a time period during which the passengers stay overnight on a vessel for an appropriate fee which is pre-established and publicly available. Depending on the services provided by the charter company, three chartering activities are distinguished: daily charter with or without crew, multiple day charter without crew, and multiple day charter with crew.

There were three important years that marked the development of charter activities in Croatia. The first was 2005, i.e. the year when the new Maritime Code of the Republic of Croatia entered into force with related bylaws (Ordinance on boats and yachts) also entered into force. Before that, chartering services in Croatia, due to the lack of adequate legal regulations, were conducted, more or less without following any particular rules, so the main attribute of charter activities until then was the so-called black charter. At that time, it was forbidden for vessels under a foreign flag to carry out charter operations, the obligation of electronic registration of crew and passengers on all charter vessels was introduced, and the conditions, as well as the rules for chartering of yachts and
boats were prescribed. After that it did not take long for the results of the new charter regulation. [6] The black charter that was widespread until then was rapidly abolished, and the quality and security of charter services significantly improved, which ultimately resulted in the increase in supply and demand for charter vessels in Croatia. [7]

The following year, highlighted as important for the development of charter operations in Croatia, was 2013 when, due to the alignment of national legislation with the acquis communautaire, radical changes took place in the conditions and ways of conducting chartering of yachts and boats with or without crew, including the provision of accommodation services to guests on these vessels. Since Croatia’s accession to the European Union, charter operations in Croatia were again possible for vessels under the flags of EU Member States and vessels of third countries, greater than 40 meters in length, with prior cabotage arrangements. This led to enhancing competitiveness on the Croatian charter market, as well as to increasing the quality of services in this sector. [7]

The third year, which should mark the new era in yacht charter for Croatian nautical tourism, is the 2019 when the Maritime Code amendments are expected, with provisions, which, among other things, for the first time in Croatian legislation regulate the yacht and boat charter party agreement and the contracts on berth such as nominate contracts, which will improve legal certainty, the predictability of legal protection and facilitate business to all participants in nautical tourism. [8] [9]

It should be emphasized that Croatia is one of the most important charter destinations in the world as shown by data on the number of overnight stays in nautical tourism. Thus, in the period from January to September 2018 more than 440,000 arrivals and more than 3 million overnight stays in nautical charter were registered in Croatia, which is approximately at the level of previous year. The total number of charter vessels in Croatia reached almost 4,400 (4,375) in 2018, and over half a million of nautical visitors made almost 3.5 million overnight stays. The number of registered vessels in the first nine months of last year exceeded the figures of 2017 (124,394 by the end of September 2018 compared with 122,964 in the twelve months of last year), with the increase in the number of registered yachts to almost 3,000. There were 17,000 berths in marinas last year with the income of 855 million kunas (about 115 million euros). [10] These figures clearly show that nautical tourism is one of the key segments of our tourism economy, and is especially important for extension of tourist season and diversification of tourist offer. For this reason, every improvement of the legal framework for yachts and boats and contractual arrangements for berths should be welcomed.

II. VESSELS AND PARTIES IN NAUTICAL TOURISM

A. Vessels in nautical tourism

In nautical tourism there are numerous vessels of different characteristics and uses. The common purpose of all these vessels is to serve for recreation. [11] In the Law on Amendments to the Maritime Code of 2019 (hereinafter: Amendments to MC 2019 or MC 2019), the meaning of the terms ship, boat and yacht was substantially altered (Article 7, MC 2019). New definitions of the terms ship, yacht and boat will only come into force on 1st January 2020, meaning that existing definitions will be in use until the end of 2019. Under the new provisions, a ship, except for warships, is a seagoing vessel intended for sea navigation, more than 15 meters in length, or authorized to carry more than 12 passengers. [4]

A boat is a waterborne craft intended for sea navigation, exceeding 2.5 and less than 15m in length and a gross tonnage of 15 tons, or one authorized to carry more than 12 passengers, or the total power of propulsion units greater than 5 kW. The term boat does not include vessels belonging to another maritime object for the purpose of collecting, rescuing or carrying out operations; vessels intended solely for competitions; canoes, kayaks, gondolas and pedal boats, windsurf boards and sailing boards (Article 5, p. 7, MC).

A yacht is a waterborne craft for sports and recreation, regardless of whether it is used for personal needs or business, exceeding 15 m in length and intended for a longer stay at sea, which is furthermore authorized to carry no more than 12 passengers in addition to the crew. A foreign yacht is a waterborne craft for sports and recreation of foreign nationality and considered as such according to regulations of the country it belongs to. The amendment to the MC 2019 introduces the term of a large passenger
yacht exceeding 24 m in length and, in addition to the crew, it is authorized to carry more than 12, but
less than 36 passengers (Article 5, p. 60 MC).

According to the Ordinance on boats and yachts, there is a more comprehensive division of vessels in
nautical tourism, based on the technological characteristics of the vessel. There are different types of
boats for personal use, commercial boats, commercial yachts, private yachts, recreational boats and
speedboats. A personal boat is a sports and recreational boat not used for commercial purposes, while
a commercial boat for passengers and / or cargo boat for a fee, a recreational boat for renting, boats for
professional fishing, and other business activities. A yacht for commercial use is a yacht intended for hire
with or without crew, while a yacht that is for personal use cannot be engaged in commercial use. Rec-
reational boat is a boat of any kind intended for sports and recreation from 2.5 to 24 meters in length
measured according to the standard, regardless of the type of propulsion. A speedboat is a boat or a
yacht that slides on the surface of the sea using a mechanical propulsion device. From the aforemen-
tioned yacht and boat classification it is apparent that the subject matter of the charter party agreement
can be any yacht for commercial purposes and only commercial boats intended for recreation. [υφ]

Charter activity can be performed: by vessel of Croatian state affiliation; a vessel belonging to the EEA
Member State (EEA) or a third country nationals for whom a cabotage authorization has been granted.
The vessels used for the provision of accommodation services must be built and equipped in such a way
as to allow for multiple day accommodation and stay of crew and passengers (Article 5, paragraph 1 of
the Ordinance on the conditions for conducting the activity of chartering of vessels...).

B. Parties in nautical tourism

The parties participating in nautical tourism or charter activities are the yacht or boat owners (registered
owners or holders), chartering companies and charterers. The parties to the yacht charter party agree-
ment are an owner a charter company, and a charterer. The charter company is a registered owner or
holder of the vessel, or the one who has taken responsibility for the management of the vessel from
the owner on the basis of a written contract and who assumes, by taking over such responsibilities, the
powers and responsibilities prescribed by the Ordinance on the conditions for conducting the activity
of chartering of vessels with or without crew and the provision of guest accommodation services on ves-
sels and positive regulations of the Republic of Croatia on the safety of navigation and the protection
of the sea against pollution. [3] The owner (charter company) is considered to be a yacht or a boat holder,
and according to the Amendments and Additions to MC 2019, a yacht or boat holder is a natural or legal
person who holds a yacht or a boat in his possession as a shipowner or under a bareboat charter or a
leasing contract, assuming, until it is proved contrary, that the holder of a yacht or boat, is a person
registered as the owner in the register of ships.

The provisions of the sixth part of the Maritime Code on Ship Operator (Article 5 p.17 of the MC) shall
apply to yacht and boat holders, as appropriate. One of the rights of a yacht or boat holder as a ship op-
erator is the right to limited liability (Article 673a, paragraph 4 of the MC). The yacht or boat holder cor-
responds to the term of “ship operator”, he or she is the owner of a yacht or. a boat, or a lessee (from a
lease agreement), and the owner of a yacht or boat from a yacht charter party agreement. The charterer
is the end - user. The Maritime Code prescribes the charter’s liability to third parties, but only in the case
of chartering a yacht or a boat without crew. Such a charterer has legal responsibility for the use of the
vessel and is therefore properly subjected to the provisions of the ship operator relating to the limita-
tion of liability. However, he does not have the ship operator’s characteristics nor is he entered in the
register of ships.

In the main book of the register of ships for yachts and boats, the company must be entered in List B,
i.e. the name and registered office of the yacht or boat holder or the name and residence of the natural
person who is the yacht or boat holder. In the case of registration of vessels fully owned by a foreign
natural or legal person (that predominantly resides in the Republic of Croatia), the yacht or boat owner
shall authorize a Croatian legal or natural person with residence or seat in the Republic of Croatia that,
in his/her absence from the Republic of Croatia could represent him/her before the competent bodies
in Croatia. Data on a legal or natural person shall be entered in the register of ships. [3]
III. DEFINITIONS AND PARTIES TO THE YACHT CHARTER PARTY AGREEMENT

For the first time, the Amendments to the MC 2019 define the yacht charter party agreement (hereinafter referred to as: charter party agreement) as the agreement whereby an owner undertakes to deliver a yacht or a boat to a charterer for use, and the charterer undertakes to pay him a hire (Article 673a, paragraph 1. MC). A yacht or a boat is hired for sailing, for the purpose of recreation (Article 673a, paragraph 2 of the MC), and not for carriage. Yachts and boats can be chartered only for commercial use. The main point of the charter agreement is that a yacht or a boat is delivered to the end-user (who will use a yacht or a boat for their own recreation) and not for commercial purposes, as is the case with a bareboat charter party agreement. The use as opposed to exploitation does not include its beneficial use (making profit, etc.), i.e. the use excludes the charterer’s gaining benefits of the hired vessel. [13]

Depending on services an owner (a charter company) provides, charter activities can be divided into a day charter with or without crew, multiple day charter without crew and multiple day charter with crew. The vessel used for the services of providing accommodation must be built and equipped in such a way as to allow accommodation for multiple day stays of crew and passengers. The technical fitness of the vessels for carrying out charter operations in the Republic of Croatia is determined by a technical survey (Article 5 of the Ordinance on the conditions for carrying out the chartering activity ...).

The parties to the yacht charter party agreement are the owner - a charter company and a charterer, as a person who uses the chartered pleasure craft. The conditions to be met by a person who carries out the activity of chartering a yacht or a boat are prescribed by the Ordinance on the conditions for conducting the activity of chartering of vessels with or without crew and the provision of guest accommodation services on vessels.[3] According to the Ordinance, the charter company is a natural or legal person, shipowner or user of the vessel, or he/she has assumed the responsibility for the management of a vessel from the shipowner or the user that owns his/her vessels or vessels owned by another natural or legal person on the basis of a written agreement provided that the vessel is registered in the register of boats as a commercial craft, or it is registered in the register of yachts as a yacht for commercial purposes. The charter company has all rights and obligations, including the responsibility for meeting the above conditions, not excluding the liability of the shipowner if it is not the same person. In the domestic legal literature it is stated that the charterer can only be a natural person because the subject matter of the yacht charter party agreement is delivered for use, which does not consider exploitation, and thus it means that a pleasure boat can only be used by one or more natural persons. [13] We believe that there are no legal, practical, nor theoretical barriers for the legal person to assume the role of a charterer if he or she takes a vessel for use without making profit, i.e. for non-economic purposes, for example for the recreation of his/her employees. [14]

IV. ESSENTIAL ELEMENTS OF YACHT CHARTER PARTY AGREEMENTS

According to the legal characteristics, a charter party agreement is a nominate, consensual, double-bound, onerous and causal contract. The hire cause is the transfer of the subject matter for use in exchange for the payment of hire. [13]

The yacht charter party agreement is an informal contract. The reasons of legal certainty in respect of the real rights over vessels, their nationality, as well as their great value and economic significance, have led to the legal solutions according to which ships, yachts and boats are subject to a registration regime. This, however, does not affect the form of a yacht charter party agreement. The charter party agreement is an informal legal transaction and a written form of contract is not mandatory, as opposed to a bareboat charter party contract that shall be concluded in writing in accordance with the Maritime Code. [12]

Objective essential components of a yacht and boat charter are: the subject matter of the contract (pleasure craft - yacht or boat registered for economic purposes) and a hire. The use of the craft itself (yacht and boat) is not an essential part of the contract because the craft can be hired and not used (e.g. the charterer does not stay on the yacht or boat). In such a case, the yacht charter agreement remains in force provided that the charterer pays or has paid the hire. However, it should be noted that the purpose of concluding a yacht charter party agreement is to use the vessel for recreational purposes, which means that the parties are willing for the craft to be delivered to the charterer as the subject matter of the contract for temporary use with the payment of the hire. [16]
A yacht charter party agreement is concluded for a limited period of time (Article 673e), in practice it is usually a shorter period of time, unlike a bareboat charter between a shipowner and a charter company where the agreement is more frequently concluded for a longer period of time which is in line with the characteristics of bareboat chartering in the shipping industry.

V. OBLIGATIONS OF THE OWNER – CHARTER COMPANY

The owner’s, i.e. the charter company’s principal obligation is to deliver a yacht or a boat to the charterer at the agreed place and time, appropriately equipped, seaworthy and fit for contractual use (Article 673b MC). If a particular vessel is the subject matter of the contract, the owner is obliged to deliver the vessel that has been contracted. Characteristics of a vessel can also be stated in the contract. In that case the charterer is obliged to deliver a vessel with these characteristics. Regarding the condition of the vessel, the charterer is obliged to deliver the vessel in such condition that it can be used in accordance with the contractual or customary purpose. The delivery of a yacht or a boat in a yacht charter party agreement as a consensual contract does not imply the conclusion of a contract, but fulfillment of the contractual liability. The right of the charterer to require the delivery of the yacht or boat from the owner is derived from such contractual relationship. [15]

The owner is not obliged only to deliver a yacht or a boat, but the vessel shall be handed over in seaworthy condition and fit for contractual use. It is common that the vessel is delivered clean and orderly, equipped and seaworthy with full water and fuel tanks. Since this is about a yacht charter, there are a number of provisions of the maritime administrative law on the conditions to be met by chartered vessels. The most important condition that must be met by any vessel is its seaworthiness. The yacht or boat is seaworthy in certain areas of navigation and for a particular purpose if it complies with the provisions of the Maritime Code, the Ordinance on Boats and Yachts and the Technical Rules for the Statutory Certification of Yachts and Boats, and if it has the minimum prescribed crew members required for safe sailing with the required qualifications. A crew member must be trained and possess a document proving his / her qualifications (Article 9, paragraph 1) of the Ordinance on conditions for conducting leasing ...). In addition, prior to the commencement of the vessel charter, the owner shall submit a request to the Ministry of the Sea, Transport and Infrastructure for the access to the central database in which all entries of the crew and passenger lists are recorded (Article 11, paragraph 2 Ordinance). [3]

The delivery of a vessel between the charter company and the charterer represented by the yacht master or skipper shall include at least the following elements: verification of the skipper’s competency (not applicable to a charter company providing accommodation services, exclusively on yachts with professional crew); hand over of all valid documentation and the vessel certificates; checking the correct operation of vessel’s gear and equipment; acquaintance with the basic rules of navigation safety and the prevention of pollution of the sea; getting familiar with telephone numbers of search and rescue services at sea and other emergency services; getting acquainted with the procedure in the event of a maritime incident and with weather reports and weather warnings, etc. (Article 25 of the Ordinance). The delivery of the vessel which provides accommodation services shall be carried out in a suitable place owned or leased in by the charter company or used on the basis of a concession authorization. [3]

Papers and documents to be handed over to the yacht master or skipper, which need to be kept on the vessel are: proof of the vessel’s seaworthiness; proof that the master or skipper and crew members are trained to operate the vessel in compliance with the national regulations of the flag State, or in accordance with the regulations of the Republic of Croatia; proof of liability insurance for damage to third parties; a list of crew and passengers, except for vessels that are chartered without the provision of accommodation services and the vessel’s delivery record. [3]

The owner shall always be responsible for the regular and exceptional maintenance of a boat or a yacht during the yacht charter party agreement (Article 673b, paragraph 2 of the MC). If the boat or yacht is delivered in a non-seaworthy state, unfit for the contractual use or in such condition that would significantly restrict its use, the charterer may terminate the contract and shall be entitled to compensation (Article 673b, paragraph 3 of the MC). If the owner cannot prove that the defect which existed at the time of delivery to the charterer, could not be detected with due diligence, he shall be liable for damage caused by those defects resulting in a boat or yacht being non-seaworthy or in its decreased capacity for contractual or customary use (Article 673 .b, c of the MC). [4]
VI. RIGHTS AND OBLIGATIONS OF THE CHARTERER

In the yacht charter party agreement the principal obligations of the charterer are the following: the use of vessels in accordance with the agreement and the purpose, the payment of hire and the redelivery of the vessel after termination of the charter, and the payment of operating costs, inventories, small repairs unless otherwise agreed. The charterer’s obligations are only considered after the owner has fulfilled his obligation of delivering the chartered property, except for the payment of the hire which is usually paid in advance. From the moment of delivery, the charterer may use the vessel in accordance with the purpose for which the yacht charter party agreement was made.

A yacht or a boat can be chartered with or without crew (Article 673c, paragraph 1 of the MC). If a yacht or a boat is chartered unmanned, the charterer is obliged to ensure that a yacht or a boat during the charter is managed by a properly trained and authorized person as a yacht’s master or skipper, and that sufficient number of persons qualified and authorized to perform duties of the crew in accordance with the regulations in force, which is checked by reference to the documents proving the crew members’ competency (Article 673c, paragraph 2 of the MC). If the charterer fails to fulfill this obligation, the owner has the right to terminate the contract and claim damages (Article 673c, paragraph 3 of the MC).

During the charter period a yacht or a boat is delivered without crew into the charterer’s possession, and the charterer, along with the yacht or boat holder and registered owner, is legally liable for its use according to the provisions of the Maritime Code relating to the ship operator liability, including inter alia the provisions on the ship operator limitation of liability (Article 673c, paragraph 4 of the MC). In particular, this refers to tort liability such as liability for death, bodily injury of swimmers and other persons in the sea and liability for damage to property and environmental pollution, as well as for damages caused by collision or vessel contact with fixed or floating objects, liability for bunker oil pollution.

If a yacht or a boat is chartered with a crew, the crew is obliged to execute the charterer’s orders with respect to the navigation plan and they are not obliged to execute orders which could directly jeopardize the safety of a yacht or a boat or a person on the yacht or boat, nor orders that do not correspond to the type, purpose or technical capacity of the yacht or boat (Article 673c, paragraph 5 of the MC).

A. Use of vessels in compliance with their purpose and agreement

The charterer is obliged to use a yacht or a boat in accordance with the agreement and its purpose, while complying with the regulations on the safety of navigation and the protection of the marine environment and other valid regulations on navigation (Article 673 (1) of the MC).

The charterer shall bear the costs of the propulsion, inventory, small repairs and regular use unless otherwise agreed (Article 673c, paragraph 2 of the MC). However, he/she is not liable for the regular wear and tear of a yacht or a boat as a result of its age. (Article 673, paragraph 4), he/she shall not bear the cost of repairing a yacht or a boat necessary to remove the latent defects, or loss of, or damage of a yacht or a boat due to force majeure (Article 673 paragraph 5 of the MC).

The charterer shall be liable for any damage caused by the wrong or irregular use of a yacht or a boat, whether or not it is used by him/her or any other person under his/her authority (Article 673d, paragraph 1 of the MC). If the charterer uses a yacht or a boat in contravention of the agreement, regulation or purpose, or if he or she damages the yacht or boat, especially if the third party makes unauthorized use of the yacht or boat, the owner may terminate the contract and be entitled to compensation for damages (Article 673d, paragraph 2 of the MC). The charterer can make a subcontract for a yacht or a boat only on the basis of the owner’s consent.

B. Payment of hire

A yacht charter party agreement is an onerous contract, which means that hire payment is an essential element of the contract and represents the underlying obligation of the charterer. The hire is the economic purpose of chartering a vessel and is an essential part of a yacht charter party agreement. In the absence of a contractual provision, the hire is payable at the inception (Article 673.dz, paragraph 10f the MC). When determining the amount of hire, the parties also determine when it will be payable or paid. The rules on hire payment deadlines are of dispositive nature, so the parties may arrange for payment of the hire in advance. When chartering a vessel, it is customary that the hire is paid in the form of
an advance payment. In practice, 50% of the hire is usually paid at the time of booking, and the rest no later than one month prior to the commencement of the vessel use.

By inspecting various yacht and boat charter party agreements it is evident that the parties often use the deposit as a pecuniary amount which the debtor (the charterer) gives to the lender (owner) as a guarantee for the fulfillment of the obligation. It is primarily about the use of vessels in accordance with the charter agreement. If the charterer redelivers the vessel in the condition it was delivered (fulfills the obligation of redelivery of the vessel) the owner is obliged to return the deposit amount. [15]

If the charterer does not pay the hire on the due date, the owner may terminate the agreement without affecting the right of the owner to compensation (Article 673dž, paragraph 1 of the MC). The hire does not belong to the owner while the charterer is prevented from using a boat or a yacht on account of the fault of the owner or latent defect (Article 673dž, paragraph 1 of the MC).

C. Vessel redelivery
The charterer shall, after the expiration of the charter party agreement, redeliver the yacht or boat in the condition and the place where it was delivered, unless otherwise agreed (Article 673, paragraph 3 of the MC). If the charterer does not redeliver the yacht or boat to the owner within the agreed time period, he is obliged to pay a double hire rate in proportion to the delay (Article 673g, paragraph 1 of the MC). If the charterer is at fault for delays in redelivering the yacht or boat, he/she is liable for any damage above the double rent amount (Article 673g, paragraph 2 of the MC). If the charterer has used a yacht or a boat in contravention of the contract, regulation or purpose, or if he has caused damage to the yacht or boat, the owner has the right to claim damages, and the charterer is not liable for the ordinary wear and tear.

VII. DURATION AND TERMINATION OF YACHT CHARTER PARTY AGREEMENT
The yacht charter party agreement shall be concluded for a specified period of time (Article 673e of the MC) and shall cease at the expiration of that time. The owner and the charterer can accurately determine the date of termination of the agreement or determine that the agreement is for a certain period of time from the date of its conclusion. After the expiration of the agreed time the charterer is obliged to return the vessel to the owner. [13]

The yacht charter party agreement terminates in the event of a vessel’s failure or its permanent unfitness for use unless the owner replaces it with a substitute yacht or boat of equal or similar characteristics suitable for the intended use and purpose. This provision does not affect the right to compensation for damages by a contracting party responsible for the destruction of a yacht or a boat (Article 673f of the MC).

The hire ceases if the chartered vessel is destructed due to force majeure or event for which none of the contracting parties is liable. A vessel that is the subject matter of a yacht charter party agreement may accidentally become defected or damaged from the time the charter party agreement is concluded until it is fully executed. It is about the occurrence of an unforeseeable cause that could not be prevented, avoided or eliminated. The delivery of a chartered vessel does not result in the transfer of the risk of its accidental failure or damage from the owner to the charterer. Therefore, the risk of accidental loss or damage is borne by the owner for the entire duration of the yacht charter party agreement. [15]

The charterer may terminate the agreement if the yacht or boat is delivered in a non-seaworthy state for navigation, unfit for the intended use or in a condition that would significantly limit its use. The owner may terminate the agreement if the charterer does not pay a hire when it is due, and if the charterer uses the yacht or boat in contravention of the agreement, regulations or its purpose, or he/she causes damage to the yacht or boat, especially if he/she lets the third party make unauthorized use of the yacht or boat. Also, the owner can terminate the agreement if the yacht or boat is chartered without crew and the charterer does not ensure that the yacht or boat during the charter is navigated by a properly trained and authorized person in the capacity of the yacht master or skipper and if there is no sufficient number of persons qualified and authorized to perform the crew duties in accordance with the applicable regulations.
VIII. CONCLUSION

The development of nautical tourism is defined as the strategic interest of the Republic of Croatia. Consequently, such an intensive and significant economic activity should be accompanied by appropriate legal upgrading. The adoption of the Amendments to the MC 2019 is an addition to permanent improvement of the regulations in the Republic of Croatia. The new provisions define the issues in the nautical tourism sector more precisely, and create the prerequisites for sustainable development which facilitates business operations of economic operators engaged in nautical tourism activities. In this respect, the definition of a boat and a yacht is amended in such a way that a yacht is defined as a sailing craft of more than 15 meters in length, and the term for the large passenger yacht is defined for the first time. A new tax regulation is introduced for yacht crew members in international navigation, and the nautical tourism market is regulated within the scope regulated by the Maritime Code.

At the same time, the introduction of yacht taxation per tonnage enables greater competitiveness of the nautical sector with regard to the market of the European Union and it promotes further development of nautical sector. Prerequisites for more efficient ship registration are created with the aim of attracting large passenger yachts to enter the Croatian Register of Ships creating conditions that are motivating for longer stays of these vessels in the Republic of Croatia. In order to increase legal certainty, the Maritime Code shall, regulate yacht and boat charter party agreements, as well as berthing contracts as typical nominate contracts.

Croatia is one of the most important charter destinations in the world, and charter activity is an important component of the overall nautical tourism. It is based on yacht or boat charter party agreements. For the first time in Croatian legislation the Amendments to the MC of 2019 regulate the chartering of yachts and boats as nominate contracts. This contributes to the improvement of charterer’s business practices, ensuring a fair balance between the contracting parties and achieving greater legal certainty and predictability of legal protection as well as uniform judicial interpretation of these contracts.

A yacht charter party agreement is a contract whereby the owner undertakes to deliver a yacht or a boat to the charterer for recreational use and the charterer undertakes to pay an agreed hire. Such an agreement will be concluded for a specified period of time. A yacht charter party agreement often includes accommodation of persons on these vessels (chartered vessels). According to the Ordinance on the conditions for conducting the activity of chartering of vessels with or without crew and the provision of guest accommodation services on vessels, chartering a vessel means delivering it to the end user for the purpose of recreation, with or without crew, without the provision of accommodation service for guests, while the provision of accommodation means delivering vessels to the end user, with or without crew, for a period during which the passengers stay on board over night.

The charter party agreement has been regulated by special legal provisions since 2019, meaning that it has become a nominate contract, and according to its legal characteristics it is a consensual, double-bound, onerous and causal contract. From the legal definition of yacht charter, it is clear that objectively essential elements of the contract are: subject matter of the charter – a yacht or a boat registered for commercial purposes) and a hire.

The rights and obligations of the parties - the owner (the charter company) and the charterer - arise from the yachts charter party agreements. Thus, the charter company’s principal obligation is to deliver the yacht or boat to the charterer at the agreed place and time, suitably equipped, seaworthy, and fit for contractual use. The owner remains responsible for regular and extraordinary maintenance of the boat or yacht also during the charter. The principal obligations of the charterer as the end-user of the yacht charter party agreement are: the use of the vessel in accordance with the agreement and its purpose, the payment of the hire and the redelivery of the vessel after termination of the charter. The hire is the economic purpose of chartering a vessel and therefore, it is an essential part of a charter party agreement. In the absence of contractual liability, the hire is payable at the inception of the contract.

By adopting new legislation, legal preconditions have been created for successful development of charter activities. The latest provisions contribute to uniform interpretation of the yacht charter party agreements, the quality of service with respect to legal certainty and the optimal balance between the rights and obligations of the contracting parties. The new legislative provisions consistently implement the
current business practice, which has developed in the operations of the charter companies. This ensures the continuity and stability of business practices.

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Applying Expert Ice Breaker Knowledge to Arctic Navigation: A review of Ice Breaker navigation methods

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ABSTRACT

The literature on Arctic shipping suggests a transit option which is likely to experience significant growth, due to the economic benefits associated with these routes such as reduced distances and shorter transit times, and increased tourism industry demands. Furthermore, as a result of potential oil and gas exploration opportunities, it is suggested that the Arctic is extremely likely to experience significant increases in shipping activity. The potential increase of activity, specifically in the context of mainstream commercial shipping, pose a number of challenges for the industry as the harsh environmental nature and technical limitations imposed by these regions, are likely to increase the risk and frequency in which accidents and incidents are likely to occur. This research therefore sets out to identify some of the key components of Arctic navigation which distinguish it from mainstream shipping, in an effort to highlight the proposed ‘non-routine’ nature of operating vessels within these regions. Furthermore, this focus also investigates how methods used by expert ice navigators such as Ice Breaker deck officers can be applied in the mainstream shipping context. In terms of methodology, the proposed ‘emerging’ nature of Arctic navigation as a research focal point poses a number of challenges in relation to theory deduction, resulting in this research adopting a theory induction perspective/approach. Such approaches lend support to the primary objective of this research, which is to capture and present a broad range of Arctic navigational knowledge and experience, from expert Ice navigators. In addition, these methods support the capturing of Arctic operational scenarios, which can be used for future research efforts across a broad range of disciplines.

KEYWORDS: Arctic, Arctic shipping, Arctic navigation, Arctic bridge equipment & aids to navigation

I. INTRODUCTION

The Arctic is an environmentally harsh domain, which poses a number of challenges for mariners transiting what can be severely ice affected regions. Such challenges include navigation limitations, lack of accurate weather/sea ice data [1], generic bridge designs unsuited for polar navigation, and bridge teams lacking specialist Arctic knowledge. Until recently, transiting Arctic regions was a specialist field fulfilled by a niche component of the maritime sector [2]. However, due to external factors such as climate change and macro-economic considerations resulting in a desire to seek out shorter transit times, the volume of Arctic shipping continues to experience significant growth [3] [4] [5]. Increases such as those outlined by [2] [3], in which suggested transits of areas such as a the Northern Sea Route increased from four to seventy one vessels per annum between 2010 – 2013, suggest an area which is likely to experience further growth. Furthermore, with suggested significant savings to be made in terms of transit times and fuel consumption, oil and gas exploration opportunities, and increased demands from the tourism sector, such micro and macro-economic considerations and opportunities are likely to continue contributing to this proposed growth [2] [6] [4] [7]. Such increases in volume are suggested to increase the risk and likelihood of accidents and incidents which may occur within these regions, the consequences of which are likely to be amplified when compared to mainstream shipping routes due to the environmentally harsh and sensitive nature of these region [8] [9] [10] [11].

As a relatively emerging ‘mainstream’ navigation or indeed transit option, it is proposed that navigation and ship handling are not ‘routine’ within these contexts. Furthermore, it is suggested that such considerations are likely to pose a number of unique challenges which would not be experienced in other shipping and navigational contexts. It is also proposed that such focuses have received a limited amount of empirical investigative efforts, highlighting a need to identify arctic specific navigation considerations, while presenting solutions outlined within literature review and field study efforts. This research paper therefore sets out to “pave the way” for future Arctic navigation research by presenting a review of Arctic navigation literature, and a brief snapshot of research findings from field studies completed during
SEDNA, a H2020 funded project focusing on Safe Arctic Navigation, with a view to identifying solutions for commercial shipping operating within the Arctic. It is proposed that by investigating and capturing specialist knowledge and methods used by Ice Breaker deck officers, that this will present opportunities for identifying navigation and ship handling considerations which could be applied during generic deck officer training. These efforts also present opportunities to investigate and discuss bridge design considerations in the context of Arctic navigation, highlighting unique Arctic navigation end-user perspectives, which could contribute to the development of human-centred Arctic bridge designs.

The initial focus of the review identifies day-to-day shipping scenarios so as to provide an overview of Arctic/ice navigation operations and highlight the various proposed ‘non-routine’ aspects of such shipping. The Arctic weather section outlines the unique meteorological nature and conditions experienced within these regions, while also presenting navigation/transit considerations such as preparation, aids to navigation, ship handling, and operating in convoy. The methodology section outlines the research methods used and the rationale for selection, which in this instance make use of theory induction and layered task analysis bridge equipment and design approaches. The findings section presents results in relation to the validation of proposed scenarios, while also outlining challenges for commercial shipping, and highlighting potential solutions identified by specialist ice navigators. Finally, the discussions section provides an analysis of research findings, while also outlining areas for future research.

II. REVIEW OF ARCTIC NAVIGATION LITERATURE

A. Arctic Ice Navigation Scenarios

In identifying potential Arctic/ice navigation scenarios, the initial literature review focus set out to identify potential day-to-day or routine scenarios in which vessels operating within these environments are likely to face. As outlined in table I, numerous sources suggest that routine operations likely to be experienced within the Arctic consist of mooring, anchoring, pilotage, coastal navigation, Sea/ocean passages, ice breaking operations, ice escort operations (single vessel), ice escort operations (multiple vessels) and ice towing [12] [13] [14] [15].

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Brief Description</th>
<th>Specific Arctic Navigation Considerations</th>
<th>Specific considerations for Ice Breakers</th>
<th>Specific considerations for Commercial Shipping</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mooring</td>
<td>Vessels departing or returning to a berth</td>
<td>Unknown</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Anchoring</td>
<td>A vessel proceeding to anchor within an ice affected area</td>
<td>Yes</td>
<td>Unknown</td>
<td>Unknown</td>
</tr>
<tr>
<td>Pilotage</td>
<td>Vessels transiting harbour areas to commence coastal/ocean passages</td>
<td>Unknown</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Coastal Navigation</td>
<td>Vessels transiting coastal regions applying coastal navigation techniques</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Sea/Ocean Passages</td>
<td>Vessels making ocean passages and applying navigation techniques</td>
<td>Yes</td>
<td>Unknown</td>
<td>Unknown</td>
</tr>
<tr>
<td>Ice Breaking Operations</td>
<td>An Ice Breaker vessel providing clear shipping routes for commercial vessels</td>
<td>Yes</td>
<td>Yes</td>
<td>Unknown</td>
</tr>
<tr>
<td>Ice Escort Operations (Single Vessel)</td>
<td>An Ice Breaker escorting a single vessel while transiting ice affected areas</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Ice Escort Operations (Multiple Vessels)</td>
<td>An Ice Breaker(s) escorting multiple vessels while transiting ice affected areas</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Ice Towing</td>
<td>An Ice Breaker towing a commercial vessel</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

While these sources outline directly or in some instances indirectly a prevalence of such scenarios, as outlined in table I, the relevance to Arctic navigation is not always specified, or whether or not such scenarios are relevant to specific vessel types such as ice breakers or commercial merchant shipping activity. Although the reviewed literature highlights certain shortcomings in relation to classifying Arctic or
ice navigation scenarios, the direct or indirect focuses provide a starting point for Arctic navigation focuses when attempting to capture task analysis data.

B. Arctic Weather Considerations

The Arctic is an ocean which is surrounded largely by land [16], and despite being the world’s smallest ocean covering a distance of 14 million square kilometres, the Arctic is almost six times larger than the Mediterranean [17]. As a result of these geographical features, the climate is moderated by ocean water which cannot drop below −2°C [18]. This can be relatively warmer during winter periods, with polar ice cap coverage contributing to the North pole not experiencing some of the coldest conditions to be experienced within the northern hemisphere.

<table>
<thead>
<tr>
<th>Phenomena</th>
<th>Characteristics</th>
<th>Affected Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polar Front</td>
<td>A dynamic, mobile, and ever changing system, which creates a sequence of cloudy, humid, weather, followed by brighter colder weather</td>
<td>Mid latitudes – 70° Degrees North</td>
</tr>
<tr>
<td>Polar High</td>
<td>A semi-permanent high pressure system which is centred on the North Pole. The system develops as a result of cold temperatures located around the pole, which causes air to descend.</td>
<td>Widespread throughout polar regions depending on other weather influences.</td>
</tr>
<tr>
<td>Icelandic Low</td>
<td>A semi-permanent low pressure system which is at its most intense during winter periods. During the summer, the system reduces in intensity, and generally divides itself into two separate systems.</td>
<td>Between Iceland and Southern Greenland</td>
</tr>
<tr>
<td>Polar Easterlies</td>
<td>Dry and cold prevailing winds that exert force in the direction of low pressure areas at higher latitudes. While considered a recurrent feature, they are suggested to be weak in intensity, occurring infrequently throughout the year.</td>
<td>Westerly regions of polar latitudes</td>
</tr>
<tr>
<td>Arctic Oscillation</td>
<td>A significant contributor to weather within the Arctic, depending on whether or not positive or negative oscillation is being experienced.</td>
<td>Northern mid latitudes and Arctic latitudes</td>
</tr>
<tr>
<td>Arctic Dipole Anomaly</td>
<td>An atmospheric pressure pattern which can be observed when high pressure is experienced throughout the North American components of the Arctic and low pressure is experienced within the Eurasia region. Such a phenomena can at times replace Arctic Oscillation.</td>
<td>Northern mid latitudes and Arctic latitudes</td>
</tr>
<tr>
<td>Polar Vortices</td>
<td>A large scale low pressure system which centres on the North Pole, surrounding the polar high phenomena and trailing the polar front. These systems strengthen during winter months, while weakening in the summer due to ranges in seasonal temperatures.</td>
<td>Various locations throughout the Arctic with an approximate diameter of 540° nautical miles</td>
</tr>
<tr>
<td>Polar Lows</td>
<td>Cyclones which are intense in nature, responsible for creating weather conditions such as heavy precipitation, snow, and strong surface winds. One of the most extreme characteristics of these systems, are the dramatic variations in weather which can be experienced over short distances.</td>
<td>65° N – 75° N</td>
</tr>
</tbody>
</table>

During the summer periods, the presence of colder water prevents coastal areas from increasing in temperature as they may do within other regions. In terms of prevailing climate, when in close proximity to the ocean, a maritime climate generally prevails over all others, thus resulting in significant influences on local climates experienced within Arctic land margins [20]. The unique geographical nature of the Arctic results in these regions experiencing unique annual weather patterns. Some patterns can be found in other regions such as high and low pressure systems, while others are more unique to the Arctic, and are not experienced within more temperate latitudes. Also, the volatile and changeable nature of these regions result in significant variations in terms of the occurrence of such patterns. Such variations are as a result of the multifaceted and complex nature of the interaction between the air mass above the Atlantic Ocean and the Arctic continental air mass that dominates northern latitudes. The point of interaction in which these air masses collide is known as the ‘Polar Front’, with factors such as
the major ocean currents such as the North Atlantic Drift, East Greenland Current, and Transpolar current adding further complexity [19]. Table II provides a brief overview of the primary Arctic systems, while outlining geographical and climatic characteristics.

C. Vessel Preparedness
In terms of entering Arctic or ice affected waters, research suggests the need to complete additional preparations so as to ensure the safe operation and transit of a vessel through Arctic waters. Such preparations include and should not be limited to deck equipment, aids to navigation, search lights, bridge resource management, and bridge fixtures [26] [12] [16]. Additionally, industry regulatory considerations such as UNCLOS (United Nations Convention on the Law of the Sea) and SOLAS (International Convention for the Safety of Life at Sea) outline a number of additional responsibilities for Masters on board vessels entering or operating within these waters [17]. Such responsibilities are in relation to the speed at which vessels travel and course alterations, highlighting a legal requirement for vessels to proceed at reduced speeds and to make the necessary course adjustments to ensure the safe passing of ice, when operating in areas in which ice has been reported, particularly during the hours of darkness [27]. Furthermore, additional legal requirements are placed on Masters to make various reports depending on the conditions encountered. For example, on encountering dangerous ice, a report must be transmitted providing critical safety information which includes the type of ice, position and UTC and date of observation.

D. Aids to Navigation
Research suggests that vessels operating within the Arctic and indeed areas of higher latitudes, must take a number of precautions, and complete various additional actions in order to ensure safe and efficient navigation and operations [14] [28] [29]. [14] highlights the potential effectiveness of radars for early warning ice detection, while also suggesting the need to ensure that OOWs consider the prevailing weather and ice conditions when completing radar setup and monitoring. Specific to Arctic regions, research suggests a prevalence of atmospheric interference known as sub-refraction [14]. Such interference occurs as a result of the extreme moisture and temperatures experienced within the Arctic, resulting in increased ‘refractivity’ of radar electromagnetic pulses, resulting in potential loss of detection as a result of vertical deviations in radar transmissions as outlined in Fig 1. Ice berg composition will also play a role in detection, with factors such as dimensions, size, and ice thickness all playing a role in radar detectability [30]. Additionally, international regulations for the prevention of collision at sea, outline a number of regulatory requirements in relation to radar setup for the purpose of safe navigation and collision avoidance [31].

In relation to navigating with GNSS (Global Navigation Satellite System), research suggests a need to adopt caution as a result of numerous technical shortcomings, and limitations in accuracy when operating within the Arctic and higher latitudes (70 – 75 degrees North) [32] [33] [34] [35] [36] [15] [37]. It is proposed that inaccuracies exist due to orbital altitudes and coverage of mainstream GNSS units such as GPS, GLONASS, and Galileo. Furthermore, it suggested that although efforts have been made to address such short comings in coverage, that a lack of infrastructure in relation to land earth stations used as means of providing referencing mechanisms such as those used in Differential GPS at lower latitudes, significantly inhibits the system from providing the accuracy needed for precision navigation [37]. It is
therefore suggested that OOWs should apply caution and use every available means to cross check positional data acquired from such sources.

Navigating with compasses at higher latitudes pose a number of challenges for OOWs. Firstly, in relation to gyro compasses, the gyroscopic forces and influences present at lower latitudes in close proximity to the equator, become much less prevalent the further north a vessel proceeds. Such lack of influences cause a number of limitations in terms of accuracy and directional referencing information [12]. As a result of proposed inaccuracies, it is recommended that regular gyro celestial navigation cross checks be complete in order to assess accuracy, and to highlight the necessary adjustments or corrections which may need to be made when using gyro compasses [14]. Similarly to gyro compasses, magnetic compasses pose a number of challenges in terms of accuracy as a result in variations in relation to magnetism as a result of the close proximity in which vessels operate to the north pole at higher latitudes [12] [14] [15]. It is therefore suggested that efforts be made to ensure that magnetic compasses are ‘swung’, and checked for accuracy at lower latitudes prior to proceeding north.

Navigating with charts and fixed points create a number of challenges for OOWs in terms of accuracy and situational awareness. Firstly, challenges associated with perceived changes or difficulties in accurately identifying navigational marks can be an issue as a result of the extreme variations which occur during the winter periods within the Arctic [38] [39]. Furthermore, when navigating with floating navigational aids, numerous sources suggest a prevalence of movement within floating navigational aids as a result of extreme ice and snow conditions, highlighting a need to make use of all available means of cross checking the accuracies of such aids to navigation [40] [39].

As a result of the above outlined inaccuracies, numerous industry sources suggest the need to make use of celestial navigation when operating within Polar Regions [12] [14] [26]. However, regardless of the suggested advantages associated with a lack of reliance on electronic aids to navigation when making use of these methods, its use can potentially pose a number of challenges.

Firstly, in relation to weather, the extreme conditions outlined within the arctic climate section can pose a number of challenges, particularly if a vessel is operating within an area which is experiencing prolonged cloud cover. Furthermore, the prolonged periods of darkness and day light experienced during the winter and summer months respectively, pose a number of celestial navigation challenges, as nautical twilight does not always occur throughout these periods (Fig 2 refers). Additionally, atmospheric considerations cause a number of inaccuracies in celestial observations, resulting in a need to apply additional corrections to sextant altitudes [14] [26].
E. Ship Handling

When handling vessels in ice affected regions, research suggests that a number of critical design considerations will influence the efficiency, or potential likelihood of whether or not a vessel will safely transit an area [13] [12] [15]. Additionally, numerous sources suggest the need to take into account factors such as the angle in which ice should be entered, the vessel’s speed, ice characteristics, and the need to apply what may be considered ‘unorthodox’ in mainstream shipping terms, backing and ramming techniques. In entering ice at right angles, it is proposed that such an approach is more likely to achieve successful entry, as any angular contact is far more likely to result in the vessel experiencing damage due to ice compression and the angles in which forces are applied [13]. The vessel’s speed and ice characteristics must be considered, suggesting the need to adjust speed as necessary depending on the ice conditions experienced on scene [15]. The practice of backing of ramming is concerned with the use of applying continuous, controlled forward and stern force when attempting to enter or indeed break free from ice. Such practices may be considered “unorthodox” in mainstream terms, as it is engrained within OOWs from an early stage of learning development to avoid contact with objects regardless of the context.

Although not necessarily an Arctic specific operation, the practice of transiting in convoy within ice affected regions can place a number of additional overloads on OOWs attempting to navigate within these areas [13] [15]. In most cases, such operations are unavoidable for mariners as local geographical regulations or by-laws in certain areas will generally enforce the requirement to avail of ice breaker assistance, which in turn will likely result in the need to proceed in convoy [41]. Such an operation is generally associated with a scenario in which a number of vessels may require simultaneous assistance from an ice breaker. As outlined in fig. 3, research suggests that such an operation will generally consist of vessels operating in a column type formation, as any lateral manoeuvring formations will negate the benefits associated with ice breaker assistance. Sources such as [15] [13] suggest that in general terms, vessels will arrange themselves in a straight line directly astern of an ice breaker at intervals of 200 metres. It is the responsibility of each vessel to manage individual collision avoidance factors, however it is essential that this range be maintained as any additional distance can significantly reduce the ice breaking benefits provided by the other vessels. Slight variations may also be applied depending on the number of ice breakers providing assistance (fig 3. refers).

