Impressum

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

PUBLISHER
Faculty of Maritime Studies
Ruđera Boškovića 37,
21000 Split, Croatia
office@pfst.hr

DESIGN
Offstudio, Zagreb, Croatia
Ana Banić Göttlicher and Maša Vukmanović

Abstracting/Indexing:
Web of Science (Emerging Sources Citation Index)
Scopus
Hrčak
Index Copernicus
TRID (the TRIS and ITRD database)
BMT | Marine Science and Technology
Google Scholar
Digitale Bibliothek Braunschweig
INSPEC

Published twice a year.
Printed on acid-free paper (print ISSN 1848-3305).
ToMS online (ISSN 1848-3313) offers free access to all articles.
www.toms.com.hr

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

~ Marine Engineering,
~ Navigation,
~ Safety Systems,
~ Marine Ecology,
~ Marine Fisheries,
~ Hydrography,
~ Marine Automation and Electronics,
~ Transportation and Modes of Transport,
~ Marine Information Systems,
~ Maritime Law,
~ Management of Marine Systems,
~ Marine Finance,
~ Bleeding Edge Technologies,
~ Multimodal Transport,
~ Psycho-Social and Legal Aspects of Long-Term Working Aboard.

The journal is published in English both as an open access journal, and as a classic paper journal (in limited editions).

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

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

All papers are checked by
CrossCheck Powered by iThenticate

Contents

From Editor-in-Chief:

Scientific Productivity in the Time of Pandemic

Igor Vujović

There has been a lot of discussion about scientific productivity in the time of pandemic. It cannot be generalized, because it depends on the research field. For example, researches dealing with viruses and vaccination have been intensified. Some social sciences can suffer, because of the strict protection measures that can limit standard research procedure. From my perspective, I have published papers and performed reviews for several prominent journals. I would say that, if anything, scientific productivity has increased. We may not live our lives outside our homes and jobs as we used to but, fortunately this has given us more time to perform research.

Judging by the number of papers submitted to ToMS, I think that this has been a very productive year. We have records in submissions and many papers had to be declined.

This has presented a problem for editors: namely, a lot of papers have passed the review process. Some journals have a fixed number of papers which are published per volume (issue). However, it is rather unjust for authors who have to wait a year or more to be published. Alternatively, editors who risk an increase in the number of published papers can thereby decrease an impact factor. Finally, this could lead to a change in the review process, which would consequently result in the level of marks and the threshold of acceptance. This is a very sensitive process, which might be implemented in future.

For this issue we have prepared papers on ship's construction and shipbuilding at the beginning. Then we consider electronic and cyber security aboard. The third group of papers is related to maritime traffic and navigation, followed by a paper about climate changes, maritime logistics and dry ports. Education and terminology is considered next, after which maritime law has been dealt with. Finally, satellite imagery is applied to the microregion of the Cetina River.

ITF position about crew change in time of COVID-19 has been presented in the News section.

We once again take the opportunity to present the Croatian cultural heritage by publishing two poems, written in the idiom of the Island of Brač, by the late Ive Marković Kora, poet, painter, and sculptor. This contribution comes in a bilingual form in the inspired translation of Mirna Čudić Žgela, our long-standing collaborator.

Best whishes
Editor – in - chief

Collision Damage Analysis of FPSO Hull Caisson Protection Structure

Ozgur Ozguc

The protection structures for the Floating Production Storage and Offloading (FPSO) caissons should be sufficiently strong to avoid contact with the caisson pipes even when the protection structure is damaged by the impact of the accompanying vessels. Collision events of protectors of appurtenances such as risers, mooring lines, and seawater lift caissons with supply vessel may cause structural damage to protection structures and even to the appurtenance structures and hull structures. This study introduces the collision impact analyses on three protective structures of FPSO against striking supply vessel whose displacement is 7,500 tons. The capacity of protection structures in view of strain energy has been assessed with simple beam FE models. The striking vessel has been modelled as a small rigid body, and impact simulation has been performed including material and geometric nonlinearities where ABAQUS Explicit tool, which is a commercial explicit code, has been used for non-linear collision analyses with protection structures. The results from the current work will be a guide to understanding the impact response of offshore structures and evaluation approaches, and will provide useful indications for the FPSO hull caisson protection design and operation. In addition, the findings obtained by the current study will be informative in the safe design of FPSO facilities.

KEY WORDS

~ Protection structures
~ Structural damage,
~ Collision event
~ Caisson pipes
~ FPSO hull vessel

Faculty of Naval Architecture and Ocean Engineering, Istanbul Technical University, Turkey

e-mail: ozguco@itu.edu.tr

doi: 10.7225/toms.v09.n02.001

1. INTRODUCTION

Collision is a major threat to the safety of a ship or other offshore facilities and can result in significant economic damage, environmental pollution, and death. The main concern regarding ship collisions with offshore structures focuses mainly on the consequences. Because the cost of repairing the offshore structure is higher than that of the striking ship, a number of studies have focused on the method of increasing the crashworthiness of the offshore structure during accidental collision scenarios (ISSC 2018).

These collision events could cause substantial damage to an offshore installation and, for a Floating Production Storage and Offloading (FPSO), the puncture of cargo tanks could result in significant spillage of hydrocarbons as well as the loss of life, disruption of safety functions and loss / delay of production. In certain situations, the damage may result in fire and explosions, or a significant structural failure leading to the FPSO's total loss.

FPSO vessel is the dominant unit for floating offshore oil and gas field production. FPSOs are efficient deep-water and ultra-deep-water production facilities and their key benefit is the ability to store and process the hydrocarbons.

Wang and Pedersen (2007) reviewed the work and analyses relating to ship-FPSO collision risk assessment. The emphasis was on the current requirements, FPSO collision occurrence, FPSO collision design scenarios, collision dynamics, impacts and acceptance requirements. The study developments of the collision and grounding of the ships have been implemented since the 1990s. Issues unique to ship-FPSO collisions have been addressed which deserve further development.