The literature review highlights and presents a number of additional considerations and requirements, lending further support to the proposed “non-routine” nature of Arctic navigation. The brief review of Arctic weather phenomena presents an outline of some of the prominent potential weather characteristics and geographical considerations. Furthermore, this review highlights the volatile and changeable nature of weather conditions within the Arctic, further supporting the proposed unique nature of Arctic shipping and navigation. The vessel preparedness section highlights a number of additional regulatory
requirements placed on Masters within these regions, while also outlining technical shortcomings, and additional arctic considerations that deck officers must consider when using aids to navigation such as radars, GNSS, compasses, and celestial navigation. Finally, the ship handling factors and convoy operations, highlight a number of additional Arctic/ice navigation considerations, which place a proposed considerable additional overload on deck officers. Such additional overloads further support the proposed “non-routine” nature of Arctic navigation.

III. PRIMARY RESEARCH METHODOLOGY

The primary research data for this study has been gathered through the completion of one on site interview with deck officers on board an ice breaker, followed by the completion of three field studies on board three separate ice breaker vessels. In keeping with research ethics considerations, the names of the vessels, crews, and participants have been omitted from this paper. In relation to ethical procedures, a research ethics checklist was complete, while also providing an information letter for participants prior to commencement which outlined the research focus, the voluntary nature of the study, and potential uses of the information required. Once participants had an opportunity to review this document, permission was then sought from individuals in order to complete the research.

A. Methodology Rationales

In gathering primary research data during this research, two key aspects were focused on; 1.) The data collection methods and 2.) Data analysis processes. With regards the data collection, it was determined at an early stage that this research set to pave the way for future research, seeking theoretical induction as opposed to deduction. Also, as the study sought to capture broad focal points and in-depth knowledge, a methodology which would facilitate such characteristics was deemed to be essential. Sources such as [42] outline that quantitative research focuses on theory testing or deductive approaches, in which the relationship between theory and research is being tested, while qualitative approaches focus on theory generation or inductive approaches in which attempts are made to generate theory. Research completed by [43] lend support to this, suggesting that quantitative methods are confirmatory and deductive in nature, while qualitative methods focus on exploration and induction. When deciding the type of research method to be used throughout a study, [44] highlights the importance of not adopting a bias approach by simply categorising quantitative research as data which can be “counted” or “quantified”, and qualitative which cannot. Research suggests that the application of “quantifiable” methods to qualitative research highlights that the difference is far more complicated than a mere ability to measure [42] [44]. It is therefore suggested that the distinguishing features between qualitative and quantitative research, are the interpretative frameworks used when analysing data, and the knowledge claims that they make [45]. Given the emerging nature of this focus, which sets out to capture ‘in-depth’ knowledge from expert ice navigators, a decision was made to apply qualitative research methods.

With regards selecting a data collection method, sources such as [42] suggest that the flexibility associated with semi structured interviews assist the researcher not only in effectively answering the research question, but also in discovering depth or knowledge not considered previously by the researcher. Furthermore, [46] suggest that semi structured interviews can provide a researcher with an effective means of gathering information, while also gaining a deeper understanding of a topic. The proposed primary data collection method adopted for this study therefore consisted of semi-structured interviews with ice breaker deck officers on board three separate vessels.

Additionally, another factor to consider was that of data analysis and approaches to capturing data associated with “real-world” and “end-user” operations. Such an approach would involve the capturing of, and analysis of data which was associated with how ice breaker navigators approach and complete day-to-day tasks, while also highlighting the human machine interface in order to understand the rationales for certain approaches. Research completed by [47] in the context of ice navigation highlights the challenges associated with such focuses, suggesting a need to make use of methods which take into account the complexity of such operations. Furthermore, this research proposes that such an emphasis is key to gaining a greater understanding of end-user task analysis [48] [49] [47]. With regards the tasks themselves, an analysis method which could capture and present field work data in bridge operation/navigation task analysis terms would be critical to ensuring that the necessary data was gathered. A layered mapping scenario methodology was therefore applied, as such an approach was specifically designed to
capture and present field work observational data in the context of maritime navigational scenarios [50]. Also, as one of the focal points of this research was to investigate the potential application of AR (Augmented Reality) within the Arctic navigation domain, a focus was therefore placed on potential AR solutions as outlined within the research findings.

IV. RESEARCH FINDINGS

The findings presented within this section focus on two primary areas; 1.) The identification of scenarios that ice breaker vessels face on a day-to-day basis and 2.) Navigation and Bridge equipment considerations for vessels transiting Arctic regions.

A. Arctic Navigation Scenarios

With regards scenarios, table III outlines the scenarios observed during the field study, while also presenting additional non-observed scenarios in which the research participants suggested to be prevalent. Table III also outlines which scenarios were deemed to be relevant in the commercial shipping context as well as Ice Breaker vessel operations.

B. Arctic/Ice Navigation Considerations

With regards specific Arctic/ice navigation and bridge equipment considerations, table IV provides an overview of proposed shortcomings identified by Ice Breaker deck officers which if addressed, could potentially increase the efficiency in which commercial vessels transit Arctic/Ice affected regions, while also increasing safety, and in turn reducing risk.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Brief Description</th>
<th>Specific Arctic Navigation Considerations</th>
<th>Relevant to Ice Breakers</th>
<th>Relevant to Commercial Shipping</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mooring</td>
<td>Vessels departing or returning to a berth</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Anchoring</td>
<td>A vessel proceeding to anchor within an ice affected area</td>
<td>Yes</td>
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<tr>
<td>Pilotage</td>
<td>Vessels transiting harbour areas to commence coastal/ocean passages</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Coastal Navigation</td>
<td>Vessels transiting coastal regions applying coastal navigation techniques</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Sea/Ocean Passages</td>
<td>Vessels making ocean passages and applying navigation techniques</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Ice Breaking Operations</td>
<td>An Ice Breaker vessel providing clear shipping routes for commercial vessels</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Ice Escort Operations (Single Vessel)</td>
<td>An Ice Breaker escorting a single vessel while transiting ice affected areas</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Ice Escort Operations (Multiple Vessels)</td>
<td>An Ice Breaker(s) escorting multiple vessels while transiting ice affected areas</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Ice Towing</td>
<td>An Ice Breaker towing a commercial vessel</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Ice Mooring</td>
<td>A vessel being ‘made fast’ in thick ice conditions</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
**Table VI. Field Study Observations**

<table>
<thead>
<tr>
<th>Focal Point</th>
<th>Identified Shortcoming</th>
<th>Resultant Challenge</th>
<th>Identified Solution</th>
</tr>
</thead>
</table>
| **Sea Ice and Weather Forecasting** | It was suggested that information presented within such forecasts is treated with a certain level of scepticism, as a result of industry-wide acceptance of inaccuracies. Such inaccuracies are proposed to increase the further north a vessel travels. | Such inaccuracies pose a number of challenges when attempting to passage plan, without accurate weather and sea ice forecasts, deck officers cannot plan with an adequate degree of certainty that the proposed route will be safe or indeed efficient. | • Ice breakers avail of 24-hour satellite ice imagery, and suggested that all merchant vessels should only navigate within these areas.  
• It was suggested that not all vessels will do so due to the cost associated with such services.  
• Ice breakers make use of a GIS (geographical information system) which can overlay sea ice forecasts and AIS track data on to a geographical projection of a region. It was suggested that such a system would be extremely useful for merchant vessels, particularly in the context of voyage planning.  
• In relation to timeframe, forecast information which covers up to a 54-hour period was deemed to be sufficient for operating within these areas. |
| **Visibility from Bridge**         | Merchant vessel bridges are not designed to provide 360 degrees. Aft views were highlighted as a significant shortcoming, particularly when operating in convoy. | Deck officers’ experience restricted visibility in ice, or must move away from critical bridge equipment to avoid certain aspects. | • Bridge design solutions for new vessels.  
• Increased manning  
• Technology applications such as cameras or AR. |
| **Illumination during hours of darkness** | Merchant vessels operating within these regions are generally lacking significantly in terms of illumination capabilities. It was suggested that this may be a result of cultural industry norms, in which achieving darkness and maintaining personal night vision is critical. | Deck officers’ experience challenges when trying to observe ice or monitor close quarter situations. | • Bridge design solutions for new vessels.  
• Install increased illumination on older vessels.  
• Increased awareness within merchant navy deck officers of the need to apply significant levels of illumination when transiting ice affected areas. |
| **Identifying coastal features or navigational marks which are affected by ice** | Visual and radar views of land topography will vary greatly during winter/ice seasons. | Difficulties in terms of achieving precision navigation and potential disorientation which can result in groundings or collisions. | • The use of conventional radar/EC-DIS sectoral/LDL (Limiting Danger Line) applications to provide an efficient visual referencing tool.  
• The application of such solutions to technology such as AR or bridge window overlays. |
| **Floating navigational aids**     | Floating aids to navigation such as buoys can become inconspicuous or sometimes shift position significantly as a result of extreme ice conditions. | Difficulties in terms of achieving precision navigation and potential disorientation which can result in groundings or collisions. | • The use virtual overlay solutions such as virtual buoys using technology such as AIS. |
| **Celestial navigation**           | Weather anomalies create challenges when attempting to identify the horizon or celestial bodies. | Such challenges can cause significant difficulties when attempting to achieve precision accuracy. | • No mainstream solutions highlighted by the Ice Breaker deck officers.  
• AR/overlay technology could provide a solution as such applications can in theory filter out some of the proposed interference. |
| **Bridge layout and equipment placement** | It was suggested that as merchant vessels will generally have single conning positions, restricting an OOW’s ability to move around the bridge. | Such restrictions result in OOWs attempting difficult manoeuvres from conning positions which are generally obstructed or have restricted line of sight. | • The installation of multiple conning positions would alleviate such restrictions.  
• For older vessels, the installation of additional communication handsets would assist as OOWs may have to leave conning positions. |
| **Use of ECDIS in ice affected regions** | It was suggested that ECDIS units which are designed for mainstream shipping and therefore have limited functionality, are not fit for purpose for OOWs attempting to navigate safely within these areas. | Such reduced functionality inhibits an OOW from overlaying ice chart information, or creating sector type zones suggested in the context of identifying coastal features in the above rows. | • The ice breaker crew suggested the need to develop specific applications within such aids to navigation in order to increase functionality.  
• The vessels visited during the site visits maintained older non-compliant electronic chart displays as a result of the high cost associated with such services.  
• In the context of voyage planning, forecast information which covers up to a 54-hour period was deemed to be sufficient for operating within these areas. |
### V. Discussion

In completing a review of Polar/Arctic/Ice navigation literature, and a number of field studies this paper has presented a number of findings which support the suggested proposal that mainstream commercial shipping within the Arctic is in need of significant attention and indeed developments, in order to ensure that the proposed increase in scale and activity, does not result in an increased number of accidents and incidents within these environmentally harsh, and sensitive areas. Furthermore, these investigative efforts, albeit brief, have highlighted a number of additional Arctic specific considerations which support the suggested “non-routine” nature of such navigation.

In terms of the identified Ice breaker operation scenarios, the presented data suggests that the majority of mainstream shipping operations are relevant within the context of Arctic navigation, with the exception of two scenarios. In relation to anchoring, it was widely suggested during the field studies that anchoring in ice affected areas is simply not a viable option due to the potential damage which could be experienced by anchoring fixtures and indeed a vessel’s hull. It was suggested that the use of anchors and anchor cables which can be dynamic in nature, further add to the complexity of an already challenging situation. One scenario identified within the field study which did not feature during the review is one which was labelled as ‘ice mooring’ by the Ice Breaker crew. In this instance, a merchant vessel which arrived within the vicinity of a port twelve hours ahead of schedule was in need of a solution as a berth would not be available until the designated time period. As this was a smaller bulk carrier vessel, it

<table>
<thead>
<tr>
<th>Operating in convoy</th>
<th>It was suggested by the ice breaker crew that commercial vessels lack significant capabilities in relation to operating in convoy due to a lack of training</th>
<th>The proposed knowledge gaps were suggested to be one of the primary causal factors of accidents, incidents, and collisions within the arctic.</th>
<th>Increased levels of training for deck officers &amp; Masters wishing to sail within ice affected regions.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bridge resource management</td>
<td>The current mainstream manning levels for merchant navy vessels were deemed not fit for purpose within the Arctic due to increased pressures associated with operating within these regions.</td>
<td>Placing a single officer on the bridge to handle the increased overloads of ice and prolonged close quarter scenarios such as escorts, convoys, towing etc significantly increases the likelihood of an accident or incident occurring.</td>
<td>Review current manning levels for operating in ice affected regions. Ice breaker vessels maintain a “pi-lo”&amp; &quot;co-pilot&quot; system in such scenarios.</td>
</tr>
<tr>
<td>Inaccuracies associated with navigation equipment and surveying at higher latitudes</td>
<td>It was suggested that inaccuracies associated with aids to navigation such as GNSS, and a lack of accurate survey efforts of Arctic regions, pose a number of challenges for vessels attempting to navigate with precision within these regions.</td>
<td>Such a lack of accuracy results in the increased likelihood of incidents such as groundings and collisions. It was also highlighted that there is a certain distrust within such systems, and a greater acceptance that groundings can simply be a routine occurrence in certain Arctic regions.</td>
<td>Ice breaker deck officers were unable to offer any solutions, as such shortcomings go beyond the scope of navigational training. It was suggested that a greater level of training on how to cross check equipment accuracy and not relying on one method/system, can at the very least reduce the likelihood of such incidents occurring.</td>
</tr>
<tr>
<td>Ice sensor capabilities</td>
<td>A suggested lack of ice sensor capabilities, particularly for vessels operating at high polar latitudes creates a number of challenges for vessels attempting to determine ice characteristics/conditions.</td>
<td>This can result in deck officers being unable to make the necessary informed decisions in terms of course and speed as they are reliant on visual and aural appraisals of ice conditions. Such appraisals are particularly challenging for merchant vessels as the high constructions nature of their bridges, make height determinations for pressure zones such as ridge extremely difficult to make. Such challenges can result in vessels experiencing damage as a result of collisions with ice.</td>
<td>In the absence of ice sensor equipment, additional training could alleviate or at the very least reduce certain risk factors associated with this hazard. Ice breakers will be at the very least equipped with visual appraisal equipment such as ice thickness poles.</td>
</tr>
<tr>
<td>Polar Code Limitations</td>
<td>Although regulatory focuses received very little attention, it was suggested that the Polar Code was extremely broad in nature, and did not provide the necessary detailed guidance for vessels operating within these harsh environments.</td>
<td>Such proposed limitations are suggested to be resulting in wide spread uncertainty in all aspects of merchant shipping.</td>
<td>Specific recommendations in this regard are beyond the scope of this work.</td>
</tr>
</tbody>
</table>
was suggested that remaining underway was not an option as the vessel would become continuously beset within ice. Also, for the reasons highlighted previously, anchoring was not an option. The Ice Breaker therefore had no choice but assist the merchant vessel in proceeding to an area of thick ice where the crew could make the vessel ‘fast’, by placing it in an area in which drifting would be impossible due to ice concentrations. This scenario also provides an example of the “non-routine” nature of Arctic shipping, as vessels would not would attempt to moor in any other context without making use of mooring lines or anchor cables. Such a scenario would benefit from additional research focus, particularly in the context of identifying hazards and identifying guidelines. In addition, the identification of scenarios presents future opportunities when attempting to further investigate Arctic maritime operations from the perspective of a number of disciplines.

The brief review of meteorological literature suggests an environment which can be extremely harsh, volatile, and changeable to operate within, which could pose a number of potential challenges for mariners. While the harsh nature of these environments was prominent throughout field study observations and interviews, the primary concern for the participants within this study was a lack of accurate forecasting capabilities which could meet the ever changing complex demands of these regions. Such a lack of accuracy, has resulted in a suggested “scepticism” of Arctic weather data. In relation to sea ice, while it would appear that relatively accurate and up to date earth observation data is available for mariners, Ice Breaker specialists suggest that there is in a lot of instances an unwillingness within merchant shipping to cover the costs associated with up to date or near real time ice chart data. Furthermore, it was suggested that the development of a GIS type system for commercial mainstream shipping, which can overlay ice chart, GNSS, and AIS data, would provide a navigational planning tool which could contribute greatly to safe and efficient merchant shipping within the Arctic and ice affected regions. While this finding offers a potential solution, it is somewhat limited in nature, and in need of future research which should focus on the perspective of commercial merchant navy operators in order to determine if such solutions would be of benefit.

Although not directly cited within the literature, during the field studies and interviews, unobstructed visibility was cited as being one of the most critical areas for consideration for any vessel proceeding to the Arctic or ice affected regions. The design features of merchant navy bridge layouts, which in most cases do not facilitate 360° visibility, significantly reduce an OOWs ability to pilot a vessel safely and efficiently within these regions. Such limitations are proposed to be particularly prevalent when attempting to view aft of the vessel, which can create significant challenges during convoy operations. It was suggested that such restrictions result in OOWs having to move away from critical conning positions during manoeuvres in order to make visual observations, resulting in significant overload and brief disorientation which can result in collision related incidents. In the absence of an ability to adjust design characteristics, the installation of equipment such as CCTV, rear view mirrors, or if available – additional manning were proposed as potential solutions used on board Ice Breaker vessels. AR technology developments were discussed, with the respondents suggesting that such innovations could add significant value within this context. Gaining these insights from the perspective of Ice Breaker deck officers impose certain limitations to these findings, highlighting an area in need of additional research in terms of design and “real-world” testing and validation.

A lack of sufficient illumination equipment was cited as a significant shortcoming by the Ice Breaker deck officers, suggesting that in most cases, the equipment housed on board merchant vessels is not conducive for safe Arctic navigation. It was speculated that such short comings were as a result of cost implications and cultural norms within the industry, in which the need to achieve total darkness, and maintain night vision during hours of darkness is deemed to be critical within mainstream shipping. It was therefore suggested that vessels should be equipped with additional lighting, and that there is a need to increase awareness in relation to need for increased lighting within the industry. Such focus would benefit from additional research efforts, particularly in relation to the perspectives of merchant navy deck officers and their perceptions of the use of illumination equipment during hour of darkness.
Coastal navigation, particularly in relation to identifying land marks, floating aids, and navigational hazards were highlighted as a challenge within the literature and during the field studies. The application of coastal navigational methods used by Ice Breaker deck officers such as LDLs, or mapping functions on radars/ECDIS such as sector zones could assist commercial merchant shipping in achieving increased accuracy in terms of navigation and situational awareness. In the context of AR technology, the use of overlay or ‘layered’ displays as outlined in fig. 4 received a positive response in terms of potential to improve safety, however such innovations would need further empirical testing and validation.

![Fig. 4. Potential AR Overlays (Credit Oslo School of Architecture and Design)](image)

The proposed lack of functionality associated with mainstream ECDIS and Radar units which has resulted in the reviewed vessels maintaining older non-ECDIS compliant units in addition, highlights a significant technical shortfall when attempting to use such equipment in challenging environments/scenarios. The use of methods such as sectors or LDLs to increase safety and reduce risk, would benefit from additional research, as such findings will be limited in nature without the use of appropriate practical validation efforts. Furthermore, the proposed limited functionality, and the restrictions placed on deck officers would benefit from future research, particularly from the varying perspectives of the broad range of commercial vessels including bulk cargo, tankers, passenger vessels, exploration, and the various others.

The subject of manning appeared to be of significant relevance, and highlighted as a potential challenge for commercial vessels. When completing operations which have a suggested increased level of overload associated with them such as towing, escorts, or ice mooring, the ice breakers make use of a ‘pilot’ and ‘co-pilot’ type system, in which there will be two trained deck officers on the bridge at times who will at times receive further back up by the Master. It was suggested that most commercial vessels will only maintain one person on the bridge as there is no specific regulatory direction on such matters. Furthermore, it was suggested that there are significant knowledge gaps within the crews of these vessels in relation to Arctic navigation/operations, suggesting a need to increase the level or indeed frequency of training that merchant navy deck officers must complete to operate in such regions. Such shortcomings were suggested to be of particular prevalence within convoys, and when dealing with the challenges associated with inaccurate aids to navigation, and determining ice thickness and characteristics. The subject of manning and training is potentially related to a broader industry debate and in need of additional focus in order to provide any significantly definitive findings. The field work efforts do however at the very least, present an indication of the challenges which are present as a result of the “non-routine” nature of Arctic shipping/navigation.

Finally, the challenges associated with celestial navigation highlighted within the literature continue to be an issue, with ice breaker deck officers unable to provide any specific recommendations or solutions. It could be suggested that such challenges are extrinsic to training or technology shortcomings, as much of the limitations are suggested to be associated with external uncontrollable factors such as weather and atmospheric conditions. Although this is an area in need of additional focus both in terms of training and potential technology solutions, a number of challenges posed by the Arctic, and the suggested reliance on such methods as a result of Arctic specific factors, further reinforce the proposed unique and specialist nature of Arctic navigation.
VI. CONCLUSIONS

Overall, this research captures and presents an number of findings which support the proposed “non-routine” and challenging nature of Arctic navigation, and would suggest the industry has some considerable ground to make before ‘mainstream’ shipping within these regions can become the norm, or indeed routine.

The identification and subsequent classification of Arctic navigation scenarios “paves the way” for future research, providing focal points which could be investigated from broad or more focused perspectives across a multitude of disciplines. Furthermore, highlighting the challenges associated with scenarios such as anchoring, and the use of previously unidentified scenarios such as ‘ice mooring’, not only provide additional research opportunities, but also present knowledge which could have “real-world” and “end-user” implications.

The suggested changeable and volatile nature of Arctic weather combined with the proposed unreliability of weather and sea ice forecasting, pose a number of additional challenges on vessels which transcend routine navigation and shipping operations.

Ship construction and design features are a proposed significant challenge, as the current bridge layouts, obstructed views, and lack of adequate illumination would appear to highlight that commercial merchant navy vessels, which are designed and equipped for mainstream shipping, are simply not fit for purpose within this context. Such challenges further support the proposed non-routine nature of Arctic navigation.

Challenges associated with coastal navigation continue to be an issue for vessels operating within these areas. Although the presented findings are in need of additional empirically tested efforts, the Ice Breaker deck officers do provide some solutions which may be of use to commercial vessels. In relation to navigation methods, the cited challenges in relation to celestial navigation highlight additional overloads placed on deck officers. Furthermore, the reliance on such methods in the absence of regular accurate GNSS technology, a challenge not experienced in mainstream shipping regions, further supports the proposed “non-routine” nature of Arctic navigation. The use of technology such as AR to address such challenges is supported as a potential option, however such methods would benefit from additional research focus.

In relation to manning and training, while such considerations are suggested to be part of a broader debate, the findings within this research at the very least highlight the need to address these areas as it is proposed that current mainstream manning levels and training considerations, do not address the increased demands placed on mariners navigating within these regions.

ACKNOWLEDGMENT

The author wishes to acknowledge the European Commission Horizon H2020 research and innovation programme. The field work completed during this research was completed as part of the SEDNA project, which has been funded under grant agreement no. 72356. The author wishes to thank fellow Cork Institute of Technology and Halpin Centre researchers Maria Looney and Paul Shanahan in their contributions to field studies completed as part of the SEDNA project. The author also wishes to thank the Oslo School of Architecture and Design for their contributions to the field work preparation and implementation, while also acknowledging efforts from AALTO University and Chalmers University of Technology. Finally, the author wishes to thank the vessels and participants who facilitated the field studies for their patience, honesty, and tireless efforts to assist us.
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Digital Nautical Publication Data Base in Support of Voyage Planning

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ABSTRACT
Development of vessel navigation is moving towards full digital integration of navigational equipment. This means faster processing of data, easier existing data updating, time savings and to unstress of Officer of the Watch (OOW) and the most important contributes to safe of navigation. Voyage planning process is still based on nautical publications books, which leads to high amount of publications, that must be updated on regular bases and also being replaced when the new edition is issued. This process is time consuming and requires extra caution from OOW, who is also in charge for nautical publication and charts. Making a mistake in updating can lead to navigational risk or disaster.

This article presents solutions how to improve safe navigation by use of electronic data base for voyage planning. The concept is based on similar approach as digitalization of nautical charts with use of Electronic Chart Display Information System (ECDIS). Providers of nautical charts and nautical publications have already changed their publications into digital form that could be updated via their website by using their authorisation code.

The next step with digitalization of navigational publicaƟon would be to form a complete data base with all the information in one unit. Furthermore, Digital Nautical Publication Data Base (DNPDB) could be then interlinked with ECDIS system that could enable even a wider range of information in one place at short period of time.

KEYWORDS: Digital Nautical Publication Data Base (DNPDB), voyage planning, safe of navigation & interlink ECDIS with DNPDB

I. INTRODUCTION
In the new amendments to SOLAS (Safety of Life at Sea) Chapter V (Safety of Navigation) Regulation 19 are determined Carriage Requirements for Shipborne Navigational Systems and Equipment. This rules are requiring obligatory carriage of ECDIS for certain ships built on or after 1 July 2012, and time plan for equipping vessels with ECDIS system. [15]

Charts, as defined in Regulation 2.2, or an Electronic Chart Display and Information System (ECDIS) using Electronic Navigational Charts (ENCs) or Raster Navigational Charts (RNCs) have to meet the requirements of the Regulation 19.2.1.4 with the necessary back-up arrangements in accordance with the Regulation 19.2.1.5. The back-up arrangements may either be duplication of the ECDIS or a reduced folio of paper charts. [15]

“Nautical publications are used by mariners and ship administrations to meet SOLAS chapter V, regulation 19.2.1.4 requirements for nautical publication to be on board a vessel for an intended voyage. The requirements for nautical publications to be on board SOLAS class vessels were also restated by IMO and The Maritime Safety Committee in MSC-MEPC.2/Circ.2. Nautical publications presented in electronic format are acceptable when issued by or on the authority of an authorised Hydrographic office or other relevant Government institution” [15]

Chapter V of SOLAS Convention; requires use of nautical publication in term of safe navigation. Nautical publication must be regularly updated. Subsequently this leads to a time loss and possible mistakes, that have been made by corrections, overstretch of OOW in correcting nautical publication and charts, planning a purchase of new or new editions of marine nautical publication and charts.

Digital Nautical Publication (DNP), which can be updated through computerized program, might be a solution to those problems. Digitalization of nautical publication is the future in voyage planning. The step further is DNPDB in support of Voyage planning.
In one term, there could be one data base which could include all information obtained from digital or paper nautical publications. By inserting departure and next port of call into DNPDB program, computer based program automatically gives output of all required information necessary for voyage planning, i.e. safe navigation. Furthermore, most of this information, are already overlaid on ECDIS.

II. NAUTICAL PUBLICATION AND UPDATES

To meet the requirements of Regulation 27, Chapter V of SOLAS, digital publications should provide a capability for updating information at least at the same frequency as provided in any paper equivalent. [14]

Updates for e-NPs (Electronic Nautical Publications) are provided weekly via an on-line updating service allowing both updates and new editions to be downloaded. Updates are applied automatically and the sections updated should be clearly marked. Updates should be applied to both primary and backup systems. Available updates must be applied before passage planning process. The automated updating available minimises workload of OOW and the opportunity for human error associated with manual processes. [14]

“Admiralty Digital Publications (ADP) are a fully approved digital version of the United Kingdom Hydrographic Office (UKHO) paper Nautical Publications used by mariners around the world. ADP meets SOLAS carriage requirements and, depending on a vessel’s flag state, can replace the requirement for carriage of traditional paper publications.” [14]

Some of the publications listed below are already part of the Maritime Information Overlay (MIO) on some ECDIS systems:

1. Admiralty sailing directions (NP 1 to 72)
   - Supplied automatically with chart outfits supplements issued every two years.
   - a. Information relating to Admiralty charts and publications, general navigation and meteorology. Index chart for area covered by volume.
   - b. Chapter 1:
      i. Navigation – Regulations
      ii. Country – Port Information
      iii. Natural Conditions
   - c. Appendices:
      i. Dockyard Ports – Orders in Council
      ii. Territorial waters
      iii. Reported radar ranges
      iv. Views (older editions only)
2. Admiralty list of lights and fog signals (NP74 to 84)
   - a. Index chart showing limits of volumes (A to L)
   - b. Introductory remarks on types of lights, fog signals etc.
   - c. Range tables
   - d. Details of all navigational lights (except buoys)
3. Admiralty list of radio signals (Vol. 1-8)
   - a. Volume 1: Coastal Radio stations
   - b. Volume 2: Radio navigation Aids (e.g. Loran C)
   - c. Volume 3: Radio weather services and Nav. Warnings
   - d. Volume 4: Meteorological stations
   - e. Volume 5: GMDSS
   - f. Volume 6: Pilot Services & Port Operations
   - g. Volume 7: Vessel Traffic Services (VTS) & Reporting Systems
   - h. Volume 8: Satellite Navigation Systems (e.g. GPS / GLONASS)
4. Admiralty distance tables (3 Volumes) (NP 350)
   - a. Shortest navigable distances for ships drawing up to 10 m
   - b. Link points between sections and volumes shown in red on chart lets N.B. Advisable to add 5% when passage planning
5. **Admiralty tide tables and tidal stream tables (3 Volumes)**
   a. Worldwide coverage
   b. Tidal levels at standard ports
      i. Chart datum’s relative to ordnance datum’s
      ii. Notes in use
      iii. Notes on storm surges
6. **Tidal prediction by the simplified harmonic method (NP 159 A)**
   a. Intended as a useful supplement to all three volumes of ATT and not as a replacement
   b. Programme can be used to calculate predictions for any port for which harmonic constants are known and for any date – past present or future
   c. “total tide” UKHO Products / Agency
7. **Admiralty tidal stream atlases**
   a. Pocket editions for UK waters
   b. Interpolation table for stream between neaps and springs
8. **Ocean passages for the world (NP 136)**
   a. Recommended routes
   b. Distances between principal routes
   c. Details of wind, weather, currents and ice hazards
   d. Diagrams showing
      i. Main ocean routes for power driven vessels
      ii. World charts of climate and ocean currents
9. **The Mariners handbook (NP 100)**
   a. Complements Sailing Directions
   b. General remarks on charts and publications
   c. Use of charts and navigational aids
   d. Observing and reporting hazards
   e. Basic Meteorology

III. **MARITIME INFORMATION OVERLAY (MIO) ON ECDIS**

MIO is based on the Vector Charts in ECDIS and is designed to help identifying areas of possible navigation risks at the passage planning stage. Almost all information obtained from DNP i.e. paper nautical publication is usually displayed on 46-inch screen by simply clicking or pressing on symbol, which opens and shows information.

MIO is provided in various formats, including International Hydrographic Organization (IHO) S-57 (Transfer Standard for Digital Hydrographic Data). IHO authorised for producing ENCs; must comply with S-57 standard, which is the base for chart carriage requirements of SOLAS Chapter V.

**MIO overlays that are already in force on some ECDIS systems:**

1. Depth contours, depth numbers, buoys, lights, obstacles
2. Radar tracks, symbols, bearing lines
3. Position fix and parallel indexing
4. MIO it is possible to display T&P (Temporary and Preliminary Notices to Mariners) as separate overlay
5. Tide and current overlay
6. Safety contour
7. Passage planning route optimisation based on weather reports
8. AIS (Automatic Identification System)
9. Navigational Area Warnings (NavArea Warnings)
10. ADP (Admiralty Digital Publication)
11. e-NP (electronic nautical publication)
12. Meteorological and oceanographic overlay:
   - ice coverage
   - meteorological information
   - tide/water level
- details of marine protected areas
- current flow
- oceanographic information

**Considerations regarding MIO**. Electronic Preliminary Notice to Mariners (EPNM) role is to help OOW to resolve inconsistencies they might be faced with using ENCs and paper charts. Temporary and Preliminary Notices to Mariners (T&P NMs) - All ADMIRALTY T&P NMs in force are included in the overlay. Each NM is displayed as a simple red polygon (usually rectangular) with red hatched fill which indicates the area affected by the NM. Each NM carries the same NM number that is used in the ADMIRALTY Notices to Mariners Bulletins. The full text of the NM is included as an associated text file which can be displayed by selecting the ’Temporary Notice to Mariners’ or ’Preliminary Notice to Mariners’ feature in the ECDIS Pick Report. The third option is without overlay; to show where UKHO is unable to provide either EPNMS or T&P information. [8]

**IV. CONCEPT OF DIGITAL NAUTICAL DATA BASE (DNPDB)**

Evolution of ECDIS system is proceeding towards implementation of all navigational equipment; such as: DGPS (Differential Global Positioning System), ARPA (Automatic Radar Plotting Aid), AIS, VDR (Voyage Data Recorder), LRIT (Long Range Tracking and Identification System), Speed & Log device, Echo Sounder, Gyro Compass. The next step has already begun with MIO as presented.

Most of nautical publications are available in digital form and could be interlinked in one data base. Vessel needs constant satellite connection with Internet connection for automatic DNPDB update. This is interlinked to ECDIS system that presents all information, found on paper or digital nautical publication. That brings us to a challenge, how to present all information on ECDIS system without over cluttering the screen, which can become unreadable and might lead to unsafe navigation. The solution would be an extra screen i.g. third ECDIS on which we could display information from DNPDB as a replacement to symbols in a pop-up window. However, the question remains, how to determine appropriate symbols and not to confuse the mariner in his decision making process.

**There are several symbols to be determined:**

- port information
- climatic Information
- pilotage Information
- VTS information.

Separate screen mode can provide visual digital text and chart recommendations regarding the most common ocean passages for the world assisting mariners to find the most appropriate route.

Selecting and interpreting them on ECDIS system requires capable processing unit, with three functions, as follow:

First is a digital nautical publication overlay on ECDIS. Its further development leads to automatic sound alarm, which is a warning to call VTS, Port authority or pilot and presents statistical/dynamical data to be reported. Most Port authorities request pre-arrival information 72, 36, 24 hours before entering the port. The fact that ECDIS is already connected to AIS and Speed Log, computer program can calculate a time to make port call; or can have capability to automatically send an information.

Second function could be the search function in DNPDB to obtain certain information regarding voyage. By inserting departure and the next port of call in search function, there should be available nautical publication file (NPF) that include all information obtained from DNP or paper nautical publications, applied just to current voyage plan. As explained, mariners would get access to all necessary information in a quick and consistent manner.
Third function is an automatic voyage plan output. First option is a shorter version, which is requested by Port state control in case of inspection or by Shipper, or other authority. First part of voyage plan consist of waypoints and distances, that can be automatically transferred from ECDIS to voyage plan form. Some of the systems have option to automatically calculate Squat effect and providing information about departure and arrival port contact details. All other columns must be entered manually. With the new processing unit, this could be inserted automatically. Second possibility would be a digital version of all information obtained from DNP related to voyage between the two ports. It could be separated in sections for easier clarification.

**TABLE I. CONCEPT OF DNPDB IN SUPPORT OF VOYAGE PLAN**

<table>
<thead>
<tr>
<th>Digital nautical publication base</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sailing Directions (Pilots)</td>
</tr>
<tr>
<td>Ocean Passages for the World (NP136)</td>
</tr>
<tr>
<td>Distance tables</td>
</tr>
<tr>
<td>ADMIRALTY TotalTide (ATT)</td>
</tr>
<tr>
<td>Tidal stream atlases</td>
</tr>
<tr>
<td>ADMIRALTY Digital Radio Signals aids</td>
</tr>
<tr>
<td>List of lights and fog signals</td>
</tr>
<tr>
<td>The Mariner’s Handbook (NP100)</td>
</tr>
</tbody>
</table>

**Processing unit**

- Automatic update via internet connection
- Paper version requested by Port state control and Shipper
- Digital version (NPF) of all information obtained from digital publication
- Automatic sound alarm to call VTS, port authority or pilot
- Automatic information transmission concerning vessel in navigation
- Search function in digital nautical publication
- Advance Search function in digital nautical publication

**V. DISCUSSION**

DNP contribute to safe of navigation as OOW does not need to perform corrections and updates manually. This results in faster processing of data corrections. In recent years DNP became part of MIO; almost all data, that can be obtained from DNP is displayed on ECDIS screen as additional overlay. This wide range of data must be processed by capable processing unit that could be a subject to different types of malfunctions i.e. computer virus, electrical shock wave, power supply failure. For this purpose there should be an additional processing unit with dependable power supply.

The ECDIS system is a complex system with more and more maritime information overlays. Its primary function is aid to navigation, for monitoring vessel position and path. A new trend is going towards implementation of even more overlays on ECDIS which will over clutter screen and could confuse navigator and consequently lead to an unsafe navigation. A solution might be to reorganise bridge console or to implement an additional screen for showing the extra MIO. This function would allow mariners to find all information concerning navigation in a quick and a safe manner. Since ECDIS screens are quite larger there might be a question where to install them on smaller vessels or where to find a proper place to install an additional screen/display for showing pop-up windows with different nautical information categories.

It is a fact that OOW in charge for the voyage planning must be familiarized with the capabilities and limitations of ECDIS. Technology and concept of modern navigation is in constant development. Thus, showing a constant need for familiarization of seafarers. They must get regular familiarization and excess to information about the
new systems such as ECDIS with MIO. It should be noted that use of ECDIS system can noticeably vary from
different procedures. Even if a seafarer is familiar with ECDIS on one vessel it does not mean that could be fa-
miliar with ECDIS system on other. That’s way it must not be overlooked importance of the onboard bridge
familiarization. Seafarer must be confident and capable of using above mentioned navigational equipment,
otherwise the new technology can even contribute to unsafe navigation.

Development and capability of MIO on ECDIS does not relief OOW of knowing how to use paper and digital
nautical publication in case of emergency situations that have been mentioned.

Below is a table of problems and solutions to new DNPDB concept.

**TABLE II. PROBLEMS AND SOLUTIONS ENCOUNTERING DNPDB CONCEPT**

<table>
<thead>
<tr>
<th>Problems Encountering with DNPDB concept</th>
<th>Solutions to the problems of the DNPDB concept</th>
</tr>
</thead>
<tbody>
<tr>
<td>Processing a large amount of data</td>
<td>Capable computer, with additional support processing unit in case of malfunction</td>
</tr>
<tr>
<td>Appropriate selection from large amount of data</td>
<td>Consistent and logical selection from data base</td>
</tr>
<tr>
<td>Extended MIO must be shown on one (two) limited ECDIS size screen</td>
<td>Rearangement of bridge console, Determining new symbols for interpreting extended data from ECDIS</td>
</tr>
<tr>
<td>OOW will have to adapt/learn to constant changes during DNPDB system modifications</td>
<td>Performing appropriate trainings and refreshments regarding DNPDB system</td>
</tr>
<tr>
<td>DNPDB system failure</td>
<td>Support system or carriage of Digital publication in CD form</td>
</tr>
<tr>
<td>Over cluttered display with other Additional chart layers</td>
<td>Trained OOW that is still capable to perform voyage plan manually</td>
</tr>
<tr>
<td>Black out of all systems on board vessel</td>
<td>Additional screen for subdivisioning overlay informations</td>
</tr>
<tr>
<td></td>
<td>Additional power supply. Equipment should be protected by Faraday cage</td>
</tr>
</tbody>
</table>

**VI. CONCLUSIONS**

With development of ECDIS almost all nautical publication went from paper to digital version allowing to over-
lay this data on ENC.

Almost all navigation equipment on vessel and also other equipment on board, which is requested for normal
operation, is becoming connected in one unit. That means less manpower and all navigational aspects of the
vessel can be monitored from one place. The evolution of navigating ocean going vessels is leading towards
unmanned vessels, which are operated by remote operator from Shore Side Control Center (SCC). Implement-
ing ECDIS and connecting it with other equipment sources is the important step towards it.

**REFERENCES**


Safety Aspect of Navigation Bridge Lighting During Night Watch

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ABSTRACT

The navigation bridge is illuminated by natural and artificial light. The natural light is the light of the celestial bodies. Artificial light is provided by lighting fixtures such as electric lighting on the bridge and outside the bridge, light emitted by electronic navigational devices, etc. The human eye needs time to adapt from light to darkness. It depends on several factors. Eye adaptation is a continuous process during keeping night watch. Thus, adaptation time can be a critical moment for accidents.

KEYWORDS: safety of navigation, bridge lighting, watch keeping, officer of the watch & night vision.

I. INTRODUCTION

A Marine Accident Investigation Branch (MAIB) study on “Bridge Watch-Keeper Safety” was conducted in 2004 and was based on 652 collision and grounding cases over a 10-year period. A (MAIB) is UK government agency, with headquarters situated in Southampton. Study revealed three critical areas [1]:

- About 66% of the vessels involved in collisions had issue with a proper lookout and handing a bridge watch.
- About 33% of all accidents occurred during a night watch while Officer of the watch (OOW) was alone on the bridge, without an AB (Able body seamen) for lookout.
- About 33% of all groundings showed that fatigue and sole bridge watch were main cause of the accident.

Although International Safety Management Code and International Convention on Standards, Training, Certifications and Watchkeeping strictly prescribe how responsible and professional bridge watch should be carried out, sometime companies do not obey those rules. Reason for that could be found in nature of work, increased workload and reduced number of crew. No matter what each bridge watch should be kept by one OOW and one certified AB. This is very important in a dense traffic areas and areas with large number of small fishing boats.

It is very important for OOW to pay attention for fishing boats and smaller boats, because when they have been seen it could be too late to take a proper action to avoid collision.

Masters, owners, and operators are reminded that the Maritime and Coastguard Agency (MCA) considers it dangerous and irresponsible for the OOW to act as the sole look-out during periods of darkness or restricted visibility. Root cause analysis of some recent accidents reported in the industry has revealed various underlying causes for poor lookout such as OOW doing paper work, listening to loud music, doing chart corrections, and in one case sleeping [2].

If OOW keep a sole bridge watch during night and for example doing a paper work problem with bridge lighting may occur. Bridge lighting, changing illumination (light and dark) causing a risk period of eye adaptation which could last 15 minutes. Studies have proved that the human eye adaptation to the reduced light, i.e. night watch is around 15 minutes [3, 4].

In certain circumstances of clear daylight conditions the Master may consider that the OOW may be the sole look-out. Even in that case AB should be constantly available and on call if needed. Jobs as chipping and grinding which could interrupt communication between OOW and AB should be avoided.
II. HUMAN EYE VISION MODES AND ADAPTATION

Night vision has not received the same attention in maritime operations as it has in aviation. Bright lighting in cabins and alleyways greatly reduces night vision to human eye. The traditional lore has been to use red lighting to allow sufficient light to read charts and the equipment, yet maintain a good night vision. But red light is not the best choice for displays of electronic devices installed on the bridge [5].

When the sun is out, and we are under normal indoor lighting, we use our daytime vision provided by cones in the eye. Three types of cones (red, green, and blue) allow us to see colours [6].

There also three modes of vision [7]:

- Photopic vision – vision under well-lit condition. Allows colour perception, higher visual acuity and temporal resolution (luminance level $10^{-1}$ to $10^{4} \text{ cd/m}^2$ - candela per square meter).
- Scotopic vision – vision under very low lighting. (luminance level $10^{-3}$ to $10^{4} \text{ cd/m}^2$)
- Mesopic vision – photopic and scotopic vision in combination, low but not quite dark lighting (luminance level $10^{-3}$ to $10^{4} \text{ cd/m}^2$).

Those modes allow us to see under different conditions. For night time vision we use mostly scotopic and mesopic visions. In humans and many animals, photopic vision allows colour perception, and a significantly higher visual acuity and temporal resolution than available with scotopic vision.

At night, with little or reduced light, we can see by help of rods in the eye. That is scotopic vision. They are $10,000$ times more sensitive to light than the cones. In the dark, the rods can see things that the cones cannot. Unlike the colour vision used in daylight, rod vision is black and white.

A person with normal healthy eye will see $10$ times worse in the dark of a reduced illumination room [5]. Scotopic vision is the vision of the eye under low-light levels. The term comes from Greek skotos, meaning "darkness", and -opia, meaning "a condition of sight".

![Luminance and visual mode at various sky conditions](https://www.visualexpert.com/Resources/nightvision.html)

Figure 1 show eye in each operating mode. Adaptation is the ability of the eye to adapt to different levels of light and darkness. When entering a very bright or very dark space for a while we see nothing. The time necessary for complete adaptation to darkness depends on the amount of light the eye is exposed
to before entering the darkness, while the adaptation to the light occurs by exposing the eye to the shining of light after adaptation to the darkness. It is necessary about 15 to 30 minutes that human eye fully adapt from the bright light to the full darkness, become it is ten thousand to one million times more sensitive than in full light. In this process, also the eye colour perception is changed. However, the eye needs only about 5 minutes to adapt to full light after darkness. Depending on the initial adaptation level, complete dark adaptation may require 45 minutes [8].

The exact timing of dark adaptation depends on two factors:

- the higher the level of initial adaptation, the longer the time, and
- the lower the final resting adaptation, the longer the time [8].

The eye adaptation on different levels of light and darkness could cause risk for a night watch and safety of navigation. Consequences for the Officer of the Watch which frequently change levels of lighting during the night watch could be catastrophic. Time necessary for eye adaptation (15-30 min) could cause delay in visual target detection and reduce time for collision avoidance. For that reason sole lookout during the night watch should be restricted and proper bridge design should create smooth transitions from light to dark.

III. INFLUENCE ON THE BRIDGE WATCH AND SAFETY OF MARITIME TRAFFIC

At sea, same as on the road, different illumination conditions and twilight are critical period for traffic safety. Many outdoor and marine accidents occurred during that time. Reason for that is reduced level of contrast. Contrast is the difference in luminance or colour that makes an object visible.

Time of the day before sunrise and after Sunset is twilight. During that time sky is lightened by the scattered Sun's light. There are three types of twilight: civil, nautical and astronomical [9, 10]. Each of this types can occur at evening and in the morning.

During night-time navigation, in order to see a ship in the distance, rod vision is needed. For reading charts and displays of electronic devices, cone vision is needed. The problem is that they cannot be in use at the same time.

OOW needs higher light levels for the cones to be active and to read the fine print. At that level of illumination, the rods are not as sensitive as they would be in the total darkness. Turning off the lights would not be sufficient because time is needed for adaptation.

Rods and cones are sensitive to different wavelengths of light. To visible spectrum, i.e. the wavelength of light that the eye can see, goes from 400 nm (nanometres, or billionths of a meter) to about 700 nm.
The short wavelengths (at 400-450 nm end of spectrum) appear violet or blue using daytime vision, and the longer wavelengths (at 650-700 nm end of the spectrum) appear red. Under normal daytime vision, human eye is most sensitive around 555 nm (appears yellowish-green), whereas night-time vision (rod vision) is most sensitive around 505 nm. The US Navy recommends very dimly lit bridge at night, i.e. 0.5 - 2.0 foot candles (fc).

<table>
<thead>
<tr>
<th>Example</th>
<th>Lightness (fc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Navy bridge light</td>
<td>0.5 - 2.0</td>
</tr>
<tr>
<td>Office light</td>
<td>50 - 60</td>
</tr>
<tr>
<td>Street light</td>
<td>1</td>
</tr>
<tr>
<td>Full moon</td>
<td>0.03</td>
</tr>
</tbody>
</table>

On the bridge with illumination of 1.0 fc with red lighting and no other lights the eye needs 3 - 4 min. for adaptation. Use of white light increases adaptation to 1 - 1.5 min. Therefore, use of red light instead of white makes insignificant difference in the adaptation.

It is important to understand that measuring contrast is only the starting point of a visibility analysis. Perception depends on many variables. Here are just a few of the factors which must be considered:

- Adaption,
- Object size, distance, orientation and shape,
- Visual field location
- Duration
- Motion/Flicker
- Masking and camouflage
- Colour
- Glare
- Viewer age, adaptation state, arousal level, uncertainty, expectation, optical correction and eye disease

Although mariners passing strict medical examinations, including eye examination, eye testing in different illumination ambient is not included. Especially testing of vision while changing conditions from well-lit to very low-lit condition etc.

Contrast sensitivity declines with age. The graph below shows how contrast must be increased with age. Using the sensitivity of a 20-year-old as the base line, the graph shows the factor by which contrast must be increased in order to maintain visibility level. Required contrast increases gradually to a factor two in the 60's. The loss of contrast sensitivity then accelerates, reaching a factor of 6 by the age 80 [11].

SOLAS describes main display units which should be used on the navigational bridge for navigation. Companies should consider some important factors when making decision for configuration of bridge navigational equipment. Location of equipment should be also closely considered. Small amount of light from bridge navigational equipment can interfere with night lookout [12]. This could be a risk for safe navigation especially in areas with dense traffic. Because of traffic OOW will spend longer time in front navigational equipment such as ECDIS, RADAR, AIS etc. to obtain safest route and avoid close quarter situations. Exposure to the various displays (lighting) will reduce OOW visual perception and it is possible that some targets which are not detected by equipment will not be noticeable visually. Difficulties such as the foregoing may be overcome by the use of display visors. However, there is no precise information on the strength of illumination for producers.

SOLAS also regulate illumination and direction of lights for workplaces, entrances and exit of enclosed work space areas. Convention propose that [13]:

- lights controllers should be visible at night,
- there is enough brightness for performance of any tasks,
- it is possible to dim lights to zero,
- lighting necessary for safe operation on the bridge should be of a type that provides the least impact on night vision,
- it should be possible to dim equipment displays and indicators providing information to individual workstations and the lighting covering the workstation area, at the workstation in use.

Decreasing of illumination is proposed, but with no requirement for the producers or ship-owners.

IV. INCREASING SAFETY IN NIGHT NAVIGATION BY USE OF TECHNOLOGY

Modern technologies should help and solve problems with navigational bridge illumination. Unfortunately maritime international conventions do not follow fast development and it is hard to introduce those technologies on board. Starlight scope night vision systems are a light amplification technology. They are the most affordable way to see in the dark.

Night vision technology has become essential on board vessel as it has great advantages that make navigation easier and safer as it is essential for:

- Vessel piloting and navigation
- High seas vessel identification
- Night time mooring
- Sea navigation buoys from much greater distance
- Man overboard search and rescue [14].

![Fig. 4. View by help of night vision system](http://www.raymarine.com/view/?id=q8z8)
Modern technologies for night vision were reserved for military and scientific users. Night vision cameras, binoculars etc. can and should be used on yachts, cruise-ships, and many other vessels. They can detect objects floating in the water which may damage a vessel, or even worse, sink it. Other vessels, shipping lane traffic, buoys, and bridges are all seamlessly detected by thermal imaging. Even objects which cannot be detected by a radar system such as sailboats, wooden boats, floating debris become clearly visible when a thermal imager is used.

New instruments for night vision applications on board ships use powerful, multi-sensor, mid-range thermal night vision system. It features two thermal imaging cameras and one daylight / low-light camera. Night vision appliances allow to detect objects which are the size of a human being at more than φ km away. Objects floating in the water, the size of 2.3 × 2.3 meters, can be detected up to even 6 km away. They can be detect even in total darkness, through smoke, light fog, and in the most adverse weather conditions [15].

V. Conclusion

The human eye needs time to adapt from light to darkness. It depends on several factors. Eye adaptation is a continuous process during the ship’s night watch-keeping. The adaptation time can be a critical moment for accidents. Studies have found that most accidents happen during the adaptation process (start of night watch-keeping, watch-keeping officer coming to the bridge, distraction by other paper work, etc.).

SOLAS requires double watch keepers, especially during reduced visibility and at night. Human eye is not perfect for observation in the dark. Electronic appliances such as radar have limitations in detecting of objects made from absorbing materials (e.g. wood), small objects, and objects in heavy weather.

SOLAS does not require vessels to use night vision appliances. In high-density traffic, traffic in fishing areas, and in navigation at high speed, these appliances can be very helpful.

SOLAS recognised the need of reducing the illumination of electronic appliances on the bridge, but has provided no data about the permitted illumination.

There is no SOLAS proposal about night vision tools although these appliances are helpful in keeping the safety of navigation.

REFERENCES


The Creation of Polynomial Models of Hydrodynamic Forces on the Hull of the Ship with the help of Multi-factor Regression Analysis

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ABSTRACT
Among the non-inertial forces and moments on the ship’s hull, special attention is paid to their hydrodynamic components, which are considered in describing any ship maneuvers such as braking, acceleration, circulation, Kempf zigzag, dynamic positioning, etc. Based on known experimental data, using a multifactorial quasilinear (linear in the coefficients) regression analysis, expressions for hydrodynamic constants of polynomial models of hydrodynamic forces and moment on the hull of the vessel are obtained. As the factors (regressors), various dimensionless ratios of vessel geometric parameters, such as length, breadth, draft, and block coefficient are taken. When selecting these regression models, the values of the normalized R-square and the value of standard errors were estimated. The significance of the models and the significance of all the factors (regressors) included in the model were estimated with the help of the Fisher and Student criteria.

KEYWORDS: planar motion of a ship, hydrodynamic forces, hydrodynamic characteristics & hydrodynamic constants

INTRODUCTION
The study of hydrodynamic forces and the moment on the hull of the vessel devoted a lot of works [1-12]. For small drift angles $|\beta| < 15^\circ$, empirical polynomial models are mainly used. Numerical characteristics of such models are obtained, as a rule (see, for example, [1–7]), on the basis of processing data from sea tests and model tests in wind tunnels, experimental pools, rotary installations and planar mechanisms. A similar approach to the construction of models of hydrodynamic forces is also implemented in the MMG method (Maneuvering Modeling Group), described in [8-12]. There are also expressions for hydrodynamic derivatives up to the fourth order for a large type of fishing, merchant ships and tankers. One of the key stages of the above approaches is the choice of the method of analysis and processing of experimental data. Thus, in [11], using the least squares method with respect to one explanatory variable (regressor), hydrodynamic models were constructed for ships with the value of the block coefficient $C_b \in (0.5; 0.7)$. In [12], for vessels with a block coefficient mainly from the range: $C_b \in (0.7; 0.9)$, models were obtained for derivatives of longitudinal hydrodynamic forces using several regressors based on the AIC (Akaike Information Criterion) minimum.

This paper proposes a unified approach to the construction of models of hydrodynamic forces based on multivariate regression analysis, using the Fisher and Student criteria. The analysis of existing models was carried out and adequate models of derivatives of longitudinal hydrodynamic forces were obtained with a high level of significance for both the models as a whole and each regressor separately for a wide range of values of the block coefficient: $C_b \in (0.5; 0.9)$.

GENERAL REPRESENTATION OF HYDRODYNAMIC FORCES
Among non-inertial forces and moments on the hull of the vessel, special attention is paid to their hydrodynamic components, which are considered when describing any vessel maneuvers. As a rule, the projections $X_h, Y_h$ of these forces on the coordinate axes associated with the vessel, and the moment $M_h$ around the Z axis are expressed as follows

\[ X_h = v^2 C_h^X (\beta, \omega), Y_h = v^2 C_h^Y (\beta, \omega), M_h = v^2 C_h^M (\beta, \omega). \]
Here \( v, \beta, \omega \) — respectively, normalized: the magnitude of the resulting velocity, the drift angle and the angular velocity of the vessel. The values \( C^p_{h}(\beta, \omega), C^v_{h}(\beta, \omega), \) and \( C^m_{h}(\beta, \omega) \) are called hydrodynamic characteristics of the hull. The solvability of the corresponding systems of differential equations of vessel motion [4–7] causes sufficient smoothness of their right-hand sides, which suggests that the Maclaurin series exist for the hydrodynamic characteristics of the vessel

\[
C^p_{h}(\beta, \omega) = C^p_{h}(0, 0) + \sum_{j+k=0}^{m} C^p_{jk} \beta^j \omega^k, \quad \{p\} = \{x, y, m\}, \quad C^p_{jk} = \frac{1}{(j+k)!} \frac{\partial^{j+k} C^p_{h}(\beta, \omega)}{\partial \beta^j \partial \omega^k} \bigg|_{\beta=0, \omega=0}
\]  

(2)

\( C^p_{jk} \) are called the hydrodynamic constant (or hydrodynamic derivatives) of the force and moment on the hull. Representations (2) allow, at small drift angles and angular velocity, to approximate the hydrodynamic characteristics of the hull by polynomials. If, for example, we confine ourselves to expansion (2) by terms of the order of smallness not higher than the third, taking into account the properties of hydrodynamic forces [1–7], and, equality \( C^p_{jk} = 0 \) resulting from them \( (j, k) \neq (0, 0), (j, k) \neq (2, 0), (j, k) \neq (1, 1), (j, k) \neq (0, 2), (j, k) \neq (0, 4) \) and also, the equalities \( C^v_{jk} = 0 \), \( C^m_{jk} = 0 \) for \( (j, k) \neq (1, 0), (j, k) \neq (3, 0), (j, k) \neq (1, 2), (j, k) \neq (2, 1), (j, k) \neq (0, 3) \) then we get the following expansions

\[
C^h_{x}(\beta, \omega) = C^h_{00} + C^h_{20} \beta^2 + C^h_{11} \beta \omega + C^h_{02} \omega^2 + C^h_{12} \beta \omega^2,
\]

\[
C^h_{v}(\beta, \omega) = C^h_{10} \beta + C^h_{01} \omega + C^h_{20} \beta^2 + C^h_{11} \beta \omega + C^h_{02} \omega^2 + C^h_{12} \beta \omega^2,
\]

\[
C^h_{m}(\beta, \omega) = C^h_{11} \beta + C^h_{02} \omega + C^h_{20} \beta^2 + C^h_{12} \beta \omega^2 + C^h_{11} \beta \omega^2 + C^h_{03} \omega^3.
\]  

(3)

The hydrodynamic constants in the expansions (3) are expressed in terms of the geometric characteristics of the vessel by processing experimental data.

### III. Criteria and Methods for Determining the Constant Mathematical Models of Derivatives of Hydrodynamic Forces

To determine the hydrodynamic constants, will apply multiple regression analysis [13], using a quasilinear polynomial model (linear in coefficients) relative to the main factors (basic regressors):

\[
\eta_1 = C_0, \eta_2 = \frac{B}{L}, \eta_3 = \frac{T}{L}, \eta_4 = \frac{T}{B},
\]

(4)

where \( L \) — the length of the vessel at the waterline, \( B \) — the width of the vessel at the current waterline, \( T \) — the draft of the vessel in the middle. We will use the basic regressors (4) or their multipliers (products of degrees) as the defining regressors (explaining parameters) of the models, i.e. we will look for hydrodynamic constants in the following form

\[
C^p_{jk} = \sum_{j=0}^{k} \lambda_j \xi_j, \quad \xi_j = \prod_{i=1}^{k} \eta_i^{\kappa_i}, \quad \{p\} = \{x, y, z\}, (j, k = 0, \ldots, 4).
\]  

(5)

The indicator \( \kappa \), coefficients of the regression model \( \lambda_j \) and indicators \( \kappa_j, c_j \) of regressions are determined for each hydrodynamic constant \( C^p_{jk} \).

When constructing dependencies (5), we will evaluate both the level of significance of the model as a whole and the significance of each regressor separately. Therefore, the model will be considered adequate if the following criteria are met, based on regression and dispersion analysis.

1) The maximum possible value of the multiple correlation coefficient \( R \) should be achieved:

\[
R > \alpha_0.
\]

(6)
Here the parameter $\alpha_0$ ($0 \leq \alpha_0 \leq 1$) determines the level of connection (correlation) of hydrodynamic derivatives $C^p_{jk}$ with regressors included in representations (5). In this case, if $0.5 \leq \alpha_0 < 0.7$ the connection is considered medium (satisfactory), if $0.7 \leq \alpha_0 < 0.8$ the connection is high (good) and if $0.8 \leq \alpha_0 < 1$ that connection is considered very high (excellent). Otherwise, the relationship cannot be considered acceptable.

2) The statistical significance in the whole of each model (5) will be determined on the basis of the Fisher criterion:

$$F_c > F_{nk}(1 - \alpha_F, m - 1, n - m),$$

where $F_c = \frac{\hat{R}^2}{1 - \hat{R}^2/m - 1}$ - the observable statistics having a Fisher-Snedecor distribution (F-distribution); $m$ - the number of non-zero coefficients of models (5); $n$-sample size; $F_{nk}(1 - \alpha_F, m - 1, n - m)$- critical value of F-distribution for significance level $\alpha_F$. The smaller $\alpha_F$, at which inequality (7) is satisfied, the higher the overall statistical significance of the model. Great is the level $\alpha_F \leq 0.05$.

3) The level of significance of statistics $F_c$ will be determined using probability $\gamma_F = P(F_c \leq F_{nk}(1 - \alpha_F, m - 1, n - m))$. In this case, the smaller $\gamma_F$, the level of significance of statistics is considered higher. The level of significance can be considered acceptable if the following condition is met

$$\gamma_F < \alpha_F.$$

4) The standard error $\sigma_j$ of the regressor $\xi_j$ must satisfy the condition

$$\sigma_j < |\lambda_j|.$$

5) The statistical significance of each regression coefficient is determined based on Student's $t$-criterion:

$$|t_j| > |t_{kr}|,$$

where $t_j = \frac{\lambda_j}{\sigma_j}$, $t_{kr} = t(1 - \alpha_s, n - m)$- the critical value of the t-distribution for significance level $\alpha_s$. The smaller $\alpha_s$ at which inequality (10) is satisfied, the higher as a whole the statistical significance of the coefficients of the model. Excellent can be considered level $\alpha_s \leq 0.05$.

6) The level of significance of the regressors of the model is determined by the probability $\gamma_j = P(t_j \leq t_{kr}(1 - \alpha_s, n - m))$. In this case, the smaller $\gamma_j$, the level of significance of the corresponding regressor is considered higher. The level of significance can be considered acceptable if the following condition is met

$$\gamma_j < \alpha_s.$$

7) The absence of multicollinearity of the models obtained, i.e. the absence of regressors with high pair correlation:

$$|R_{\xi_j, \xi_i}| < \alpha_{mk}, \quad j \neq i,$$

where $\alpha_{mk}$ an indicator of the level of correlation of regressors. It is considered that there is no multicollinearity in the model, if $\alpha_{mk}$ does not exceed $0.7 \div 0.8$.

When constructing models, the key condition is (6). However, the dependencies obtained should be statistically significant with a sufficiently high level of significance, that is, conditions (7) and (8) should be fulfilled with a sufficiently small value $\alpha_F$. Condition (9) allows to discard non-significant regressors, con-
ditions (10) and (11), with enough small value \( \alpha_p \), allow to estimate respectively the significance and significance level of each regressor model. The condition (12) allows to exclude regressors, leading to the multicollinearity of the obtained models.

The procedure of adding regressors (explaining parameters) is applicable to constructing mathematical models of the derivatives of hydrodynamic forces. For this, the most significant regressors of the model are first determined (i.e., regressors having the highest values of the pair correlation coefficients with the corresponding hydrodynamic derivative). Then, starting with some minimal regression model, with the most significant regressors, we add new defining regressors until criteria (1) - (6) are met. At the same time, at each stage we check the fulfillment of condition (12). Note that in this way several adequate regression models can be obtained. In this case, choose those models for which the values \( \alpha_p, \alpha_q \) and \( \kappa \) will be minimal, and the value of the multiple correlation coefficient \( R \) is the maximum possible.

**IV. Analysis of Existing Models**

To analyze the existing models and determine the coefficients of the models (5), we use the known experimental data bases for hydrodynamic derivatives of vessels of various types in deep water given in [11, 12]. From this data, depending on the values of the block coefficient \( C_p \), we make 3 samples of the volume: \( V_1 = \{ n = 30, C_p \in (0.5; 0.9) \}; V_2 = \{ n = 14, C_p \in (0.5; 0.7) \}; V_3 = \{ n = 16, C_p \in (0.7; 0.9) \}. \) In the work [11] presented models, obtained with the same regressors, based on the databases given there (respectively, samples \( V_1, V_2, V_3 \)).

The upper coefficients in representations (13) and (14) were obtained, respectively, in [11] and [12], on the basis of the databases given there (respectively, samples \( V_4, V_5 \)). The second row of coefficients

\[
C^x_{20} = \begin{pmatrix}
0.18 \\
0.2 \\
-0.04
\end{pmatrix}, C^x_{10} - m^y_0 = \begin{pmatrix}
-1.91 \\
-1.6 \\
-1.77 \\
-0.10
\end{pmatrix}, \eta_0 + \begin{pmatrix}
0.08 \\
0.04 \\
0.06 \\
-0.17
\end{pmatrix},
\]

\[
C^x_{02} = \begin{pmatrix}
7.14 \\
2.48 \\
-75.31
\end{pmatrix}, \eta_1 + \begin{pmatrix}
38.4 \\
4.94 \\
-91.19
\end{pmatrix}, \eta_2 - \begin{pmatrix}
46.6 \\
7.35 \\
-91.19
\end{pmatrix}, \eta_1 \eta_2 - \begin{pmatrix}
5.94 \\
0.55 \\
-129.1
\end{pmatrix},
\]

\[
C^x_{20} = \begin{pmatrix}
0.0182 \\
0.0169 \\
0.0159
\end{pmatrix}, \eta_1^{-2} + \begin{pmatrix}
-0.0026 \\
-0.21 \\
0.242
\end{pmatrix}, C^x_{10} - m^y_0 = \begin{pmatrix}
-3.99 \\
-1.8 \\
-2.29 \\
-4.1
\end{pmatrix}, \eta_0 + \begin{pmatrix}
-0.0113 \\
-0.0008 \\
-0.0018 \\
-0.0006
\end{pmatrix}, \eta_1^2 + \begin{pmatrix}
0.755 \\
0.093 \\
0.172 \\
0.725
\end{pmatrix},
\]

\[
C^x_{02} + m^y_0 = \begin{pmatrix}
-5.20 \\
-0.087 \\
-0.075 \\
-5.139
\end{pmatrix}, \eta_0 + \begin{pmatrix}
-14.7 \\
-0.672 \\
-0.952 \\
-15.36
\end{pmatrix}, \eta_3 + \begin{pmatrix}
107.8 \\
3.093 \\
3.972 \\
113.94
\end{pmatrix}, \eta_2 \eta_3 + \begin{pmatrix}
0.701 \\
0.021 \\
0.032 \\
0.679
\end{pmatrix},
\]

where \( m^y_0, x^y_0 \) — respectively, normalized: added mass of inertia, coordinate represents the location of the C.G. in x-axis direction. In [12], on the basis of the sample \( V_5 = \{ n = 18, C_p \in (0.5; 0.9) \} \) the models obtained using multivariate regression analysis using the AIC minimum (Akaike Information Criterion) are presented. We write these expressions, as well as models obtained with the same regressors, based on the samples \( V_1, V_2, V_3 \).
corresponds to the V1 sample, the third V2 sample, and the fourth V3 sample. Table I shows the values of the coefficient of multiple correlation, the levels of significance of models (13).

Analysis of the data presented in Table I shows that for the values of the block coefficient \( \upsilon \), theRegressor (\( R > 0.7 \)), and for the hydrodynamic derivative \( C_{11}^x - m_y \), this relationship turns out to be completely excellent (\( R > 0.9 \)). In all cases, there is a fairly high level of significance of the models and the regressor. For the whole range of values of the block coefficient \( \upsilon \), the model \([\upsilon \chi] \) establishes a satisfactory correlation, with a regressor, for \( C_{11}^x - m_y \) - an excellent one. However, the significance of the regressor for \( C_{11}^x - m_y \) is not high; \( \alpha_s = 0.2 \). In all other cases, the model \([\upsilon \chi] \) is not adequate. In particular, for the hydrodynamic derivative \( C_{02}^x + \psi' m_y \), it turns out to be inadequate for all ranges of variation of the block coefficient.

**Table I. Analysis of the Model (\( \upsilon \chi \)) [11]**

<table>
<thead>
<tr>
<th>Hydrodynamic derivative</th>
<th>Sample</th>
<th>( R )</th>
<th>( \alpha_F )</th>
<th>Condition (9)</th>
<th>( \alpha_s )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( C_{20}^x )</td>
<td>V4</td>
<td>0.7</td>
<td>0.01</td>
<td>+</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>V1</td>
<td>0.55</td>
<td>0.002</td>
<td>+</td>
<td>0.002</td>
</tr>
<tr>
<td></td>
<td>V2</td>
<td>0.72</td>
<td>0.004</td>
<td>+</td>
<td>0.005</td>
</tr>
<tr>
<td></td>
<td>V3</td>
<td>0.16</td>
<td>0.55</td>
<td>-</td>
<td>0.8</td>
</tr>
<tr>
<td>( C_{11}^x - m_y )</td>
<td>V4</td>
<td>0.9</td>
<td>( 10^4 )</td>
<td>+</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>V1</td>
<td>0.81</td>
<td>( 10^7 )</td>
<td>+</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>V2</td>
<td>0.91</td>
<td>( 10^5 )</td>
<td>+</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>V3</td>
<td>0.03</td>
<td>0.91</td>
<td>-</td>
<td>0.2</td>
</tr>
<tr>
<td>( C_{02}^x + \psi' m_y )</td>
<td>V4</td>
<td>0.14</td>
<td>0.66</td>
<td>-</td>
<td>0.85</td>
</tr>
<tr>
<td></td>
<td>V1</td>
<td>0.12</td>
<td>0.55</td>
<td>-</td>
<td>0.55</td>
</tr>
<tr>
<td></td>
<td>V2</td>
<td>0.05</td>
<td>0.86</td>
<td>-</td>
<td>0.86</td>
</tr>
<tr>
<td></td>
<td>V3</td>
<td>0.34</td>
<td>0.2</td>
<td>+</td>
<td>0.2</td>
</tr>
<tr>
<td>( C_{40}^x )</td>
<td>V4</td>
<td>0.7</td>
<td>0.013</td>
<td>+</td>
<td>0.013</td>
</tr>
<tr>
<td></td>
<td>V1</td>
<td>0.41</td>
<td>0.025</td>
<td>+</td>
<td>0.025</td>
</tr>
<tr>
<td></td>
<td>V2</td>
<td>0.73</td>
<td>0.003</td>
<td>+</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td>V3</td>
<td>0.013</td>
<td>0.96</td>
<td>-</td>
<td>0.96</td>
</tr>
</tbody>
</table>

Table II shows the values of the coefficient of multiple correlation, the levels of significance of models (14). Analysis of the data presented in Table II shows that for the hydrodynamic constants \( C_{20}^x \) and \( C_{40}^x \) models [12] are not adequate for all ranges of variation of the values of the block coefficient. As for the hydrodynamic constant \( C_{11}^x - m_y \), a good correlation is observed for the range (\( R = 0.71 \pm 0.92 \)), however, at the same time there is multicollinearity: \( \alpha_{mk} = 0.92 \). The latter leads to the fact that with an increase in the sample: \( n = 30 \), the model is not adequate with a low level of significance of the regressors. The same is observed for the ranges \( C_{02}^x \in (0.7; 0.9) \) and \( C_{40}^x \in (0.5; 0.7) \). As for the hydrodynamic constant \( C_{02}^x + \psi' m_y \), the model [12] can only be used with \( C_{02}^x \in (0.7; 0.9) \).

**Table II. Analysis of the Model (\( \upsilon \chi \)) [12]**

<table>
<thead>
<tr>
<th>Hydrodynamic derivative</th>
<th>Sample</th>
<th>( R )</th>
<th>( \alpha_F )</th>
<th>Condition (9)</th>
<th>( \alpha_s )</th>
<th>( \alpha_{mk} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( C_{20}^x )</td>
<td>V5</td>
<td>0.59</td>
<td>0.12</td>
<td>+</td>
<td>0.05</td>
<td>0.9</td>
</tr>
<tr>
<td></td>
<td>V1</td>
<td>0.63</td>
<td>0.01</td>
<td>-</td>
<td>0.4</td>
<td>0.79</td>
</tr>
<tr>
<td></td>
<td>V2</td>
<td>0.75</td>
<td>0.07</td>
<td>-</td>
<td>0.5</td>
<td>0.98</td>
</tr>
<tr>
<td></td>
<td>V3</td>
<td>0.53</td>
<td>0.25</td>
<td>+</td>
<td>0.23</td>
<td>0.93</td>
</tr>
<tr>
<td>( C_{11}^x - m_y )</td>
<td>V5</td>
<td>0.71</td>
<td>0.05</td>
<td>+</td>
<td>0.05</td>
<td>0.92</td>
</tr>
<tr>
<td></td>
<td>V1</td>
<td>0.81</td>
<td>( 5 \times 10^{-6} )</td>
<td>-</td>
<td>0.48</td>
<td>0.78</td>
</tr>
<tr>
<td></td>
<td>V2</td>
<td>0.61</td>
<td>0.06</td>
<td>+</td>
<td>0.05</td>
<td>0.9</td>
</tr>
<tr>
<td></td>
<td>V3</td>
<td>0.92</td>
<td>( 3 \times 10^{-5} )</td>
<td>+</td>
<td>0.25</td>
<td>0.89</td>
</tr>
<tr>
<td></td>
<td>V5</td>
<td>0.52</td>
<td>0.03</td>
<td>+</td>
<td>0.03</td>
<td>0.64</td>
</tr>
</tbody>
</table>
Thus, the analysis of existing models for derivatives of longitudinal hydrodynamic forces shows that
none of them can be used for the entire range of changes in the values of the block coefficient. Not a
bad correlation can provide only some of them on a limited range. Obviously, single-factor correlation
analysis \([\nu\nu]\) cannot ensure the construction of adequate models with a high level of significance for the
entire range of variation of values \(C_b\). As for the approach of \([\upsilon\phi]\), it is obvious that the application of
only the AIC minimum criterion cannot ensure the fulfillment of criteria \(\upsilon\) - \(\omicron\).

V. MODELS OF DERIVATIVES OF LONGITUDINAL HYDRODYNAMIC FORCES ON THE HULL

The analysis of the known models, conducted above, indicates the need to build new adequate models
of the derivatives of longitudinal hydrodynamic forces on the hull with a high level of significance that
meet the criteria \(\upsilon\) - \(\omicron\). The standard scheme of multivariate regression analysis \([\upsilon\chi]\), and the method-
ology described in the second section, made it possible to construct a number of adequate models of
the derivatives of longitudinal hydrodynamic forces. We write out some of these models that have the
highest level of correlation and significance levels.

A. Hydrodynamic Derivative \(C_{x0}^{x}\).

For the whole range of changes of the block coefficient: \(C_b \in (0.5; 0.9)\), the following expressions de-
serve attention:

\[
C_{x0}^{x} = -0.362\eta_4 + 4.67\eta_1\eta_3, \\
C_{x0}^{x} = -0.113\eta_1 + 3.74\eta_0\eta_3.
\]

For the range of the block coefficient \(C_b \in (0.5; 0.7)\), the following models provide excellent correlation

\[
C_{x0}^{x} = -0.173\eta_1 + 4.855\eta_0\eta_3, \\
C_{x0}^{x} = -0.528\eta_1\eta_4 + 6.088\eta_0\eta_3, \\
C_{x0}^{x} = 2.529(1 - \eta_1)\eta_2 - 1.714(1 - \eta_2)\eta_4,
\]

For a range of the block coefficient values \(C_b \in (0.7; 0.9)\) may also be used a model

\[
C_{x0}^{x} = 2.529(1 - \eta_1)\eta_4 - 15.086\eta_1\eta_2\eta_3.
\]

Table III shows the values of the coefficient of multiple correlation and the levels of significance of mod-
els \(15\) - \(20\).

<table>
<thead>
<tr>
<th>Model</th>
<th>Sample</th>
<th>(R)</th>
<th>(\alpha_x)</th>
<th>Condition (g)</th>
<th>(\alpha_y)</th>
<th>(\alpha_{mk})</th>
</tr>
</thead>
<tbody>
<tr>
<td>(15)</td>
<td>V1</td>
<td>0.76</td>
<td>8.10^6</td>
<td>+</td>
<td>5.10^4</td>
<td>0.25</td>
</tr>
<tr>
<td>(16)</td>
<td>V2</td>
<td>0.75</td>
<td>1.1.10^3</td>
<td>+</td>
<td>2.10^3</td>
<td>0.27</td>
</tr>
<tr>
<td>(17)</td>
<td>V2</td>
<td>0.81</td>
<td>0.003</td>
<td>+</td>
<td>0.003</td>
<td>0.04</td>
</tr>
<tr>
<td>(18)</td>
<td>V2</td>
<td>0.84</td>
<td>0.001</td>
<td>+</td>
<td>7.10^4</td>
<td>0.6</td>
</tr>
<tr>
<td>(19)</td>
<td>V2</td>
<td>0.85</td>
<td>0.001</td>
<td>+</td>
<td>5.10^4</td>
<td>0.79</td>
</tr>
<tr>
<td>(20)</td>
<td>V3</td>
<td>0.8</td>
<td>0.001</td>
<td>+</td>
<td>0.14</td>
<td>0.59</td>
</tr>
</tbody>
</table>

B. Hydrodynamic derivative \(C_{11}^{x} - m_y'\).

For the whole range of changes of the block coefficient: \(C_b \in (0.5; 0.9)\), the following expressions de-
serve attention:
For the range of the block coefficient $C_b \in (0.5; 0.7)$ also the following models provide excellent correlation

$$C_{11}^0 - m_{y}^{l'} = -0.504\eta_1 \eta_4 - 3.086\eta_2 \eta_3,$$

(22)

For a range of the block coefficient values $C_b \in (0.7; 0.9)$ may also be used a model

$$C_{11}^0 - m_{y}^{l'} = -0.396\eta_1 \eta_4 - 3.634\eta_2 \eta_3,$$

(23)

Table IV shows the values of the coefficient of multiple correlation and the levels of significance of models (25) - (28).

**TABLE IV. COMPARISON OF THE OBTAINED MATHEMATICAL MODELS FOR $C_{11}^0 - m_{y}^{l'}$.**

<table>
<thead>
<tr>
<th>Model</th>
<th>Sample</th>
<th>$R$</th>
<th>$\alpha_f$</th>
<th>Condition (g)</th>
<th>$\alpha_s$</th>
<th>$\alpha_{mk}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>(21)</td>
<td>V1</td>
<td>0.98</td>
<td>$10^{-17}$</td>
<td>+</td>
<td>0.04</td>
<td>0.68</td>
</tr>
<tr>
<td>(22)</td>
<td></td>
<td>0.98</td>
<td>$10^{-16}$</td>
<td>+</td>
<td>5.10^{-5}</td>
<td>0.14</td>
</tr>
<tr>
<td>(23)</td>
<td>V2</td>
<td>0.99</td>
<td>$10^{-8}$</td>
<td>+</td>
<td>5.10^{-5}</td>
<td>0.56</td>
</tr>
<tr>
<td>(24)</td>
<td>V3</td>
<td>0.98</td>
<td>$10^{-12}$</td>
<td>+</td>
<td>0.14</td>
<td>0.38</td>
</tr>
</tbody>
</table>

C. Hydrodynamic derivative $C_{02}^x + x_{4}^{l'} m_{y}^{l'}$

For the range of changes of the block coefficient: $C_b \in (0.5; 0.7)$, the following expressions deserve attention:

$$C_{02}^x + x_{4}^{l'} m_{y}^{l'} = 0.074\eta_1 + 0.341(1 - \eta_1)\eta_2 - 0.371\eta_1 \eta_4,$$

(25)

$$C_{02}^x + x_{4}^{l'} m_{y}^{l'} = 0.303(1 - \eta_1)\eta_2 - 0.166\eta_1 \eta_4,$$

(26)

The following model is also adequate for the range $C_b \in (0.7; 0.9)$

$$C_{02}^x + x_{4}^{l'} m_{y}^{l'} = 0.491\eta_1 + 9.681\eta_0 \eta_1 \eta_3 - 0.484$$

(27)

Table V shows the values of the coefficient of multiple correlation and the levels of significance of models (25)-(27).

**TABLE V. COMPARISON OF THE OBTAINED MATHEMATICAL MODELS FOR $C_{02}^x + x_{4}^{l'} m_{y}^{l'}$.**

<table>
<thead>
<tr>
<th>Model</th>
<th>Sample</th>
<th>$R$</th>
<th>$\alpha_f$</th>
<th>Condition (g)</th>
<th>$\alpha_s$</th>
<th>$\alpha_{mk}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>(25)</td>
<td>V2</td>
<td>0.68</td>
<td>0.07</td>
<td>+</td>
<td>0.24</td>
<td>0.586</td>
</tr>
<tr>
<td>(26)</td>
<td></td>
<td>0.68</td>
<td>0.05</td>
<td>+</td>
<td>0.08</td>
<td>0.378</td>
</tr>
<tr>
<td>(27)</td>
<td>V3</td>
<td>0.66</td>
<td>0.02</td>
<td>+</td>
<td>0.03</td>
<td>0.271</td>
</tr>
</tbody>
</table>

D. Hydrodynamic Derivative $C_{40}^x$.

For the whole range of changes of the block coefficient: $C_b \in (0.5; 0.9)$, the following expressions deserve attention:

$$C_{40}^x = 2.85\eta_1 \eta_4 - 33.225\eta_0 \eta_3,$$

(28)

$$C_{40}^x = 0.899\eta_1 - 26.105\eta_0 \eta_3,$$

(29)

$$C_{40}^x = 4.89\eta_1 \eta_4 - 17.463\eta_1 \eta_3,$$

(30)
For the range of the block coefficient $C_b \in (0.5; 0.7)$ also the following models provide excellent correlation:

$$C^{x}_{40} = 1.78\eta_0\eta_3 - 35.83\eta_4,$$  \hspace{1cm} (31)

$$C^{x}_{40} = 5\eta_1\eta_4 - 18.057\eta_1\eta_3,$$  \hspace{1cm} (32)

For a range of the block coefficient values $C_b \in (0.5; 0.9)$ may also be used a model

$$C^{x}_{40} = -26.973(1 - \eta_1)\eta_2 - 167.485\eta_0\eta_3,$$  \hspace{1cm} (33)

Table VI shows the values of the coefficient of multiple correlation and the levels of significance of models (34) - (35).

<table>
<thead>
<tr>
<th>Model</th>
<th>Sample</th>
<th>$R$</th>
<th>$a_f$</th>
<th>Condition ($\eta$)</th>
<th>$a_0$</th>
<th>$\sigma_{mk}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>(28)</td>
<td>V1</td>
<td>0.8</td>
<td>$10^6$</td>
<td>+</td>
<td>$10^6$</td>
<td>0.25</td>
</tr>
<tr>
<td>(29)</td>
<td>V1</td>
<td>0.79</td>
<td>$10^6$</td>
<td>+</td>
<td>0.002</td>
<td>0.28</td>
</tr>
<tr>
<td>(30)</td>
<td>V2</td>
<td>0.79</td>
<td>$10^6$</td>
<td>+</td>
<td>$10^7$</td>
<td>0.55</td>
</tr>
<tr>
<td>(31)</td>
<td>V2</td>
<td>0.79</td>
<td>0.004</td>
<td>+</td>
<td>0.003</td>
<td>0.75</td>
</tr>
<tr>
<td>(32)</td>
<td>V3</td>
<td>0.75</td>
<td>0.009</td>
<td>+</td>
<td>0.006</td>
<td>0.75</td>
</tr>
<tr>
<td>(33)</td>
<td>V3</td>
<td>0.86</td>
<td>$10^6$</td>
<td>+</td>
<td>0.12</td>
<td>0.73</td>
</tr>
</tbody>
</table>

VI. Conclusions

Analysis of the data given in Tables III - VI shows that all the models obtained for the derivatives of longitudinal hydrodynamic forces with a high degree of correlation and excellent levels of significance establish a relationship with the regressors. The presence for each hydrodynamic derivative of several adequate representations with approximately the same regression characteristics that satisfy the criteria 1) - 7) allows us to make the choice of the optimal model. So, if a maneuver is being investigated for ships with a wide range of changes of the block coefficient $C_b \in (0.5; 0.9)$, then models built using sample V1 should be used. For narrower ranges of change $C_b$, it is advisable to use models built on a sample of V2 or V2.

Thus, an approach has been proposed that allows obtaining adequate models of derivatives of longitudinal hydrodynamic forces with a high degree of correlation. Similarly, with this approach, adequate models for lateral hydrodynamic forces and moment can also be obtained.

REFERENCES


The Impact of Shipping Accidents on Marine Environment in Albanian Seas

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ABSTRACT

Shipping accidents are unexpected events that result in financial loss and properties, damages and loss of people. Several reasons as human error, technical failures, natural conditions, shipping factors, route conditions and cargo related factors play role in these accidents. Unfortunately, shipping accidents are inevitable in the maritime field, in contravention of creative and innovative technologies in shipping sector and execution of precautionary safety rules and regulations. Marine accidents adversely affect the human, the marine environment, properties and activities aboard ships and ashore in various forms and degree of extent. The effects of accidents vary from minor injuries to fatalities and from insignificant damage to very severe damage to the environment and property. The cost of accidents, including fatalities and injuries, damage to property and the environment, prevention and mitigating measures and insurance accounts for a considerable share of transport costs. The main purpose of this paper is to investigate the effects of shipping accidents on marine environment in Albanian Seas. Within this scope, the author reviews the literature related with shipping accidents and marine environment. Then, the statistics of shipping accidents and marine environment in Albanian Seas are analysed. Lastly, future projections are provided in the light of presented matters and current developments.

KEYWORDS: shipping accidents, marine environment, Albanian seas & shipping sector

I. INTRODUCTION

The concept of a maritime accident is the occurrence of an event on a ship, involving any equipment, investment and property exposed to the marine environment, resulting in damage to property and persons at sea or in the port. It includes accidents at sea or in port, on the seafront or on the boat... etc. Marine accidents are caused by exposure to marine environment hazards, where accidental events are at sea or at port and can be protected by a maritime security policy. It is immaterial whether the ship or the object involved in the accident is floating or stationary at the time and time of the accident.

Risks at sea continue to be a subject of many documents that describe the differences of road transport from carriers engaged in maritime trade. Current policies are aimed at developing a common insurance to cover the risks, to which the vessels are exposed. In particular the crew that should be covered in the event of accidents. Currently, one of the biggest obstacles in the way of progress of the maritime industry on an international level is the lack of methods for determining the levels of risk. The volume of commercial activities and pressure on the market requires orientation towards new methods and techniques of risk management. In other words the elaboration of a risk management plan, which has the purpose of risk control. It should be considered a coherent management plan to include techniques of identifying potential accidents and analysis of risks, in order to improve security measures and to reduce the loss of human lives and also to enhance the quality of decisions. Efficient management practice requires certain quality standards to be defined, which should be in place progressively, after a careful analysis of the ports and to take into account the perspective of evolution.

The shipping industry is no exception and there are several factors that must be taken into consideration. Safety, problem solving, distribution time, distribution of accurate, goods lost, fees, taxes, and insurance are some factors that should be considered when dealing with the shipping industry to minimize as much as possible risks.

Marine accidents adversely affect the human, the marine environment, properties and activities aboard ships and ashore in various forms and degree of extent. The effects of accidents vary from minor injuries to fatalities and from insignificant damage to very severe damage to the environment and property. The cost of accidents, including fatalities and injuries, damage to property and
II. SHIPPING ACCIDENTS

A. Shipping Accidents and Marine Environment

The ship is the basic and predominant mean of transport for world trade, while the Earth is almost covered by the sea. About 90,000 ships of various dimensions and more than 250 different types, specialized in cargo or passenger trade, or both, serve the world trade.

However, transport is the mechanism of distribution in most of international trade and plays a massive role in the welfare of mankind; billions of tons of raw materials and finished goods are transported in ships between port terminals and various locations around the world [1].

The ship is a world trade tool in a high-risk operating environment. At today's precision and satellite navigation, many maritime accidents still occur at sea. Even sophisticated navigation instruments available and enhanced communication technologies have been unable to stop maritime accidents.

Every ship accident, wherever it is, is the nightmare of every seaman. It can happen in a closed area, in a channel or a strait where traffic is heavy as a result of the movement of ships with different destinations. On the other hand, a serious ship accident becomes even more critical in water breach cases, thus facilitating the loss of ship stability in heavy weather or strong currents. In some other accidents, however, the issue becomes more "environmental" due to the oil spill. A transport accident is a term generally used for any accident resulting in financial loss, either in people's lives or in loss of property, or in both of them [3].