Ozguc (2015) evaluated the collision strength of Semi-Submersible type CPF (Central Processing Facility) riser safety frame (RPF) and protection net (PN) supports. The PRF and PN supports are evaluated for their collision capacity when a supply vessel collides with them. It was estimated that the vessel

colliding from the north side is 18,000 tons and the one colliding from the east / west side was considered as 7,000 tonnes in accordance with the NORSOK N-004 code. The paper focused on general methodology and design of CPF accident scenarios using more sophisticated tools such as the non-linear FEM which predicts more accurately the structural responses during and after a collision. There were two separate designs for the supports for RPF and PN and, thus, there are four systems such as RPF-01, RPF-02, PN-01, and PN-02 respectively. The estimated kinetic energy from the North side was 20MJ for the collision. The east / west side of the collision energy was 14MJ for side collision, and 11MJ for bow / stern collision. Collision energy and plastic stress parameters were employed to predict the collision capacities of the RPF and PN supports for the specified collision energies along the period of the structures.

Cho et al. (2017) introduced the structural design method, and non-linear commercial packages were used for the analysis of collisions. Non-linear collision analyses using commercial software tools, however, were time-consuming and costly to run, particularly during the initial design stage. Within the analysis, the first use of collision test results on single pipes and H-shape pipes was conducted to substantiate the adopted commercial package. Afterwards, a detailed parametric analysis was carried out by modifying the variables of design. A basic analytical expression was extracted assuming the striking vessel's kinetic energy had been dissipated by plastic pipe elongation and plastic hinges rotation. Using the results of the parametric analysis, design equations were obtained for calculating the maximum deflection and overall bending damage which could consider the effects of local denting and dynamic behaviour. In addition, an equation was also developed to determine the degree of local damage to the denting. The established technique was substantiated numerically using the expected magnitude of the damage to a real protection structure.

Ning et al. (2013) developed numerical methods to assess the structural integrity of a generic Spar hull in collision with a large supply vessel and to expose its progressive characteristics of the collision damage. The analysis of dynamic and non-linear finite elements is carried out for two collision scenarios using ABAQUS / Explicit tool, respectively. One was a practical simulation where the impact kinetic energy controlled by an initial velocity of impact and a ship's total mass during the collision was slowly depleted. The other was a simpler theoretical approach where a ship bow's impact velocity was constant during the collision, or the total impact energy was infinite. Progressive collision damages of the hull structures were accurately recorded for structural integrity evaluation using a combination of optimized material progressive damage models and Mises plasticity.

Hagen (2018) studied the collision damage in the Sevan 1000 FPSO when subjected to impacts from a 150,000 deadweight tonnage shuttle tanker and two types of supply vessels. The emphasis was on the shuttle tanker impacts. The objective was to determine energy dissipation involved in the drive-off impacts, and to study the relative strength and the local structural response in both the striking ship and the struck FPSO. The impact scenarios were defined by upper limit drive-off velocities and drafts corresponding to the initial and final offloading phase. Both head-on and glancing (non-central) impacts were studied for each scenario. A finite element model of the Sevan 1000 FPSO was created in the software Sesam GeniE and imported into the numerical code LS-DYNA for non-linear finite element analysis.

Ju and Jang (2019) evaluated the crashworthiness of the striking vessel and the struck vessel when the collision occurs because it can cause severe consequences. In this study, a simplified method was suggested for small-scale ship collision event and compared with the solution obtained from the finite element method. The shapes of the striking vessel and struck vessel were selected as a bow (bulbous bow and stem) and a double hulled structure respectively. From the finite element results it was confirmed that the stem case was more vulnerable than the bulbous bow case because its sharp shape could cause the local failure of struck vessel much earlier.

Ozguc (2019) focused on the general approach and design of FPSO accident scenarios using more advanced methods such as the non-linear FEM used in order to provide structural responses during and after a collision. Due to the various collision scenarios and impact energy levels, the degree of FPSO hull damage was assessed using the criteria found in the NORSOK Standard. The accident case of 5 years on-site setting was accounted for the Accidental Limit State (ALS). The different collision scenarios were described as supply vessel collision bow on, supply vessel collision side on, supply vessel collision stern on, and take tanker collision bow on off. Conservatively, the impacting vessel during the collision (full energy consumed by the FPSO) was deemed non-deforming. Damage assessment to FPSO hull, including foundations for flare and flares, aft muster station, offloading reel and piping, and safety of green water above cargo deck, was investigated

The objective of this study is to carry out the collision impact analyses on three protective structures of FPSO against striking a supply vessel with displacement of 7,500 tonnes. The capacity of protection structures in view of strain energy is assessed with simple beam FE models. The striking vessel is modelled as a small rigid body and impact simulation is being performed including material and geometric nonlinearities, where ABAQUS/EXPLICIT, which is a commercial explicit code, is used for non-linear collision analyses with protection structures. Collision events of protectors of appurtenances (e.g. risers, mooring lines, and seawater lift caissons) with the supply vessel may cause structural damage on the protection structures, and even on the appurtenance structures and hull structures. Therefore, these

protective structures should be designed to withstand accidental collision with the supply vessel.

2. FPSO VESSEL DESIGN

Single bottom and double side hull is designed as shown in Figure 1 with topsides weighing 32,300 tons. This has a refining capacity of 200,000 barrels of oil and 150 million cubic feet of gas a day, and a storage capacity of around 1.9 million barrels of crude oil. It has living quarters that can accommodate about 150 employees. The FPSO is moored in a fixed position, and the suction piles and ground chain are linked. The facilities at the FPSO are planned for a service life of 20 years. The topside control system of FPSO is designed to suit 21 wells and a fourth subsea separation unit. Such subsea production lines, injection lines and risers to a spread moored the FPSO.

The principle dimensions of FPSO are given as follows:

- Overall Length (L): 325.05 m,
- Length between perpendiculars (Lbp): 325.00 m,
- Moulded Breadth (B): 61.00 m,
- Moulded Depth (D): 32.00 m,
- Design Draft (Td): 24.58 m,
- Scantling Draft (Ts): 25.55 m,
- Block Coefficient for Scantling (Cb): 0.983.

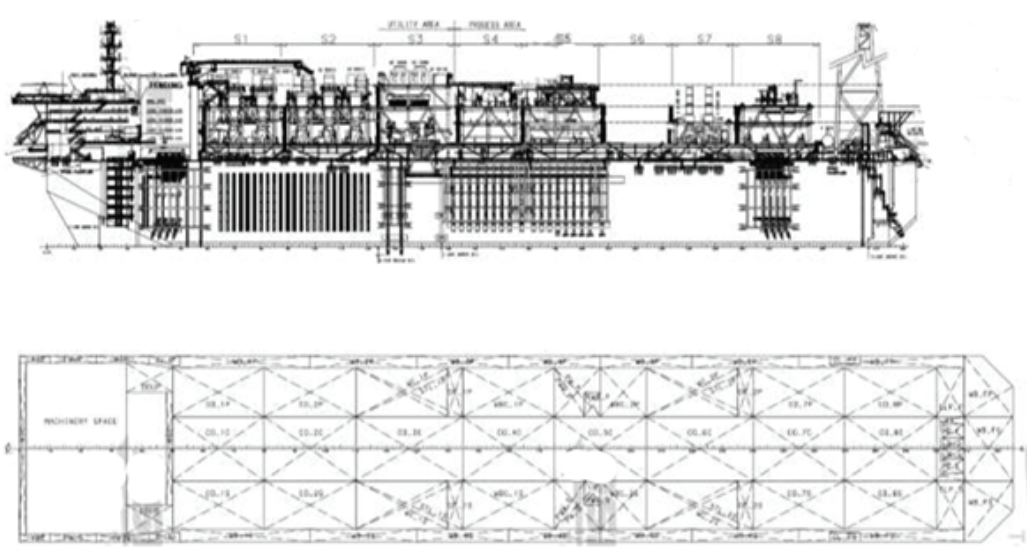


Figure 1.
FPSO vessel general arrangement.

3. DESIGN REQUIREMENTS OF IMPACT ENERGY

Impact energy to be considered in the protectors' collision impact analyses is shown in Table 1. The locations considered in the collision impact analyses are illustrated in Figure 2.

Table 1.
Levels of impact energies required for collision impact analyses of protectors.

			Protectors				
Collision Position	Loading	Acceptance Criteria	Colliding Direction	Speed	Colliding Vessel	Displacement	Impact Energy
Riser/ Mooring/ Seawater Lift Caisson	Accidental	Energy absorbed by plastic deformation (clearance 300 mm for riser only)	Bow	1 m/s	Supply Vessel	7,500 t	4.2 MJ
			Side				5.3 MJ

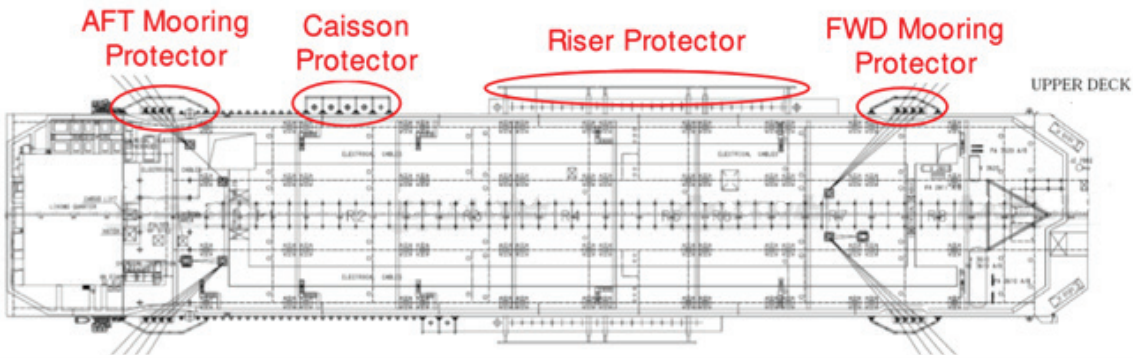


Figure 2.
Description of locations for collision impact analyses of the protectors.

Collisions on side shell and stern hull plating of the FPSO are assumed to be caused by a 7,500 ton supply vessel. The impact velocities are calculated as Eq.1.

$$E = 0.5\,(M + Ad)\,V^2 \quad (1)$$

M = striking vessel displacement (t)
Ad = Added mass (t)
V = Impact velocity (m/s)

A supply vessel with a displacement of 7,500t will be considered in the collision event with protection structures of appurtenances such as risers, mooring lines, and seawater lift caissons. The impact of the 7,500 ton supply vessel at the speed of 1m/s causes kinetic energy of 4.2MJ in bow/stern impact and 5.3MJ in side on impact with an added mass factor of 10% and 40% of the displacement of the colliding vessel respectively. The protection structures may be subjected to significant plastic deformation, but the risers (not other protected structures) should remain undamaged with a minimum clearance of 300mm between the deformed protector and the risers. The other appurtenances should remain untouched during the deformation of protection structures.

The striking vessel is assumed to be a rigid body and this assumption is considered to give conservative results in view of safety. In addition, the FPSO is assumed not to move during collision events. The amount of kinetic energy absorbed to strain energy is required to be assessed as per NORSOK Standard, which allows energy dissipation by the movement of the struck vessel (FPSO). However, it is assumed that all the kinetic energy is absorbed to strain energy for the conservative approach.

4. SCENARIOS FOR COLLISION IMPACT ANALYSES

Various collision scenarios are taken into account in collision impact analyses. Three (3) vertical impact locations are selected considering depth and draught of typical supply vessel as well as FPSO's operating drafts. During on site, FPSO may have various drafts between minimum draft of 11.19 m (normal operation) and maximum draft of 24.58 m (full draft).

A typical supply vessel has moulded depth of 8.0 m with draught of 6.5 m. This means that the bow end of the supply vessels is located 1.5 m above seawater level. The main dimensions of a typical supply vessel are summarized in Table 2.

Table 2.
Main dimensions of typical supply vessel.

Overall length	90.00 m
Length waterline	78.00 m
Overall beam	19.00 m
Moulded depth	8.00 m
Draught	6.50 m
Max. dead weight	3,800 t
Light displacement	3,700 t
Loaded displacement	7,500 t
Cruise speed	12 knots
Max. speed	16 knots

Two different attack angles (0 / 90 degrees) were considered mainly in collision with protection structures to evaluate the protector itself and to obtain reaction forces that should be used for the design of support structures. Zero degree attack angle

was accounted by supply vessel and was applied to mooring protectors and seawater lift caisson protectors on the vessel landing area (Zhang, 1999). In addition, the slanted parts of mooring protectors were considered to be impacted by supply vessel perpendicular to the protectors (about 42 degrees with FPSO). Table 3 summarizes collision scenarios to be considered.

Table 3.
Collision scenarios for the simulations.

	Protection Structures		
	Riser	Mooring	Caisson
FPSO Draft	Three drafts (full/mid/min.)		
Collision Angle	90 degree	0/42/90 degrees	0/90 degrees
Note	Side shell longitudinal stiffeners' locations are considered		

The proposed locations for collision impact analyses on protectors are illustrated in Figure 3, while Figure 4 illustrates the attack angles for collision on protector structures.