Reasons for maritime accidents are numerous and complex. Increasing the size of ships to reach economies of scale and reducing transport costs is one of the main reasons. The size of the vessels increases correspondingly to the cargo and passenger capacity; therefore when an accident occurs, the risk of life and property becomes immediately higher. Reducing ship manoeuvring capabilities, which ultimately increases the risk of accidents, is another factor contributing to marine accidents.

- There may be some causes for transport accidents. In broad terms these are: natural conditions, technical failures, cargo-related factors, human error and cargo-related factors. Natural conditions can be natural phenomena such as current, tidal flow, heavy winds, reduced visibility (fog, heavy snow and rain), sea storms, darkness, etc.[5]
- Technical failures are failings inside the ship, such as corrosion, constructive damage, engine failure or other damage to the ship resulting from poor maintenance and lack of ship services.
- Route conditions may include navigation error such as reliance on inaccurate maritime charts, narrow channel directions with unexpected movement changes allowing very limited manoeuvrability and exposure to dense maritime traffic, mooring close to TSS, sealed maritime areas, and cruise dangers, such as rocks, reefs, shallow waters,...etc.[6]
- Factors associated with ships can be the weakness of a ship, tied to its large dimensions, so it has less manoeuvrability.
- Human errors may include, lack of knowledge and experience, technical inadequacy, bad eyesight, inappropriate observance of procedures and rules, lack of command of the ship, misinterpretation of radar information, fatigue, overload, inadequate rest periods ...etc.
- Factors related to the load include mainly dangerous goods and heavy loads; e.g. (oils, chemicals, nuclear substances), the cargo place(s) in the ship (hold or deck), and the degree of care that such loads need (cereals, hardwoods) all related to the validity of the vessels.[2]

Any accident may have more than one cause. However, statistical analysis based on major causal trends explicitly shows that human error, albeit diminishing, continues to be the main cause for all transport accidents, being almost 80 percent. In other words, "actions or omissions of human beings play a part in almost any accident, including failures, such as structural or equipment, which may be the immediate
cause. Most accidents are attributable to human error; followed by weather conditions and some also for major reasons. [4]

B. Shipping Accidents and Marine Pollution Statistics in Albania

The maritime transport system is vital for Albanian economy. Shipping accidents adversely affect humans, marine environment, properties and activities aboard ships and ashore in various forms and degree of extent. The effects of accidents vary from minor injuries to fatalities and from insignificant damage to very severe damage to environment and property. As in many other countries, marine accident data are recorded by the Albanian Ministry of Transport. [4]

Particularly, current maritime regulations have very reactive approaches to accidents. These regulatory improvements have been imposed to prevent recurrence of specific type of accidents or incidents. In spite of taking action against the accidents, the collision, incidents and accidents are still a major concern of maritime field not only in all the seas in the world but also in Albanian Seas. [5]

As it can be seen from figure 1, ships involved in marine accidents contain loss of human life and various injuries. The number of accidents and ships involved in them is relatively small. This is explained by the fact that the number of ships with Albanian flag is small, but also by the implementation of the rules of navigation and ship safety. Those few accidents belong to the fishing sector where shipping standards are below the required level.

Issues dealing with traffic pollution in marine protected areas are numerous and they are virtually linked to the nature of the area, with marine traffic, the condition of ports and traffic management mode. Discussions on issues relating to the protection of the marine environment and navigation safety in Albania, requires constant attention which may include [3]:

- Possibility that ships meet the necessary standards considering technical improvements, use of cleaner fuels and enforcement of international conventions for the preservation of the marine environment from pollution;
- Proposal of measures for environmental protection in marine protected areas, given that this is sensitive areas, including urban and tourism areas;
- Taking unilateral measures possible to regulate the movement of fishing vessels in sensitive areas;
- Discussion on the application of control in relation to the movement of fishing vessels and the creation of an agency or dispatcher for the cruise control regime for all ships that handle fishing or other activities uncontrolled and without licensed. [5]
There were numerous more accidents and collisions that affected marine environment negatively in Albania. There numerous more accidents and collisions resulting in oil spills occurred in the past in maritime region of Albania with damage to marine environment and human life. These examples were selected in this study only to shed some light on the magnitude of marine pollution from shipping accidents. [4]

C. Marine pollution from shipping activity

The marine environment is the space along with fauna and flora, water resources, the ultimate surface of the sea and its subsoil, including the coastal line, beaches, ports, lanes and their land territories, lagoons, river estuaries, water line lakes, communicating with the sea. It is a state property and its administration is overseen by state agencies. No one else has the right to authorize the use of the marine environment. The marine environment is used and exploited for economic, commercial, scientific, social, sporting, tourist and military activities. This environment may be used by state agencies, persons, domestic or foreign companies, only under the conditions provided by law.[2]

Albania is a member of the United Nations Convention on the Law of the Sea 1982, and thus has the obligation to protect and preserve the marine environment against pollution. Pollution in itself implies direct or indirect introduction of substances or energy into the marine environment that damage sea and coastal sources, reduce seawater quality, endanger human health, and hinder marine activities and fisheries. There are lists of activities that are prohibited in maritime transport, among which we mention:

- disposal of poisonous substances and wastes;
- disposal of hazardous and explosive substances;
- pouring hydrocarbons and wastewater;
- disposal of solid materials and materials of any nature and type with the exception of fishing gear and equipment and materials and tools necessary for the construction of ports, jetties and other constructions, according to projects approved by the Ministry of Environment and under the conditions set by it;
- the disposal of waste and any kind of material from ships, platforms, installations and by the coast;
- transportation of hazardous materials and wastes;
- the sinking of ships, cargo and goods of any kind and type;
- the sinking and abandonment of any installation that has served for various activities;
- construction and operation of equipment that emit ionizing radiation;
- burning of materials of any kind;
- access to ports of ships of any type and tonnage with unclean ballast;

In the general context of development, the role of ships is very important and positive. Of course no one has the right to deny the giant contribution of these tools to global trade. But, of course, we must consider the impact that ships have on the marine environment. Although air pollution from ships does not cause a direct effect, hence the negative effects that can be caused by incidents do not affect people; there are natural damages that are worrying.[7]

III. CONCLUSIONS

Nowadays, shipping accidents have become more sporadic and the results of them crucial for all parties in terms of human lives, marine environment, trading and financial losses. Not only shipping accidents, collisions and oil spills harm the marine environment, but also ship’s bilge water, ballast water, and discharging solid waste into the sea cause environmental hazards and create irrevocable marine pollution. Therefore, many regulations related to pollution and accidents are constituted to enhance safety of human life, property and preserve the environment by alleviation of accidents, incidents and collisions.[3]

Transport accidents are also a threat to the smooth flow of shipping trade and damage to the environment. Ships are exposed to various external hazards such as darkness, different viewing conditions;
heavy weather and currents, which in one way or another may contribute to transport accidents such as collisions, congestion or collisions. Loss of situation control, not taking the necessary measures, the presence of a third ship, which prevents early action and a timely manoeuvre, overcoming and completing the final rules.

Almost every new ship built today and many others as existing ships are equipped with sophisticated ship equipment to reduce navigation risks and to support and improve life, environment and property safety,

Accident is a common phenomenon. It is not divided based on the time and place of the event. If they are on the ground, in the sea or in the air, the consequences are devastating, causing personal injury and pain, damaging the valuable property and the reputation of the organization involved. The conclusion drawn from this study is that some human errors are contributing factors to marine accidents in the waters of Albania.

Marine pollution sources involve the discharge of used waters, accidental oil discharge from tankers and operational discharge.

Correspondingly, the negative effects of the introduction of pollutants into the marine environment have been created. Effects seem to harm the marine ecosystem and human health. Precautionary and control measures have been introduced, which include the adherence and implementation of standard operations, as contained in Annexes I to VI of the MARPOL Convention.

ACKNOWLEDGMENT

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REFERENCES


Detecting A Man in The Sea

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ABSTRACT

The fall of man into the sea, especially from the ship, is a very frequent accident that usually ends tragically. If man-overboard (MOB) situation is not early detected, i.e. if the fall into the sea did not see by the crew, visually or by some other means, the loss of man is very imminent. To increase probability of survival in the sea it is very important to have appropriate personal life saving appliances, for example floating equipment, such as lifejackets, and systems for improved detection, for example light and smoke signals, whistles, or electronic devices. Unfortunately, SOLAS (The International Convention for the Safety of Life at Sea) requirement doesn’t include modern personal locator beacons or automatic tracing devices as obligatory equipment. In this context we can say that practically nothing significant has been improved since Titanic. This paper elaborates standard personal man-overboard life-saving appliances—primary lifejackets as well modern electronic MOB locators. Also, appropriate analysis of standard and modern equipment will be given, their practical usability and limitations, including recommendation to improve system of detection and location of man into the sea.

KEYWORDS: man overboard (MOB), lifejacket, light and sound signal & personal locator beacon (PLB)

I. INTRODUCTION

Today we are still witnessing of situations in which the search for man in sea lasting for a days, and often without success. It is hard to believe that in modern age, within which we have so many possibilities in communication and positioning, relatively simple situation such as falling a man in sea from ship can have relative high rate of mortality. To improve probability of rescue a man in the sea the key element is early detection of this situation. Improved detection is reachable by use of devices that can immediately detect fall into the sea, and devices, independent or attached to the standard life-saving appliances, which can allow efficient detection from higher distances, in all conditions. The main Personal life-saving appliances required by the SOLAS are Lifebuoys, lifejackets, lifejackets lights and immersion suits and thermal protective aids [1]. Only for lifejackets there is requirement to be available for all crewmembers and passengers on board, accordingly lifejacket could be considered as the prime appliance, for rescuing man in water. To improve identification at sea and to call help, each lifejacket shell be fitted with a whistle and lifejacket light [2]. Besides these whistles and lights there are no other obligatory means which could improve identification. But, on the market there are devices which could significantly improve identification at sea, such as: locator based on AIS technology, radio-beacons, acoustic beacons, locator based on satellite tracking, VHF communicators, etc. Among these modern devices, personal locator beacons based on AIS and radio-beacons technology are easily reachable and between most favorable ones, accordingly within this analysis they would be compared to the standard lifejackets additions (lights and whistles).

II. MAN-OVERBOARD (MOB) ACCIDENTS

In the British merchant fleet during the 10-year period, from 2003 to 2012, there were 66 deaths, of which 4 were related to the fall in the sea and 7 to the missing at sea. Taking into account total number of seafarers at that time, mortality rate per 100.000 seafarer-years was 1.2 for falls overboard and 2.1 for missing at sea [3]. Regarding cruise ships, between 2000 and 2016 around 270 Man Overboard Events have been reported; on average 22 people fall off a cruise ship every year and 86% of those victims do not survive, or are never found [4]. On the other hand, statistical likelihood of a man overboard incident on the cruise ship is relatively low, for example, the Carnival Cruise Line transports more than 11.5 million passengers a year and in 2017 they had four man overboard incidents [5]. Although 60 % of overboard deaths occur in the first few minutes of being in the water (often due to the temperature or
fractures from the landing), 20% overboard deaths occur during the rescue [6]. The BoatUS Foundation compiled statistics on USA boating fatalities from 2003 through 2007. The Foundation reported that of 3,133 boating fatalities in the five years, 749 were MOB deaths. Also, 24% MOB fatalities were characterized as “falls overboard”, 24% died at night, and 76% died in daytime [7]. Table I shows the relationship between falls overboard and MOB fatalities, according Boating Accident Statistics compiled by USCG1.

### Table I. Recreational Boating Statistics-MOB Fatalities

<table>
<thead>
<tr>
<th>Year</th>
<th>MOB Fatalities</th>
<th>Falls overboard</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>205</td>
<td>359</td>
</tr>
<tr>
<td>2012</td>
<td>197</td>
<td>331</td>
</tr>
<tr>
<td>2013</td>
<td>149</td>
<td>281</td>
</tr>
<tr>
<td>2014</td>
<td>168</td>
<td>311</td>
</tr>
<tr>
<td>2015</td>
<td>155</td>
<td>259</td>
</tr>
</tbody>
</table>

(source: http://marine.the-justgroup.com)

Table II shows statistics of SAR action under the jurisdiction of Republic of Croatia, as well number of action related to the situation man in the sea, and number of missing persons.

### Table II. SAR Action 2013-2017, MRCC Rijeka-Croatia

<table>
<thead>
<tr>
<th>Year</th>
<th>Total SAR actions (MRCC Rijeka-Croatia)</th>
<th>Man in the sea</th>
<th>Missing person</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>283</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>2014</td>
<td>342</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>2015</td>
<td>324</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>2016</td>
<td>447</td>
<td>13</td>
<td>1</td>
</tr>
<tr>
<td>2017</td>
<td>454</td>
<td>17</td>
<td>6</td>
</tr>
</tbody>
</table>

(source: SAR actions-MRCC Rijeka)

To evaluate how difficult it is to find a man in the sea, the best way is to take some examples from practice. Accordingly in the following text are some examples that were happened in the water of Republic of Croatia.

The official ship of Port Authority Dubrovnik "Danče" on Tuesday 25 April 2017 at 21:20 h collided in Koločep Channel, around 1 km from coast, with rubber boat on which they were nine people. Marine accident took place at a time when the official ship of Port Authority Dubrovnik was engaged in action of emergency medical transportation to the island of Mljet. Wind was 20-30 kn, waves 1 - 2.5 m, cloudy with occasional rain. Immediately after the accident, two people with minor injuries were rescued from the sea; one was found dead and the other dead a few hours later. The third body was found the next day, the fourth almost two days after the accident, and the fifth one month later. Two people have not been found [8]. Although in collision participated SAR vessel which did not suffer any damage and although later on in SAR operation were joined other ships, planes, divers, etc., the result was disappointing.

September 12 2014 around 19:00 h near the island of Mali Drvenik, a small fish boat with two fishermen capsized after an unsuccessful attempt to assist sailboats. The distress call was sent at 19:52 h, and the police boat arrived at 21:45 h [9]. At 23:15 h the search was suspended due to night, and continues in the morning next day from 06:00 h. At 11:15 h they were found, but accidentally, far away from area of search. Both survived [10].

On August 18 2018 around 23:45 h from the cruise ship that was underway from Pula to the Venice, the female passenger threw herself into the sea. The SAR operation was launched on Sunday early in the morning at 2:17 h. After extensive search, from the sea and from the air, she was found at 09:40 h, alive [11].

If we compare these accidents, also and other similar, we can conclude that detection of man in the sea is very difficult, especially during the night. Also, people who accidentally fall overboard are usually without life-jacket and other similar appliances. Lifejackets increase the probability of surviving, but

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1 USCG - United States Coast Guard
identification still remains difficult. To increase probability of surviving it is therefore necessary to have system of early detection of fall into the sea, and also use appliances that can remotely determine position regardless of the weather conditions and the time of day or night.

III. LIFEJACKET

Lifejacket is the basic personal life-saving appliance on board, readily accessible to all crew members and passengers. Lifejacket must be provided for every person on board the ship, and some extra [1]. Each life jacket (SOLAS) must meet the prescribed criteria (see LSA Code, Chapter II), and between these criteria the most interesting, concerning topic of this work, are requirements for light and whistle.

Each lifejacket lights shall [2]:

- have a luminous intensity of not less than 0.75 cd in all directions of the upper hemisphere;
- source of energy capable of providing a luminous intensity of a 0.75 cd for a period of at least 8 h;
- be visible over as great segment of the upper hemisphere as is practicable when attached to a lifejacket;
- be of white color;
- if the light is a flashing light, it shall, in addition: be provided with a manually operated switch and flash at a rate not less than 50 flashes and not more than 70 flashes per minute with an effective luminous intensity of at least 0.75 cd.

Each lifejacket shall be fitted with a whistle firmly secured by a lanyard [2]. So, for easier detection of a man in the sea, provided he has a lifejacket on himself, according SOLAS we have only lights and whistles. Taking into consideration the number of MOB accidents and the number of fatalities this is definitely not enough. A common wax candle emits light with a luminous intensity of roughly one candela. Candle flame is the same brightness as a magnitude 0 star at a distance of 392 m. Magnitude 0 stars are 251.2 times brighter than magnitude 6 stars. The faintest stars humans can see by bare eye have a magnitude 6. Accordingly, candle should be visible from distance of 1.39 miles [12]. This is theory; in practice this distance is much smaller. The main reasons are: influence of meteorological elements, visibility, waves and other obstructions due to small height, imperfection of human eye, etc. “Fig. 1” shows how visibility affects the range of light (standard diagram for use in maritime navigation).

![Fig. 1](https://www.iho.int/iho_pubs/standard/S12_ENG.pdf)

“Fig. 2” shows an led lifejacket distress light with an effective luminous intensity over 0.75 cd on the whole of the upper hemisphere. This light has been tested and the results show that it is clearly visible only up to 100 m, in good outdoor conditions.
On “Fig. 3” is lifejacket whistle. A loud of this whistle is around 110-120 dB, sound critical for being heard above the roar of wind and emergency vehicles (“Fig. 4”). The distance from which this whistle can be heard is difficult to determine. It depends on the background noise, wind, meteorological conditions, terrain configuration, etc. Mostly, if the observer is on a large motor ship and on the windward side, the probability to hear sound of whistle that is on sea level is minimal.

IV. ADVANCED MOB APPLIANCES

To maximize the chances of survival of a man falling into the sea, two things are crucial; as soon as possible detect a fall into the sea and determine its exact location in the sea. The systems that enable it today exist, but are not obligatory; accordingly they are used very rarely, especially on merchant ships.

A. Automatic detection of falls into the sea

On the large cruise ships there are systems for automatic detection of MOB incidents. These systems are not only for detection but also to give the best support during all research and rescue phases, minimizing, in this way, the intervention time and maximizing the chances of survival of the shipwrecked victim. They combine Radar and laser systems, IR/TV and ultraviolet electro-optic technologies [14]. The principle of work can be summarized as follows [14]:

- Multiple radars simultaneously monitor ship wall ensuring falling objects are detected and tracked;
- Radar tracks are confirmed by collocated independent radar sensors;
- Behavior of confirmed track is analyzed (based on speed, fall direction, shape, strength);
- MOB radar track is verified with infrared signature (heat, object shape, dimension, range);
- Visual confirmation by crew based on video replay; within seconds crew can confirm MOB alarm.

These systems are very complex and expensive for smaller ships. But there are other solutions, mostly based on the principle that a crew member or a passenger wear a sensor (tag), wirelessly connected to the base station, and when the sensor (crew member) get far away from it, alarms sound on board of vessel (Wireless Man Overboard system). One of them is Raymarine LifeTag Man Overboard System [15]. Raymarine LifeTag is a personal man overboard system that consists of a base station and wireless tags worn by crew members. It can be used as a standalone system or integrated into a network. In the event of an actual man overboard situation, the victim’s LifeTag signal is rapidly degraded by immersion in water, or as the distance between the victim and boat increase, typically 9m.
The LifeTag “Fig. ω” base station responds automatically by sounding an audible alarm onboard to rouse other crew members. Each LifeTag is also fitted with a manual activation button.

Today there is a variety of wireless technologies on the market that could be used, or already in use, for MOB systems. Some of them are follows:

- Bluetooth-useful when transferring information between two or more devices that are near each other when speed is not an issue, 2.4 GHz, range 5-30 m;
- Wi-Fi - better suited for operating full-scale networks, enable faster connection and better range from the base station (up to 95 m), 2.4; 3.6; 5 GHz frequency [16];
- Zigbee is a low-cost, low-power, wireless mesh network standard, bands: 2.4 GHz in most jurisdictions worldwide; though some devices also use 784 MHz in China, 868 MHz in Europe and 915 MHz in the USA and Australia, transmission distances to 10–100 m line of sight [17];
- Sigfox-wireless networks to connect low-power objects such as electricity meters and smartwatches, which need to be continuously on and emitting small amounts of data; it uses 868 MHz in Europe and 902 MHz in the US, also utilizes a wide-reaching signal that passes freely through solid objects, average range of about 30-50 km in rural areas, and in urban areas may be reduced to between 3 and 10 km, limited up to 140 messages per object per day [18], [19];
- LoRa (Long Range) is a digital wireless data communication technology using bands 169 MHz, 433 MHz, 868 MHz (Europe) and 915 MHz (North America). LoRa enables very long range transmissions (more than 10 km in rural areas) with low power consumption. The technology is presented in two parts — LoRa, the physical layer and LoRaWAN (Long Range Wide Area Network), the upper layers [20].

On “Fig. 6” is MOB alert system compatible with smartphones and based on Bluetooth technology, and does not require any installation on the ship. This is simple and cheap solution, ideal for small boats.

When wristband (“Fig. 6”) is turned on, it continuously transmits a signal that one or more Smart phones can monitor using the application. Smartphone signals an alarm if the wristband wearer falls overboard.
When a wristband is immersed, the signal is interrupted and the monitoring phone (or phones) automatically triggers an alarm and records the GPS\(^2\) position at the time of the incident. The Sea-Tags application displays the MOB’s position, the real-time position of the boat, and provides real-time updates of the heading and distance to retrieve the MOB. Battery life, in continuous use, is 600 hours, coverage 100 m in open environment [21].

B. Personal Locators

In the market today there are a whole number of mini personal locators who can, after falls a man into the sea, alert other nearby vessels or directly rescue center. The most interesting ones are that can be attached to life jackets, or other personal life saving devices, with automatic activation, and at an affordable price.

C. AIS, DSC and 121.5 MHz locators

AIS is currently mandated on all commercial vessels over 300 GT, also it can be found on lots of smaller ships. Accordingly, MOB locator based on AIS technology can be very useful. AIS MOB devices, after activation, provide immediate notification to the own or neighbouring vessels relating to a MOB incident and provide a location to determine the position of the man in the sea. AIS locators can be stand alone or can be combining with other principles of operation, most commonly DSC and 121.5 MHz (“Fig. 7”).

![AIS & DSC](source: http://oceansignal.com; https://www.mrtsos.com)

“Fig. 7a)” shows the world smallest personal locating AIS MOB with integrated DSC, compatible with the most compact inflatable life-jackets. It is activated automatically on inflation, sending the first alert within 15 seconds, waterproof up to 10 m, range up to 5 nautical miles, dependent on conditions, 24+hours operational life, compatible with most modern AIS plotters and DSC VHF, may be configured by the user to enter the vessels DSC MMSI number [22].

“Fig. 7b)” shows the Man overboard device incorporating both AIS and 121.5 MHz homing beacon. Upon activation transmit a 121.5 MHz homing signal in addition to the AIS. It is designed for automatic activation in inflatable life jacket, capable for 12 hours transmission, waterproof up to 10 m.

The price of the above devices is between 300 and 500 USD. On the market there are a whole range of similar devices (AIS and/or DSC) from other manufacturers, and the best of them have automatic activation in contact with water and are fully GMDSS compatible [23], [25], [32].

On “Fig. 7c)” is untypical locator basically designed for submarines. On reaching the surface, locator activates, acquires GPS and transmits distress and position data.

\(^2\) GPS – Global Positioning System
Transmits unique device identity and GPS data via AIS, VHF DSC and VHF voice message, and also transmits continuous 121.5 MHz direction finding tone [24].

D. Satellite based locators (PLBs)

The AIS MOB devices provides real time positioning to support localized rescue by using the AIS, however this devices are not part of the COSPAS SARSAT search and rescue network. But there is so called Personal Location Beacon (PLB) who is a personal safety device designed to alert search and rescue services and to allow them to locate distress position. When activated PLB transmits a coded message on the 406 MHz distress frequency which is monitored by the COSPAS-SARSAT satellite system, a relayed to the nearest Rescue Coordination Centre (RCC) (“Fig. 8b”). Also, may combine 121.5 MHz homing signal. The PLB is basically a smaller version of the Position Indicating Radio Beacon (EPIRB). [33]

On “Fig. 8a” is a very small and practicable PLB (Ocean Signal rescueME PLB1). When activated it transmits position and ID to a Rescue Coordination Centre via satellite link. Easily fits in lifejacket, have 24 hour operational life, high brightness strobe light above 1 candela, GPS receiver and operates on the global COSPAS SARSAT rescue system. The accuracy of the COSPAS SARSAT fix is approximately 5 nautical mile radius, but when the GPS has a reliable fix, the accuracy is typically within 100 m. It does not require any fees to use or subscription fees. The price of this and similar PLBs is in the same range of AIS locators described above. There are PLBs built into hand watches, however, they cannot be considered as standard in a technical or cost-effective way [25].

![a) Ocean Signal PLB1][b) PLB-principle of work]

Fig. 8. Satellite based locators (source: https://rescue-me.ch/product/ocean-signal-plb1/)

E. Other locators

The possible way to locate a person in the sea is by using the radar beacons (x band) or the acoustic beacons [26], [27]. These devices are not common, certainly not on the usual ships (merchant marine, passengers, pleasure, etc.). SART is well known search and rescue transponder, used to locate a distressed vessel by creating a series of 12 dots on a rescuing ship’s radar display (9 GHz X-band, 3 cm wavelength). The standard SART is not adapted to MOB situations: its dimensions are too large, requires manual activation, and the range is significantly dependent on the height of the antenna above the sea level (should be at least 1 m). Also, the distress position is visible only on the x band radars. To adopt these devices for personal use in MOB situations, the antenna height requirement is one of the biggest obstacles.

Acoustic beacons are almost ideal for the guiding rescue teams to the distress position, but here is problem that ships who can detect acoustic signal are very rare, as a rule military ships use this technology. Therefore, portable voice communicators, such as VHF. The problem is that such devices require manual activation and user must be conscious. Also, position and homing is not available (if no GPS and continuous signal transmitting).

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3 SART - Search And Rescue Transponder
V. MOB DETECTION SYSTEM ENHANCEMENTS

According to available options, the question remains how to improve the existing system of personal life saving appliances under the SOLAS Convention. Equipping all lifejackets on all ships with the appropriate locators is difficult to justify, financially but also in terms of efficiency. But, the partial fitting of these devices could be considered acceptable, depending about the type of vessel, the number of passengers and the area of sailing.

On large passenger ships the early detection of MOB can be achieved by installing an automatic fall detection system, while on smaller passenger ships the network of Wi-Fi/Bluetooth sensors could be quite enough. Also, some number of the lifejackets, especially inflatable ones, for potentially dangerous works on deck, it could be equipped with AIS or DSC or similar locators.

On large merchant ships the number of crews is not large; accordingly, it is easy to justify fitting up personal locators on the lifejacket. But on these ships MOB fatalities are mainly happened due to accidental fall in to the sea, when nobody sees it. Accordingly, use of inflatable lifejackets with MOB locators (AIS/DSC) with automatic activation, also and Wi-Fi locators for everyday work on deck, can be recommended. Some number of standard lifejackets may be equipped with PLB-s.

On small boats that are in coastal waters, like fishing ones, at least one locator (AIS/DSC) should exist. In the area without significant traffic and outside VTS coverage, the PLB-s are better choice. On yachts and boats capable to sail on open sea, PLB on lifejackets is also a reasonable choice.

For all passengers and skippers, especially on fast boats, water scooters, pleasure craft, working boats, etc, recommendation is to wear the lifejackets all the time, and each should be equipped with appropriate emergency locator, at least AIS.

VI. CONCLUSION

People falls into the sea from the ship since ages, and they will falls as long as the crew it will be on board. MOB is a very dangerous situation, especially on an open sea and during the night. According to the statistics, MOB fatalities have very high percentage of all overboard incident. To prevent fatalities in MOB situations two main problems need to be solved; the first is how to enable the early detection of fall, the second is how to improve the way of positioning of man in the sea. Solutions exist, and both problems can be solved with personal locators, already available on the market, like AIS, DSC and PLBs (satellite) locators, also their price is affordable. There are also 121.5 MHz homing devices, but they are most useful when are combine together with before mentioned. In addition, for instant detection of MOB situation there are solutions like WIFI/Bluetooth network, as well as automatic MOB detection systems. It is hard to believe that formal legislation still does not require use of these appliances and systems, especially if we know that investment of few hundred USD per person can significantly increase the probability of surviving.

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New Risks in Cruise Industry with Impact on Safety of Navigation

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**ABSTRACT**

The cruise industry is the fastest-growing category in the leisure travel market. Transport is the cause and the effect of the growth of tourism. In order to access sought-after destinations, tourists have a range of transportation modes that are often used in a sequence. Sea transport is the main mode for international tourism, which normally entails travel over tourist destination. Their confidence in the structural and management systems associated with safety and security must be such that it does not prejudice their enjoyment of the cruise experience. Crews on passenger ships are faced with a new safety risks that can increase significant impact on safety of navigation, the occurrence of continuous stress in the crew and ultimately the overall reputation of the company. The aim of the paper is to point out the importance of a serious approach to the safety risks at cruiser as a tourist destination.

**KEYWORDS:** cruise industry, safety risks, safety of navigation & stress

**I. INTRODUCTION**

Each year millions of people vacation aboard cruise ships, some carrying thousands of passengers and crew members. These ships are small, floating cities that offer many options for food and entertainment and calling at various ports wide world. While the development of the cruise business signify an extremely successful business model, the cruise sector also faces several significant challenges, such as an exceptionally competitive commercial environment, concerns about over-capacity, concerns about the marine environments, and the destinations ability to cater for new larger ships. Similarly, while destinations seek to embrace the industry’s expansion, they also have to manage the often diverse needs of communities at the same time as protecting the local environment and minimizing any costs associated with being a sustainable cruise destination [υ]. Mobility is one of the most fundamental and important characteristics of economic or social activities as it satisfies the basic need of going from one location to the other, a need shared by passengers, freight and information. Irrespective of its aim, mobility enables the diffusion of highways and the automobile had profound impacts in contemporary societies and continue to do so [φ]. Demand and supply are still relatively concentrated in North America, with the Caribbean as the most important destination. In recent years, however, Europe, and to a lesser extent the Asia and the Pacific, have been rapidly gaining in importance [χ]. For instance, the Department of Tourism and Commerce, Government of Dubai, estimated the cruise tourist arrivals in Dubai for φττό till now to be increased compare to the previous year [ψ].

**II. RISKS IN CRUISE INDUSTRY**

To prevent unwanted events on board ships, it is important to assess situations which may cause accidents or damage to health, properties or sea environment. By systematically mapping different work operations, effective measures may be implemented and serious con-sequences may be avoided [ω]. Fig. υ. illustrates that are large modern cruise ships are a potential target for terrorists when anchored off-shore or when passengers are embarking/departing alongside the publicly available itineraries which document their route [ο].

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Scenario-planning research has identified the previous extent of suicide bombings and terrorist attacks in an effort to identify the probability of specific risks from terrorism [6]. Their study was based on a combination of historical data regarding previous attacks, and on a series of interviews with counterterrorism experts. Information on threat and vulnerability were used to estimate relative risk in connection with various attack scenarios. Qualitative methods for generating risk estimates involved the use of defined ordinal scales to assess terrorists' intents and capabilities, target vulnerabilities and attack consequences. Greenberg’s principal findings were that the highest risk threats passengers were likely to encounter emanate from an on-board bomb, attack or food/water contamination. Piracy and the risk of hijack were considered a much lower risk. Their study concludes that many perceptions of maritime terrorism risks do not necessarily align with the reality of threats and vulnerabilities.

First, there is little evidence that terrorists and piracy syndicates are collaborating. The economic motivations for piracy (which depend for fulfilment on the stability of maritime trade) may be in direct conflict with the motivations of terrorists (i.e. in achieving maximum disruptive effects in connection with attacks).

Second, some plausible forms of maritime terrorism (e.g. the sinking of a cargo ship in order to block a strategic lane of commerce) actually present a relatively low risk, in large part because the targeting of such attacks is inconsistent with the primary motivation for most terrorist groups (i.e. achieving maximum public attention through inflicted loss of life).

Third, any effort to sink a cruise ship would need to overcome engineering designs intended to prevent catastrophic failure of a ship’s hull. Experts believe that improvised explosive devices would have limited capability to cause such failure [6].

These technical and theoretical assumptions remain largely irrelevant to the customer who perceives there simply to be a risk. Greenberg's study also considers the concept of civil liability and how this creates the prospect that independent commercial defendants (i.e. cruise shipping companies) will be held responsible for any damages caused by terrorist attacks. This gives a strong incentive for the private-sector prevention and mitigation efforts discussed in subsequent paragraphs. Yet a further recent development in the cruise market, most notably with cruise lines as venues for meetings and conferences. It is clear that the perception of potential conference organisers and cruise passengers is increasingly important as a work stream running alongside scenario planning research to assess the potential effects of terrorism on cruising. Yet the relationship between terrorism and tourist travel raises many conceptual issues to which attention now turns [7].
### III. Impact on Safety of Navigation Due to Risk

The origins of cruise safety regulations were precipitated by the Titanic disaster in 1912. The SOLAS Convention or the International Convention for the Safety of Life was first adopted in 1914. This convention and all its successive forms are regarded as the most important of all international treaties concerning the safety of merchant ships (IMO, 2014). Cruise ships are “like cargo vessels” for the purpose of this Convention [8]. In order to strengthen maritime security the International Maritime Organisation reviewed its International Convention of Safety of Life at Sea (1974, 1988) replacing it with a new International Ship and Port Security (ISPS) code (2004). It has since been adopted by 108 countries and has helped to introduce uniform safety and security standards across the maritime industry.

All ships and ports are expected to provide:
- Company/port security officers responsible for assessing the vulnerability and threat to ships and ports.
- Company/port security plans.
- Annual audits of ship and port security measures.
- Staff training together with ship/port drills and exercises to be undertaken every 3 months.
- A continuous synopsis record including a permanent record of the ships operations movements and ownership.
- Ship security alert systems directed at informing land-based authorities of any potential terrorist attacks, hijackings or acts of piracy.

Given the increasing level of concern about terrorist attacks in tourism, it is also pertinent to consider the wider literature on risk perception as the principal area in which this research is located because the risk perception is what influences consumer behaviour and shapes the decision to book and take a cruise. How tourists perceive risk is an important determinant of how terrorism impacts upon international travel [9]. This makes tourism extremely sensitive to perceived changes in risk and operating conditions [10]. Terrorism is one of the major risk factors that can affect the tourism industry alongside wars and political instability, health concerns, natural disasters and crime. Crime, tourism and trust in a developing country [7]. From Fig. 2. it is visible that the cruise shipping industry is vulnerable to many external threats, all of which can affect its operational efficiency. Foremost amongst these threats are political instability at port destinations, natural disasters and adverse weather conditions. However, visitors to CRUISE saw a potential terrorist attack as the major threat to cruise shipping companies.

![Fig. 2. Customer perceptions of threats to the cruise shipping industry](image)

In highlighting such a response, respondents identified with the work of who concluded that today one of the greatest threat to passengers and ships comes from terrorism [11]. Fig. 3. illustrates a number of these responses allowing for a free flow of comments [12]. Respondent views were varied, but reflected perspectives outlined in the existing literature.
IV. PREPARATION OF A RISK CONTROL PLAN

For implementation of improvement measures here are some guidelines:

- How is ship security handled?
- When and where does the exercise take place?
- Are there any ship plans or other instructions?
- What other improvements have the company taken to ensure safety, a ship plan showing the routes to the nearest rescue boats, etc.?
- How do the crew of a ship be trained to manage lifeboats?
- How often is the rescue boat testing conducted?
- Are there provisions for fire protection on ships?
- What measures are being taken to prevent fires on MSC Cruises?
- Which fire control system is in place if a fire breaks out?
- Is the crew trained in fire protection? [13]

As the crew is more ready and as the drills are carried out at regular basis as per drill matrix leading to improvement knowledge and based on this is increased safety and the stress is parallel reduced. According to this reaction in crisis situation are more accurate and more strengthen and with this risk is reduced. After determining the level of risk, it should be decided what actions will be taken to improve the safety of work practices or operational procedures [13], taking into account the precautionary measures and controls that are already active. When selecting risk control measures, the following must be taken into account:

- possible losses,
- replace with something less dangerous or less risky,
- isolation / protection of people,
- safe working conditions and reduction of the level of risk to an acceptable level,
- written procedures that are well-known and understood,
- adequate supervision,
- establishing the necessary training,
- reporting, informing and teaching and
- Personal protective equipment.

For example, in addition to the emergency and evacuation plan, it is necessary to ensure all the proper safety equipment designed for specific hazards. Always at a conscious level, it should be borne in mind...
that repetitive training, whether verbal or physical, should never be missed, no matter how boring, adopted and unnecessary.

V. CONCLUSION
This study has shown that marine terrorism is a largely neglected theme in tourism research despite the growing significance of the global cruise shipping industry. While several potential types of risk can be identified, the greatest risk was thought to come from a terrorist attack on a ship or a port by an extremist group. The level of risk was thought to be low. This was because passengers had confidence in the security measures adopted by the cruise ship companies. In fact, safety and security was seen as the ‘hallmark’ of cruising, an attitude expressed most frequently by experienced cruise ship passengers. While passengers appeared generally resigned to the fact that risk is associated with travel in the twenty-first century, this did not necessarily mean that cruise shipping companies should ignore risk or play down the likelihood of an attack on one of their vessels. The survey indicated that passengers considered risk to be a serious issue to the point that they believed safety and security measures both aboard ships and in ports could and should be improved. The cruise shipping industry recognises that any attack on a vessel would have devastating consequences for their business. It would result in a reduction in passenger confidence culminating in a drop in bookings. The severity of such an impact would, in all probability, reflect the nature and scale of such an attack. Simultaneous attacks on several vessels would intensify concern and could cause passengers to cancel trips or delay the booking of a cruise holiday. Further, knowing the factors that contribute to cruise ship mishaps and failures can provide a foundation of preparedness that may prevent future disasters in the cruise industry.

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ABSTRACT
Transport of large amounts of cargo is characterized by high risk, even if the latest technologies are employed.
Thousands of people lost their lives in catastrophes of ships, off-shore oil rigs and other marine objects. It is estimated that around 80% of accidents at sea are caused by making wrong decisions by persons keeping watch on the bridge, especially during difficult navigational and weather conditions. Accidents can also be caused by lack of skills necessary for crews or absence of appropriate tools of training centers. Therefore, it is important that seafarers should be trained in accordance with the highest standards. The scope of crew research and training may include both static, dynamic and damage stability. This stand bad also enables the analysis of the influence of the free surface effect of the liquid occurring in the compartments or tanks after damage to the ship's hull and the analysis of the impact of cargo operation on the ship's initial stability. Experiences gained on the research stand lead to a better understanding of the phenomena occurring in the current operation of the ship and to improve the safety of swimming. The aim of this article is presentation selected scenarios for the model tests of vessels and to familiarize with the construction of selected types of ship models and the capabilities of stability test stands in the aspect of improving the safety at sea.

KEYWORDS: model test, ship's stability & buoyancy

I. INTRODUCTION
In order to learn about the phenomena occurring during the operation of the ship, such as: failures, damage to the hull, weather conditions, it was designed and built stand beds enabling model tests of ships in situations of threat to the buoyancy safety. The article presents description of stand bed construction for stability and vitality tests of the training ship model, for vitality of the missile ship model, submarine model and their research capabilities in the aspect of maritime traffic safety of vessels. Thanks to the appropriate construction and innovative solutions of stands, it is possible to conduct the study of the position of undamaged naval models, but also in selected emergency states. Model research creates a much larger spectrum of issues compared to real units due to the ability to carry out them in all conditions, even leading to the model tipping over [3]. The purpose of the marine properties research is to create technically useful calculation methods for forecasting the position of the vessel at sea. The main role played by model tests and measurements on real objects is the verification of these methods. Both types of experiments are also a source of inspiration for creating new modified mathematical models and accounting methods based on them [4,5]. These tests can contribute to the improvement of the safety of vessels at sea.

Model tests of the naval properties of the ship and their results must be conducted and interpreted in accordance with the requirements of similarity laws. Geometric similarity includes the underwater part of the ship, its watery part of the hull to the upper deck. If phenomena related to the impact of water on the deck and elements on board are investigated, it also will be required additional geometric similarity with respect to the deck, bulwark, lower parts of superstructures, etc. In the model studies of the marine properties of the ship, because of the rolling of the ship, main forces that determine the course of phenomena are mass forces like gravitational and inertia (caused by the unidentified movement of the sip) the same numbers of Strouchala and Froude are observed [2,3]. Assuming that the ship and model are floating in water of the same density, there are dependencies of the scale of times, speed and forces on the geometric scale:
II. DESCRIPTION OF STAND BEDS RESEARCH

At the Polish Naval Academy in Gdynia, a stand for modeling research the stability and unsinkability of warships with the mission to improve the safety of their operation at sea was designed and built. The elements of the stand are models of naval vessels of the Polish Navy. Currently, advanced work on models of cargo ship is also under way. The description of the stand bed for testing model warships is presented in the following chapters.

A. Main stand bed for stability research

The model of the type όόό training ship was made for tests related to the stability of the ship. The basic technical data of the model are as follows [ι,ϋ]:

- length of the model                     \( L_{cm} = \upsilon,\phi\psi\psi\psi \) m,
- length between perpendiculars   \( L_{ppm} = \upsilon,\phi\phi\phi\psi \) m,
- breadth                                    \( B_{m} = \tau,\phi\chi\chi\phi \) m,
- displacement                                    \( D_{m} = \upsilon\chi,\upsilon\omega \) kg.

In order to maintain geometric similarity of the model, having an effect on the quality of investigations, the hull construction was based on body lines in scale, whereas elements of the superstructures and deck equipment were appropriately simplified. All elements, whose size have an effect on the lateral area used in stability calculations, were placed aboard the models.

The ship model όόό used as the main investigation object was equipped with specialized instrumentation for simulating hull damage, fixing position and analyzing model’s performance in various operation conditions hazardous to ship safety. The array of the main elements of the model measuring system is presented in fig. υ[ϋ,ό]. Single compartments PIII, PV, PVII, which have the largest volume and whose flooding has significant effect on stability and water-tightness, were selected for the investigations. The process of flooding the compartments to the level of the overboard water is realized after remotely controlled bottom valves marked with numbers υ,φ,χ are opened. The other group of valves is designed to flood the compartments used in a refloating process or righting a ship in cases of asymmetric damage. The ship model is also equipped with a water installation and sensors used e.g. for measuring the water level in compartments. These valves, fitted in compartments PIII, PV, PVII, measure the water level using hydrostatic pressure measurements. A healing indicator, fitted in the fore of the model, was used in order to measure the healing and trim of the model. Signals received from the sensors, are transmitted, in the wireless manner, to a computer fitted with two analogue-digital cards, and then are read from a display in the form of ready-made results.

The measuring instruments and execution elements fitted in the model are connected to the computer by means of cables having low unitary mass. The computer is used for reading measurement data shown on the display. Using the computer software it is possible to flood selected compartments in the model and to drain them. To carry out these operations a software package was developed in the Delphi environment. The image on the display is presented in Figure. φ. [υ,ό].
The amount of water in the compartment seen in the upper part of the window on the display of the computer software is given in per cent. The data relating to the model’s position such as heel angle, trim angle, forward draught in the perpendicular, after draught in the perpendicular are displayed in real time [8].

A strong wind and wave pose a large hazard to maritime transport safety in everyday operation of floating vessels and a frequent cause of accidents at sea. In order to take into account the effect of the natural environment on safety of floating vessels in the investigations it was necessary to add a set of ventilators simulating air movement to the described test site. Two type of ventilators with variable adjustment were fitted. They worked in the range from 0 to 2775 rpm – ventilators type HRB/2-250-AN and from 0 to 2685 rpm – ventilators type HRB/2-200BN. The ventilators generating air movement can be started in three configurations:

- low power generators,
- high power generators,
- combined work of high power and low power generators.

The maximum air velocity recorded during the work of all the ventilators was 9 m/s. Due to safety reasons the ventilators were placed in a casing protected with a net. Such a solution makes it impossible for any objects to access the area of rotating ventilator blades. A general view of the set of ventilators is presented in Figure 3 [6,7].
Another investigation problem was to determine the axis of model rotation during wind action. The position of the axis of model rotation is important to calculate the heel moment caused by wind action. In these investigations, the height of the center of the lateral area measurement in relation to the floating water plane was assumed in accordance with the regulations of the Polish Registration of Ships. The draft corresponding to this water plane was marked with a white line. At this height seats were installed on the ship hull. Rods which make it possible to rotate the hull are placed in the seats. The way the model is fitted in the rods is shown in Figure 4 [8]. The solution presented in Figure 4 also allows for free vertical movement of the model owing to the rod ways in which the rods move. In order to obtain the appropriate velocity of air flow the structure of the ventilator casing was reduced to an aerodynamic tunnel.