Detailed load cases for each protector are summarized in Table 4, and sketches of impact locations for the protectors are given in Figure 5 to Figure 8.

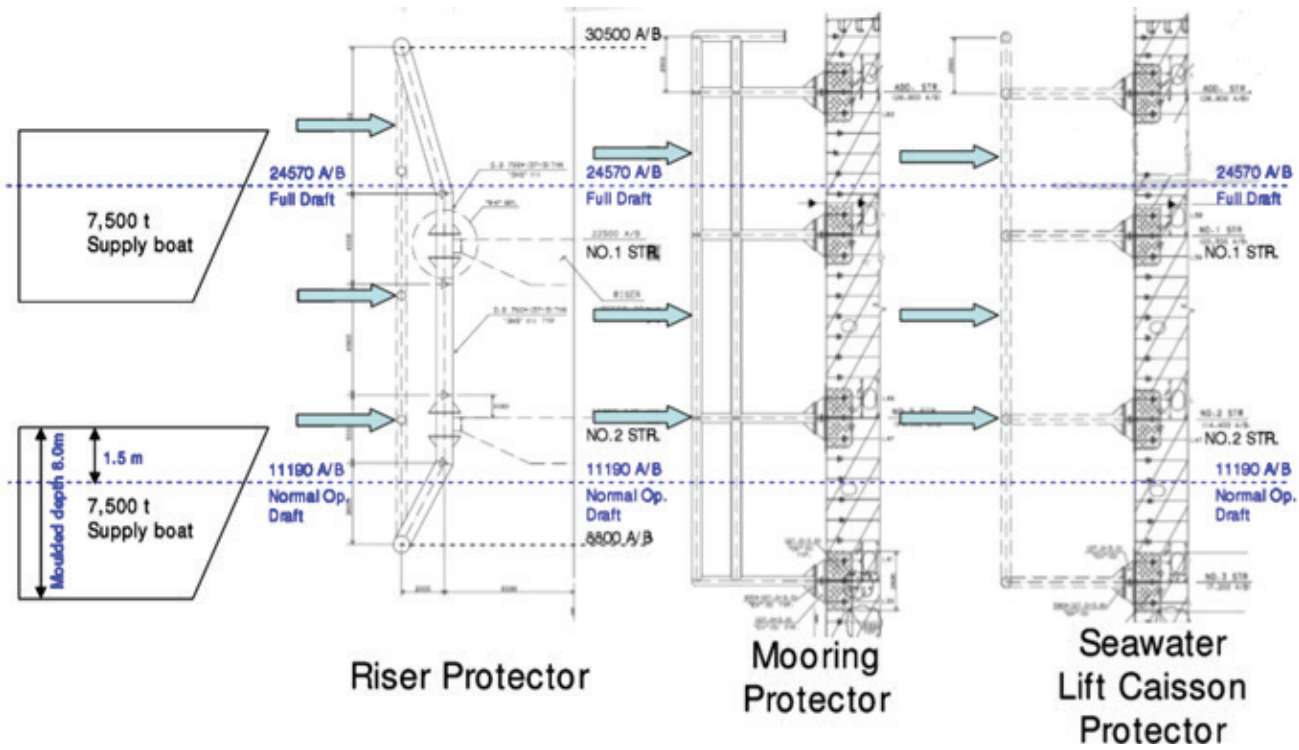


Figure 3.
Vertical locations for collision impact analyses on protection structures (NORSOK N-004).

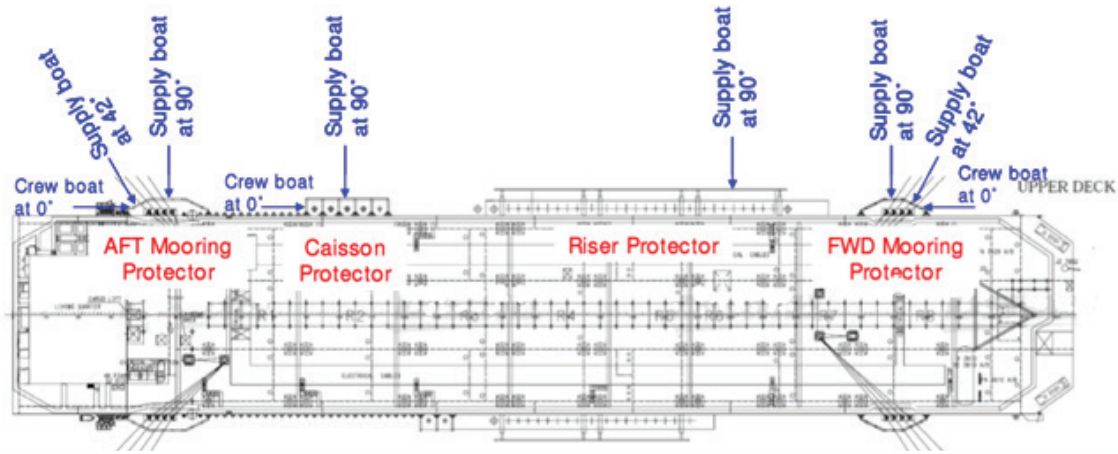


Figure 4.
Attack angles for collision impact analyses on protection structures.

Table 4.
Detailed load cases for collision impact analyses.

Riser Protector				
LC	Impact angle	Impacting vessel	Approaching direction	Energy to be absorbed
1 ~ 8	90 degree	Supply vessel (7,500 t)	Bow	4.2 MJ
9 ~ 12			Side	5.3 MJ
Mooring Protectors				
LC	Impact angle	Impacting vessel	Approaching direction	Energy to be absorbed
1 ~ 5	90	Supply vessel (7,500 t)	Bow	4.2 MJ
6 ~ 8	42			
9 ~ 11	90		Side	5.3 MJ
12 ~ 14	42			
15	0	Crew boat (478 t)	Bow	0.263 MJ
Seawater Lift Caisson Protectors (PORT)				
LC	Impact angle	Impacting vessel	Approaching direction	Energy to be absorbed
1 ~ 9	90	Supply vessel (7,500 t)	Bow	4.2 MJ
10 ~ 16	90		Side	5.3 MJ
17	0	Crew boat (478 t)	Bow	0.263 MJ
Seawater Lift Caisson Protectors (STBD)				
LC	Impact angle	Impacting vessel	Approaching direction	Energy to be absorbed
1 ~ 8	90	Supply vessel (7,500 t)	Bow	4.2 MJ
9 ~ 14	90		Side	5.3 MJ
15	0	Crew boat (478 t)	Bow	0.263 MJ

Bow collision was simulated by one (1) contact point instead of surface area, which might give severer results since it is certain that the bow of the striking vessel is blunt. Furthermore, even though the supply vessel has over 90m of beam, only two (2) vertical beams were taken into consideration. The striking views simulated in FEA are shown in Figure 5.

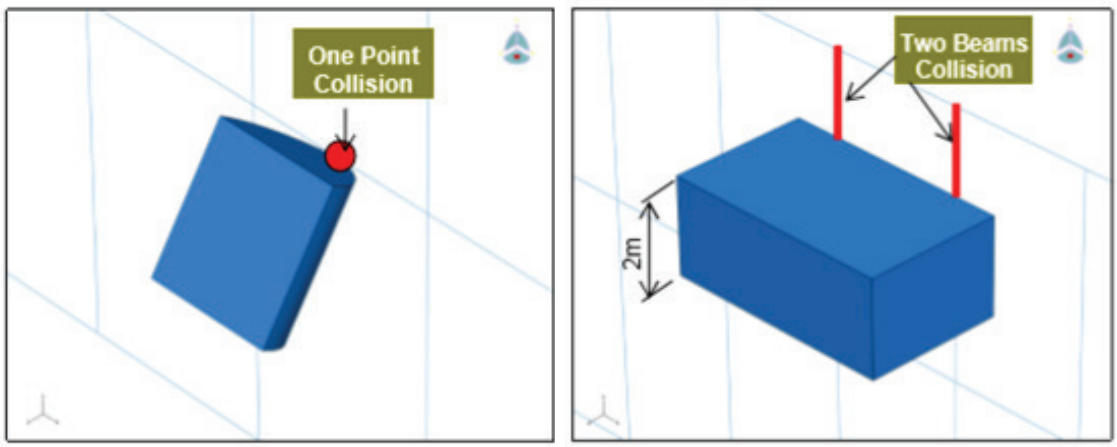


Figure 5.
Striking view simulated in finite element analyses.

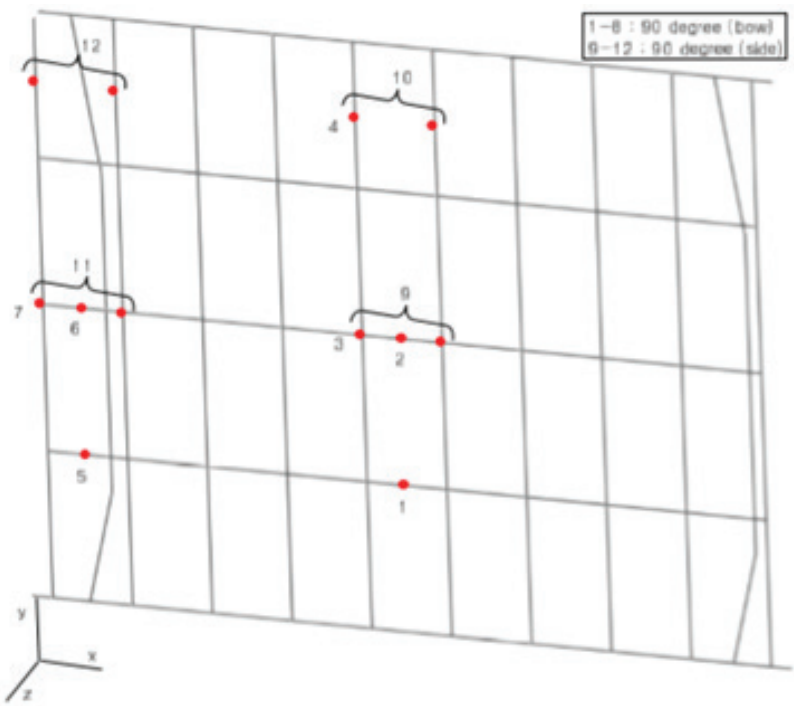


Figure 6.
Load cases and impact locations for riser protector.

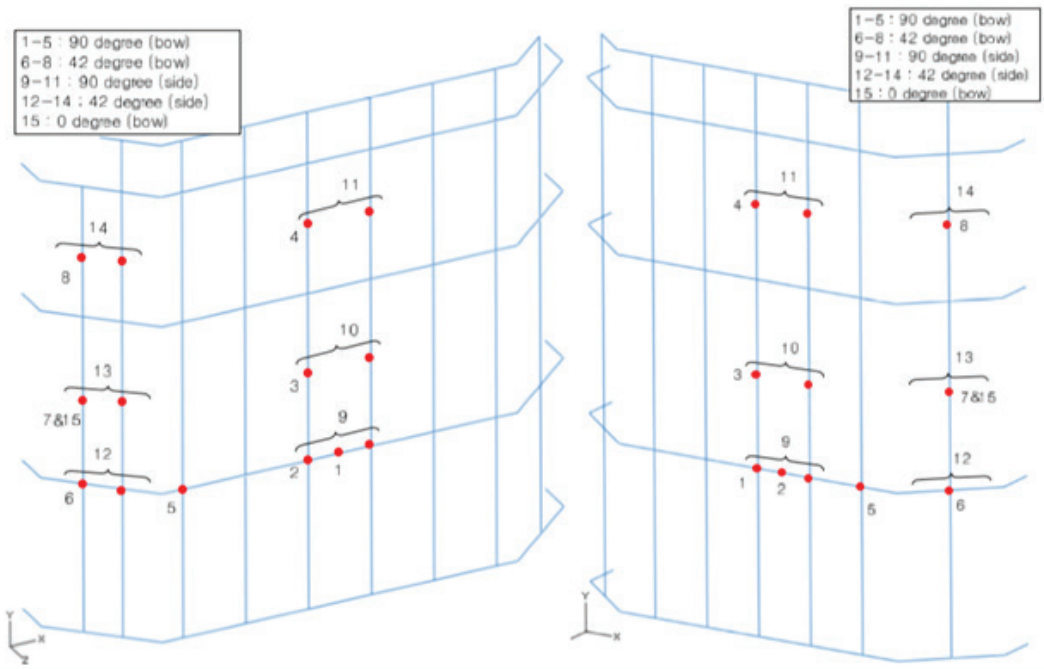


Figure 7.
Load cases and impact locations for mooring protectors (left: Aft Mooring Protector, and right: Forward Mooring Protector).