![Image 1](image1.png)

Fig. 3. The view of the set of ventilators fitted in the laboratory site

![Image 2](image2.png)

Fig. 4. The design of the rotation axis of the ship model
1 – road seat; 2 – ship model; 3 – rotary rod; 4 – rod way; 5 – mount

Air velocity measurements were made using a portable measuring device type CTV 100, in which magnitudes are measured in the range from 0 to 30 m/s. In order to make air velocity measurements at different points of the cross-section of the control aerodynamic tunnel a holder was designed and built for fitting the measuring device in the air flow velocity sensor. It is presented in Figure 5. Owing to this structure it is possible to measure air velocity at various ranges from the aerodynamic tunnel and any height above water surface. This fitting method and the way of changing the position of the air flow sensor are presented in Figure 5 and 6.

![Image 3](image3.png)

Fig. 5. The view of the model basin with the fitted holder
The preliminary investigations on the air velocity showed that a position of the wind velocity measuring device in relation to the direction of air flow has substantial effect on the measurement accuracy. In order to avoid measurement errors the device had to be fitted at the right angle to the direction of air flow so that it could not rotate during measurements.

![Diagram of holder for mounting the measuring sensor]

The initial tilting tests of the model were made on such an equipped and prepared station. It required heeling the model to windward side reaching the heel angle magnitudes 5°. The angle magnitudes are derived from the weather criterion calculations made for the model following IMO regulations.

While recording the heel angle the ventilators were working with constant rotary velocity, which corresponded to the constant characteristic of the heel moment. Examples of the measurement results of the heel moment of the model ship are presented in the graphic form in Figure 7.

![Graphs of measurement results]

Employing the developed investigation methodology it is possible to carry out experiments aimed at determining heeling moments which pose hazard to navigation safety in various stages of ship operation.
B. Stand for testing the unsinkability of the ship model type 660

The research on stability and unsinkability includes numerous issues whose presentation on one model only is impossible. Therefore, the station was provided with a second model of the ship type 660 which is designed to conduct the research, especially from unsinkability domain. The model of this ship is shown in Figure 8 [6,7].

The model is adapted to flooding the compartments in any way and to any level. On the hull of the model the draught line and draught signs are plotted. Moreover, the position of bulkheads is marked, which helps the user to locate a damaged place.

The model of ship type 660 was adapted to the presentation of the problem of influence a free surface effect of the liquid on the stability. In this connection a special superstructure was designed. In its higher part there is a hole used for providing water inside. The water from the high placed compartment can be moved out or moved to the lower watertight compartment. Such operations are carried out while restoring or correcting the stability. In this way it is possible to demonstrate a change of stability after changing the position of the gravity center and to conduct research on flooding time either of damaged compartments or of the whole model.

C. Stand for testing the stability and unsinkability of the submarine model

Research on stability and unsinkability of submarines make a source of knowledge about the watercraft’s performance after her compartments have been flooded [1]. Possibility to simulate punctures of hulls on models of real objects adopted for this reason is an advantage of that research executed in the laboratory station. A simplified scheme of the stand for tests on the submarines’ stability and unsinkability is given in Figure 9 [6,7].

![Fig. 8. Model of the ship type 660](image)

Fig. 8. Model of the ship type 660

![Fig. 9. Scheme of stand for tests on stability of submarine’s model](image)

1- operator’s stand, with computer controlling and registering parameters of model’s position, 2 – basin of submarine’s model, 3 – submarine’s model, 4 – feeding cables, 5 – grip of feeding cables.
The main components of the test site are: a submarine’s model, a computer used to control processes of submerging and surfacing and record basic data relating location of the model, and a basin. In the site presented operations of diving and surfacing of a submarine are carried out like in a real object. The device controlling the submersion and ascent of the model is a PC.

Her hull was made using body lines in an appropriate scale. The model is equipped with specialized instrumentation for measuring location in different operating conditions. His form is shown in Figure 9. The inside of the hull was divided into five watertight compartments.

Total volume of all the model’s compartments is $\omega \omega \omega \chi$ dcm. It is equipped with - located in bow and stern compartments - ballast tanks enabling diving and emerging of the watercraft and with a ballast system for piping water in and from the tanks.

Correction of trim and the model’s position at assigned depth are shall be executed by means of two regulation tanks and the ballast system. The ballast system is functionally connected with a system of compressed air. Filling and expelling water from the tanks shall be executed with an appropriate sequence of opening and closing BURKERET type electromagnetic valves installed on the submarine’s model. The system of filling and expelling water from the model’s tanks designed in such a way has allowed minimization of a number of applied operating elements. Hence, it has decreased degree of complication of electrical and pneumatic systems and resulted in reduction of the model’s weight. View of the submarine model’s is given in Figure 10.

In order to measure a heel and trim angles a clinometers type ISA P$v$ working having the range $\pm 600$ was used. The measuring devices and actuators mounted on the model are connected to the computer by wires of low unit weight. The computer performs operations of embedding selected model ranges and drying them. Signals from sensors, transmitted by wire to a computer, are read on the monitor in the form of ready parameters of the position of the ship.

III. SUMMARY

The experience gained on the research stand leads to a better understanding of the phenomena occurring in the current operation of the ship and to improve the safety at sea. A modern method of testing the stability and unsinkability of vessels with the use of physical models of real objects made on an appropriate scale has been presented. The tests carried out on the described research stations allow the measurement of heel angles depending on the wind speed, load shift, time of flooding of ship compartments after their damage affecting the buoyancy safety of vessels. Conducting research and laboratory exercises in such a prepared position will enable continuous improvement of qualifications and level of training of persons responsible for reliability and safety of ship operation.
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A Comparison of Port Governance Models Across EU Countries and Albania

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ABSTRACT
At the beginning of the 90’s Albania started a process of transition from a centralized economy to an open market economy. As strategic resources, Albania ports were subject of substantial reform, shifting from the service port governance model to government-owned commercial entities with the aim to overcome identified deficiencies of the national port system. Responsibility of port governance was transferred to commercially driven port authorities. Although, the reform has surely had positive impact and increasing the overall financial performance of Albanian ports some rigidities are still present and further steps of modernization and restructuring of Port Authorities are essential. Little or absent involvement of the private sector in ports is evident, leaving the burden of investments on the public sector. On the other hand, examples of good port governance can be found across EU countries. The aim of this paper is to present a comparison of port governance models across EU countries and Albania, and to identify components that can improve Port Authorities performance and port competitiveness. It is important to understand that Governance models are just a tool to achieve good governance, not a goal as such. Good governance is about both achieving desired results and achieving them in the right way.

KEYWORDS: port, governance, reform & authority

I. INTRODUCTION
The dynamic environment where the shipping and port industry operates had changed dramatically in the last decades. Globalizations, changing trade patterns, technological development, environmental legislation, raising share of containerized cargo and the advent of mega container ships, have put strong pressure on the traditional role of port authorities. Port authorities must govern ports as market orientated enterprises, therefore increasing the substantial prerequisite for the devolution of responsibility for port management from governments to port authorities. The European Sea Ports Organisation, [1] notes different changing attitudes in ports policy by the Commission of the European Communities. Whereas initiatives such as the original 2001 proposal of the port services’ Directive, advocated a rather strict landlord role, the Commission’s 2007 ports policy communication explicitly supports financially autonomous port authorities which take responsibility for the strategic development of their ports, stimulate dialogue between all possible stakeholders and pro-actively intervene in market processes to safeguard the general interest of the port (Commission of the European Communities, 2007, as cited in [1]). It is a clear statement of the evolution of EU perception for the role of port authorities. Nevertheless, we must consider that EU cannot formally impose a common management model. However, EU law and policy have (in)direct influence towards the evolution of a common philosophy of port management [2].

II. PORT GOVERNANCE ACROSS EU
Nowadays, most port authorities in EU remain under public ownership. Full ownership by the state or by the municipality remains predominant. Only very few port authorities combine ownership of different government levels, such as State-municipality or province-municipality. Alternatively, mixed public-private ownership is still very rare, existing only in a few countries. However, even in this case, the public sector dominates owning the majority of shares, while private shareholders’ participation is limited. Full private ownership remains an exception, characteristic of ports in the UK, where the port authority is fully owned by one or more private parties [3]. Historically, European ports developed in their own diverse ways, even when located in the same country [4]. Regional traditions still explain considerable part of this diversity of European PA-s. The geographical governance typology or traditions, identified by [5] still persists in Europe. [5] distinguishes
between three major port governance traditions, respectively: The Hanseatic, Latin and Anglo-Saxon tradition.

The Hanseatic tradition of landlord PA-s is dominant in The Baltic and North Sea regions, prevails in Germany, the Netherlands and Belgium. The ownership pattern consists of strong local, mostly municipal governance. Hanseatic port authorities have the most autonomy in setting the rules and regulations on land ownership and the contracting out of port’s land [6]. However, [7] argues that even in this local, municipal port governance model the government still plays a crucial role in financing significant parts of new port infrastructure projects, besides drafting and enforcing environmental, traffic and building regulation. Example, the financing of the Rotterdam Port Authority for the new Maasvlakte expansion by the Dutch government. Hanseatic port authorities main task consist of managing port areas and granting concessions to companies, while decisions on major investments and subsidies for new infrastructures and maintenance works are competences at the regional/national level.

The Latin tradition of central governance, reigns in France and countries around the Mediterranean. Latin tradition consists of ownership and intervention by the national government, via a governmental managerial body. The central government plays a prominent role in safeguarding the concept of public welfare services and national authorities act as both regulators and service providers, through a state appointed and controlled, public PA. In the 90’s, Italy, Spain and Greece started a process of devolution and delegated power to autonomous public entities [8]. However, an umbrella organization was created, acting as an executor of port policy of the Government, coordinator and controller for port authorities. In Spain, Puertos del Estado act as the umbrella organization for the 28 Spanish Port Authorities.

The Anglo-Saxon tradition of independent governance is characteristic of ports in the United Kingdom and Ireland. The purpose of port privatization in UK was to improve the financial and economic performance of the ports by introducing private capital, thus reducing the financial burden of the public sector. Through private management and ownership, ports are expected to maximize profit, the main economic objective, and encourage employee share ownership [9]. Furthermore, Anglo-Saxon port authorities have highest autonomy in port charges compared to the Hanseatic and Latin PA-s [1].

III. TRENDS IN PORT GOVERNANCE IN EU

Since 1990, major changes happened in port governance in Europe. Countries in Southern Europe of Latin tradition port governance, such as Spain (1992), Italy (1994) and Greece (1999) devolved power to newly established, autonomous public entities. In addition, in 2008 France transferred the operation of terminals from the public to private sector, with the largest ports shifting to the landlord port governance model [8]. Similar examples can be also found in Northern Europe, where the Hanseatic or Landlord port governance model reigns. In January 2004, the Rotterdam Port Authority separated from Rotterdam Municipal Port Management and became a public limited liability company, with the aim to improve commercial and financial objectives [10]. However, the founded company remains totally in public ownership. The Rotterdam Municipality is the main shareholder of the company and retains port’s land ownership. The fore mention case and [1] confirm and emphasizes that port’s land ownership in Europe is still predominantly in public ownership.

On the other hand, when looking at the port authority ownership - ownership of the port authority is not necessarily the same as ownership of the port land - most ports in Europe are publicly owned [1]. The two most important categories of owners are State governments and municipalities, fig. 1. Even though a port authority is not a port asset in itself, the ownership of the port authority is an indicator of the degree of private sector precipitation in a port [9].
ESPO [3] notes that in the last decade, compared to 2010, more port authorities are structured as independent commercial entities, operating in a commercially-oriented manner. In a ESPO survey, conducted in 2016 with 86 port authorities from 19 EU Member States, representing more than 200 ports, the results revealed that 51% of the respondents were PA-s structured as independent commercial entities, whereas 44% of PA-s were still independent public bodies with their own legal personality and different degrees of functional and financial dependency from the public administration [3]. Market developments, carriers and logistics service providers organized on global scale have put strong pressure on the traditional role of public port authorities. Therefore, creating the requisite for port authorities to be proactive in these contemporary market-driven processes, by offering efficiently supplied complementary, user-driven, value-added, port-related services [4]. The single corporate hierarchies and monopolistic market structures of port services provision are changing to market based networks of organizations and interpersonal relations between providers and users [4].

IV. PORT GOVERNANCE IN ALBANIA

Noteworthy, until 1992 the main ports in Albania - port of Durres, Vlore, Saranda and Shengjin - were socialist enterprises managed by the state. At this time, Albanian ports were characterized by antiquated work practices and processes, stifling and burdensome central government control, therefore lacking innovation, flexibility and competitiveness. Furthermore, the central planning strategies of port development were far too rigid and highly hierarchical. The port sector - like all the others strategic sectors at that time in Albania - was reaching a point of inefficiency, and management changes were necessary.

In the beginning of the 90-s, Albania following political and social changes all over East Europe, started a process of transition from e centralized economy to an open market economy. As strategic resources, Albania ports were subject of substantial reform, starting a process of corporatization, Law 7638/1992 “On commercial societes” [11], with the aim to modernize port services and infrastructure, according to international standards and market needs. The port reform was finalized on 2003, with the final arrangement of Port Authorities, by the Law 9130/2003 "On the Port Authority" [12]. The Law targeted the reorganization of the Albanian ports from the Service port governance model to the Landlord port governance model and aims to implement a development strategy in infrastructure, superstructure, equipment, resources financial and human rights of the commercial ports for achieving social and economic objectives at the local and regional level. In addition, Law 9130/2003 emphasizes the need of economic development through direct investments from the private sector, to reduce public spending and to modernize ports. Through the decree no. 596, of 2004 [13], the government decided to give the Port Authority status for the port of Durres, as the main and most important Albanian port.
The PA has the right of administration of state property and any rights associated with it, whereas the state retains ownership of the land. Furthermore, the port authorities operate as commercial societies and the Law 9130/2003 [12] provides a high degree of independence for port management as well as for different operators, performing services at the port. Corresponding with trends in other parts of Europe, the Albanian government aspired to achieve the managerial efficiencies that distinguish private sector companies, while maintaining ownership of the port authorities and ports land in state hands.

Certainly, ensuring professional managerial staff and a well-organized hierarchy, defines the managerial efficiencies of private sector companies and enterprises. Nowadays, as a commercial society a PA in Albania is composed of the Board of Directors and the Executive Directorate, which are assisted and advised by the Port Consultative Council. Fig. 2 (below) shows the composition of the Board of Directors. The members of the port authority Board of Directors - 7 members in total - are appointed by the responsible minister for Albanian ports, with the proposal of the respective institutions [12].

Consecutively, the BD appoints the executive director - the executive director is not a member of BD - and his deputies on the basis of Minister’s proposal.

![Board of Directors Composition Diagram](image)

**Fig. 2. Port Authority Board of Directors [12]**

The port’s Board of Directors is the only body responsible for running the PA’s activity and exercising property rights as a port property manager. The PA operates as a self-financing commercial society owned by the state, with (partly) privatized port functions/services. Like many other countries in Europe, even in Albania the port authority and port’s land is owned by the government/state. The government owns 100% of the shares of the commercial society, being the only exclusive owner. The PA has the authority for providing the leasing, concessions and licensing of some port facilities designated for operations through service contracts or granting concessions. However, each concession case is made in compliance with the existing legislation on concessions, article 31 of Law 9130/2003 [12]. In the case of the port authority of Durres each concession is approved by the Council of Ministers, article 9 of decree no. 596, of 2004 [13]. Later decrees of the Council of Ministers define the Ministry of Public Works and Transport as the contracting authority for the concession contracts at the port of Durres, example CM’s decree no. 493, of 2012 [14]. Furthermore, the PA exercises control to guarantee performance and implementation of contracts.
V. CONCLUSIONS

It is appropriate to highlight that in the last decades the port reform in EU has a common direction in further reforming port management in Europe. The common direction consists in making port management independent through corporatization or privatization. The management of ports and the respective responsibilities were transferred from the governments, regions or municipalities to public owned port authorities or fully private operators. Several survey conducted by ESPO confirmed that both port authority ownership and port land ownership remains predominantly in public hands. The private sector is mostly active in port operations and superstructure investments.

Albania port reform has gone in the common direction with other EU members. It has undergone a process of devolution by corporatization of PA - corporatization serving as the basis for commercialization - and adopting the landlord concept. However, the significant difference between being a corporate (in form) and following the principles of good corporate governance resides in what objectives - economic and non-economic - port authorities have, appointment of executives and professionals, public transparency in procedures of concessions and service contracts to private operators. In Albania, the members of the PA Board of Directors are appointed by the responsible minister for Albanian ports, which also proposes the PA executive director and his deputies. Altogether, this dominion of the political authority does not guarantee independence from political considerations. In other words, political considerations means supporting of favoured groups who vote or provide campaign funds for political parties and their candidates. These political considerations can undermine the principles of good corporate governance. A solution could be the involvement of the private sector in PA ownership. Considering the circumstances - private ownership of PA-s being an exception of UK and Ireland in Europe - not a fully privatization of the PA, but a partial privatization, where the state remains the majority shareholder in order to safeguard the public interest.

Although, is noted the presence of local and regional representatives, however the PA’s Board of Directors is dominated by the central government representatives. One of the aims of the Law 9130/2003 “On the Port Authority” is that through the development of commercial ports to achieve social and economic objectives at the local and regional level. It would be appropriate more involvement of representatives from local and regional level in order to achieve these targets. A decentralization process may be considered, with some of the decision making and planning handed from the central level to local and regional level.

Despite the fact that the Law gives the PA the landlord rights, the PA does not act as landlord, not having full rights on concessions and land use. Certainly, this limits the functions of the PA, therefore undermining the achievement of objectives, such as, full privatization of commercial activities in port. This in turn affects port productivity, by limiting the wide participation of the private sector in new investments in port infrastructure and superstructure. Therefore, it is of paramount importance, to give the PA all the necessary power, including full rights on granting concessions and land use, to act as a Landlord.

REFERENCES


Analysis of Passenger Terminal Infrastructure as An Important Factor Affecting on Choice of Destination for Cruise Ships

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ABSTRACT
Cruise traffic is in last decades becoming an increasingly popular way of travel, this is leading to a constantly increasing demand of passengers. Cruising is also a good economic income mostly for already attractive big cruise ports, but also for small ports. This is the reason why more and more small ports are trying to get involved in cruise business and at the same time existing ports are striving to gain more passengers. This is consequently leading to the need of expanding/reconstruction of existing passenger buildings, or to construct new modern passenger terminal. Investments in a terminal are pre-condition and basis for attracting cruise ships and for economic growth rate in port and country. Consequently, investments and modernization of terminals contribute to increase in demand for maritime passenger service. In this research will be analysed cruise ports in the Adriatic Sea, to compare the existing infrastructure of terminals with passenger throughput and other elements of cruise traffic.

KEYWORDS: cruise ports, passengers, terminal & infrastructure

I. INTRODUCTION
The article considers the infrastructure of passenger terminal as an important factor affecting on potentially competitiveness of cruise ports. Infrastructure has also an important effect on cruise lines decision making whether to visit port or not. Ports need to be constructed in such a way, that they can provide a pleasing environment for passengers, otherwise will any negative experience have an equal negative impact on passenger’s perception of the port, and consequently on the cruise company’s willingness for their ship to return. Concerning this, port authorities have to decide about port and their facilities and prepare a long term plan whether to build cruise facilities or not. Also, the port community has a significant effect on this decision, with a willingness to welcome cruise ships and their passengers. Many port cities are already facing with overcrowds of cruise ships and passengers, so that they are not ready to welcome cruise ships in their city is minor. But, on the other hand, we have small ports with huge willingness to welcome bigger cruise ships in their port. This small ports are in competition to attract more cruise ships and to establish homeport operations. If ports want to hold competitive market structure in cruise market, they need to be able to serve large cruise ships.

The new ships are bigger in size and for ports this means that they need to adapt port facilities on maritime and on land side to serve cruise ship needs and passenger needs. Cruise port can be described as an important node in transport system, which is connecting cruise ships and their passengers with city ant hinterland attractions. Each port has a different touristic attractions in the city and in the hinterland. We can say that hinterland of cruise port is geographical area that is so close to the port that it may be visited by passenger in time when cruise ship is in the port. To ensure this, ports need to have good transportation connections to the hinterland.

The strategic planning of a cruise passenger terminal is oriented in the future coming traffic flows. So we need to predict the passenger flows for the next couple of years and take them into consideration when planning passenger terminal. Passenger traffic flows can be successfully managed with appropriate design of passenger platform and access points into passenger facility in order to avoid overcrowding and consequently high densities of pedestrian flows (Lorenčič & Twrdy, 2018). To avoid “overbuilding” of cruise passenger terminal is good to have a top-down review of all needed requirements of the passenger terminal, this helps us to eliminate unnecessary offices and areas in the passenger terminal. The
main question of passenger facility planner is, what kind of services and areas are needed for normal operation of the passenger terminal. The second question is how many passengers can be handled, according to arrivals and departures of cruise ships or more precisely according to embarked passengers?

In the article we give an overview of requirements need for normal operation of the passenger terminal and we explain cruise port facilities, areas and services needed for passenger terminal. The development of ports is a long-term issue associated with the strategic planning and development of cruise companies and port authorities.

II. INTERDEPENDENCE OF PORTS AND CRUISE COMPANIES

Supply and the demand of the cruise service are a subject of individual choice and interactions of the three basic actors within the cruise supply chain of cruise industry. This actors are cruise liners which plan and offer itineraries to buyers of cruise trips, the destinations which are composed by the ports and their hinterland, and cruise passengers or buyers of cruise trips (Pallis (2015), Niavis and Vaggelas (2016)). According to Marti (1990) infrastructure and the superstructure are very important factor when we want to increase a port’s traffic, therefore special attention must be given to this topic.

In this research, we are focusing on the player Destination, more precisely on Ports as an important element of the cruise supply chain. Destinations have an effective influence on attracting cruise companies and passengers. Here are two main players of destination which have a crucial role on both other players:

- hinterland and its activities that are generating the demand for visits;
- ports for cruise lines with good capacity performance.

Consequently the demand of cruise ports is mainly generated by cruise passengers and cruise companies (Niavis & Vaggelas, 2016). One of the most important concern of the cruise companies is the quality of the services and safety protections of their passengers. Requirements of the cruise ships are often including also wide range of dedicated infrastructure and services for passenger such as gateways, service facilities and port areas, docking and anchoring facilities, passenger and crew area, transport connections to hinterland, etc.

Alfred J. Baird (1997) researched maritime port infrastructure of the ports in the North Europe. He considered port infrastructure in term of the physical restriction placed on vessel size. The analysis finds out that poorly designed infrastructure at a given port may lead to a restriction for a certain cruise ships to dock.
Another author’s that have analysed ports as an important player motivating cruise companies to select specific port were Wang, Jung, Yeo, and Chou (2014). Their study identified the main factors which are crucial for cruise lines to select specific port:

- natural environment of the hinterland – port climate, port security,
- cruise terminal facilities – infrastructure in the cruise port with berthing facilities and ship services as are support facilities for fuel and water, port charges and sea rescue systems,
- tourism attractions and
- port connectivity and accessibility to the hinterland.

It is normally that the cruise port is the one who is in charge of investing in port infrastructure but, the major beneficiary of the investments get the city, the region, of the private cruise operator. So we are witnessing that the global cruise companies are investing in building and improving existing cruise facilities and docs.

III. CRUISE TERMINAL FACILITIES AND SERVICES

With growing demand in the cruise business, the selection of a cruise port is conditioned by the state of the ports infrastructure. The ports need to be well-functioning and competitive if cities want to have benefit from it. The selection of cruise destination ports has attracted much interest over time.

To allow the port to become a chosen cruise ship destination is important to ensure needed infrastructure to provide efficient and effective port services. The state of the ports and their infrastructure are affecting on the growth of the cruise in a given port. It is also important to provide safe (dis)embark and fast transfer to onward journeys or day excursions. Ports success to become a chosen destination attracting calls is relying on five different factors, this are location and attractiveness of the port; tourist attractiveness of the destination; accessibility of the destination; port facilities and services on offer; port fees (Pallis, 2015).

Passenger terminal can operate as a Home Port or as a Port of Call. A Home Port is where passengers either begin or end their trip. And Port of Call is where cruise ship calls the port and passengers can leave the cruise ship for onward journeys or day excursions. The role and the function that a port serves in a cruise itinerary (i.e. as a home port, technical stop or a port of call) heavily influence the impact of cruising on the port destination (e.g. income generation to local businesses, port revenues, job creation, environmental impacts). Because of that, destination management organizations try to invest in port infrastructure, amenities and attractions in order to increase the importance and services offered by their port, attract/persuade cruise companies to use the ports as home or hub ports and so multiply the economic benefits of cruising in the port area and the vicinity. Good port infrastructure also heavily influences the efficiency of cruise companies’ operations and the quality/attractiveness of the services offered to their customers. Because of these common interests, collaborations between private cruise companies and public destination organizations are formed globally with the aim of developing good port infrastructures (Kingston & Weeden, 2017).

Thanos Pallis (2015) listed requirements of the passenger facility in port of call and in home port. Required facilities and services in home port for normal operation are: entrance and berth facilities, manoeuvrability draught, berth dimensions, anchorages, bollards, fenders, passenger services, presence of passenger terminal, parking facilities, shops, passenger throughput range, security procedures, and availability of baggage storage. Required facilities and services in port of call for normal operation are: cruise ship and services, dedicated cruise ship piers, berth reservation process, tug boats, pilotage, fresh water service, fuel services, food and drink, waste reception facilities, speed of ship clearance, quality of shipping agents, stakeholder cooperation, passenger services, separation of pier users, pedestrian paths, tourist information’s, cleanliness, immigration quickness, port aesthetics, ship to coach quickness, and sufficient availability of taxis (Pallis, 2015).
The terminal area can be divided into five basic areas: (dis)embarking passenger area; administrative area, cruise ship support area, passenger support area and facility support area. In large-sized cruise terminals can be separate embarking and disembarking areas as well as waiting areas. This is preventing bidirectional passenger flows in the facility. The entrance into the facility can also serve as an exit at the same time. Embarking and disembarking passenger’s area includes spaces for security screening, passport check, and registration. Administrative areas include a variety of administration support spaces. Some spaces are directly related to passenger processing (baggage claim area, passenger support conveniences area, etc.), while other offices have little or no contact with passengers (terminal management, dispatch, storage, inspection office, communication office etc.). Cruise ship support area includes activities with baggage, fuel and fresh water services, storages, crew area, etc. Passenger support areas are including restrooms, food services, gift shops, phones, ATM, etc. All facilities require support spaces for basic building functions. These utilities are the backbone of the building, they provide for the daily operations and include custodial services, mechanical and electrical room, communication room, etc.

Fig. φ is presenting a schematic representation of general cruise terminal elements:

![Cruise terminal components](image)

Trip generation of ground transportation depends on the function of the port terminal. The trip generation assumptions of passengers in Home Port is usually: 85% with private vehicles, 10% with taxis and 5% travel with buses. The trip generation assumptions of passengers in Port of Call is usually: 73% with private tour buses, 12% with excursion buses, 12% with taxis and 3% with public transit (Tawes, 2013). Terminals in home ports should be built outside the city centre, along with convenient transportation routes for all kinds of transportation. Ports of call should be sited in or near the city centre to maximize passenger time onshore instead of in busses or taxis. Access from the port to city and hinterland ensure its growth and importance of cruise. This requires efficient and effective transportation system and network connections.

Pallis and Rodrigue (2013) divided cruise ports based on eight criteria elements. Ports divided regarding to the criteria Cruise terminal, can be divided into: dedicated terminal, dedicated pier, and multi-purpose facility. Second criteria is Ownership and operations, which divides ports on public, private and concession ports. Most common division of ports is regarding to the Function in itinerary. According to this ports can be: home ports, ports of call, or both turnaround and port of call. Forth criteria is dividing ports according to the Seasonality, which can be low (perennial port; four peak months less than 40% of visits), average (four peak months 40 to 60% of visits), high (four peak months 60 to 80% of visits), and very high (four peak months more than 80% of visits). Next criteria is dividing ports according to Attractiveness. Regarding this we have two kind of ports, marquee (“must see”) port, and discovery port. Sixth criteria divides ports according to the Local and regional integration into: destination port, gateway port etc.
and balanced port. The accessibility of ports is also an important criteria of dividing ports. Authors divided ports according to the accessibility based on three elements: air hub port, drive or Train to port. The last criteria of dividing ports is Size. This is also fundamental criteria in this research. Cruise ports divided regarding to the size can be: major ports (more than 1 million Pax), very large (from 0.5 mill to 1 million Pax), large (from 0.25 to 0.5 million Pax), medium (from 0.1 to 0.25 million Pax), or small ports with less than 0.1 million Pax per year. Criteria size indicates the level of activity of a cruise port and it is directly linked with the number of cruise ship calls, and with passenger facility (Pallis, 2015).

The development of a modern cruise terminal also depends on the seasonality of cruise activities. Seasonality of cruise activities is in some ports only for some months, so passenger terminals remain unused for a long period of the year. This is one of the reasons why ports do not invest in cruise port infrastructure and terminal. On the other hand, we have also other factors affecting on cruise activity and investments, such as the port land scarcity for passenger terminal, increasingly activities in cargo terminal, and so on (Pallis, 2015). The Mediterranean region (including the Adriatic Sea) is one of the most dynamic cruise region where is seasonality of cruise activities limited. Good climate specifics and weather conditions make allow to plan itineraries over eight months of the year, or even longer in the south regions of the Mediterranean. Because of the seasonal pattern of cruise activities in some ports, facilities could be also designed as a multi-functional building, so it can have year-round utilization.

IV. CRUISE TERMINAL PERFORMANCE AND TERMINAL INFRASTRUCTURE IN ADRIATIC SEA

The comparison of the port performance is frequently shown as a port ranking list, by using different indicators. The ranking of cruise ports is usually shown as passenger movement (Pax). Passenger flow or cruise traffic is in cruise industry measured as total passengers or passenger movements per year (Pax movements) in a certain port. We used the unit for passenger movements, Pax which means the number of passenger movements in port per year. Ports can be compared from many perspectives such as passenger movements, revenue, port capacity, etc. However, the performance of the port is a more comprehensive understanding of the overall strength of different ports, rather than based on onside criteria. The results of ranking lists need to reflect the port performance comprehensively. An indicator such as the number of passengers is the easiest and effective way to assess the performance, as well as the most widely accepted in the port industry. Although some indicators are neglected because of the availability of data and incompatible of methods, they should play an important role when evaluating the port performance. Consequently, the results of the ranking lists are not convincing in showing the port performance.

To evaluate the comparison of the Adriatic Sea ports we summarized some important indicators related to the infrastructure into 2 categories:

- First category: Cruise port dynamics (cruise passenger traffic, cruise calls)
- Second category: Port infrastructure (births and quays, max. length and depth of ships)

For more detailed analysis of the infrastructural elements, as an important factor affecting on choice of destination for cruise ships, we analysed cruise ports with more than 250,000 Pax Movements. This ports are Venice, Dubrovnik, Corfu, Kotor and Bari.

A. Cruise port dynamics in the Adriatic Sea

The analysis has been carried out by collecting data information about Adriatic Sea ports. Before analysing the most important indicators related to the infrastructure and cruise service affecting on the choice of the itinerary of cruise ship we need to analyse the first category, this is cruise port dynamics. Regarding the cruise port dynamics, we analyse cruise Pax movements and cruise calls in Adriatic Sea ports. Second category considers an analysis regarding the infrastructure and accessibility of ports, where we analysed landside connectivity, waterside access, utility infrastructure and facilities.

According to the Pallis and Rodrigue (2013) criteria of dividing ports by size, we divide analyzed ports according to the passenger throughput for the year 2017 into:
Major port: Venice
Very large ports: Corfu, Dubrovnik, Kotor
Large port: Bari
Medium ports: Brindisi, Split, Trieste, Zadar
Small ports: Ancona, Koper, Rijeka, Ravenna, Sibenik, Taranto

We took into analysis 15 Adriatic Sea cruise ports in order to analyze their absolute passenger movements (Pax) and calls. Data for the analysis has been conducted from the web page of The Association of Mediterranean Cruise Ports. Fig. 3 is showing all analyzed Adriatic Sea cruise ports and comparison of cruise Pax movements in the year 2013 and 2017.

The Port of Venice constitutes by far as the main cruise destination in the Adriatic Sea and according to the Pallis and Rodrigue (2013) is this port categorized as a major port. The most important cruise ports in Adriatic Sea are Venice, Dubrovnik, Corfu and Kotor, of which the port of Kotor, Zadar and Trieste have all a constant growth of cruise business demand in number of passenger movements or in the number of cruise calls. In last couple of the years is Venice coffering congestion problems, so cruise companies are looking for alternative cruise ports and search for new tourism attractions for their itinerary. Consequently, port authorities of small ports are struggling for ship docking as an alternative to major and large cruise ports. We are witnessing the shift of passenger movements from major ports to small ports. Example of this is port of Venice, from which have shifted passenger movements to Port of Trieste, Ravenna and Koper, basically because this are neighbourhood ports. The size of the port or more precisely the yearly number of the passenger movements in port is implying the operations of considerable size. Based on this, ports are investing in cruise terminal infrastructure and facilities to satisfy ship requirements. If we compare Pax movements and number of calls, we get Fig. 4.
From the Fig. 4 is obviously that in Adriatic Sea ports are arriving bigger cruise ships carrying more and more passengers. Based on this ports need to invest in their infrastructure to accommodate bigger ships. Another interesting comparison is the distribution of the ship calls and passenger movements in ports. Fig. 5 is presenting Adriatic Sea ports with more than 250,000 Pax. Movements. This ports are handling with 85% of all passenger movements in Adriatic Sea ports.

As has been shown the port of Venice has the largest percent of market share (market share is presented as width of the bubble) in the Adriatic Sea. But the highest number of the cruise port calls has port of Dubrovnik. We can conclude that the number of the cruise calls is significantly affecting on the market share of the port. But we need to be aware that the port of Venice is home port, so the passengers are counted twice (during the embarkation and disembarkation).

**B. Infrastructure of Adriatic Sea ports**

The cruise ship must have access to appropriate superstructure, infrastructure, supplies and services in order to facilitate the ship and the passengers (Lekakou, Pallis & Veggelas, 2009). There is a number of aspects regarding cruise infrastructure, which are affecting on selection of a cruise port. The number of cruise ships able to be in port at one time is restricted by the number of berths and quays. We can allevi-
ate this problem with scheduling cruise ships on different days within the season. Another factor affecting on cruise ship calls is the length and depth of available berths in port. For cruise ships is especially important factor length. Because, as the size of the cruise ship increases, some ports will require the lengthening of wharves before cruise ships can dock. If the length of the berth is insufficient cruise ships are not able to dock in port. There is also another important factor affecting on choice of destination for cruise ships, this is passenger facility. Especially are passenger facilities required in home port where passengers start or finish their cruise there. For very large cruises, these facilities must be capable of processing thousands of people in a short amount of time. For home ports and their passengers is also essential meaning the supply of transportation.

In this section we aim to establish whether there is any specific infrastructural element which is common to leading ports in Adriatic Sea. These elements will be than possible to compare between ports. In this analysis we focused on the port physical restrictions in relation to the cruise ship. In Table 1 are presented physical restrictions for cruise ships at the main ports in the Adriatic Sea.

<table>
<thead>
<tr>
<th>Port</th>
<th>Available cruise quays</th>
<th>Total quays length [m]</th>
<th>Max. draught of ship [m]</th>
<th>Max. length of ship [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dubrovnik</td>
<td>7</td>
<td>1455</td>
<td>11</td>
<td>615</td>
</tr>
<tr>
<td>Venice</td>
<td>7</td>
<td>3450</td>
<td>9.1</td>
<td>340</td>
</tr>
<tr>
<td>Bari</td>
<td>3</td>
<td>1700</td>
<td>12</td>
<td>330</td>
</tr>
<tr>
<td>Kotor</td>
<td>5</td>
<td>665</td>
<td>7.8</td>
<td>280</td>
</tr>
<tr>
<td>Corfu</td>
<td>7</td>
<td>2240</td>
<td>11</td>
<td>770</td>
</tr>
</tbody>
</table>

In Fig. 6 are presented essential indicators related to the cruise port infrastructure and cruise ship.

Port of Venice is regarding the passenger movements on the first place with 1,427,812 Pax in year 2017. From Fig. 6 it is evident that in port of Venice is arriving large number of the small cruise ships. An advantage of the Port of Venice is draught. This is bringing access to a large number of cruise ships and consequently it multiplies itineraries of cruise ships to the port of Venice. With every new cruise itinerary are coming more passengers in port. We can conclude that port infrastructure is significantly affecting on cruise ship arriving’s. This is a case when cruise ships are anchored at the quay. But cruise ships have additional option to anchor and use the tendering services, which open a wide array of ports of call (Rodrique & Notteboom, 2017). Presented indicators related to the cruise port infrastructure are considered to be essential attributes which may enable port to compete in cruise industry. It can be concluded
that at ports where infrastructural elements have not equivalent dimensions, then effective competition may be difficult to provide.

V. DISCUSSION AND CONCLUSIONS

From literature review we have evident that authors have come to conclusion that the most important factor which is affecting on the cruise liner decision to select a port of call, is the attractiveness of the location. On the second place they ranked connectivity and on the third place terminal facilities. From the analysis we can conclude that port infrastructure is truly significantly affecting on the decision of cruise lines whether to select port. The relationship between cruise lines and ports is a very complex, because in some sense they are at the same time collaborate and compete to serve their passengers (Gui & Gusso, 2011).

According to Esteve-Perez and Garcia-Sanchez (2015), the main factors that effect on cruise traffic are related to port infrastructure, port pricing policies and to hinterlands activities. They used factor analysis to measure the effect, where the dependent variable of the regression model was cruise traffic. The results of the research indicated that the number of cruise passengers is depending on the attractiveness of the hinterland and on the transportation connectivity of the hinterland and port.

We can conclude that ports and terminals must be equipped with new and appropriate facilities and infrastructure, to be able to offer to cruise ships all the service they need. The development of the new ports could be cheaply by developing a terminal by using old warehouses, but in contrast the legacy ports are struggling for massive capital investments into redevelopment of the port. Despite the fact that small ports have a huge willingness to welcome and accommodate new cruise ships, they will remain inefficient and unattractive for home port, until they realize that the need is in investing in infrastructure is essential for the future development of the port and for growth of traffic flows. Ports need to adjust their seabed in order to be able to accommodate ships with deeper draught. If this is not possible, the port will be automatically excludes from hip itineraries. It is also important to have a high standard of services to supply cruise ships as well as their passengers.

Assuming that ports strive toward port modernization or expansion in order to meet the contemporary needs of the cruise industry, the cruise demand in the Mediterranean ports will consequently increase in future years.

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Berth Allocation Problem: A Literature Review

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ABSTRACT
Berth Allocation Problem (BAP) is recognized as one of the most investigated problem at container ports, in literature described as a very complex process that begins when ships arrive at the port, waiting to moor at the quay. This problem is defined as a NP-hard optimization problem. For solving it, different approaches have been used with the emphasis on (meta) heuristic methods. This paper reviews the methodologies and techniques applied in journal papers published by Elsevier from 2012 to 2018 in order to give the comprehensive analysis of BAP. Some publications considered the integrated BAP with quay crane (QC) assignment (scheduling, allocation), denoted here as BAPQC. The review of this literature is also reported. Such theoretical approach can serve as a basis for further analysis in the field.

KEYWORDS: container port, NP-hard problem, methods & review

I. INTRODUCTION
Berth Allocation Problem (BAP) is widely presented in the literature of container ports whereas it begins when ships arrive at the port, waiting to moor at the quay. Sometimes BAP is analyzed together with the quay crane (QC) assignment (scheduling, allocation, denoted as BAPQC) along the berth in order to find the optimal solution at the quayside and to improve crane productivity at container terminal. Having in mind that the mooring locations, i.e. berths are occupied, the ships have to wait until processed [1, 2]. There are different approaches for servicing container ships at terminal and accordingly the berth allocation is in dependence of the terminal manager/operator. Mostly, ports utilize a first-come first-served discipline, but on the other hand, there are dedicated terminals that provide the priority rules. The ship arrival at port could be denoted as a static or dynamic. In the first one, ships are already in the port and wait for servicing, while in the second one, ships have not arrived yet, but their arrival times are known and estimated in advance [2].

Based on the similar investigation done in Škurić and Popović [2] we present the overview of the methods used for solving BAP and BAPQC collected from a database of journal papers published by Elsevier from 2012 to 2018. The reported research is based on the theoretical content of the problems and represents an initial step for the detail citation analysis that will make a part of the further investigations. However, the review of one problem recognized as very important segment of container terminal makes always an additional contribution to the literature.

The paper is organized as follows. In Section 2, we give a theoretical background of BAP with the literature review papers published in the last two decades. In Section 3 we concentrate on different approaches that were used for solving BAP. The overview of BAPQC is provided in Section 4. The paper is summarized in Section 5.

II. THEORETICAL BACKGROUND
One of the pioneer investigations of BAP was done by Imai et al. [3]. The authors solved this problem using Hungarian method, by treating BAP as a classical assignment problem. This study was not realistic because port systems are mostly defined as dynamic. Moreover, later researches provided by other authors were concentrated on applying different techniques in solving BAP with crane assignment at berth [2]. Later, Lim [4] reported that berth planning is a NP-hard problem and after formulating BAP, he assumed that berthing times should be set by the arrival times. He treated berth allocation with continuous line and discussed the minimization of sum of the lengths of ships that should be berthed at the same time [2]. Generally, in this paper we focus on review of heuristic techniques paying attention at the diversification and combinatorial optimization models.
Park and Kim [5] proposed a two-phase solution procedure for solving the mathematical model. The first phase determines the berthing position and time of each vessel as well as the number of cranes assigned to each vessel at each time segment. The subgradient optimization technique is applied. In the second phase, a detailed schedule for each QC is constructed based on the solution found from the first phase. The dynamic programming technique is applied.

A detailed literature overview and new classification schemes for BAP and QC scheduling problems are described in Bierwirth and Meisel [6]. The paper develops a classification scheme for BAP, QC scheduling problem and integrated approaches. This survey comprised the optimization models for seaside operations planning in container terminals. This paper reviews the relevant literature. New classification schemes for BAP problems and QC scheduling problems are developed. Second study of Bierwirth and Meisel [7] continued the literature review of BAP and BAPQC and analyzed 120 new publications from 2009. Therefore, the authors identified the trends in the field and discussed about the methods developed, used algorithms and established further directions.

For more convenient review of BAP and BAPQC, we divided the review in two sections. First, the publications of BAP are classified chronologically, and the explanation of the problems is provided in the Tables 1-3. Second, the publications of BAPQC are systemized in Tables 4-5.

### III. Overview of BAP

In Tables 1 and 2, a literature review of publications from 2012 to 2015 of different approaches for solving BAP is presented.

<p>| Table 1. Review of different approaches used to solve BAP (Year: 2012) |
|-------------------------------------------------|----------------|----------------|----------------|</p>
<table>
<thead>
<tr>
<th>Problem description</th>
<th>Objective function</th>
<th>Solver/programming language</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>The authors developed a robust schedule for BAP with the level of uncertainty regarding vessels’ arrival time and operation time. Additional heuristic is proposed for solving large-scale problem cases.</td>
<td>It is proposed a bi-objective optimization model for minimizing cost and maximizing robustness of schedules.</td>
<td>C#</td>
<td>Zhen and Chang [8]</td>
</tr>
<tr>
<td>The authors presented a hybrid integrated method known as Clustering Search with the using of Simulated Annealing Algorithm to solve BAP. They compared it to recent methods found in the literature.</td>
<td>Minimizing the sum of service time, weighted by an associated cost.</td>
<td>C++</td>
<td>de Oliveira et al. [9]</td>
</tr>
<tr>
<td>Dynamic BAP is considered. A hybrid metaheuristic that combines Tabu Search with Path Relinking is used and the obtained results are compared with Generalized Set Partitioning Problem recognized as the best mathematical model in the literature for BAP.</td>
<td>Minimizing the service time of the vessels is described by the objective function.</td>
<td>Ansi C</td>
<td>Lalla-Ruiz et al. [10]</td>
</tr>
<tr>
<td>Logical and pragmatic platform to integrate the quayside operation problem is solved by a new exact solution method called the combinatorial benders’ cuts algorithm.</td>
<td>Minimizing the maximum relative tardiness of all ships in a planning horizon.</td>
<td>CPLEX</td>
<td>Chen et al. [11]</td>
</tr>
<tr>
<td>For solving the problem, it is employed a branch-and-bound scheme and Timed Petri Net approach.</td>
<td>The objective is to minimize the make span of the schedule.</td>
<td>Java</td>
<td>Legato et al. [12]</td>
</tr>
<tr>
<td>Bi-Level Programming approach is used to characterize the highly interrelated relationships between the two processes and simultaneously, identify an integrated solution for ship’s waiting time.</td>
<td>The objective function minimizes the sum of each ship’s waiting time for a berth, plus the container handling time to reduce the ship handling costs.</td>
<td>LINDO</td>
<td>Song et al. [13]</td>
</tr>
<tr>
<td>Problem description</td>
<td>Objective function</td>
<td>Solver/programming language</td>
<td>References</td>
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<tr>
<td>Two quadratic outer approaches (static and dynamic) that can handle general fuel consumption rate functions were proposed.</td>
<td>Minimization of the fuel consumption of all the ships.</td>
<td>C++ and CPLEX</td>
<td>Wang et al. [14]</td>
</tr>
<tr>
<td>The efficient heuristics for BAP of the two terminals is developed. The results emphasized to the channel berths as the most preferred option.</td>
<td>Minimization of the total service time of ships.</td>
<td>C</td>
<td>Imai et al. [15]</td>
</tr>
<tr>
<td>Discrete and dynamic BAP is studied.</td>
<td>Minimization of the total service time which includes waiting time and processing time of all ships.</td>
<td>C++</td>
<td>Ting et al. [16]</td>
</tr>
<tr>
<td>Decision making for the BAP is supported by a beam-search heuristic to obtain a weekly plan at the tactical level, followed by a simulated annealing-based search process to adjust allocation decisions at the operational level.</td>
<td>Minimization of costs in non-optimal conditions.</td>
<td>Monte Carlo simulator</td>
<td>Legato et al. [17]</td>
</tr>
<tr>
<td>The Tactical BAP is applicable to efficiently solve by Biased Random Key Genetic Algorithm (GA).</td>
<td>Maximization of the sum of the values of the chosen QC profiles assigned to all the ships and minimization of yard-related housekeeping cost generated by the flows of container exchanged among the ships.</td>
<td>Ansi C</td>
<td>Lalla-Ruiz et al. [18]</td>
</tr>
<tr>
<td>The tactical BAP with deterministic and stochastic scheduling models is reported. First one is formulated with considering the periodicity of schedule. Due to the uncertainty of the discharged and loaded containers that need to be handled, the second (stochastic) model is proposed. Some metaheuristic algorithms are suggested for solving the models.</td>
<td>Deterministic environment: minimization of the total cost of the deviations between the ships' assigned berthing time and their expected time. Stochastic environment: minimization of the expected cost for handling potential conflict time during the execution of the baseline schedule for BAP.</td>
<td>CPLEX</td>
<td>Zhen [19]</td>
</tr>
<tr>
<td>A berth-flow network modelling approach is used for solving the dynamic BAP. The model is formulated as an integer multi-commodity network flow problem.</td>
<td>Minimization of the total waiting time plus the penalties.</td>
<td>CPLEX and C++</td>
<td>Yan et al. [20]</td>
</tr>
<tr>
<td>Two models for the tactical BAP incorporating the utilities lead to more efficient and equitable BAP. The utilities estimated by shipping lines are much more accurate than those estimated by port operators.</td>
<td>To maximize the utility of the shipping lines (which corresponds to revenues of the port operators) reduced by the transportation cost of transshipment containers.</td>
<td>-</td>
<td>Wang et al. [21]</td>
</tr>
<tr>
<td>The discrete BAP is considered. A bi-objective model considering daytime preference with the assistance of multi-objective GA are established to minimize the delayed workloads and the workloads in nights.</td>
<td>Minimization of the sum of weighted delayed times comparing to the estimated time of departure.</td>
<td>MATLAB</td>
<td>Hu [22]</td>
</tr>
<tr>
<td>The continuous BAP at the operational level is solved. An integer linear model is developed and a GA with a local search procedure help to improve further the solutions produced by the GA.</td>
<td>To minimize the sum of the four types of costs (waiting, delay, costs of assignment and deviation costs for each vessel and quay).</td>
<td>C++</td>
<td>Frojan et al. [23]</td>
</tr>
</tbody>
</table>
In the publications from [8] to [13], it is noticeable that the main aim of the investigations was related to the minimization of the costs at container terminal. To solve this, the emphasis is mostly on (meta) heuristics. First, the authors proposed a robust schedule of BAP including the stochastic background of vessels’ arrival and operation time in port [8]. The problem was solved by applying the additional heuristic. Clustering Search with Simulated Annealing Algorithm as hybrid method at time was used to solve BAP in [9]. On the other hand, authors in [10] proved that developed hybrid metaheuristic based on Tabu Search and Path Relinking was the best method for solving dynamic BAP. An exact method – combinatorial benders’ cuts algorithm is proposed in [11] as a platform to deal with quayside operation problem. An application of branch-and-bound scheme and Timed Petri Net is given in [12]. Bi-Level Programming approach is implemented in [13].

Specific types of BAP have been investigated. For example, static and dynamic BAP was studied in [14] in order to improve the general fuel consumption of ships. Discrete and dynamic BAP is studied in [15] with the aim to reduce service costs of ships. The importance of channel berths is reported in [16] as a preferred option for BAP. Another dynamic BAP evaluation was done in [17]. The authors used berth-flow network modelling approach. In [18] discrete BAP is considered. The author used a bi-objective model and multi-objective GA.

BAP was also investigated at the different levels of decision making at container terminals. For example, at operational level, the continuous BAP is elaborated in [19] and the research showed that GA with a local search procedure will improve the operations at container terminal. Tactical BAP is described in [20] where a beam-search heuristic followed by simulated annealing-based search to adjust allocation decisions at the lower – operational level is proposed. Another tactical BAP was solved by Biased Random Key Genetic Algorithm (GA) in [21]. Deterministic and stochastic scheduling models of tactical BAP have been considered in [22]. Metaheuristic algorithms are proposed for solving the models. Finally, the utilities estimated by shipping lines are superior than those estimated by port operators and this was proved for tactical BAP described in [23].

In Table 3, a literature review of publications from 2016-2017 of different approaches for solving BAP is presented.

<table>
<thead>
<tr>
<th>Problem description</th>
<th>Objective function</th>
<th>Solver/programming language</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>This paper deals with discrete and continuous models for BAP. An Adaptive Large Neighborhood Search heuristic to solve the problem.</td>
<td>Minimization of service time of ships.</td>
<td>C++</td>
<td>Mauri et al. [24]</td>
</tr>
<tr>
<td>Differential evolution algorithm for solving dynamic BAP is proposed. It is applicable for continuous space problems.</td>
<td>Minimization of total costs.</td>
<td>CPLEX and MATLAB</td>
<td>Sahin and Kuvvetli [25]</td>
</tr>
<tr>
<td>The discrete and hybrid BAP is solved. An exact combinatorial algorithm was used as a prove of superiority compared to exact solvers. It is useful to solve large size problems.</td>
<td>Minimization of the port penalty costs.</td>
<td>C</td>
<td>Kordić et al. [26]</td>
</tr>
<tr>
<td>A bi-objective robust berth allocation model is formulated. The model aims to optimize the robustness of the berth allocation policy, and an adaptive grey wolf optimizer algorithm is developed to solve the proposed model.</td>
<td>Minimization of the total cost of berthing allocation and maximization of minimum customer satisfaction.</td>
<td>CPLEX</td>
<td>Xi et al. [27]</td>
</tr>
<tr>
<td>The paper introduces a mathematical formulation that extends the classical BAP to cover multiple ports in a shipping network under the assumption of strong cooperation between shipping lines and terminals.</td>
<td>Minimization of costs both for the terminal operators and the liner shipping company.</td>
<td>CPLEX</td>
<td>Venturini et al. [28]</td>
</tr>
</tbody>
</table>
In [27], a bi-objective robust BAP model is formulated and solved. An adaptive grey wolf optimizer algorithm is developed to solve the proposed model. Another extension to the classical BAP formulated as a novel mathematical formulation to cover multiple ports in shipping network at time was proposed in [28]. Discrete, continuous and hybrid models of BAP have been investigated in 2016, respectively [24, 26]. In [24] an Adaptive Large Neighborhood Search heuristic is proposed to solve discrete and continuous BAP. On the other hand, in [26] discrete and hybrid BAP is analyzed. An exact combinatorial algorithm showed better performances than exact solvers. In addition, an application for continuous space problems in solving dynamic BAP is given in [25].

IV. LITERATURE REVIEW OF BAPQC

Different (meta) heuristics have been evaluated in solving BAPQC as shown in Tables 4-5.

<table>
<thead>
<tr>
<th>Problem description</th>
<th>Objective function</th>
<th>Solver/ programming language</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAP and QC assignment problem multi-user container terminal are solved by using an evolutionary algorithm with nested loops to obtain optimal solutions.</td>
<td>Minimize the average service time of the incoming ships – BAP problem. Minimize the average number of QC shift operations per ship – QC assignment problem.</td>
<td>MATLAB</td>
<td>Yang et al. [29]</td>
</tr>
<tr>
<td>Berth and QC allocation problem based on QC allocation, sailing speed of ships and fuel consumption of ships by applying nonlinear multi-objective MIP model is solved.</td>
<td>Minimizing fuel consumption. Minimization of QC moves. Minimization of port operational costs.</td>
<td>MATLAB and CPLEX</td>
<td>Hu et al. [30]</td>
</tr>
<tr>
<td>BAP and QC assignment is solved by formulating a new binary integer linear program integrated with the QC assignment (specific) problem as well.</td>
<td>Minimization the total costs including costs of deviation from the desired berth section, costs of berthing later than the arrival time and costs of departing later than the due time.</td>
<td>CPLEX</td>
<td>Turkogullari et al. [31]</td>
</tr>
<tr>
<td>The integrated BAP and QC assignment problem is investigated. The effects of different discretization schemes and the impact of using a time-variant/invariant QC allocation policy is analyzed.</td>
<td>Minimization of the sum of the costs for the selected variables and a sum of column costs (which include speedup, lateness and penalty costs) including QC assignments costs.</td>
<td>CPLEX and C++</td>
<td>Iris et al. [32]</td>
</tr>
<tr>
<td>The paper investigates a BAP considering the periodic balancing utilization of QC. In the case study, several heuristics are developed: rolling-horizon heuristics, neighbourhood search heuristics and parallel computing is used to improve the algorithmic performance.</td>
<td>Minimization of the total service cost for all vessels in the planning horizon.</td>
<td>MATLAB</td>
<td>Hu [33]</td>
</tr>
<tr>
<td>A two-phase model for BAP and QC assignment is proposed. A particle swarm optimization algorithm for BAP was developed.</td>
<td>BAP: Minimization of stay time of ships and minimization of increased time (cost). QC assignment: Minimization of the range of maximum and minimum QCs and minimization of the movements of QCs.</td>
<td>Python</td>
<td>XiaoLong et al. [34]</td>
</tr>
<tr>
<td>Problem description</td>
<td>Objective function</td>
<td>Solver/programming language</td>
<td>References</td>
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<tr>
<td>A deterministic model is formulated by considering the setup time of QC. To handle the uncertainties, a robust optimization model is established.</td>
<td>Aim is to minimize the total weighted handling time and the waiting time for all vessels within the planning horizon.</td>
<td>CPLEX and C++</td>
<td>Shang et al. [35]</td>
</tr>
<tr>
<td>This investigation aims at a new functional integration approach for the following problems: berth allocation, QC assignment and specific QC assignment.</td>
<td>Minimizing the average handling time per vessel.</td>
<td>CPLEX</td>
<td>Karam and Eltawil [36]</td>
</tr>
<tr>
<td>GA has been used for solving BAP and QC assignment problem simultaneously. A hybrid particle swarm optimization combining an improved particle swarm optimization with an event-based heuristic is proposed.</td>
<td>Minimization of the total cost consisting of the sub-costs of waiting, delay and operation costs.</td>
<td>Java 2</td>
<td>Hsu [37]</td>
</tr>
<tr>
<td>An integrated simulation and optimization method is developed, where the simulation is designed for evaluation and optimization algorithm is designed for searching solution space. An integrated BAP and QC assignment for the trade-off between time-saving and energy-saving is reported.</td>
<td>First objective aims to minimize the cost of total departure delay of all vessels. Second objective function is to minimize the cost of total handling energy consumption of all vessels by QCs.</td>
<td>CPLEX</td>
<td>He [38]</td>
</tr>
<tr>
<td>A mixed-integer linear program whose exact solution gives optimal berthing positions and berthing times of the vessels, along with their crane schedules during their stay at the quay. An efficient cutting plane algorithm based on a decomposition scheme is proposed to solve large size of problems.</td>
<td>Minimization of total costs.</td>
<td>CPLEX</td>
<td>Turkogullari et al. [39]</td>
</tr>
<tr>
<td>A continuous berth discretized in small equal-sized sections is considered. An Adaptive Large Neighborhood Search heuristic is presented.</td>
<td>Minimization of the overall costs (speeding costs, tardiness costs, a one-time penalty cost, and costs related to the QC assignments).</td>
<td>CPLEX and C++</td>
<td>Iris et al. [40]</td>
</tr>
<tr>
<td>A metaheuristic approach based on a Biased Random-key GA with memetic characteristics and several Local Search procedures is performed.</td>
<td>Minimization of the waiting cost, delay cost, deviation cost, and exceeding horizon cost incurred at container terminal.</td>
<td>C++11</td>
<td>Correcher and Alvarez-Valdes [41]</td>
</tr>
<tr>
<td>This paper deals with the simultaneous allocation of berths and QCs under discrete berth situations with uncertainty. A rolling horizon heuristic is presented to derive good feasible solutions.</td>
<td>Minimization of total costs.</td>
<td>Java and CPLEX</td>
<td>Xiang et al. [42]</td>
</tr>
<tr>
<td>For improving the green concept, this paper considers two policies of different carbon emission taxation rates: one is unitary taxation rate and the other is piecewise taxation rate.</td>
<td>Minimization of total costs.</td>
<td>CPLEX</td>
<td>Wang et al. [43]</td>
</tr>
<tr>
<td>A mathematical model based on the relative position formulation for the berth allocation aspects is presented. A rolling horizon heuristic and a branch and cut approach is proposed.</td>
<td>Minimization of the service completion time.</td>
<td>Mosel and Xpress-IVE</td>
<td>Agra and Oliveira [44]</td>
</tr>
</tbody>
</table>

In the case of BAPQC, (non) linear programs, evolutionary algorithms and (meta) heuristics were methods that researchers used from 2012 to 2018 in the Elsevier publications. Therefore, an evolutionary
algorithm with nested loops was used at multi-user container terminal in [29]. Different discretization schemes and time-variant/invariant policy for QC assignment were applicable in [32]. A cutting plane algorithm based on mixed integer linear program that gives optimal berthing positions and QC scheduling is evaluated in [39]. Nonlinear multi-objective mixed integer programming and new binary integer linear program were considered in [30] and [31], respectively.

A deterministic model is formulated and a robust optimization model for solving the uncertainty on real-world examples of BAPQC were reported in [35]. An integrated BAP and QC assignment for the trade-off between time-saving and energy-saving is reported in [38]. Rolling-horizon heuristics, neighbourhood search heuristics and parallel computing to improve the results of BAPQC have been studied in [33]. A particle swarm optimization algorithm for BAP was developed to solve two-phase BAPQC model [34]. GA has been used together with a hybrid particle swarm optimization with an event-based heuristic to simultaneously solve BAPQC as explained in [37]. A metaheuristic approach based on a Biased Random-key GA with memetic characteristics and several Local Search procedures is performed in [41]. In addition, a rolling horizon heuristic to simultaneous allocate berths and QCs under discrete berth situations with uncertainty is discussed in [42]. An Adaptive Large Neighborhood Search heuristic is presented to solve continuous BAPQC [40]. A mathematical model based on the relative position formulation for the berth allocation aspects is presented: a rolling horizon heuristic and a branch and cut approach is proposed in [44].

This investigation described in [36] aims at a new functional integration approach for the following problems: berth allocation, QC assignment and specific QC assignment. For improving the green concept, two policies of different carbon emission taxation rates (one is unitary taxation rate and the other is piecewise taxation rate) are described in [43].

Beside the Elsevier publication, very interesting investigation is done in [45] where authors considered the Dynamic Minimum Cost Hybrid Berth Allocation Problem with fixed handling times of vessels. They used four variants of metaheuristic method Variable Neighborhood Search and the results showed good performances of the variants for this BAP problem.

V. CONCLUSION AND DISCUSSION

This paper represents an overview of BAP and BAPQC in container ports using different models, algorithms and (meta) heuristic approaches. We have reviewed 38 journal papers published by Elsevier from 2012 to 2018. The observed operations researches techniques for BAP and BAPQC were chronologically systemized and discussed. There is a strong increase in application of (meta) heuristics and different techniques in solving distinctive problems at the quayside. On the other hand, the use of GA in solving optimization problems has been reduced with the difference to the previous period. There are some conclusions that are drawn from the analysis:

- There is an evidence of more integrated investigations of BAPQC from 2012 to 2018 due to the comprehensive planning of operations at container terminal;
- Regarding the use of methods, it is obvious the use of (meta) heuristics not applied in this field before;
- Integrated heuristics based on mathematical modelling are more presented;
- More aspects of the solution quality of applied methods have been presented.

This paper represents a first step in the comprehensive analysis in the future and citation analysis with background of delivered methods in combinatorial optimization will be elaborated. However, there are still other topics that should be analyzed with the reference to improve the operations along the quay.
REFERENCES


EU Actions in Intermodal Transport Development: Guidelines for Eastern Adriatic

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ABSTRACT
The research analyses ongoing EU actions towards sustainable and efficient intermodal transport in Europe. Moreover, the research brings an overview of past and present activities to support efficient multimodal transport that should base on targeted investments, data sharing, internalization of external costs and financial support. There is a quite big gap between technical and technological basis of multimodal transport in western and eastern part of Europe. Such situation limits the use of transport chain with limited road leg, decrease of pollution and noise and road congestion decrease. Consequently, the underdeveloped regions should closely follow EU actions as guidelines for faster approaching already highly developed intermodal infrastructure and suprastructure in western economies. The eastern Adriatic region can be classified as underdeveloped region, with many potentials for future development. A wider overview of ongoing and future transport policy could be incorporated in regional transport policy, where different states should adopt a regional master plan for intermodal transport development.

KEYWORDS: intermodal freight transport, intermodal network, EU transport policy & eastern Adriatic

I. INTRODUCTION
Freight transport presents an important part to the development of the economy and the society, but the growth of freight flows is becoming challenging. The overall demand for freight transport in Europe is constantly growing; based on the data from the European Commission (EC) publication European Union (EU) Transport in figures [1] the total intra-European (EU φό) freight flows increased by υφ.ό% in the period from φτττ to φτυϊ, or in average by τ.ό% per year (φό.ϊ % in the period from υύύω to φτυϊ). This is less than the growth of gross domestic products (GDP) at φττω prices was in the same period (υ.χ% in average or in total around φτ.ό%), which is good; however, the problem is, that the freight flows are increasing much faster on roads than in any other transport mode, resulting in a growing share of road freight transport in modal split. In fact, in φτυϊ ψύ.χ% of all freight flows were done by road, while back in φτττ this share was ψϊ.ω% (the rails lost the share; in φτυϊ their share was υυ.φ%, while in υύύω υχ.ϊ%). Another issue is the existence of empty rides of road freight vehicles; around φτ% of trucks run empty and, although there is no reliable statistical evidence, partially loaded vehicles are also very common [φ]. This is clearly not a good path for European transport when knowing that the main goal of the EU transport policy is to achieve an efficient transport that is at the same time safe and secure. Moreover, the transport must be sustainable and environmentally friendly.

One of the solutions to reach this goal is by enhancing the use of intermodal transport. This kind of transport combines different traffic modes that are used on longer distances where the goods are stowed into intermodal loading unit (ILU). The transport chain should be formed at the consignor and concluded at the consignee’s premises [3]. Combined transport is a type of intermodal transport. The (European) transport chain primarily basis on rail, inland waterways or sea and just initial and/or final transport is performed by the road transport means [4]. Consequently, the last/first mile delivery should be organised by road transport, in order to provide flexibility in door-delivery services.

Bektas and Crainic [ω] expose that the main idea of intermodal transport is to collect cargo and organise unified loads for long-distance transport, where rail or large ocean vessels are primarily used. Anyhow, the transport chain must take advantage of the efficient road transport for local pick-up and delivery operations. Intermodal transport, either accompanied (road vehicles) or unaccompanied (semi-trailers, containers and swap bodies) can provide several benefits, like for example lower transport costs, shorter transit times (not always achievable) and reduced consumption of fossil fuels. Namely, the
longer section of the transport service is more fuel efficient and at the same time lower congestion on the overburdened road network is secured. [6].

With the growing concern about negative externalities of transport which can be mainly attributed to road transport, the solution in the form of intermodal transport is getting more attention. The promotion of efficient intermodal transport must base on connectivity of different transport links and nodes, and on higher efficiency of transport operations [7]. These are: maritime and river ports, airports, inland dry ports and logistics terminals. Intermodal market is complex also from the point of view of stakeholders. In complex transport chains following subjects appear with special needs and requests: end-users (seller and buyer), terminal and transport operators, forwarders and logistics integrators and infrastructural owners. They all directly or indirectly communicate at various levels and often in non-standardised forms [8]. They need to collaborate to make the system run efficiently.

In this paper the authors provide a brief overview of intermodal rail transport development in EU, analyse the policy framework for the development of intermodal transport in EU and investigate the current situation and perspectives for intermodal transport in Slovenia and eastern Adriatic.

II. INTERMODAL TRANSPORT IN EU

The beginnings of intermodal transport in Europe date back to the late 1960s when some European railways had a vision of developing combined road-rail freight transport, where the rail should have the priority on longer transport routes and the road transport should be used just on shortest possible distances [9]. Later on, it became clear that EU needs an efficient and unified transport system, as the prerequisite for the European economic competitiveness. The objective of transport policy was therefore to develop basis for optimal combination of transport services into one single product that uses efficient and cost-effective integrated transport and where competition between transport operators remains open [10].

Intermodal policy framework is based on [11]: intermodal loading unit (ILU), infrastructure development and modal shift, liberalization and competition, innovation research and development as well as on internalization of external costs. The operation of intermodal transport consists of three levels that need to be interconnected: infrastructure and transport means, services and infrastructure, and modal based services, with special regulations [10]. Undoubtedly, the intermodal transport needs adequate transport infrastructure (including terminals positioning and management), compatibility of different technologies in use on a wider market and unified standards of different procedures. In addition, it is necessary to assure data interchange through different systems, related services and infrastructural basis for efficient communication protocols and to develop uniform charging system.

All mentioned actions can be easily established by developing specialized freight corridors. These corridors can secure also optimized use of energy, lower emissions and lower operating costs int the transport chain. Special emphasis should be done on minimizing environmental impacts and limited congestion that is present on some main transport routes in EU [12]. Corridors are being established through the Trans-European transport network policy (Regulation (EU) 1316/2013) and dedicated rail freight corridors (RFCs). RFCs, defined by Regulation (EU) 913/2010 are mainly, but not completely, in line with TEN-T core network corridors which should be completed by 2030. Once completed they will remove bottlenecks, especially on border crossings and upgrade infrastructure as well as improve connections between different modes of transport.

The European Rail Traffic Management System (ERTMS) which substitutes more than 20 different train control-command systems which were/are in use in Europe with a single harmonized system is another important element in making rail sector more reliable and competitive. Once deployed, the ERTMS will increase capacity of existing lines, allow higher speeds, assure lower production, operational as well as maintenance costs and enhance cross-border interoperability. ERTMS must be fully deployed on core
network corridors by 2030. Currently, approximately 25,000 kilometers of rail tracks, and around 8,400 vehicles have been equipped with ERTMS level 1 and/or level 2 in Europe\(^1\) [13].

Modal shift has long been lauded as the way to decarbonize freight transport as the railway network in Europe is largely electric (according to Statista [14], in 2016 53.7% of EU-28 lines were electrified) and far more energy efficient than today’s truck transport. In fact, EC reports [15] that the energy consumption of rail vehicles improved by 20% from 1990 to 2010. Moreover, the analyses show that some types of vehicles achieve even 50% of savings. In 2011, 86% of train-km for freight were performed on electric traction in the EU [2]. Modern electrified rail consists on renewable energies, where the goals are on further increase of their use. International Energy Agency exposes that 40% of the electricity mix used by railways in Europe is low-carbon [15]. However, there is a variety of electrification systems on European railways, namely 750 V, 1.5 kV and 3 kV with direct current, and 15 kV and 25 kV on alternating current, causing interoperability issues on border crossings and thus making rail transport less competitive.

Nevertheless, the intermodal rail transport is gaining importance in EU. In the period from 1992 (when Directive on combined transport was set) to 2014 (when the external study on the achievements of combined transport was done) a considerable growth of the sector has been registered. In fact, 2.5 trillion tonne-kilometres were shifted from roads, and intermodal transport achieved important savings that stands at 2.1 billion EUR in 2011 [16]. UIRR [17] reports that each day over 1,200 freight trains travelled 500 km on national and 950 km on EU relations, where on average 25 truckloads were transported. These numbers are still growing, as according to Report on combined transport, 253.4 million tons of cargo were transported in accompanied or unaccompanied intermodal rail transport in 2017, almost 10% more than in 2015 [18]. The share of intermodal rail freight in total rail freight is now around 22%. The European goal is to shift 30% of road freight on longer distances (over 300 km) to alternative transport modes by 2030, and more than 50% by 2050 [19].

Fig. 1. Map of intermodal share of rail freight transport in Europe in 2016 (% in total rail freight tkm); [18]

\(^{1}\) The figures indicate the lines and rolling stock in operation as well as contracts signed as per November 2017
All European transport policies emphasize the need to stimulate a better use of the existing transport resources and to make better advantage of different transport modes through intermodality. The Combined Transport Directive from 1992 (Directive 92/106/EEC) defined the measures that were meant to push the competitiveness of intermodal transport against road-only transport. After the evaluation of the Directive in 2017, the European Commission proposed to simplify the existing rules to make combined transport more attractive; however, the Combined transport directive is the only legal instrument in EU that directly relieve multimodal transport. Consequently, it is a very relevant tool for the EU transport policy [16].

The Fourth Railway Package consists of four core aims, including cutting administrative costs for railway operators and simplifying market entry, strengthening the role of infrastructure managers and opening domestic passenger market. The package is divided into two pillars, technical and market pillar. Within technical pillar, two directives, namely Directive 2008/57/EC on interoperability of rail system and Directive 2004/49/EC on railway safety, have been recast to Directive (EU) 2016/797 and Directive (EU) 2016/798 respectively. Member states need to transpose both directives into national law by 16th of June 2019, with an option to request an extension of up to a year. Work is done also on some Directives that do not directly affect the rail or intermodal transport, but can have indirect impact, like for example Directive 96/53/EC regarding weights and dimensions of commercial road vehicles, European Excise Duty Directive or Eurovignette Directive.

But intermodal transport must be promoted through policies at all political levels [20] so some Member states established active policies to promote intermodal transport as well [21]. In some Member states restrictions for heavy good vehicles exists over the weekends, some increase the fuel price or the toll prices, while others provide national funding measures and programmes for combined transport. These measures include funding of combined transport operations, the infrastructure, the suprastructure and equipment, research and fiscal support (summarized from [18]).

<table>
<thead>
<tr>
<th>National Funding measures or programmes for Combined Transport</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
</tr>
<tr>
<td>Belgium</td>
</tr>
<tr>
<td>Bosnia and Herzegovina</td>
</tr>
<tr>
<td>Bulgaria</td>
</tr>
<tr>
<td>Croatia</td>
</tr>
<tr>
<td>Czech Republic</td>
</tr>
<tr>
<td>Denmark</td>
</tr>
<tr>
<td>Finland</td>
</tr>
<tr>
<td>France</td>
</tr>
<tr>
<td>Germany</td>
</tr>
<tr>
<td>Italy</td>
</tr>
<tr>
<td>Luxembourg</td>
</tr>
<tr>
<td>Poland</td>
</tr>
<tr>
<td>Serbia</td>
</tr>
<tr>
<td>Sweden</td>
</tr>
<tr>
<td>Switzerland</td>
</tr>
<tr>
<td>Turkey</td>
</tr>
<tr>
<td>United Kingdom</td>
</tr>
</tbody>
</table>

**Fig. 2.** Analysis of existing national CT funding programmes by funding sector; [18]

**III. THE INTERMODAL TRANSPORT IN SLOVENIA AND EASTERN ADRIATIC**

Seaport activities, and in particular container traffic in ports, is the main source of continental freight rail intermodal transport. European ports handled all together almost 113 million TEUs in 2017, which is around 25% more than in 2007 [22], while the eastern Adriatic ports summed together around 1.3 million TEUs.

Main cargo ports in eastern Adriatic are Slovenian port of Koper and Croatian port of Rijeka. There are several smaller cargo ports, like Split and Ploče in Croatia, and Bar in Montenegro; however, these ports
are currently not important source of intermodal transport. Their throughput is rather small (all together around 4 million tons), and the throughput structure is mainly bulk dry and liquid cargos.

### Table 1. Main East Adriatic Ports and Their Basic Characteristics

<table>
<thead>
<tr>
<th>Port</th>
<th>Koper</th>
<th>Rijeka</th>
</tr>
</thead>
<tbody>
<tr>
<td>Port area [000 m²]</td>
<td>2,800</td>
<td>1,500</td>
</tr>
<tr>
<td>Quayside [m]</td>
<td>3,300</td>
<td>8,652</td>
</tr>
<tr>
<td>Berths</td>
<td>26</td>
<td>58</td>
</tr>
<tr>
<td>Max sea depth [m]</td>
<td>18</td>
<td>28</td>
</tr>
<tr>
<td>Throughput (2018)</td>
<td>24,048,618</td>
<td>13,404,784</td>
</tr>
<tr>
<td>Containers (TEU)</td>
<td>988,501</td>
<td>260,375</td>
</tr>
</tbody>
</table>

Source: [23], [24], [25]

All eastern Adriatic countries, except Montenegro, were included in Pan European corridors V, VII or X. Now, Slovenia and Croatia as EU Member states, are crossed by TEN-T corridors (Baltic-Adriatic and Mediterranean corridor, while a branch of Rhine Danube passes over Croatia with inland waterways connection) and by RFC corridors (RFC 5 – Baltic Adriatic, RFC 6 – Mediterranean, RFC 10 – Alpine-Western Balkan and RFC 11-Amber corridor). This is good in terms of better funding possibilities for infrastructure development and finally provision of more reliable and improved rail freight services. Core network infrastructure requirements in the context of the RFCs actually obliges the countries to assure a minimal length of trains of 740 m, 22.5 t axle load, 100 km/h line speed on electrified tracks equipped by ERTMS [26].

![Fig. 3. TEN-T and RFC corridors in eastern Adriatic region; Adopted from [27], [28]](image)

Railway infrastructure already links all cargo ports in eastern Adriatic to the countries of Central and Eastern Europe. However, the railroad sector is underdeveloped and there are still significant infrastructure lacks even on corridor routes or main lines. In addition, the contribution of rail transport is decreased due to the overaged rolling stock [29], old signalling devices and systems as well as high number of level crossings.
Fig. 4. Railway network in eastern Adriatic countries; [30]

TABLE II. SOME CHARACTERISTICS OF FREIGHT RAIL TRANSPORT IN SLOVENIA AND CROATIA

<table>
<thead>
<tr>
<th></th>
<th>Slovenia</th>
<th>Croatia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rail network</td>
<td>1,208 km</td>
<td>2,604 km</td>
</tr>
<tr>
<td>Double track</td>
<td>334 km</td>
<td>254 km</td>
</tr>
<tr>
<td>Electrified</td>
<td>605 km</td>
<td>970 km</td>
</tr>
<tr>
<td>Freight wagons</td>
<td>3,049</td>
<td>5,519</td>
</tr>
<tr>
<td>Rail freight traffic</td>
<td>21.275 million</td>
<td>12.178 million</td>
</tr>
<tr>
<td>Combined rail freight</td>
<td>5.015 million</td>
<td>0.513 million</td>
</tr>
<tr>
<td>Density of freight</td>
<td>185 (714)</td>
<td>115 (745)</td>
</tr>
<tr>
<td>Average delay of freight trains</td>
<td>103 min / 100 train km</td>
<td>127 min / 100 train km</td>
</tr>
<tr>
<td>Average speed of freight trains</td>
<td>37 km/h</td>
<td>23 km/h</td>
</tr>
<tr>
<td>Defects on signalling devices</td>
<td>17,157</td>
<td>27,432 h</td>
</tr>
</tbody>
</table>

Note: Majority of data refers to 2015
Source: [31], [32]

Nevertheless, Slovenia has tradition in combined transport; intermodal rail freight transport has been in use since 1974, with the first “piggy-back” trains connected Ljubljana with Köln and Munich. Now, the company Adria kombi ltd. has a wide spread network of trains transporting containers, semi-trailers and swap bodies to 72 terminals in Europe and offers nine specialized services both in domestic and international traffic. In 2017, around 5 million tons of cargo were transported in combined transport in Slovenia [33], while in Croatia this number was almost ten times lower; only around 513,200 tonnes [32].
<table>
<thead>
<tr>
<th></th>
<th>From Slovenia (1,000 TEU)</th>
<th>To Slovenia (1,000 TEU)</th>
<th>From Slovenia (1,000 t)</th>
<th>To Slovenia (1,000 t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>8.09</td>
<td>49.55</td>
<td>78.89</td>
<td>675.84</td>
</tr>
<tr>
<td>Belgium</td>
<td>1.00</td>
<td>11.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bosnia and Herzegovina</td>
<td>0.01</td>
<td>0.01</td>
<td>0.11</td>
<td>0.01</td>
</tr>
<tr>
<td>Croatia</td>
<td>0.63</td>
<td>0.86</td>
<td>4.72</td>
<td>5.99</td>
</tr>
<tr>
<td>Czech r.</td>
<td>25.52</td>
<td>25.96</td>
<td>181.10</td>
<td>228.08</td>
</tr>
<tr>
<td>Finland</td>
<td>0.03</td>
<td>0.28</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>10.64</td>
<td>15.17</td>
<td>44.32</td>
<td>258.83</td>
</tr>
<tr>
<td>Greece</td>
<td>0.10</td>
<td>0.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hungary</td>
<td>64.12</td>
<td>115.10</td>
<td>643.28</td>
<td>954.16</td>
</tr>
<tr>
<td>Italy</td>
<td>2.84</td>
<td>4.32</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Luxembourg</td>
<td>0.01</td>
<td>0.07</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Macedonia</td>
<td>0.03</td>
<td>0.09</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Netherlands</td>
<td></td>
<td>1.86</td>
<td>23.27</td>
<td></td>
</tr>
<tr>
<td>Norway</td>
<td>0.02</td>
<td>0.08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Serbia</td>
<td>0.19</td>
<td>0.21</td>
<td>1.88</td>
<td>0.36</td>
</tr>
<tr>
<td>Slovak r.</td>
<td>65.44</td>
<td>193.48</td>
<td>446.93</td>
<td>1,440.44</td>
</tr>
<tr>
<td>Sweden</td>
<td>1.15</td>
<td>11.49</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>177.5</strong></td>
<td><strong>404.48</strong></td>
<td><strong>1,405.79</strong></td>
<td><strong>3,610.15</strong></td>
</tr>
</tbody>
</table>

Source: [34]

While there are ten locations in Slovenia with multiple logistic terminals and storage facilities, five of them are important for combined sea-road-rail transport. Those are the port of Koper (sea-road, sea-rail), Ljubljana (road-rail), Celje (road-rail), Maribor (road-rail) and Sežana (road-rail). Intermodal nodal points-terminals, which enable the transfer from one transport mode to another, practically do not exist in Croatia (just extended rail freight stations) [29] and even more rare in other countries of eastern Adriatic as can be seen from following figure. Anyhow, Serbia started with new project of building intermodal terminal near the capital city of Belgrade. Consequently, such investment and positive operational development would speed-up other similar projects in the future.

Adria Kombi, the Slovenian combined transport operator, which works closely with the Port of Koper, and CroKombi, the Croatian combined transport operator, are responsible for the major part of...
intermodal freight rail transport in all freight rail transport; this share is 28% in Slovenia, and 13% in Croatia [18]. However, this region has the potential.

The two busiest eastern Adriatic ports have large hinterland including north Italy, Slovenia, Croatia, Austria, Hungary, Switzerland, south Germany, Czech Republic, Slovakia and even closest parts of Luxembourg, Romania, Bulgaria and Ukraine. These countries have a great economic potential, which will potentially be emphasized by the movement of “blue banana” – Europe’s industrial heartland – towards east, where the labour force is cheaper. In addition, Baltic-Adriatic corridor is indicated as one of the most important trans-European road and railway axes. The establishment of this corridor would permit Adriatic ports to completely exploit their competitive advantage of the favourable geographic position to attract more cargo coming from the East. At the same time, this corridor should resolve the supply problem in the repositioned “blue banana”.

![Legend: Blue banana, Adriatic hinterland, Baltic-Adriatic corridor](image)

Fig. 6. Opportunities for eastern Adriatic ports and development of intermodal transport in their hinterland; [36]

**IV. DISCUSSION**

European Commission has recognized the important geostrategic position and transport potential of eastern Adriatic countries back in 1990s with the definition of Pan European corridors and has continued giving this region transport importance with further definitions of TEN-T and RFC corridors. The sea route between the Suez Canal and the ports of Adriatic is much shorter than the sea routes to the ports of the North Sea or Baltic Sea, so the south entrance to Europe is of strategic importance for the Community. RFC and TEN-T corridors, especially Baltic-Adriatic corridor, are planned to link the Adriatic to the continental Europe, but the neglect of railways system for many decades and the delays in rail infrastructure construction as well as suprastructure and system modernization might become an obstacle to the development of ports and consequently the entire region.

Both ports (important intermodal nodes regionally), port of Koper and port of Rijeka have ambitious expansion plans and foresee huge expansion in total throughput (Koper to 35.1 million tons [37] and in port of Rijeka to 33.5 million [38] tons by 2030), and in particular in container throughput. But these plans could potentially be achievable only if hinterland infrastructure backs them up. Slovenia and Croatia have created transport development strategies until 2030 and currently, in both countries, major work is being done on rail infrastructure on corridor routes to increase capacity and speed. Croatia plans to invest around 2.310 billion EUR into their railway system in the period 2016-2020 [39], while Slovenia plans an investment of around 1.7 billion EUR in the period 2018-2020 [40]. Member states can attain some valuable financial resources from different European funding instruments, that is The Connecting Europe Facility (CEF), The European Fund for Strategic Investment (EFSI), The European Structural and Investment Funds (ESIFs), including The Cohesion Fund (CF). For non-EU countries Instrument for Pre-
Accession Assistance (IPA) is available. In fact, Serbia is expected to receive EUR 175 million for transport projects from IPA in the period 2014-2020, while Montenegro should receive EUR 32.1 million [41].

Railways in Bosnia and Herzegovina and in Montenegro are performing rather well in regards to the condition of the railways system; in Bosnia and Herzegovina rails transport around 9 million tons of cargo per year, while Montenegrin railways transport in average 60% more cargo than the road vehicles do (this trend started in 2012). But in total, railways in the eastern Adriatic region (including Serbia) transport only around 60 million tons of cargo, and the combined transport, which is mainly present in Slovenia and Croatia, represents only around 10% of total rail freight. We should bear in mind, that the main prerequisite for combined transport are large, stable and balanced cargo flows. Port of Koper and also Port of Rijeka generate such flows, while Montenegro together with Serbia has to investigate the role of Port of Bar for the Serbian economy, and Bosnia and Herzegovina must identify the competitive position and potential of the Port of Ploče to the supply Central European countries and eventually support them with the intermodal infrastructure.

The Logistics Performance Index (LPI)² supports the general statement that the logistics sector is under-performing in eastern Adriatic countries. However, from the following table we can see, that the improvements have been done in all the analysed countries, but still these countries are lagging far behind majority of European countries.

<table>
<thead>
<tr>
<th>TABLE IV. Selected elements of LPI for Eastern Adriatic countries</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2018</strong></td>
</tr>
<tr>
<td>LPI</td>
</tr>
<tr>
<td>Rank Score</td>
</tr>
<tr>
<td>Bosnia and Herzegovina</td>
</tr>
<tr>
<td>Croatia</td>
</tr>
<tr>
<td>Montenegro</td>
</tr>
<tr>
<td>Serbia</td>
</tr>
<tr>
<td>Slovenia</td>
</tr>
<tr>
<td><strong>2010</strong></td>
</tr>
<tr>
<td>LPI</td>
</tr>
<tr>
<td>Rank Score</td>
</tr>
<tr>
<td>Bosnia and Herzegovina</td>
</tr>
<tr>
<td>Croatia</td>
</tr>
<tr>
<td>Montenegro</td>
</tr>
<tr>
<td>Serbia</td>
</tr>
<tr>
<td>Slovenia</td>
</tr>
</tbody>
</table>

Note: shaded in grey are the elements that have been marked and ranked worse in 2018 than in 2010 Source: [42]

EU has been long planning the introduction of user-pays and polluter pays principle to assure fair intermodal competition. If this occurs before the countries of eastern Adriatic manage to setup their transport infrastructure in adequate manner, it could mean that the region could be left out of global freight flows. Consequently, this would affect social and economic condition in the region as well.

V. CONCLUSIONS

EU has strong focus on developing intermodal transport. Different strategies and approaches are undertaken by the EU, where the modernisation of railway infrastructure and service standardisation has a

² LPI is a benchmarking tool created to help countries identify the challenges and opportunities they face in their performance on trade logistics. The LPI in composed of 6 elements, namely infrastructure (quality of related infrastructure), customs (efficiency of process), international shipments (possibilities of arranging competitively priced shipments), logistics competence (competence and quality of logistics services), tracking and tracing (ability to follow consignments in real-time) and timeliness (possibilities that shipments reach destinations within the scheduled time). LPI is based on a worldwide survey of operators on the ground (global freight forwarders and express carriers), providing feedback on the logistics “friendliness” of the countries in which they operate and those with which they trade (WB, 2019).
special priority. The analysis shows that western EU markets have better infrastructural basis and achieve higher share of intermodal transport. The development of the railway infrastructure is necessary in the eastern Adriatic countries to develop complex transport chains and increase the value of intermodal transport. Such an approach is necessary also to disburden congested roads and to provide safer and environmentally friendlier transport. These countries have lower GDP per capita and are primarily import oriented economies, thus the development of intermodal transport depends on the future concentration of goods flows. In any case, if these countries want to make economic progress on account of transport, they must be more pro-active and create scenarios for their transport development together with their neighbouring countries as especially rail and intermodal transport. The Slovenian development of intermodal nodes (especially Port of Koper), of infrastructure modernisation and attraction of transit freight flows can be a regional case for faster development of southern Balkan markets. The entire region should:

- analyse past cargo flows, determine the elements for future cargo flows and predict those flows in a scientifically sound manner;
- analyse the state of transport infrastructure, define necessary investments in particular to rail and maritime and dry-dock terminal infrastructure;
- analyse financial possibilities and determine construction/modernization dynamics;
- analyse the competitiveness of intermodal transport compared to unimodal road transport;
- analyse different positioning, functions and capacities of intermodal terminals.

The elaborated strategy would intensify the drawing of European funds for transport infrastructure modernisation. Once the infrastructure is constructed and intermodal terminals are built it would be necessary to develop interoperable data and information sharing system, which would support dynamic definition of route, train capacity, departure timing and frequency of service and thus affect the attractiveness and reliability of intermodal transport. This could have impacts on greater foreign investments regionally and establishment of new production points. Undoubtedly, the question still remains – what should be developed first; the goods flow and foreign investments in new production to build intermodal network or vice versa.