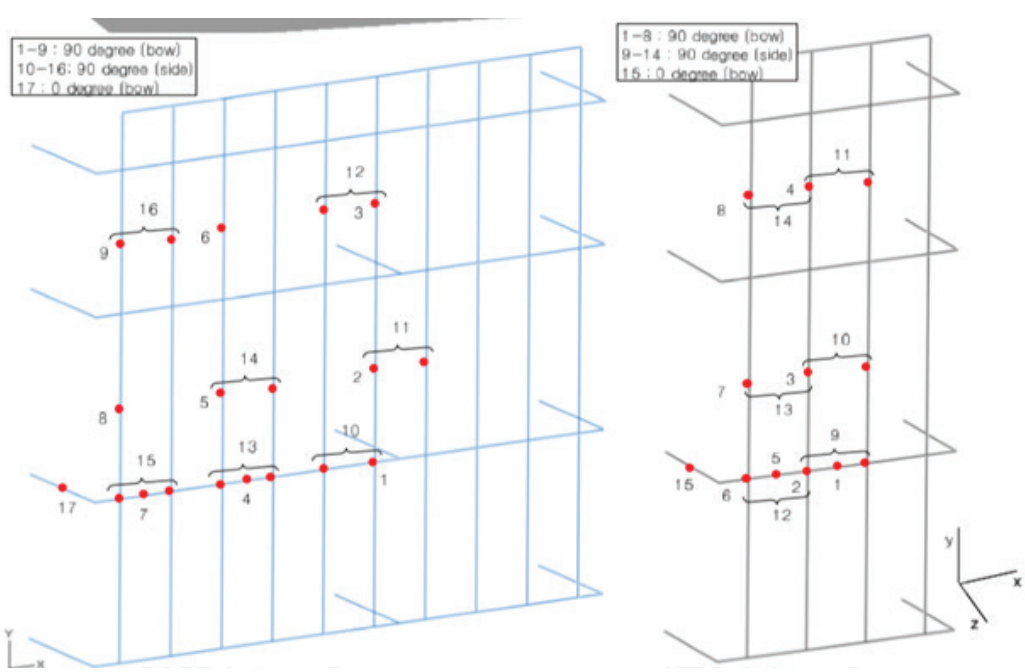


Figure 8.
Load cases and impact locations for seawater lift caisson protectors (left: PORT Caisson Protector, and right: STBD Caisson Protector).

5. RUPTURE STRAIN AND MATERIAL PROPERTY

The amount of kinetic energy absorbed as strain energy must be assessed in accordance with the NORSOK standard. It is presumed, however, that all of kinetic energy is consumed in a conservative way to rupture strain. The percentage of rupture strain is also determined depending on the grade of steel, as shown in Table 5 below, as per the NORSOK Standard. Interpolation calculated the percentage of rupture strain for the grade of steel that is not specified in the table. In addition, material properties used in collision analysis are depicted in Table 6.

Table 5.
Proposed values of εcr for different steel grades by NORSOK.

Steel Grade	Critical Strain (εcr)
Mild	20%
HT 32	16.7%
HT 36	15%

Table 6.
Material properties to be used in non-linear F.E. analyses (DNVGL-RP-C208).

Steel Grade	Mild	HT 32	HT 36
Yield stress	235 MPa	315 MPa	355 MPa
Elastic strain	0.20%	0.20%	0.20%
Ultimate tensile stress	450 MPa	530 MPa	560 MPa
Critical failure strain	20.0%	16.7%	15.0%
Density	7,850 kg/m3	7,850 kg/m3	7,850 kg/m3
Young's modulus	2.06e+11 N/m2	2.06e+11 N/m2	2.06e+11 N/m2
Poison's ratio	0.3	0.3	0.3
Tangent modulus	1,085 MPa	1,303 MPa	1,385 MPa
Hardening parameter	1.0	1.0	1.0
Strain rate (C)	40.4	3200	3200
Strain rate (P)	5.0	5.0	5.0

6. ASSESSMENT METHOD

In this study, FE analyses focus on the assessment of a multitude of possible scenarios of ship collision and structural configurations to be analysed. An FE analysis is the most flexible method and can account for possible effects occurring as well as be used to assess the relevant factors such as impact energy, boundary conditions, material, and discrete indenter shape, and stiffness and indentation location. Assessing non-linear material behaviour is essential when determining the response of a structure.

The properties of the elastic-plastic materials should be described by application:

- An initial yield criterion;
- A hardening rule where the yield condition is modified due to the history of plastic flow;
- A flow rule that updates the plastic stiffness using an incremental stress-strain relationship.
- The explicit method of analysis for the FE has the following properties:
- Can manage very low dynamic response times, allowing highly discontinuous processes for large models;
- Allows for large deformations and rotations;
- It can analyse assembled parts with very general contact definitions;
- A linear geometrical deformation theory can be employed if small deformations and rotations are presumed;
- Adiabatic stress analysis may be used if heat generation is assumed to be associated with inelastic dissipation;
- Allows for quasi-static analysis of models with complex contact definitions;
- Allows the deletion of the element to the rupture model.

To check the strength of the structures against collision impact, explicit nonlinear FE simulations are carried out, including large deformation of structures and the properties of elastoplastic material. Strain hardening effect together with ultimate stress is accounted for nonlinear FE simulations as a bi-linear strain-stress curve based on material grades as shown in Figure 9 and Figure 10. The fracture was determined on the basis of the critical plastic strain of the material used in accordance

with the NORSOK standard. Figure 11 shows the properties of the material used in non-linear simulation. Ultimate stress data are average values and critical strain data are based on the NORSOK standard. The Cowper-Symonds rate enhancement formula is employed to account for the effect of strain rate on material properties as given in Eq.2, Eq.3 and Eq.4 that are shown in Figure 9 and Figure 10.