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REFERENCES


Intermodal Network Development in Eastern Adriatic Region

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ABSTRACT

The research analyses actual state of the intermodal network in eastern Adriatic region, with special emphasis on the hinterland railway network in Montenegro. The aim of the study is on highlighting the orientation of EU towards intermodal network development and exposing differences and good practices in rail infrastructure development between three eastern Adriatic countries Slovenia, Croatia and Montenegro. Consequently, national railway Network Statements were analysed and compared, with special focus on connection port-railway. On this basis, the research contributes to the overview of differences between intermodal transport basis in western and south-east Balkan region. The cognitions can be used for faster and appropriate development of intermodal transport in southern Adriatic region that should serve central Balkan market as the shortest transport route in the future. Finally, the research exposes actual situation of the Port of Bar regarding deployment of multimodal rail-sea transport as regional intermodal node.

Keywords: intermodal transport, Port of Bar, port-railway connection & network statement

I. INTRODUCTION

Rising environmental problems, increasing fuel price and congestion along some road networks urge freight transport operators to seek for alternatives. Besides, an integrated multimodal transport network is a key prerequisite for seaports in terms of running smoothly their business, both nationally and internationally [1].

Integrated multimodal transport is conceived to ensure more efficient transportation in terms of financial, environmental and time aspects. Multimodal transport optimally sublimates the advantages of each mode of transportation, including high flexibility of road transport, large capacity of railways and low costs of short and/or deep-sea transport. In addition to road transport, which plays predominant role in the freight transport in some European countries, several alternative modes of transport, such as rail, inland waterway and short and/or deep-sea shipping are accepted as being less damaging to the environment in respect to CO₂ emission and green house impacts [2,3]. The European Union (EU) Commission advocates numerous measures aimed at developing European transport system composed of different modes of transport, supporting in such manner usage of multimodal transport in greater extent [4].

Multimodal transport means transportation of goods by two or more different modes of transport (road, rail, air, inland waterway, short- and/or deep-sea shipping) as part of the contract where usually multimodal transport operator is responsible for fulfilment of the requirements contained in the haulage contract from departure to arrival point [5]. The shipment of goods could be within one country or international and it can include additional procedures like good clearance at customs, etc. Instead of multimodal transport, terms such as intermodal, co-modal and synchromodal transport are sometimes used. Apart from this, there are fine differences between those terms; multimodal is considered as a type of transportation which uses at least two different modes of transport; intermodal can be seen as a particular type of multimodal transport that uses the same loading unit (e.g., a TEU or FEU container), co-modal means the efficient use of different modes, while synchromodal emphasizes the real-time dimension of the transport.
The study highlights the aspect of railway network support for the development of the port activities as intermodal node, with a special emphasis on the market of Montenegro. Consequently, national rail network is analysed and compared with infrastructure of two young EU members in Slovenia and Croatia. All three countries form the core intermodal network of the eastern Adriatic region. Moreover, the study exposes differences in rail infrastructure on one hand, and deficiencies in the railway Network Statement, that should be more representative and oriented to different stakeholder. On this basis, the interest for intermodal transport development might increase.

II. TEN-T: A “GLUE” BETWEEN PORTS AND RAILWAY NETWORK

Beginning in January 2014, the EU has a new transport infrastructure policy that should connect better its East and West, North and South parts. It aims to decrease the gaps between Member States’ transport networks, remove bottlenecks that prevent smooth functioning of common market, and win out technical barriers such as nonconforming standards for railway traffic. It supports and advances seamless transport chains for both passenger and freight, while taking into account the latest technological trends. These endeavours will ensure the economy recovery and grow, thanks to the budget of approximately 24.05 billion € up to 2020 [6].

The aim of Trans-European Transport Networks (TEN-T) project is to enable rail, road, air and sea transport to become key drivers not only for tighter integration among Member States and their peoples, but also for upring economic growth and competitiveness. The TEN-T contains two stratums: the “core network” that carries out the most important passenger and goods flows; and the “comprehensive network” conceived to provide access to the core network. The “core network corridors” has to enable the development of the core network.

In June 2015, WB6 Transport Ministers met with the EU Transport Commissioner at the TEN-T Days in Riga (Latvia), and conditionally specified three core network corridors to be extended for the Western Balkans along with the priority projects along sections of these corridors for potential funding. Enlarging the core network corridors to the Western Balkans ensures closer integration within Europe.

The core network corridors have to provide high quality transport services for citizens and businesses, with seamless integration within the regions and at the entire EU level. The priority projects should eliminate bottlenecks, strengthen interoperability, and develop missing cross-border connections [7].

The Bar-Belgrade railway at the territory of Montenegro is one of the Orient-East-Med corridor extensions. The works on the railway reconstruction has started at the end of 2015 and finished until the end of 2017. The partners from Montenegrin side were: Railway Infrastructure of Montenegro (“ŽICG AD Podgorica”) and Montenegro Ministry of Transport and Maritime Affairs.

The extension of the Orient-East-Med corridor into the Western Balkans along Route 4 is approximately 580 km long and runs from Vršac (Serbia – Romania border) to Belgrade and then to Podgorica and Bar. Bar – Vrbnica (at the Montenegro – Serbia border) is the most important section of the Montenegrin rail network, carrying about 20% of all passengers and about 60% of cargo (Fig. 1). Rail transportation is an important segment of the Montenegrin economy. The Bar – Vrbnica railway section is opened to traffic in 1976 and since then there has been no major repair of the signaling systems, nor of the 91 concrete bridges located on the route. With this investment project, signaling systems covering about 9 km of line are replaced in Podgorica, and about 5.3 km of bridges on the Vrbnica – Bar section have been renovated [8-10]. The advantages of this reconstruction can be summarized as follows:

- Increased security and efficiency of rail transport for around 750 000 passengers using the Bar – Vrbnica railway route on an annual basis;
- Enlarged passenger and cargo rail carrying capacities, along with average travelling time reduction;
- Reduced operational and maintenance expenditures for the railway operators, giving better services to passengers and cargo operators;
Enhanced interregional trade and integration, accompanied by a positive impact on the economy in the region;

- Intermodal transport development through Port of Bar (increased traffic of containers and finished vehicles in transit to the neighbouring countries);
- Reduction of CO₂ emission, and like.

It should be also pointed out that the EU advocates through its official politics a comprehensive, holistic approach to the integration of the regions into a single EU area. Thus, it does not focus solely on one type of industry, business, branch of the transport, or multimodal transport solely, but it should take care about employment policy, renewable energy resources, market expansion, environmental sustainability, etc. It seems a quite complex, long-lasting process, which requires active participation of all involved parties and stakeholders in the Western Balkans region and at wider EU level, too.

III. RAILWAY NETWORK SUPPORT AND PORT’S VISIBILITY IN THE RAILWAY NETWORK STATEMENTS

In aim to study the place and role of railway intermodal node at the Port of Bar, main railway infrastructural data that support port’s throughput development and how port is visible in the Montenegrin railway Network Statement (NS) have been analyzed. Moreover, the railway NS for Slovenia and Croatia with a goal to make the appropriate comparative analysis from the infrastructural point of view, as well from port’s visibility in the national Railway Statement, have been carefully analyzed.

In this regards, the infrastructural basis that support port’s orientation towards multimodal development where the rail transport is used, have firstly been analyzed and compared. Secondly, presence, or the space that has been given to the ports of Bar, Koper and Rijeka, respectively, in these NS has been considered. Some of the main findings are given below, including the recommendations for achieving greater level of harmonization between Port of Bar, from one side and ports of Koper and Rijeka from the other.

It is important to note in this context that Slovenia became the member state of EU on the 1st May 2004, and Croatia on the 1st July 2013. As a member states, these countries are more integrated into European freight corridors and can be used to a certain extent as models to Montenegro, if one bears in mind that...
Montenegrin official policy has been for a certain time oriented towards EU integration. Namely, increased demand for freight movement via southern European transport route imposes requirements for railway network modernization.

A. Montenegrin NS and network data
In accordance to the analysis of the last available railway NS of Montenegro [11] the railway network has following main characteristics:

- Total railway network length is 327.72 km (250.51 km as open line, 77.2 km station tracks).
- Entire railway line is single line that is limiting future cargo and passenger traffic development on a national level and especially in transit towards Port of Bar.
- 68% of railway line is electrified by monophased system 25kV 50Hz.
- Railway line category D4.
- Two border stations – Bijelo Polje with Republic of Serbia for passenger and cargo trains, and Tuzi with Albania for cargo trains only.
- 10% of railway line is electrified by monophased system 25kV 50Hz.
- railway category D4.
- Two border stations – Bijelo Polje with Republic of Serbia for passenger and cargo trains, and Tuzi with Albania for cargo trains only.
- Seven freight-handling places where parcels can be handled (Bijelo Polje, Mojkovac, Kolašin, Podgorica, Bar, Nikšić and Danilovgrad).
- Four marshaling yards: Bijelo Polje, Podgorica, Bar and Nikšić.

With focus on consideration of the (port) Bar rail station as important intermodal node in Montenegro, the following can be pointed out:

- (Port) Bar rail station is insufficiently present in the Statement;
- The marshalling yard in the Port of Bar should be described in some more detail in terms of capacities, services, etc.
- The Statement should include more information about the rail capacities and services in general, and in particular when it comes to the Port of Bar station;
- Telecommunication system should be described is more detail and it seems that the system itself requires updates;
- Contemporary ICT solutions should be adopted at both rail-seaport transportation key nodes, along with the solutions for tracking and tracing transportation flows and vehicles in real-time;
- The apps for smart phones and tablets should be available to inform the customers about the rail-port capacities, schedule of services, delays, prices, etc. in real-time;
- Advanced back-end tracking and tracing ICT systems should be developed and implemented, as well, and like.

B. Slovenian NS and network data
The Slovenian rail network is much more developed compared to Montenegrin and there are strong plans for further improvement and modernization. Key infrastructural data can be summarized as follows:

- Total railway line length 1,207.7 km, out of this 333.54 km are double track lines.
- 503.5 km of railway line or 42% is electrified (3 kV system), where 17 power supply stations are used.
- The main railway line is categorized as D3 line.
- All together 14 border crossing with Italy (2), Hungary (1), Austria (3) and Croatia (8) are used.
- Four main railway nodes (Divača, Koper, Ljubljana and Maribor) support rail transport on a national level.
- Maximum cargo train length is 700 m, but the line to Port of Koper is limited to 550 m train length.

In comparison with the NS Statement of Montenegro, it can be concluded that this Statement provides more detailed information about the freight stations, terminals, marshalling yards and train formation facilities regarding the (port) Koper rail station. Additionally, the Statement provides a detail review of
infrastructure development activities, including the (port) Koper freight rail station. It gives numerous clear graphical presentations of the railway system in Slovenia and surrounding countries. It is worth to mention the layout of the rail freight station Koper [12, p.25], which includes main port rail station and marshalling area. Similar data and graph should be very useful for the customers of the Montenegrin rail system, or train operators. Also, we would like to add that the Statement gives very detail descriptions of traffic control and communication systems [12, p.31-36]. Accordingly, it is to be pointed that Slovenia should be used as a model for Montenegro in terms of adopting and using up-to-date ICT solutions in both rail and sea-port activities. The technical design of the Statement is at the high level, and it is easily understandable to all stakeholders (customers and potential investors).

C. Croatian NS and network data
HŽ (Hrvatske Željeznice) manages railway infrastructure in Croatia. In total 2,605 km of railway line is in use in Croatia, representing more than double line length compared with Slovenia and eight times more compared to Montenegro. Main infrastructural characteristics of Croatian railway network are:

- Total railway line length 2,617 km, where 2,363 km are just with one track lines, meanwhile 254 km are double tracks line.
- 38% of railway line length is electrified (977 km with 25 kV, 50 Hz system and 3 km with 3 kV system).
- The main railway line is categorized as D3 line.
- The network has 19 border crossing, out of this 9 are with Slovenia, 3 with Hungary, 2 with Serbia and 5 with Bosnia and Herzegovina.
- 13 railway nodes are used for train shunting Čakovec, Karlovac, Koprivnica, Knin, Moravice, Ogulin, Osijek, Rijeka, Slavonski Brod, Solin, Vinkovci, Zagreb Ranžirni kolodvor and Zagreb Glavni kolodvor (just for passenger trains).
- Maximum cargo train length is 700 m, but the line to Port of Koper is limited to 550 m train length.

In comparison with the NS of Montenegro, it can be concluded that Croatian Statement provides some more information about the connected railway networks, signaling system, marshalling yards, train formation facilities, including shunting ones and other facilities, e.g., refueling stations. The Statement contains in appendixes many useful and precise graphical presentations [13] of types of lines, international loading gauges, weight limits, electrical system, types of traffic control, types of safety, types of telecommunication devices, etc. These can be considered as something what is of particular importance to the operators and the customers. The suggestion is to improve the following issue of Network Statement of Montenegro with similar drawings, which can provide a possibility of quick search and present the customers visually some relevant information. When it comes to the ICT system at Croatian rail-seaport system, it should be also considered as a model for improving the existing system of this type in Montenegro.

IV. DISCUSSION
The comparison of railway network between three analysed countries shows many differences in network design, technical parameters and capacities that can support intermodal transport development through intermodal node – national ports. The Montenegrin railway network is underdeveloped in comparison to Slovenia and Croatia, because just one-track line is available representing a limiting factor for future development of larger intermodal chains. Moreover, there are just two connections to the railway network of neighbouring countries and 4 marshalling terminals are giving little support to port’s activity presently.

The smaller importance of railway network in Montenegro is evident also through NS of Montenegro. The NS does not contain in-depth data presentation as Slovenian and Croatian NS do. It has to be pointed-out that Slovenia belongs to two EU rail corridors (Baltic-Adriatic and Mediterranean) and that Croatia belongs to the EU Mediterranean corridor. It is a big advantage to these countries in comparison
to Montenegro, and it seems that Montenegro as a country might look for the partners and cooperation in terms of rail and sea transportation rather towards the eastern Balkans, the neighbouring countries and eventually Hungary. In this regards plans of the Port of Bar management for developing cooperation with Romania, Serbia, and Hungary, are meaningful. Moreover, Port of Durres, Port of Piraeus and Port of Thessaloniki are already aggressively looking towards these markets, by operational and commercial improvement of infrastructure and rail services.

**TABLE I. APPROXIMATION OF THE EU INVESTMENTS IN SLOVENIAN, CROATIAN AND MONTENEGRIN TRANSPORTATION SYSTEMS (2007-2013) [18-21]**

<table>
<thead>
<tr>
<th>Country</th>
<th>Slovenia</th>
<th>Croatia</th>
<th>Montenegro</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project / Source</td>
<td>Allocation of EU funding</td>
<td>Allocation of EU funding</td>
<td>Trans-Balkan Electricity Corridor</td>
</tr>
<tr>
<td></td>
<td>for transport (mil €):</td>
<td>for transport (mil €):</td>
<td>(I): Grid Section in Montenegro</td>
</tr>
<tr>
<td></td>
<td>960</td>
<td>229.5</td>
<td>28.5 (mil €) - 20% EU contribution</td>
</tr>
<tr>
<td></td>
<td>Trans-European Transport</td>
<td>Trans-European Transport</td>
<td>Orient/East-Med Corridor (R4):</td>
</tr>
<tr>
<td></td>
<td>Network (mil €):</td>
<td>Network (mil €):</td>
<td>Montenegro-Serbia Rail Interconnec-</td>
</tr>
<tr>
<td></td>
<td>2 898</td>
<td>30</td>
<td>tion</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>21 (mil €) - 20% EU contribution</td>
</tr>
<tr>
<td>Total</td>
<td>(mil €): 3 858</td>
<td>(mil €): 259.5</td>
<td>(mil €): 9.9</td>
</tr>
</tbody>
</table>

Slovenian Port of Koper and Croatian Port of Rijeka are on the Baltic-Adriatic (Koper) and Mediterranean (Koper and Rijeka) corridors. This gives them great competitive advantages in comparison to the Montenegrin Port of Bar, which does not belong to any core transportation corridors in EU. It means that EU has provided more funds to the ports which belong to these two important EU corridors, than to Montenegro which does not belong to any of them (Table I.). Also, Port of Koper and Port of Rijeka belong to NAPA and they can acquire some project funds through it [14-17], as well.

**V. CONCLUSIONS**

The paper though considers the barriers and perspectives in terms of developing rail-port transportation in Montenegro. The focus has been put on the TEN-T strategy for developing unique transport system in the EU including Western Balkans countries and Montenegro. Undoubtedly, EU secures much more funds for intermodal network improvement in Slovenia and Croatian (as EU members) than to Montenegro and neighbouring countries.

The railway network in Montenegro basis just on one track line and with just two connections to the railway network in the region. The total line length of 327.72 km represents 0.025 km of railway line per km² of national surface. Compared with Slovenia (0.06 km per km²) and Croatia (0.046 km per km²) the network density is two to three times lower. The railway connection to the port is also poor compared with infrastructure at Koper and Rijeka. These ports have dedicated marshalling yards that support port’s intermodal activities. The visibility of port-railway network connection in NS is also at lower level in Montenegrin NS. It should be better elaborated in the future.

It has to be pointed out that the Port of Bar development strategy is pro-rail oriented, but currently both rail and seaport existing capacities are not fully used. In general, the following can be concluded:

- The rail network Bar-Belgrade in the hinterland of the Port of Bar is in a state that requires further modernisation. Some activities are accomplished, and some are planned;
- The construction of multimodal terminals is planned, since at the present moment, there is only a marshalling yard as a link between the port and railroad. There is no multimodal terminal;
- The existing port and rail capacities are not fully used, but the increase of demand is expected at the market of port-rail services, after the completion of the major infrastructure (port-rail) reconstruction works;
The management of the Port of Bar has some plans to intensify its business activates primarily towards the Romania, i.e. Black Sea region market, then towards Serbia, Hungary, etc.;

According to the city of Bar Urban Plan, a surface of 350 hectares is dedicated to the development of the Port of Bar in the future, as well.

Although in the better position than Montenegro, Slovenia and Croatia are below the average EU level in term of the quality of railroad and seaport infrastructure and related services, due to the EU official statistical indicators. This should be used a signal for immediate and effective action towards achieving improvements in this indeed important sector for positive economical and socio-cultural transformations and development of Montenegro and the whole east coast of the Adriatic Sea in the future.

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Problems of Small Container Ports – Case Study of The Slovenian And Montenegro Ports

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ABSTRACT

The article deals with a very current topic; the impact of increasing the size of container ships on the operation and optimization of medium and small ports. Over the past two decades, the size of container ships has steadily increased and today exceeds 21,000 TEU capacities. Although such ships are intended to call at large world ports, they also have a major impact on the operations of smaller ports; such are those in the Adriatic. In so far, as they want to become competitive and interesting for the ship-owners, they have to follow the trends and be able to receive ever larger ships, which can reach up to 14,000 TEUs. In this context, ports have the biggest problem on the sea side of the terminal, that is, on the berth, as they have to provide deeper water, longer quays and cranes with greater outreach and height to allow for more containers across and higher stacks on deck.

The article points out the measures that the port of Koper has been facing in this area from 2009, when the first phase of optimization was carried out at the container terminal, which enabled the acceptance of ships with over 5,000 TEUs capacity and thus the acquisition of direct services with the Far East and further measures, which now enable to accommodate vessels of up to 14,000 TEU. Special emphasis is given to the container terminal in the port of Bar and the optimization measures that will have to be carried out in the next future in order to be able to accept larger ships and increase their competitiveness.

KEYWORDS: container ships, container terminal optimization, berth operations, Port of Koper & Port of Bar

I. INTRODUCTION

Container transport, as is widely known, increased drastically on the global scale over the last ten years. The total weight of cargo transported by container vessels surpassed 1.7 million tons in 2017. At the same time all container ports handled 752 mil. TEU that represents 55% increase from the year 2007 [9; 10]. Rapidly growing international trade and increased demand for container transport have led ship-owners to build ever larger container ships to enable them to operate with lower transport costs. In 2017 the largest container ship exceeded 21,000 TEU capacities. Although those ships are only used on the Far East-North Europe trade route they are causing a cascading effect, meaning that ships which have become redundant because of the very large new vessels are deployed in other trade lanes. For these reason the average container vessel on the Far East-Med trade lane increased by 79% in size over 2007-2014 with consequences also in the Adriatic Sea where the average vessel size growth up to 8,000 TEU [4]. This represents a significant problem for the medium and small ports in the area that face demands to accommodate larger Post-Panamax ships which have a length of approximately 300 meters, a beam of 43 meters and required a draft up to 14 meters [4]. Their existing capacities are often not sufficient for accepting such ships, yet at the same time ship-owners demand facilitation of rapid transshipment and reduced costs in the ports. In these new conditions, ports need to optimize their existing terminal capacities, modernize their facilities and include new technologies if they want to increase the throughput level which would enable them to acquire new services.

The Adriatic ports have in last decade become more and more important due to its favorable location (they offer the shortest route from Asia through the Suez Canal towards the countries of central and Eastern Europe), which influenced ship-owners to establish direct services with those ports [8]. This has caused an increase of container traffic flows but consequently also competition between port in the next proximity and those who share similar gravitational area. As a result of increasing competition between container ports, improving the capacity and the efficiency in container terminals has become an important and immediate challenge for all managers in order to gain higher competitiveness [13].
The problem of accommodating larger ships is common to all Adriatic ports. The paper points out that issues at the container terminal in the port of Koper, which is the leading container port in the North Adriatic region, with a throughput of 988,501 TEU in 2018, and the container terminal in the port of Bar with a throughput of approximately 43,000 TEU in last years. Ports vary greatly in terms of size and concept and are incomparable according to certain parameters; nevertheless, in some cases their problems are very similar.

II. THE INFLUENCE OF LARGE CONTAINER SHIPS ON TERMINAL OPERATIONS

Container terminals generally serve as a transshipment between ships and land vehicles (trains or trucks) [6]. Ship operation usually begins with the ship's arrival at the port area. After berthing, the ship-berth link handling operation begins with preparing the ship for loading/unloading and with the assignment of the proper number of quay cranes to the ship [2]. Processes of the operations of the berth subsystem, as well as of two other subsystems of the terminal (yard and handover area) have been detailed by [11], [5] and others.

The berth subsystem represents the most important part of the container terminal, since the number and size of ships that will arrive at the terminal depend on the capacity of the factors on this subsystem [3]. The main three factors defining the ship's entry capability are the depth of the sea, berth length and the number and size of quay cranes. Beside the infrastructure parts also the productivity level at the subsystem is of crucial importance when it comes to big ships. The most important measurements to take in account are ship productivity¹, quay productivity² and quay crane productivity³. Those can have a significant impact on turnaround time of the ship in a container terminal. The turnaround time includes berthing, unloading, loading and departure processes [12].

¹ Ship productivity: number of moves according to ship's working hours.
² Quay productivity: number of moves per quay meter per year.
³ Quay crane productivity: number of moves per crane per working time.
As larger ships require from ports sufficient terminal capacity and high operational efficiency both at sea and on the land side, ports are forced in continuous adjustments of their capacities. Larger ports were made for big ships in the first place, so they will not have so many problems, but medium and small ports are in a completely different position. The size of the ships that ship-owners are deploying in routes calling those ports is increasing on yearly level. This represents a significant problem as their existing capacities are often not sufficient for accepting such ships as the Post-Panamax category (>6,000 TEU). Ports have therefore two options, to focus on the optimization of their existing terminal capacities in order to gain competitiveness and follow the trends, or simply decide to focus their business “only” to regional and feeder services, which will on long term mean a decrease in traffic.

The port of Koper found itself in front of such decision approximately fifteen years ago, and decided to invest founds in terminal optimization. The investments have been going on since 2005 and will be further explained in the section 3. On the other hand, the port of Bar has, in this sense, today exactly the same problems as Koper had years ago. It is therefore crucial for ports to have a long-term investment plan that will allow the development of the terminal and the survival among the competitive ports. Nevertheless; sometimes even the required capacities at the berth subsystem aren’t sufficient to accommodate larger ships as the bottlenecks appeared at the yard area and with the connections to the hinterland. The latter is today the weakest point of all Adriatic ports.

Table 1 shows the requirements that ships of different sizes have on the berth subsystem and the possibility of receiving them in the ports of Koper and Bar.

<table>
<thead>
<tr>
<th>Ship capacity (TEU)</th>
<th>Sea depth (m)</th>
<th>Berth length (m)</th>
<th>Quay cranes (Type)</th>
<th>Koper CT</th>
<th>Bar CT</th>
</tr>
</thead>
<tbody>
<tr>
<td>20,000</td>
<td>16</td>
<td>450</td>
<td>SPP</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>14,000</td>
<td>14.5</td>
<td>400</td>
<td>SPP</td>
<td>✓</td>
<td>x</td>
</tr>
<tr>
<td>8,000</td>
<td>14.5</td>
<td>350</td>
<td>PP</td>
<td>✓</td>
<td>x</td>
</tr>
<tr>
<td>5,000</td>
<td>12</td>
<td>330</td>
<td>PP</td>
<td>✓</td>
<td>x</td>
</tr>
<tr>
<td>3,000</td>
<td>12</td>
<td>300</td>
<td>P</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>1,500</td>
<td>10</td>
<td>260</td>
<td>P</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

*Type of Quay cranes: SPP (Super Post-Panamax), PP (Post-Panamax), P (Panamax)

The port of Koper with its current capacities, which are the result of a long time investments is able to receive at the berth ships up to 14,000 TEUs, while the port of Bar is limited to feeder services up to 3,000 TEUs. The biggest problem for not being able to accept Panamax ships are currently a shallow draft in certain parts of the quay and the lack of appropriate quay cranes.

III. THE PORT OF KOPER THROUGH THE OPTIMIZATION PHASES

The port of Koper is located in the northern Adriatic and is currently the largest container port in the area. As the majority of containerized cargo handled at the port of Koper is destined for the European market (northern Italy, the western Balkans, as well as countries of central and Eastern Europe), the port can be characterized as an origin-destination port [7]. Its location on the European TEN-T Adriatic Baltic and Mediterranean Corridor has made the port quite attractive and has significantly influenced the increase of its traffic. In 2018 its throughput amounted to 988,501 TEU, which represents a 179.3% increase over the last ten years. In 2019 its throughput is expecting to exceed 1 million TEUs.

The fast arise of the port began in the middle 2000 when port authority realize that the capacity of the terminal has become insufficient to satisfy liner operator’s requests to call the port with larger ships. The proximity of the ports of Trieste and Rijeka also represented a threat to eventually lose cargo. The only possible decision was therefore to invest in modernisation of the existing capacities. At the time the quay length was limited to 300 meters and four Panamax cranes served ships, while draft reached 12.5 meters, enabling regional and feeder services. The evolution of the terminal was carried out in three phases.
The first optimization phase started with the quay extension to 450 meters, enabling the terminal to receive ships up to 5,000 TEUs. At that time this made possible to acquire new deep sea services with Far East, which importantly raised the terminal throughput. After that, in 2008 the quay has been extended for additional 150 meters and four Post Panamax cranes were purchased. This was the most important step to a further evolution as enabled the terminal to serve a Post Panamax (<8,000 TEU) and a feeder ship simultaneously. In 2009 there were 642 ships ranging from 100 to 300 meters in size and 4 to 16 containers in width in terms of capacity that entered the container terminal. In 2010 (after the crucial year for the economic crisis) the terminal reached a throughput of 476,731 TEU, meaning an increase of 38.9%.

As the container terminal traffic continued to grow in the following years the second optimization phase took place. In 2014 a deepening of the draft to 14.5 meters were carried on, while in 2017 two Super Post Panamax cranes were purchased. This made possible to serve ships up to 14,000 TEUs and increase the traffic to 911,528 TEU. Due to a large number of transshipped containers, additional space for empty container storage were provided and new yard mechanization (7 RTG and 3 RMG) for the full container yard area were purchased.

The main objective of the terminal in the next future is to improve its capacity for the reception of two Post Panamax ships at the same time. The work will be part of the third optimization phase starting approximately in 2020 and will include a further quay extension, new quay cranes and new yard capacities. The future configuration is shown in Fig. 3.

![The third optimization phase of the Koper CT](image)

After the works the terminal capacity is supposed to rise to 1.3 million TEU per year. Nevertheless, in addition to optimizing the berth and storage area, special care will be needed at the handover area. Due to the large amount of containers that will arrive with two Post Panamax ships, that area will almost certainly be related to congestion. The construction of the second railway track will therefore became a necessity in order to avoid bottlenecks on the land side of the terminal.

IV. DEVELOPMENT CHALLENGES FOR THE PORT OF BAR

The port of Bar is a small Adriatic container port, with a current throughput capacity of 50,000 TEU. However, due to a lack of hinterland investment and infrastructural upgrades in recent years, the port is not being utilised to its full potential. From 2013 a 64% of the terminal is owned by Turkish Operator Global Port Holding, which plans to attract more traffic from Serbia, Bulgaria, Kosovo, Macedonia and Albania and make the port more competitive.

Over the last two decades the terminal has had considerable fluctuations in container throughput. In 2000 it amounted to only 9,665 TEU, while in the coming years the traffic has steadily increased, until reaching its highest throughput ever 43,708 TEU in 2008 (+352.2%). Later the traffic ranged from 30,000 to 40,000 TEUs, to again reach approximately 42,000 TEUs in 2016.
The terminal business is currently based only on feeder services, as its capacity does not allow the acceptance of larger vessels. Nevertheless, in recent years, several ship-owners (Maersk, MSC, Hapag and CMA CGM) have chosen a port for part of their service, which indicates an increase in interest. The biggest port competitors are represented by the nearby ports that share the same gravitational area; the port of Ploce, which for the moment achieves lower traffic and the port of Durres, which has in 2017 increased its transshipment to approximately 120,000 TEUs.

The current berth capacities in the Bar container terminal are limited to 330 meters of quay length and 10-12 meters of draft, while the ships are being served by one Panamax crane. However, the terminal has a quite large storage surface which would enable the reception of much more cargo.

With such characteristics in sea depth and berth length the terminal is actually already capable to accommodate Panamax ships (<5,000 TEU), however the other capacities of the terminal, with the exception of the storage, are only sufficient for the reception of feeder ships. Insofar as the terminal would be compared with the development phases of the port of Koper, Bar would currently be in its first stage of development.

The first optimization step of the port will therefore have to be on the berth subsystem (purchase of new Panamax cranes) which will allow the smooth reception of Panamax ships, and then higher goals would be possible. In the second phase all three subsystems of the terminal would have to be optimized in order to be able to accommodate one Panamax and one feeder ship simultaneously. For that purpose, the berth would have to be extended for 200 meters and one or two Panamax crane would have to be purchased. In addition, new yard mechanization would become a necessity.

In case the port operators would in the future want to make even a bigger leap on ships exceeding 5,000 TEU capacities, this would require the third optimization phase with deeper draft and purchase of Post Panamax cranes. Nevertheless, this kind of investment in such a small terminal is not expected in the near future. However even a small improvement of the terminal (which would enable the reception of Panamax ships), would bring significant growth. The possible throughput increase would therefore be between 25,000-50,000 TEU at the annual level (depending on the amount of weekly movements), which would greatly improve the ports position among its competitors.

Despite all the improvements on the berth and yard area, there is a high probability that the terminal would have to improve its connections with the hinterland. Today the port land connections consist only of a single railway track and a regional road, which means that there exists a risk of congestion. The first step would be a new highway connection. Existing storage capacities would be sufficient for the first two phases of development.
V. CONCLUSION

Due to the increase of ship size, ports often find themselves in difficult position, as they do not have adequate capacities for the reception and efficient transhipment of those ships. In case of large ships, not only infrastructure facilities that allow ships to enter the ports are important, but also the equipment and working methods that enable the efficiency of the operations and thus the rapid turn-around time of the ship in a port. In that sense, medium and small ports have most problems, as their capacities were not intended for large ships at the time of construction, while ship-owners are constantly increasing the size of ships on services due to the cascading effect.

As an example of good practice, in how a terminal with 350,000 TEU of annual throughput in just ten years became a million TEU throughput terminal is the port of Koper. In spite of the current high traffic, the number of containers is willing to growth in next years, so further investment plans that will allow the terminal to raise its capacity to 1.3 million TEU have been made. The container terminal in the port of Koper can therefore serve as a role model for other small ports. In particular, the port of Bar, which is currently in a position when it has to decide in which way to go; to remain “just” a feeder port (that means loose cargo and market position in the future) or to opt for the first phase of development and invest in berth capacity in the first place, and later also in other terminal subsystems.

With the first development phase, it would be possible to reach the capacities which, in addition to the feeder services, enable the acquisition of regional services with ships of up to 5,000 TEUs. In this way their annual throughput would increase considerably, while the second development phase would allow the simultaneous reception of both Panamax and feeder ships. An important role, however, should be given to the land connection of the port, which would play a key role in transferring such quantities of containerized cargo to the hinterland countries. In making that, the competitive position of the port would increase in comparison with the adjacent port of Ploce, and it would also be considerably improved compared to the port of Durres, which is currently the leading port in this part of the Adriatic.

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Review of Nautical Tourism Port Business in Croatia

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ABSTRACT
Nautical tourism ports are one of the main indicators of development and prosperity of nautical tourism. It is considered that nautical tourism industry as a segment of Croatian strategic economic orientation significantly participates in the national economy. Creating benefits to both regional and local communities the need arises to analyse nautical tourism port business trends to identify comparative advantages, examine competitiveness and indicate development perspectives of the prosperous industry. The paper indicates the discrepancies in achieving profitability considering the use of available resources in the provision of nautical tourism services. The development perspectives should be accompanied with adoption and increase in quality and value for money of products and services of demanding users. It requires infrastructural investments, especially providing the possibility to accommodate to the growing demand in the superyacht category and redefinition of price policy in order to maintain competitiveness and achieve sustainability.

KEYWORDS: nautical tourism, nautical tourism ports, port business & Croatia

I. INTRODUCTION
Indicated as one of the perspective industries for the Republic of Croatia, the nautical tourism industry has still not accomplished the expected levels of profitability despite possessing exceptional natural resources, often indicated as one of the few Croatia’s competitive advantages on the global level [1]. The main discrepancies in achieving sustainable and desirable economic impact are often related to spatial planning of nautical tourism ports [2], their accommodation capacity [3] and implementation of the strategic goals indicated in the Nautical tourism development strategy of the Republic of Croatia for the period 2009–2019 [4]. Firstly, the spatial distribution of the nautical tourism ports and the use of coastal resources are indicators of tourism development and a prerequisite of sustainable growth. The key strategic objectives of building and distribution of nautical tourism ports should follow Strategy indicators of planned construction of berths, allocated along the Croatian coast and islands. The analysis of capacity of nautical tourism ports, classified by the type of services provided, in a five year period shows slight increase in marina category, characterized as a main accelerator of nautical tourism, along with the accompanying services, with uneven distribution of the ports along the coast where, often, the price of the berth increases in the counties having lower share of total berths in the supply segment [5]. These elements can become a main issue for the future development indicated in the Strategy vision, despite the overall rise in turnover of nautical tourism ports over the examined period [1]. Consequently, Croatia possesses only a small scale of amount of average berths and length of the coast in the Mediterranean, leaving the comparative advantages unexploited. On the other hand, the current vessel-receiving infrastructure facilities are unable to accommodate the growing trend of nautical tourism demand for berths, especially when receiving mega yacht category, which has a consequential implications on the generated revenue [2]. Finally, the development of the growing tourism sector should correspond to the prescribed strategic development indicators especially those intended to increase the infrastructural activities in nautical tourism ports, simplify administrative procedures and aligning legislation to become more suitable and easier for future investors, investment of resources for nautical tourism services, repair and service centres and value for money of the overall user services and those affecting the preservation of the environment [4]. The Republic of Croatia should exploit the comparative advantages of intended coast, weather and sailing conditions proportionally with the sustainable development of nautical tourism ports, which became highly dynamic and demanding, and the demand factor of the users in the industry [5]. Therefore, the future development of nautical tourism ports and nautical tourism in general should correspond with revised strategic objectives from the Strategy due to the change in
trends and nautical tourism activities and application of the measures for the increase of nautical tourism port revenue and profitability.

II. SIGNIFICANCE OF CROATIAN NAUTICAL TOURISM

The importance of nautical tourism and its contribution to the local Croatian economy has been an interest of different authors and research. On the EU level, European Commission identified nautical tourism as a subset of coastal and maritime tourism having the significant importance for the growth of the Blue Economy within the Communication on the Blue Growth [6]. The significance of the industry among other tourism segments is manifested though high and intense multiplicative effect, lower seasonality and investments and faster return of the invested capital [7]. Numerous authors indicated a strong and rapid expansion of nautical tourism in the last decade in Croatia [1, 2, 3, 5, 8] for the most part as a consequence of location-given resources of natural beauties, favourable climate and sailing conditions, intended coast, numerous islands and other natural features, which became a main Croatian comparative advantages among its competitors but also the users in the industry. However, the same authors also pointed out the importance of level of complementary infrastructural investments in nautical tourism as a development indicator of economic activities. Within nautical tourism, nautical tourism ports represent a development factor [7] especially for the coastal areas and islands as a source of prosperity [8], otherwise having limited economic activities. Two Ordinances on the Classification and Categorisation of Nautical Ports [9,10] define and categorize ports of nautical tourism in Croatia, where the marina category predominates the total revenue generated, primarily derived from their core activity of providing berth rent along with related services and supply chains, acting as an economic catalyst in local and regional economic development [6]. The importance of marina business for the economic and social development of local and regional community is mainly manifested through revenue generated and job creation, where according to the experts in the industry, it is estimated that for every direct job in the marina, nine indirect jobs are created, for each 100 berths, 44 direct and indirect jobs are created, every five euros in revenue earned in the marina generate five new revenues in the nearby indirect activities, and 100 berths in the marina bring around two million euros a year in direct and indirect jobs [11]. The strategic goals of the Nautical tourism development strategy of the Republic of Croatia for the period 2009–2019 laid the foundation for the industry development in order to succeed the desired vision of becoming the leader in the Mediterranean [4], where the capacity increase was highlighted as an indispensable component for the future economic growth.

III. PROBLEM DEFINITION

Having almost one-quarter of the European coastline of the Mediterranean [2], Croatia generates only 9.7% share of overall Mediterranean capacity [1], where the remaining European Mediterranean coastal countries account for 90 per cent of the overall capacity and vessels. Also, due to the length of the coastline, Croatia has 2.6 nautical berths per kilometre, where the share of the coastline length is twice the share of number of berths [4]. Such constellations neglect the Croatian comparative advantages and points the current potential constraining factors of expansion. Firstly, it indicates the insufficiently exploited natural resources which proportionally questions the management of coastal resources as a lack of infrastructural capacities of nautical tourism ports and berths. Table I. shows a five year trend in number of nautical tourism ports categorized as anchorage, mooring, marinas and uncategorized ports.

| TABLE I. NAUTICAL TOURISM PORTS IN THE REPUBLIC OF CROATIA FROM 2013 TO 2017 |
|----------------------------------|--------|--------|--------|--------|
| YEAR                            | 2013   | 2014   | 2015   | 2016   | 2017   |
| TOTAL                           | 106    | 112    | 121    | 139    | 140    |
| Anchorage                       | 22     | 27     | 38     | 58     | 61     |
| Mooring                         | 13     | 10     | 10     | 7      | 6      |
| Marinas                         | 67     | 72     | 70     | 71     | 70     |
| Uncategorized nautical ports    | 4      | 3      | 3      | 3      | 3      |

Source: [12, 13, 14, 15, 16]
The data form the table shows a slight increase in number of marinas in a five year period, which in overall perspective can be characterized as negligible, as the only significant increase was recorded in the number of anchorages, often identified as the most underdeveloped form of nautical tourism. The mentioned ascertainment can also be associated with stagnation in the number of nautical berths and building of new berths and with inconsistency in the strategy which indicated the increase in capacity as an important strategic goal for the future development of the industry predicting the construction of 15,000 berths in a ten year period. The overall number of berths in Croatian nautical tourism ports are presented in Table II.

**TABLE II. NUMBER OF SEA BERTHS AND BERTHS FOR LAND STORAGE IN CROATIA FOR PERIOD 2009-2017**

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>NUMBER OF SEA BERTHS</td>
<td>16,848</td>
<td>16,913</td>
<td>17,059</td>
<td>17,454</td>
<td>16,940</td>
<td>17,221</td>
<td>17,351</td>
<td>17,428</td>
<td>17,067</td>
</tr>
<tr>
<td>NUMBER OF BERTHS FOR LAND STORAGE</td>
<td>5,209</td>
<td>5,125</td>
<td>5,231</td>
<td>5,359</td>
<td>5,473</td>
<td>5,375</td>
<td>5,105</td>
<td>4,880</td>
<td>4,610</td>
</tr>
</tbody>
</table>

Source: [12, 13, 14, 15, 16, 17, 18, 19, 20]

The provided results expose the discrepancy between the predicted action plan of management of nautical capacities from the strategy and current capacities, where the number of land storage berths was reduced while the number of sea berth stagnated for the specific period.

Another important element is the spatial planning of marinas with related number of berths which should secure the balance between ecological and natural aspect with construction of infrastructural facilities within the boundaries of sustainable growth [2], where the spatial plan is the fundamental document in determining the site of construction of nautical tourism port [21]. Marinas along the Croatian coast are unevenly dispersed [2, 8], and the number of berths varies depending on the individual county or area. Also, the attractiveness of an area and consumer preferences and demand is not supported by the number of berths. Table III. shows segmentation in capacity of sea berths and berths for land storage according to the specific Croatian county in 2017, with specific share within the overall number of two categories of berths and berth projection scenarios.

**TABLE III. THE CAPACITY OF SEA BERTHS AND BERTHS FOR LAND STORAGE SPECIFIC SHARE WITHIN THE OVERALL NUMBER OF TWO CATEGORIES OF BERTHS IN 2017 AND BERTH PROJECTION SCENARIOS**

<table>
<thead>
<tr>
<th></th>
<th>2017.</th>
<th>DIFFERENCE (%)</th>
<th>Intensive development scenario</th>
<th>Moderate development scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. sea berths</td>
<td>No. berths for land storage</td>
<td>Overall / individual county sea berths</td>
<td>Overall / individual county berths for land storage</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Overall increase (sea berths + berths for land storage)</td>
<td>Overall increase ( 2/3 sea berth; 1/3 berths for land storage)</td>
</tr>
<tr>
<td>Primorsko-goranska county</td>
<td>2,870</td>
<td>1,398</td>
<td>16.8%</td>
<td>30.3%</td>
</tr>
<tr>
<td>Zadarska county</td>
<td>4,110</td>
<td>871</td>
<td>24.1%</td>
<td>18.9%</td>
</tr>
<tr>
<td>Šibensko-kninska county</td>
<td>3,662</td>
<td>830</td>
<td>21.5%</td>
<td>18.0%</td>
</tr>
<tr>
<td>Splitsko-dalmatinska county</td>
<td>2,414</td>
<td>593</td>
<td>14.1%</td>
<td>12.9%</td>
</tr>
<tr>
<td>Istarska county</td>
<td>3,084</td>
<td>712</td>
<td>18.1%</td>
<td>15.4%</td>
</tr>
<tr>
<td>Dubrovačko-neretvanska county</td>
<td>927</td>
<td>206</td>
<td>5.4%</td>
<td>4.5%</td>
</tr>
<tr>
<td>Ličko-senjska county</td>
<td>/</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
</tbody>
</table>

Source: [4, 16]
The share of sea and berths for land storage of individual counties within the overall berth amount in Croatia shows high variations in the distribution of berths along the Croatian coast, which is in collision with the increased demand for berths and attractiveness of destination, corresponding to the lack of berths. The capacity of county berths in 2017 shows inconsistency when compared to intensive development scenario, based on counties spatial plans berth projections until 2015 indicated in the strategy, where the evaluation and redefinition of the strategic goals, related to the construction of berths among counties are required. The strategy projected two development scenarios of nautical tourism, one intensive development scenario which was based on the counties spatial plans and included the construction of new reception facilities with a total of 33,655 berths and moderate development scenario which projected the increase in berth capacity for additional 15,000 vessels where 2/3 would be related to the increase of capacity for the sea berths and 1/3 to berth land storage, but both projections haven’t achieved the desired premises, on contrary the overall number of berth decreased in comparison with 2009.