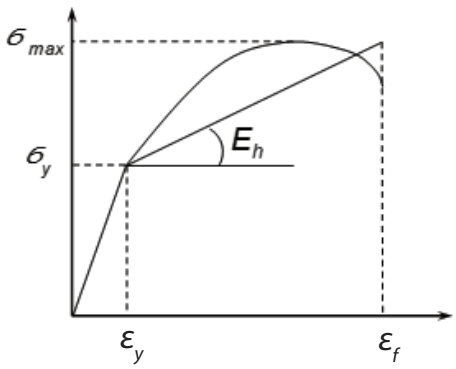


Figure 9.
Stress-strain curve for bi-linear material.

$$\sigma_p = \sigma_y + \frac{EE_h}{E-E_h}\varepsilon_p \quad (2)$$

$$E_h = \frac{\sigma_{ymax} - \sigma_y}{\varepsilon_f - \varepsilon_y} \quad (3)$$

σ_y = Yield stress
E_h = Hardening modulus
σ_p, ε_p = Plastic stress and Plastic strain
E = Young's modulus

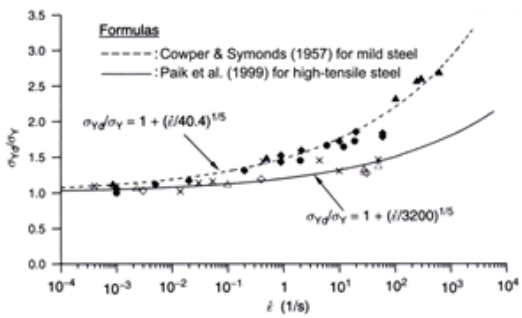


Figure 10.
Strain rate effect.

$$\frac{\sigma_{yd}}{\sigma_y} = 1 + \left\{\frac{\varepsilon}{D}\right\}^{1/q} \quad (4)$$

Mild steel:	D=40.4,	q=5
HT steel	D=3200,	q=5

It is noted that σ_{yd} is the dynamic yield stress; σ_y is the static yield stress. The material properties given to the initial configuration are in accordance with the steel quality used for the FPSO vessel. This included steel grades Mild, HT32 and HT36 as per DNVGL-RP-C208 (2019).

Collision simulation, including material and geometric nonlinearities, was performed using ABAQUS Explicit tool. To determine the strength capacity of hull plating for the supply vessel and oil tanker against collision events, advanced non-linear FE simulation is performed because complex responses are caused by these collision events. Element properties applied in the FE models are produced by deducting full of DNVGL Ship Rules corrosion addition from rule gross scantling according to DNVGL Ship Rules Part 3, Chapter 1 requirement (2019).

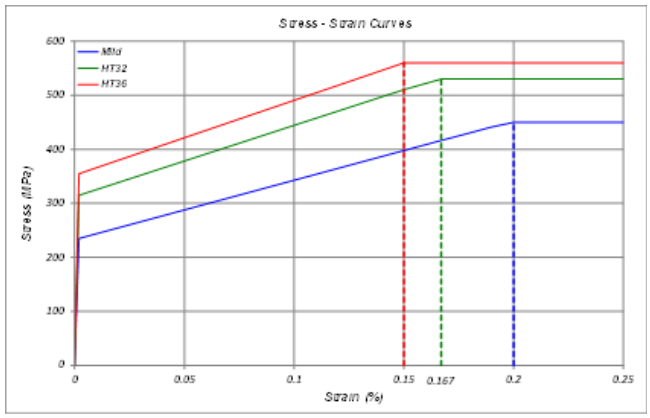


Figure 11.
Stress-strain curves for different steel grades.

7. FINITE ELEMENT (FE) MODELS

The capacity of protection structures in view of strain energy has been assessed with simple beam FE models. Due to the simplicity of structures, ABAQUS Explicit code has been employed for the collision simulation with protection structures. FE models of riser protector, aft mooring protector, forward (FWD) mooring protector, port caisson, starboard (STBD) caisson with bow and side impact rigid models are shown in Figures 12 to 21.

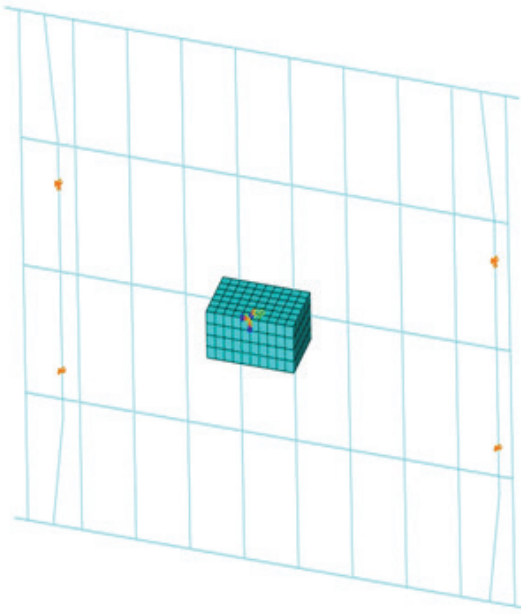


Figure 12.
FE model of riser protector and side impact rigid model.

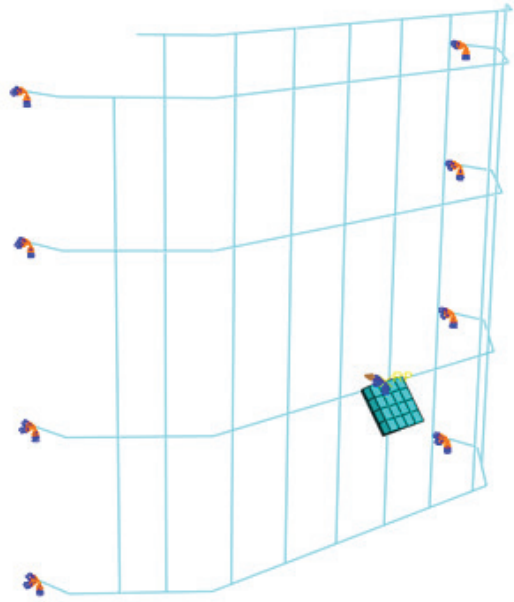


Figure 13.
FE model of AFT mooring protector and bow impact rigid model.

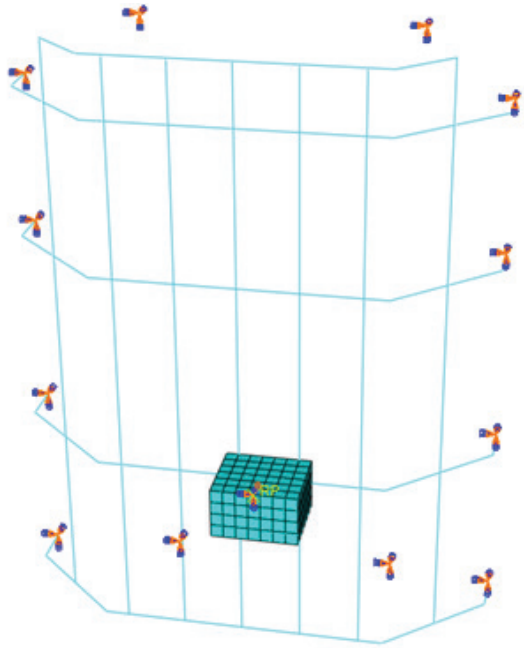


Figure 14.
FE model of FWD mooring protector and side impact rigid model.