The economic effects of nautical tourism are primarily visible in the income realised in nautical tourism ports, which recorded a steady increase in a ten year period and amounted to 855 million HRK or 115.5 million € in 2017 (Table IV.).

<table>
<thead>
<tr>
<th>TABLE IV. Nautical port revenues (in million HRK, excluding value added tax - VAT) according to the individual county</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primorsko-goranska county</td>
</tr>
<tr>
<td>Zadarska county</td>
</tr>
<tr>
<td>Šibensko-kninska county</td>
</tr>
<tr>
<td>Splitisko-dalmatinska county</td>
</tr>
<tr>
<td>Istarska county</td>
</tr>
<tr>
<td>Dubrovačko-neretvanska county</td>
</tr>
<tr>
<td>OVERALL</td>
</tr>
</tbody>
</table>

Source: [12, 13, 14, 15, 16, 17]

It should be emphasized the increase of realised income by each individual county in 2017, where only Istarska county recorded a decrease of 6.9% compared to 2016 [16]. The share of 70% of income, which noted an increase of 11.2% in 2017 compared to 2016 was realised by berths rental, divided on permanent and transit ones, as the highest income segment along the others such as the maintaining services and other income components (Table V.).

<table>
<thead>
<tr>
<th>TABLE V. Overall revenue according to the nautical port activities in 2016 and 2017 (in million HRK, excluding VAT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source: [16]</td>
</tr>
</tbody>
</table>

When analysing the economic effect of generated income of nautical ports on the strategic level, the discrepancy occurs in the nautical tourism ports income perspectives pursuant the strategic goals, presumed at the level of 15 billion HRK or around 2 billion € of income until 2019 [4], and the realised income at the end of year 2017. The achieved income represents only 5.7% of the value specified in the
strategy. The imbalance between achieved and intended revenues could be placed in correlation with low investments in building of new berths and ports with added value related services, or generally unfavourable investment environment, as the investments are crucial for further development of the intended vision of nautical tourism and revenue growth. The low investment activities are often indicated as a consequence of incompatible and inadequate legislative propositions and legal regulations [1], which are, especially in the segment of investments in construction of berths in the superyacht category, crucial for the development perspectives and intended increase of the overall market share of the industry in Croatia. The lack of berths and facilities for reception of mega yachts is continues difficulty for Croatia [2] where the users are compelled to deploy anchorages as their accommodation points [3]. The capacity of berths over 20 meters in Croatian nautical ports amounted solely to 725 berths in 2017 which was a decrease when comparing it to the recent period [16].

In order to evaluate the economic benefits of nautical tourism and simultaneously the trends in consumer preferences and demands, acting like beneficiaries in the industry, the Republic of Croatia finally continued with the Tomas Nautical survey in 2017, which was last conducted in 2012. The survey was performed as a primary research of Croatian Institute for Tourism concerning the attitudes and expenditures of yachtsmen in Croatia. The survey pointed out the fundamental and detail analysis of structure of nautical tourism demand [22, 23]. The comparison between two latest surveys on the level of satisfaction and expenditures of yachtsmen in Croatia and change in the characteristic of the nautical tourism demand are presented in table 6.

**Table VI. Comparison between Tomas Nautical survey in 2012 and 2017 on the change in main segments of nautical tourism demand in Croatia**

<table>
<thead>
<tr>
<th></th>
<th>Tomas Nautical survey 2012</th>
<th>Tomas Nautical survey 2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>The average daily yachtsmen consumption (€)</td>
<td>Overall</td>
<td>Charter</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>161</td>
</tr>
<tr>
<td>Degree of yachtsmen satisfaction</td>
<td>–</td>
<td>Growing satisfaction with all elements of nautical and tourist supply in 2017</td>
</tr>
<tr>
<td>Average number of overnight stays (days)</td>
<td>Overall</td>
<td>Charter</td>
</tr>
<tr>
<td></td>
<td>12.4</td>
<td>9</td>
</tr>
<tr>
<td>Average number of marina visit during the sail time</td>
<td>3 marinas</td>
<td>3 marinas</td>
</tr>
<tr>
<td>Most frequent sojourn</td>
<td>4 to 7 days</td>
<td>4 to 7 days</td>
</tr>
<tr>
<td>Crew size and composition</td>
<td>– 5 persons on charter boats and 4 people on their own boats (both in 2012 and 2017)</td>
<td>– Increasing use of hired skipper services in 2017</td>
</tr>
<tr>
<td>Frequency of tourist arrival in Croatia</td>
<td>Increase the share of nautical tourists on the first visit, from 11% in 2012 to 32% in 2017</td>
<td></td>
</tr>
<tr>
<td>Sociodemographic profile: age and education</td>
<td>Average age</td>
<td>Level of education</td>
</tr>
<tr>
<td></td>
<td>45</td>
<td>43% of university educated</td>
</tr>
<tr>
<td>Sociodemographic profile: monthly household income</td>
<td>49% of nautical tourist &gt; 3,500 €</td>
<td>56% of nautical tourist &gt; 3,500 €</td>
</tr>
</tbody>
</table>

Source: [22, 23]

The study follows the trends on demand for services in nautical tourism and identifies the characteristics of nautical demand in order to modify the current services to the increasing nautical tourists’ demands which are directly related to economic effects of nautical tourism.

**IV. Discussion**

The prerequisite of attractiveness of destination in performing nautical tourism activities is not conditioned only by the attractiveness of natural beauties but also by the level of infrastructure development
and quality of additional services, thus nautical ports. The potential development and growth of the industry in Croatia was prescribed in the form of strategic goals and measures, but the implementation and application of the measures of the same goals in a ten year period were left neglected. Despite the increase of nautical port revenues in 2017, they are still much below the desirable income in amount of 15 billion HRK. With 11 billion € in total revenue of tourism sector, the nautical tourism has a share of just one percent of total income from this branch of the economy. Bearing in mind that marina consists of two surfaces according to its definition, water area and shore, it is estimated that 80 per cent of capital investments in marina construction are investments in the water surface area while the remaining 20 per cent is related to the shore surface. The current relations are reversed in the case of revenue generated from marina business, where only 20 percent of the overall revenue is materialized through water surface area whilst 80 per cent of revenue comes from services on shore [24]. These relations are implication of significant progress of marina business in the world through the last 20 years, and are indicating missed opportunities for raising revenue potential for the Croatian nautical tourism, as the 70% of share of generated revenues were berth rentals and 30% other income categories. The current condition of number of new berths and nautical ports, especially marinas, do not reflect the future berth growth scenarios indicated in the strategy, where the existing number of berths were actually decreased in the observed period, with minor fluctuations. The reasons can be found in a slow and inefficient local administration, inadequate legislation, property-legal issues, problematic of maritime domain but also the inconsistency of the state bureaucracy visible in the drastically increase of the sojourn tax [25], which was adjusted later under the influence of experts and public. All the mentioned elements contributed to creation of unfavourable investment climate in Croatia. The untapped potential is also related to the level of quality of services and superstructure facilities or value added services in the marina surrounding. Nautical tourism generates the greater tourism expenditures by attracting a larger number of the high value visitors [6], often with higher education and used to higher life standard, but more demanding [7] which increases the destination spending and revenues [1]. According to the Tomas Nautica 2017 Survey, the average daily consumption of nautical tourists was 126 € while for the charter users amounted to 183 € [23]. The overall degree of satisfaction with nautical tourism and related services in Croatia was, from the users’ perspective, characterized with very high satisfaction, but form the survey it is evident that the segments indicated with lower satisfaction are generally additional services in marina and value for money for the overall supply towards users. These responses should be used to indicate the deficiencies and improve the overall product according to the change of trends in users’ preferences and demands. Besides the economic growth of the prosperous sector the future development should be also in compliance with social and ecological requirements. Having the fascinating resource of intended coast and numerous islands, investments in nautical tourism should correspond to the growth of remote and less developed areas, primarily islands where sometimes, the tourism activities are the only development perspectives. These constructions of marinas and other nautical ports initiate the rapid development of local economy which should be coordinated by government strategic goals [26]. By creating favourable and stimulating investment environment the state authorities should enable potential investors to exploit all the comparative advantages of the destination in the perspective market niche within guidelines of sustainable development, which is essential for the industry development. These facts become more important when the aggressive investments in berths for super yachts, yacht service centres and added value services and facilities of the main competitors in the Mediterranean in this category occur in the market, often evolved by converting the old brownfield facilities and leaving the inactive or unprofitable industries, Investments are needed to achieve a positive impact on the economy [1] and increase the quality of the destination. The uncertainty to meet the growing users’ demands and preferences could proportionally lead to risk of diminishing growth prospects and weakening competitive advantages of Croatian nautical tourism and its market orientation. The endeavour of the Republic of Croatia to stimulate the sustainable growth of the nautical tourism industry should also correspond to the environmental dimension of the nautical port capacity increase and their adverse effects. The capability of representatives of all levels of government in implementing an efficient and sustainable management model between natural, coastal and infrastructural resources and the application of desired vision and strategic goals will determine the future development of the prosperous sector. The efficient development of the nautical tourism assumes the existence of a system development and synergies between
state vision along with related strategic documents and those of the individual state administration bodies and local self-government development.

V. CONCLUSION
The economic effects of nautical tourism still have not achieved the desired levels, despite the high development potential and available natural resources. Nautical ports are drivers of the nautical tourism industry. They directly contribute to the development of local and regional communities, but for Croatia more important the development of islands having the peculiar importance. The industry development in Croatia, thus the marinas which are accelerators of the development, should correlate with strategic predictions, which implementation was unsuccessful. The efficient coordination and compliance between the state vision and transferred planned and supporting development activities on the local and regional government level should exist in order to achieve the desired goals set in the strategy.

REFERENCES


An Overview on a Future Trends and Smart Technologies in Maritime

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ABSTRACT
In this paper some new technology trends in near future are presented, that are happening in maritime. New the 4th technical industry revolution is happening right now, both in real world and in virtual realm. It is obvious that industry and business models are going through transformation. With new ideas and smarter solutions, a maritime is going through thorough change. With adoption of Cyber Physical Systems (CPS) it is predicted that the ships will become highly automated and independent systems. Also, with new technology trends like Internet of Things (IoT) or Industrial Internet of Things (IIoT), in process control and digital twin a smarter controlling of assets at disposal will be utilized. Using digital twin should allow us to extend lifecycle of ship and its systems. Ships connectivity and solutions from INMARSAT like Fleet Xpress will allow entire new ecosystem of maritime solutions.

KEYWORDS: Digital Twin (DT), Cyber Physical Systems (CPS), Internet of Things (IoT), ship’s connectivity & maritime

I. INTRODUCTION
Nowadays, many ordinary objects such as sensors, door locks, vehicles, ship’s, cameras, industrial control, traffic systems, to name it few, are wirelessly connected to the Internet in so called the Internet of Things (IoT). It is estimated that by 2021 there will be 22.5 billion devices connected in IoT network [1]. So, it can be safely concluded that IoT is the most important new technology since the arrival of the Internet itself. Many signal processing techniques are invented to support and augment new IoT services. IoT devices and systems are constructed on all levels simultaneously, i.e. hardware and software levels. On the hardware level there are two main challenges: device size and power consumption. They are addressed by changing the technology, instead of using CMOS transistors a new device is developing, a memristor. Memristor is an abbreviation of the term memory resistor, i.e. a two-terminal resistive switching device that can retain a memory or its last resistance state, even after being powered off which in the end ensures ample data storage and processing at an affordable energy cost. With new ideas and smarter solutions, a maritime is going through thorough change. With adoption of CPS it is predicted that the ships will become highly automated and independent systems. Also, with new technology trends like IoT or Industrial Internet of Things (IIoT) in process control and digital twin a smarter controlling of assets at disposal will be utilized. Using digital twin should allow us to extend lifecycle of ship and its systems. Ships connectivity and solutions from INMARSAT like Fleet Xpress will allow entire new ecosystem of maritime solutions. This paper is organized as follows; second chapter covers digital twin that is used as term for describing a digital replica of physical ship in virtual realm. Third chapter describes cyber physical systems which is an integral part of new ships and IoT system because it represents integrated computers and physical abilities and actions towards physical world. Fourth chapter deals with ships connectivity and Fleet Xpress network as a future network to collect data from real ships and pass them to virtual realm. Fifth chapter is conclusion and the paper finishes with list of used references.

II. DIGITAL TWIN
Digital twin (DT) refers to a digital replica of the physical asset (in virtual realm), process and system which can be used for various purposes [2]. Digital presentation provides both elements and dynamics of device through IoT. DT integrate AI (Artificial Intelligence), machine learning and software analytics with data to create live digital simulation models who are being updated and changed as the state of
the physical components of systems is changing. In various branches of industry DT are used for optimization and maintenance of physical systems and production processes. Twin is defined as collection of virtual information components which in total describe real or potential physical product that has been produced from sub-atomic levels to macro-geometry level [3]. Concept of digital twin is shown on Fig. 1 and it consists of three parts:

- Physical asset in the real world,
- Virtual asset in the virtual world,
- The connections of data and information that ties the virtual and real products together.

One of the solutions how to bind together physical and virtual is to establish so called a Unified Repository (UR) [4]. In virtual space there are all necessary information about product characteristics such as dimensions, tolerances, torque demand, measurements of hardness and together they would create a unique tag that would serve as data information for physical product. When the product is ready for manufacturing, all the tags would be collected and stored in the UR. Also, all tags would be stored in bill of processes for production of physical components. After production of each component and of product report of process would be stored also in UR. This way, instead of showing what is supposed to happen, there is actual information of what is happening in manufacturing process of product.

Using this concept in maritime industry would open many new opportunities for companies and shipyards. For example, shipyards can offer far more services this way to owners of the ships and stay competitive on market and at the same time make a profit for them but also for ship owners. Ships controls systems are one of applications for DT. Real software can be installed in digital copy of the ship for virtual integration, testing and validation of systems. Digital ship is a simulator that contains all equipment and machines, networks and control systems. They are all connected and integrated in cyber space, just as would be on a real ship. DT can be tested in simulated conditions equal to that in real environment. Keeping in mind that the maintenance of an offshore supply vessel is seen as expensive and time consuming (it costs anywhere between $58,000 and $116,000 per day to have a vessel offline [6]) shipyards can provide maintaining services through entire lifecycle of the ship using the concept of the digital twin.
DT of the ship (Fig. 2.) enables that every asset of the real ship can be analysed through digital interface. That allows various stakeholders to update digital twins with different modules and in advance make an assessment how the system would have functioned.

III. CYBER PHYSICAL SYSTEMS

Germany leads the way towards fourth industry revolution called Industry 4.0 who refers production and service based on a Cyber – Physical Systems (CPS), as shown in Fig. 3. Based on terminology of Industry 4.0, intelligent analysis of data and interfaced systems combine so that they would create entirely new aspect in transformation of production. CPS is terminology which represents integrated computers and physical abilities such as sensors, communication and actions towards physical world.

Concept of CPS is based on physical and software component which are intertwined, each operated in its own time and space scale, representing more and different modules of behaviour and acting together with each other on multiple ways that change with different context. CPS techniques [8] includes learning solutions (pattern recognition), context-aware systems, self-configuration and self-adaptation techniques, mobile and fault-tolerant implementations. CPS integrates transdisciplinary approaches, combining theories of cybernetics, mechatronics, process science and design. CPS are similar to the Internet of Things, both are based on similar infrastructure, but CPS has higher level of combinations and coordination between physical elements and software elements. CPS are not traditional embedded systems, but they have characteristics that define them [8]:

- Cyber capabilities in each physical component;
- Networked at multiple and extreme scale;
- Dynamically reconfiguring/reorganizing;
- High degrees of automation, the control loops must close;
- Operation must be dependable and certified in some cases;
- Cyber and physical components are integrated for learning and adaptation, higher performance, self-organization, self-assembly.

CPS contain a number of advantages. They allow individual entities to function and work together to assemble complex systems with greater capacities, they are more efficient that way and safer. CPS can be used in wide area of business. CPS can run critical infrastructure, take care of environment, they can work with alternate sources of energy and they can run operations for safe and efficient transport. As CPS are represented by large number of different components it presents a big challenge for research and development of CPS [9]. The problems of robustness, elasticity, reliability and security issues and reconfiguration of dynamics systems have to be solved and these are areas of great importance.

![Fig. 4. CPSs on board vessels](https://to2025.dnvgl.com/shipping/digitalization/)

Concept of CPS is not new thing on board modern vessels (Fig. 4.). Today the CPS are making wide range of systems such as regular one like dynamic positioning or critical ones for security of vessel like emergency shutdown system or blowout preventer system [7]. Machinery systems are more and more run and controlled by software who is embedded with smart sensors which allow monitoring performance and of system. Navigational instruments are also more and more dependent on advanced software and sensors so that they can help crew to choose the safest route and avoid possible dangers and warn crew of any. Since control systems are all present today on-board vessels, it is possible to refer to a ship as a CPS.

### IV. Ships Connectivity

In the next decade, when it comes to maritime communications, there will be significant advance in the way that information is transferred [10]. A lot of new approaches is already considered. New technologies that are planned for the next decade include mobile networks in coastal areas, VDES, Wifi in ports and most critical one – satellite communications, wider broadband service [6]. According to INMARSAT Maritime CEO Ronald Spithout main technological trends in maritime in next five years are analytics of Big data and IoT “right now, we are at the point in time where ships managers and ships owners start to realize that Internet of Things and analytics of Big data is giving them competitive edge for improving their efficiency. So realization makes it that satellite connectivity becomes for vessel the kind of critical infrastructure [...] and what you see happening in shipping is that realization will translate in an adoption of much more standardized architecture on board providing them always with connectivity they need and probably also together with capability to run applications to analyse whatever is needed on board and on shore and interact on that. [...]” [9].
Fleet Xpress is INMARSAT solution to raise maritime communications on whole different level than before. It provides high speed data transfer through INMARSAT Global Xpress Ka – band technology in combination with reliable INMARSAT leading Fleetbroadband L – band service. Fleet Xpress fuels revolution in transfer of maritime data. Guaranteed bandwidth offers owners and ships operators more efficient business intelligence, performance, increase in efficiency, and crew welfare. Also, its supports third party stakeholders who offer various types of applications for improving their existing services towards ships owners and operators and it opens door to the new innovations. Fleet Xpress is first global super-fast broadband network.

Fleet Xpress is based on Global Xpress. GX is satellite network (Fig. 5.) that allows global level of coverage. GX represents an important step in INMARSATs transformation from satellite operator to the digital provider.

Increase in bandwidth and network capacities and new communication solutions will allow transfer of significant amount of data from ship to coast and vice versa in real time. That will open whole new world of opportunities for new applications and systems in maritime industry that will improve ships and fleet performances such as smarter planning of routes, fuels savings, trimming, emissions management and will offer higher level of automation on board vessels. Automatization by its principle doesn’t require any control communication but still needs level of supervision and control, and in case of emergency an intervention (remote control) from shore. Key element of autonomy and remote control is in reliable communication equipment [11]. In future satellite communications will be critical infrastructure for new ideas that are being develop by researchers like e-navigation or project MUNIN [12] (Maritime Unmanned Navigation through Intelligence in Networks). Main importance will be time of delay. In case of remote navigation from shore, the time of delay will and response from the ship on the pilot commands will need to be brought down to minimum. Also, to enable seamless information exchange between various systems and across different physical communication links, its necessary to enable the

Autonomous ships will be source of endless sets of data [14]. If the companies want to improve logistics, lower emissions, save energy, fuel consumption, optimize routes etc. they will have to use Big data analytics. Companies that use Big data analytics will gain significant advantages and profits with using of their databases.

Modern ships also pose great cyber security risk. There is danger that someone skilled enough will be able to take over an entire ship or harm to chip cargo. Cyber security methods because of that will have to be developed to be proactive and dynamic and always update security systems.

V. CONCLUSION

Modern world is going through intensive changes. All areas of industry are going through transformation towards new era called industry 4.0. For now, maritime slowly embraces new solutions and concepts that modern time is offering. Looking on trends of market today, defensive style that most companies had in the beginning of the decade is now changing into offensive way and they are investing in a new ideas and innovations. Maritime industry can follow examples and learn from other industries such as automobile industry (John Deere who today offers entire new ecosystems of applications for farmers and not just tractors and diesel engines). Following that concept, we can expect new trends like digital twin, new technologies like CPS and new ecosystems of applications to change maritime world. Ships will become floating computers, crew welfare will be increased, maritime itself will become much more transparent and less prone to criminal affairs. Smarter and more efficient care of assets will also allow better care for environment. With concepts like IoT and bringing together ports and fleets it will reduce waiting in ports, increase efficiency and bring profit to companies. Insurance companies will have be better insight how its ensured property is being taking care of. Cyber threat will have to be taken seriously. Cyber security regulations and crew education is essential in the fight against new danger for maritime – cyber piracy. New standards and regulations will also be needed for navigation, communications and equipment who will have to be more standardized so that for users is easier to use.

REFERENCES


Automated Ships Security Problems

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Abstract
Automated and robotic ships are in experimental stage nowadays. Maritime Autonomous Surface Ships (MASS) are defined by IMO. In this paper, security of automatic and communication systems of such ships is investigated. MASS are dependent of communications, i.e. GPS signals, communication with a shore control centre, datalinks, etc. Hence, cybersecurity is the most important part, if hacker-pirates are to be stopped of kidnaping the ship. We also elaborate potential difficulties in usage of block chain technology for improvement of MASS communication security. This technology is already used in maritime for bill of lading. Technical demands for MASS and general systems’ redundancy must be design to increase security. Finally, relationship between MASS and other ships leads to the maritime intelligent transport system (MITS).

Keywords: cybersecurity, MASS, MITS & blockchain

I. Introduction
We are approaching predicted dates for Unmanned Surface Vessels (USV) and Marine Autonomous Surface Ships (MASS). USVs are widely used in ocean research, coast guard and military applications [υ]. The first demonstration voyage of the autonomous ferry was performed in Finland at 3rd December φτυό [φ].

The most sensitive component of the autonomous ship concept is the connectivity. Connectivity is enabled the communication system, which need to be bidirectional, accurate, and secure. Secure communication is required to avoid malicious users to interfere with the communications or even start controlling the ships. The most important threats for autonomous ship communications are [υ]: losing the data, changing the data by a malicious user, and hijacking the data. Blockchain technology (BT) is promising for prevention of these threats. Hence, this paper proposes a security based on BT to enable secure data and secure data storage exchanged between the autonomous ships and remote shore control centre. BT could play a role in identification, certification, data integrity, and information security.

The paper is organized as follows. The second section describes basic definitions and terms in autonomous vessels. The third section deals with BT application. There is a special subsection with the proposed usage of BT in autonomous vessels control scheme. Finally, conclusions are given.

II. Current Status and Future of Autonomous Ships
Autonomous surface vehicles (ASV) are completely automated ships. There can be divided into two groups: MASS and unmanned surface vehicle (USV). MASS can be grouped into [χ]: autonomy assisted bridge (AAB), periodically unmanned bridge (PUB), periodically unmanned ship (PUS), and continuously unmanned ship (CUS). Furthermore, MASS can be grouped into four classes, which differs by control level and legal regulation [ψ]: Autonomy Assisted Bridge (AAB), Periodically Unmanned Bridge (PUB), Periodically Unmanned Ship (PUS), and Continuously Unmanned Ships (CUS). The purpose of autonomy development is to replace human labour, and to obtain faster, safer, more precise, more productive, and cheaper ship’s operations [3]. “Faster” does not mean sailing with greater velocity, although it can, but it can be also related to service industry and finance [5]. A great advantage of autonomous ships is a total exclusion of human errors as a cause of accidents [6]. Human errors caused 50% damages more than 100,000 $, 83% of all accidents, 54% of all pollutions, etc.

According to the MUNIN project [3], future design of autonomous ships will greatly depend on three topics:
- New design of ship’s hull (no habitat for crew and related spaces for food, toilet, resting, no observation positions, etc.),
- Introduction of new fuels due to less necessary energy aboard (includes LNG as a thrust fuel),
- Alternative modes of operation (entity that control the engine operates with aperture and arriving as well as with more ships in convoys).

Autonomous systems can coexist, interact and communicate with operator controlled systems and ship’s environments. Autonomous operations demand programming of voyage path, navigation, and collision avoidance systems. All of these systems should be monitored by Shore Control Center (SCC). Ship’s autonomous systems should incorporate international collision avoidance rules (COLREG). Autonomous system should include also situation awareness protocols. Standard procedure is to reduce speed when visibility is low. However, it is disputable in case of autonomous vessels, because such vessels could be equipped with IR cameras, which increase objects’ detection rates. SCC can be connected to ship by any available communication technology (i.e. GSM, WiMax, VHF or satellite). SCC sends voyage plans and refreshed data relevant to ship’s voyage, and overseas ship’s voyage in case of Autonomous Ship Controller (ASC).

ASC consists of Autonomous Navigation System (ANS) and Autonomous Engine and Monitoring and Control (AEMC). These systems should make standalone navigation decisions. SCC operator should be able to identify all irregularities in systems’ operations, all unexpected threats and errors, and pass these data to others involve in SCC operation. Hence, it is necessary to develop a new interface operator-ship, which is a type of Human-Machine Interface (HMI). This new interface would improve knowledge and operator’s capabilities in getting and maintaining ship’s situation awareness and ongoing with final goal of easier decision making, which would produce safer, unmanned and autonomous voyage [7].

Autonomous ship is defined as the ship with primary and secondary navigation. Primary navigation is in ship’s systems of decision making, which is controlled by the operator from SCC. Hybrid autonomous ship’s system can be combination of two general alternatives [3]:

- Distantly controlled ships, which are controlled by the operator in SCC through wireless link. In this case, data from radar, camera, satellite, etc. are stored and interpreted at one place.
- Automated ships with embedded advanced systems of decision making. This ship is self-guided by the program and/or artificial intelligence.

III. POSSIBILITIES OF BT IN AUTONOMOUS SHIPS

A Blockchain is both a decentralized and distributed digital ledger. This ledger can be used to record transactions (not necessarily finance or money related) across a specific network of the peer-to-peer computers. This is the potential for usage in autonomous vessels. Record cannot be altered retroactively without the alteration of all subsequent blocks and the collusion of the network [2]. Hence, BT successfully withstood cyber-attacks for more than 10 years. Possible quantum computers have the same obstacle, but it is possible that the quantum computer could hack 50% of blockchain network (50% of nodes are necessary to validate false block as correct one [8]) and break it.

Blockchain is not either a single technology or novel one, but a product of multiple existing technologies integration, which also includes reliable and unique database. This database is decentralized and trustful. Blockchain’s database consists of a peer-to-peer self-organizing distributed network, which is also an Internet distributed database. This is completely different from the traditional database structure where data consistency is not guaranteed, communication between traditional distributed database nodes can be unreliable or perhaps non-existent. Ability to deal with conflicts i.e. consensus, described in [12], is the fundamental difference between traditional distributed database and BT. In case of BT, block is a data element. The block is indexed, which enables connection of blocks into a chain-like structure. Further characteristics of the BT is that such block has value that is the exchange of activity records between the creation of the previous block and the present block. Furthermore, the novel created block is linked to the end of the chain. Block data finishing ensures the consistency of the blockchain database.
Simply, if the index of the previous block is not known, it is not possible to generate the current block. As a matter of fact, each block must be chronologically linked to the previous block. The data index of the previous block represents the head of the current block. The current block also has the information, and the timestamp [10].

BT is characterized by the fact that all nodes work together to maintain all data, they act as validators since nodes are not going to accept an invalid transaction, and honest nodes will never accept a block containing them [12]. Updating of block data relies on the fact that most nodes or all of them consider the data correct and the authenticity of the record is approved [11]. Hence, if some nodes are damaged or hacked, it will not affect the data. BT validates the data ownership by the asymmetric encryption keys: a public key and a private key. The public key is open to the public, and the owner of the information is the only one who owns the private key, but both keys have to be used [12].

A. Identity Authentication on Blockchain
Examination of the user’s identity is performed by the authentication procedure. This procedure determines whether the user has right to access system resources.

With the increased cases of identity theft and data leaks around the world, authentication is a major concern. Today, most internet application systems like email system, messaging application system and websites are based on central authority technique. Certificate authority issues and activates certificates, and store all the data [9]. There is a fatal security risk in this approach, malicious users or hackers could attack certificate authority centre and counterfeit users identity or crack encrypted information.

There are several ways that blockchain network architecture can be applied. The various approaches can be categorized as Private, Permissioned or Public. Primary distinction between these network architectures is within the nature of the nodes involved in securing and/or verifying the ledger and its entries. The variance in implementation has implications for some benefits of the BT as represented in the Table I.

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Decentralization</th>
<th>Immutability</th>
<th>Transparency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private</td>
<td>Nodes in the network are majorly or entirely run by a private party</td>
<td>None</td>
<td>None</td>
<td>Not Guaranteed</td>
</tr>
<tr>
<td>Permissioned</td>
<td>Nodes in the network are run by 3rd parties who are granted specific permission by a private party</td>
<td>Low</td>
<td>Moderate</td>
<td>Not Guaranteed</td>
</tr>
<tr>
<td>Public</td>
<td>Nodes in the network may be run by any party</td>
<td>High</td>
<td>High</td>
<td>Guaranteed</td>
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</tbody>
</table>

B. Autonomous Ships and BT
Both autonomous vessels and BT are in top ten technologies to shake up maritime in 2018 [13]. There is even consortium with goal of building global shipping blockchain [14]. There are looking to improve data sharing by the BT. As an example Port of Rotterdam Authority is mentioned. This resulted in a pilot project of physical, administrative, and financial integration within international distribution chains [14]. The shipping company Maersk invested heavily in IoT (Internet of things) and BT. It is expected that the BT will save “the shipping industry billions of dollars through more accurate container tracking capability and automating shipping transactions” [15].
C. Proposed BT-improved Scheme for Autonomous Vessels Control

The proposed usage of the BT for autonomous vessels is illustrated in Fig. 1. Distributed network can be approached only by the certified user. Data is stored and shared over distributed ledger. This network is also used for vessels’ control data and for storing of essential ships’ data. New user cannot approach the network without passing through certification authority. Using blockchain disables possible cyber-attacks in sense of altering commands or stealing the sensitive data.

The certificate authority acts as the core of authentication system, verifying users’ identity, realizing the functions of issuing, updating, revoking and confirming certificates. Certified users are issued a cryptographically secure digital identification based on BT, allowing them access. Once users are verified they can access ships data, which is stored and encrypted on distributed network, and send the control data to the ship.

IV. CONCLUSIONS

This paper considers BT as improvement of safety in communications between SCC and the autonomous vessels. We proposed a scheme for implementation of BT into the command chain of the autonomous vessels. This scheme makes cyberattacks nearly impossible and makes data tampering easily detectable. BT is slowly but surely making its way into maritime industry, companies like Maersk are planning to introduce BT to solve regulation compliance, documentation issues and to support communication and automation as they expect that this technology will bring significant cost-saving opportunities in the industry. It is a desire that this study will be of use to further development of technology projects in this field.
ACKNOWLEDGMENT

A part of this paper is inspired by the master thesis of the student co-author.

The authors are members of the scientific group New technologies in maritime at the Faculty of Maritime Studies in Split.

REFERENCES


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| 2.            | Luka Vukić, Eli Marušić, Antonija Mišura & Sara Paladin Review of Nautical Tourism Port Business in Croatia |
| 3.            | Maja Stojaković & Elen Tvrday Problems of Small Container Ports – Case Study of The Slovenian And Montenegro Ports |
| 4.            | Erald Aliko A Comparison of Port Governance Models Across EU Countries & Albania |
| 5.            | Vivien Lorenčič, Elen Tvrday & Milan Batista Analysis of Passenger Terminal Infrastructure as An Important Factor Affecting on Choice of Destination for Cruise Ships |
| 6.            | Violeta Roso, Dawn Russel & Dawna Rhoades Dry Port Concept Diffusion on The US East Coast |
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<td>Use of PMS Continuous Improvement Scheme for Maintenance Adjustments in Shipping Industry</td>
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<td>Berth Allocation Problem: A Literature Review</td>
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2. Andrea Russo, Rino Bošnjak, Goran Belamarić & Danko Kezić
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3. Gheorghe Madescu, Marian Greconici, Marian Mot, Marius Birescu & Vladimir Mladenović
   Analysis of Stator and Rotor Windings of Induction Motors

4. Tomasz Praczyk, Stanislaw Hożyń, Tadeusz Bodnar, Leszek Pietrukaniec, Marek Błaszczyk & Michał Zablota
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5. Mia Jurjević, Ćedomir Dundović & Svetlana Hess
   Assessment of The Port Costs on Zagreb Pier in The Port of Rijeka

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7. Piotr Szymak, Paweł Piskur
   Using Particle Swarm Optimization for Tuning Course Controller of Biomimetic Underwater Vehicle

8. Tatjana Stanivuk, Zaloo Sanchez Varela, Marina Laušić & Kristijan Markić
   Role of Mathematics in Education of Nautical Engineer

9. Joško Šoda, Mario Majić, Igor Vujović & Branko Sorić
   An Overview on A Future Trends and Smart Technologies in Maritime

    Autonomous Systems & Ships - Training and Education on Maritime Faculties

11. Miroslav Vukičević, Sead Cvrl, Draško Kovač & Branko Lalić
    Measurement of Torsional Vibrations on Propeller Shafts Using Code Discs and Optical Forks

12. Miloš Bogdanović & Špipo Ivošević
    The Risk Assessment of The Dynamic Positioning System Based on Historical Data

13. Miloš Bogdanović
    Reduction of Particulate Matter Emission from Marine Diesel Engines

14. Željko Pekić & Nađa Pekić
    Determinants of Kinetoses And Techniques of Prevention

15. Maja Škurić & Nikolina Radulović
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2. Oleksandr Kryvyl & Myhalo Miyusov
   The Creation of Polynomial Models of Hydrodynamic Forces on The Hull of The Ship with The Help of Multi-Factor Regression Analysis

3. Jure Srše & Andrej Andrejna
   Digital Nautical Publication Data Base in Support Of Voyage Planning

4. Zvonimir Lušić, Marin Marčić, Mario Bakota & Danijel Pušić
   Detecting A Man in The Sea

5. Miroslav Vukičević, Špivo Ivošević, Rebeka Rudolf & Peter Majerič
   An Analysis of The Influence of Abrasive Particles in Fuel on The Degree of Damage To Piston Rings

6. Nikola Momčilović & Milorad Motok
   Some Dynamic Load Aspects in Ship Navigation

7. Rumen Stoyanov & Blagovest Belev
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   Analysis of Ballast Water Quantity From 2014 To 2017 In Croatian Port Authorities

2. Boris Rajnić & Tina Sule
   The Utilization of Renewable Energy Sources on Vessels

3. Žarko Kobočević, Marjan Jovančević, Mate Jurjević & Maro Car
   Integrated Systems for Processing All Types of Waste on Ships

4. Rosanda Mulić, Iris Jerončić & Luka Vukić
   What Does A Doctor of Medicine Do at The Faculty of Maritime Studies?

5. Luka Vukić, Lidija Runko Luttenberger, Katarina Babić & Merica Slišković
   External Costs Comparison of Two Traffic Modes on The Island of Vis

6. Shkëlqim Sinanaj
   The Impact of Shipping Accidents on Marine Environment In Albanian Seas

7. Damir Mihanović, Ratko Božić & Luka Burica
   Contributing to The Development Of Organizational Structures in Shipbuilding Enterprises Through the Application Of The System Dynamics Modeling
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11:15—13:00

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2. Dragana Milošević & Senka Šekularac-Ivošević
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3. Maja Krčum, Ivan Derado, Jelena Žanić-Mikuličić & Marina Brodarić
How to Manage Risk - Iso Standard 9001: 2015?
4. Jelena Čulin & Toni Bielić
Pollution of the Adriatic Sea by Chemicals Discharged from Vessels
5. Lidija Runko Luttenberger, Jadranka Matić & Draga Miheljić
Environmental and Social Impact Assessment in Coastal Zone
6. Ninna Roos
Autonomous Vessels - A Ship Master’s Status Now and In the Future
7. Sanja Bauk, Bojan Beškornik & Senka Šekularac-Ivošević
Intermodal Network Development in Eastern Adriatic Region

CONFERENCE HALL 2
Marine Engineering, Marine Automation & Electronics, Marine Information Systems
Chairpersons:
Doc. dr. sc. Hrvoje Dodig & Mr. sc. Ivica Kuzmanić
1. Ante Barbir, Đorđe Dobrota, Jani Barle & Dušan Vukojević
Optimal Strategy for Maintenance of Reliquefaction System on LNG Carrier
2. Leonid Kovalchuk, Marina Isaeva & Pavel Burakovskiy
Principles of The Invariant Standards Formation for The Work Processes Functional Diagnosis in The Cylinders of The Main Ship Diesel Engines
3. Hrvoje Dodig, Tina Perić, Nikola Račić & Ljubomir Ostović
Numerical Prediction of Radar Cross Section for Small Maritime Targets
4. Marko Rosić, Dean Sumić & Lada Maleš
Firefighting On-Board Ship Modelling Based on Agents
5. Antonija Mišura, Ladislav Stazić, Tatjana Stanivuk & Ivan Komar
Verification of The Evaluation Methodology for Ship’s Planned Maintenance System Database
6. Adrijana Agatić, Tanja Poletan Jugović & Edvard Tijan
Streamlining Logistics Services Via Collaboration Platforms
7. Igor Vujović & Ivica Kuzmanić
Some Problems in Establishing Maritime Zone Surveillance Dataset

13:00—14:00
Poster Session
Authors are kindly asked to be present for possible questions

14:00 Closing of the Conference
Day 2, Friday, 12 April 2019
Hotel Splendid, Bečići, Budva Montenegro

13:00—14:00 Poster Session II

CONFERECE HALL 2

1. Andrzej Zak
   Control of Unmanned Underwater Vehicle as A Member of Vehicles'
   Team Performing A Given Task

2. Tomasz Praczyk, Piotr Szymak & Stanisław Hożyń
   Applying Optical System to Model the Motion of Human Leg Moving In
   Water According to Swimming Style Crawl

3. Tina Perić & Nikola Račić
   Cruise Ship Traffic in The Adriatic Sea: Environmental Impact

4. Bogdan Zak, Jozef Malecki & Stanislaw Hozyn
   Stabilization of Electrical Parameters of The Ship’s Electric Power Supply
   Using Fuzzy Controller

5. Veljko Plazibat, Marina Brodarić & Maja Krčum
   Impact of The Offshore Market Crisis on The Performance of Croatian
   Maritime Shipping Companies

6. Jelena Nikčević
   Creation of Montenegrin Maritime Safety System Through the Prism
   Of Legal Solutions

7. Pero Vidan, Srdan Vukša, Luka Bekavac & Vice Mihanović
   Safety Aspect of Navigation Bridge Lighting During Night Watch

8. Nikola Mandić, Marija Pijaca & Marijan Zujić
   Inspection in Coastal Liner Shipping

9. Jakša Vujović, Špiro Ivošević & Lazo Vujović
   The Preliminary Risk Analysis of The Subsystems of The Auxiliary Engine

10. Ranka Petrinović & Vesna Skorupan Wolff
    Yacht Charter Party Agreement According to Croatian Law

11. Krzysztof Naus & Mariusz Wąż
    Application of AIS Data for Qualitative and Quantitative Analysis of Ship
    Traffic Flows

12. Kristina Radnjić
    The Importance of Highlighting Factors That Affect the Psychosomatic
    Health of Seafarers

13. Sanela Kovačević Pejaković
    General English Creativity vs. Maritime English Restrictedness

14. Milena Đeverdanović-Pejović
    Examples of Miscommunication in Maritime English
Following the centuries-long tradition of seafarers from the area of Boka Bay, maritime education in Montenegro officially started with the establishment of Maritime College of Kotor in 1959. In 1981, this institution was promoted to Faculty of Maritime Studies.

Today, in the year of its 60th anniversary, this maritime institution, as a part of University of Montenegro, is a modern centre for education and training of seafarers. It comprises four academic study programmes of Nautical Science and Maritime Transport, Marine Engineering, Marine Electrical Engineering, Maritime Management and Logistics, at both graduate and post-graduate level upon the Bologna process. In addition, it has a Training Centre for Seafarers, as well as the Centre for Innovations and Research.

The Faculty’s courses and syllabi have been constantly updated and harmonized to meet the strict requirements of international maritime conventions and classification societies in producing competitive maritime professionals. It has also established cooperation with many recognized shipping companies in order to connect the students with their prospective future employers.

In addition to regular teaching aids, classrooms, computer rooms and laboratories, the Faculty has been equipped with modern simulators (Unittest, Transas, Rolls Royce and Kongsberg) as well as GMDSS and High Voltage units for practical classes and exercises. The Faculty also provides its students with practical drills and training in workshops and on board various vessels.

The Faculty of Maritime Studies has been the holder and co-holder of many international projects. Also, through programmes such as ERASMUS+, it has been continuously working on the expanding of international cooperation and mobility of teachers and students.

For our anniversary, we have been awarded the opportunity to host of 8th International Maritime Science Conference. We therefore thank all who have sent their papers and added to the significance of the event. We wish you all a successful conference and lot of nice memories to take along from Montenegro!

Dean
ŠPIRO IVOŠEVIĆ, Ph.D., Assoc. professor
The Faculty of Maritime Studies in Split was founded in 1959. Originally, it began its activities as Maritime College, while since 2004 it has been functioning as the Faculty of Maritime Studies of the University of Split.

In the course of its development, the path was not always smooth. Several studies have been developed which have been recognised on the labour market both in Croatia and worldwide. The students of the Nautical department, Marine engineering, and Marine electrical engineering and information technologies have been recognised as professionals easily finding work opportunities on shore and on board vessels. In this undertaking we are helped by our students cherishing their love of the sea, teachers with the appropriate scientific teaching titles, but also our partners from Croatia and abroad recruiting our students.

The students of Marine yacht and marina technologies as well as those of Maritime management are oriented towards maritime industry, i.e. maritime market and nautical tourism. Through EU projects, we have recognised their qualifications for the Croatian and EU labour market.

Education at the Faculty is carried out at undergraduate and graduate levels. Since 2019 we have also begun to deliver postgraduate study. In the process of education teachers in the scientific-teaching and vocational titles (officer ranks), lecturers from economy, profession, as well as colleagues from abroad take part.

Included into the education process are our students, ex-students (Alumni) and clients (teaching bases) who help us update our programmes in accordance with the latest trends in maritime affairs. Teaching is carried out using modern equipment consisting of simulators, didactic equipment, well-equipped library, computers for CBT, and video material and e-learning facilities. Teaching also takes place on board school ships, sailboats, Faculty laboratories, workshops exterior to the Faculty, etc.

Due to successful education of maritime personnel, we have been recognised by the Japanese system of education and training in maritime affairs (Ministry of Maritime Affairs and Traffic of Japan and Japanese Shipowner Association).
Our education process has been recognised by the international Accreditation Committee of the Agency for Science and Higher Education – AZVO.

Our training and education of seafarers is aligned with the requirements of the Ministry of the Sea, Traffic and Infrastructure, and in compliance with the requirement we have developed the quality management system ISO 9001.

We are members of IAMU (International Association of Maritime Universities) with whom we have aligned our curricula.

Due to our experience in the education of high-quality maritime personnel, the Ministry of Defence of the Republic of Croatia has entrusted us with initiation in 2018 of the education of cadets for the Croatian Army, Coastguard of the Republic of Croatia, Ministry of the Interior, and NATO partners of the Republic of Croatia. The cadets are educated at the integrated studies of naval nautical studies and naval marine engineering.

Our scientific research work is disseminated through our international scientific conference IMSC - International Maritime Science Conference, and international scientific journal ToMS - Transactions on Maritime Science. The scientific research work is carried out within projects tendered by the European Union, projects by the Republic of Croatia, and internal projects.

Teaching at the Faculty is delivered in Croatian and responding to the needs of the Erasmus students in the English language. Starting with 2020, we are planning to initiate teaching in English.

The Faculty of Maritime Studies has its facilities within the University campus which is alive day and night due to students’ activities. Besides the University library, the Campus includes student accommodation for students and visiting professors, cafés, ATM, student restaurants, chapel, gym, parking lot, counselling, etc.

I recommend studying at the Faculty to all those who intend to live for the sea and from the sea. Maritime professions have to be loved.

Dean

Perka Vidan, Ph.D., Assoc. professor
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