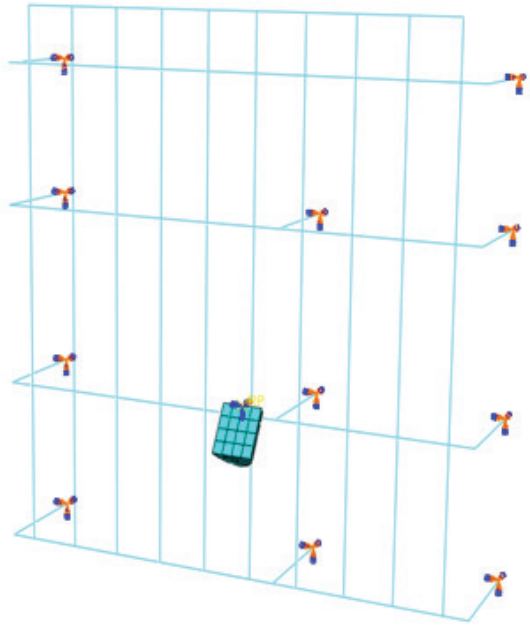


Figure 15.
FE model of PORT caisson protector and bow impact rigid model.

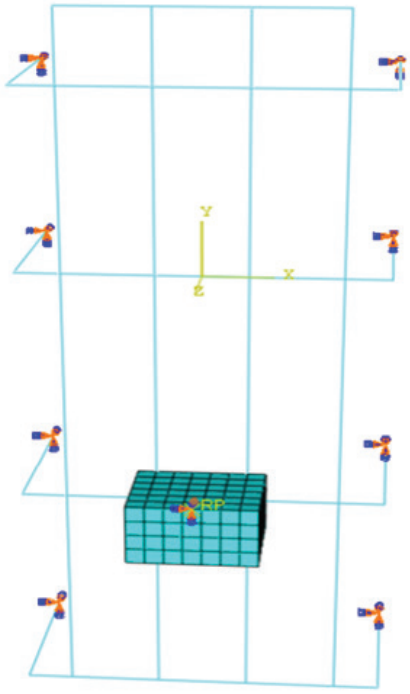


Figure 16.
FE model of STBD caisson protector and side impact rigid model.

8. BOUNDARY CONDITIONS

Boundary condition of each protector has been set according to the connection mechanism of protectors to the supporting structures.

For riser protectors, riser guard is clamped to 4 supports (2 at upper and 2 at lower), which are welded to the hull. Clamps are provided with elastometric pads and allow small rotation, as shown in Figure 17. In a practical approach, stiffness of the hull and stiffness of the clamp system have not been taken into account: upper supports are considered pinned and lower supports guided. For instance, if the upper support is assumed with pinned boundary, it is certain that the lower support does not react to lateral behaviour because the angular deformation is completely restricted at upper structure. The expected shape of protector during collision may be given as in Figure 17.

For mooring protectors and seawater lift caisson protectors, protectors are welded to supports which are also welded to hull. Hence, all the supporting locations are considered as fixed boundary, both in translational and rotational directions. The boundary conditions of supports are summarised in Table 7, and the sketch of each protector is shown in Figure 18.

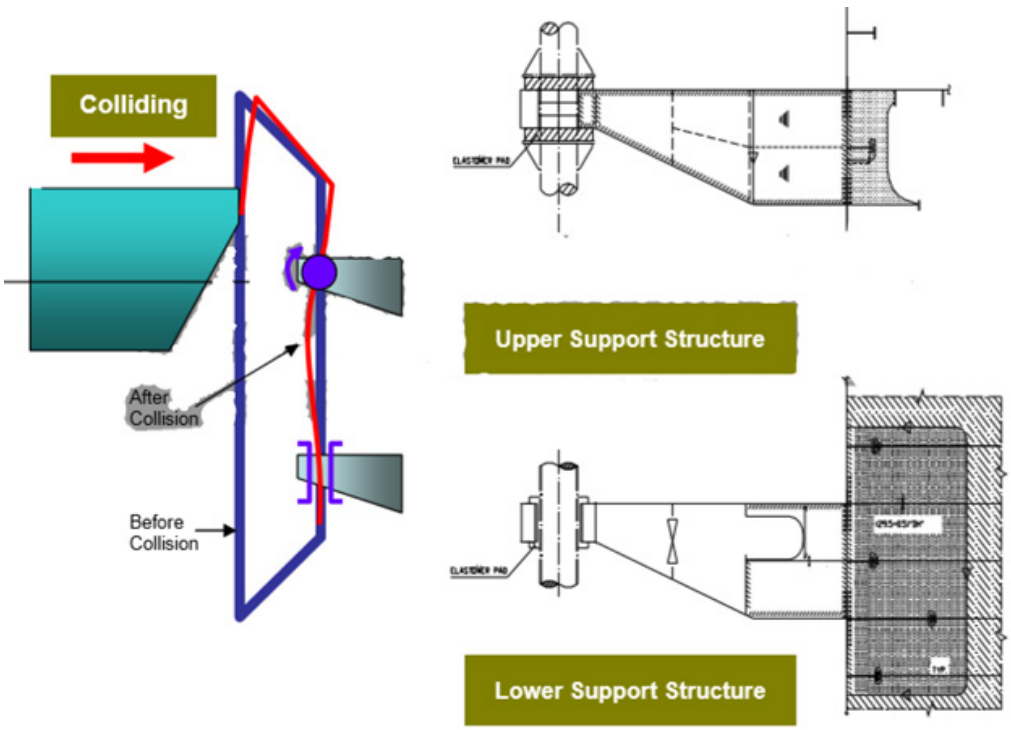


Figure 17.
Clamp and riser guard of riser protector (Upper and Lower Support).

Table 7.
Boundary conditions of each protector.

Protectors	Riser protector		Mooring / Caisson protector
Supports	Upper supports	Lower supports	All supports
Translation	UX=UY=UZ=0	UX=UZ=0, UY=FREE	UX=UY=UZ=0
Rotation	RX=RY=RZ=FREE		RX=RY=RZ=0

Note: x is longitudinal direction
y is vertical direction
z is transversal direction

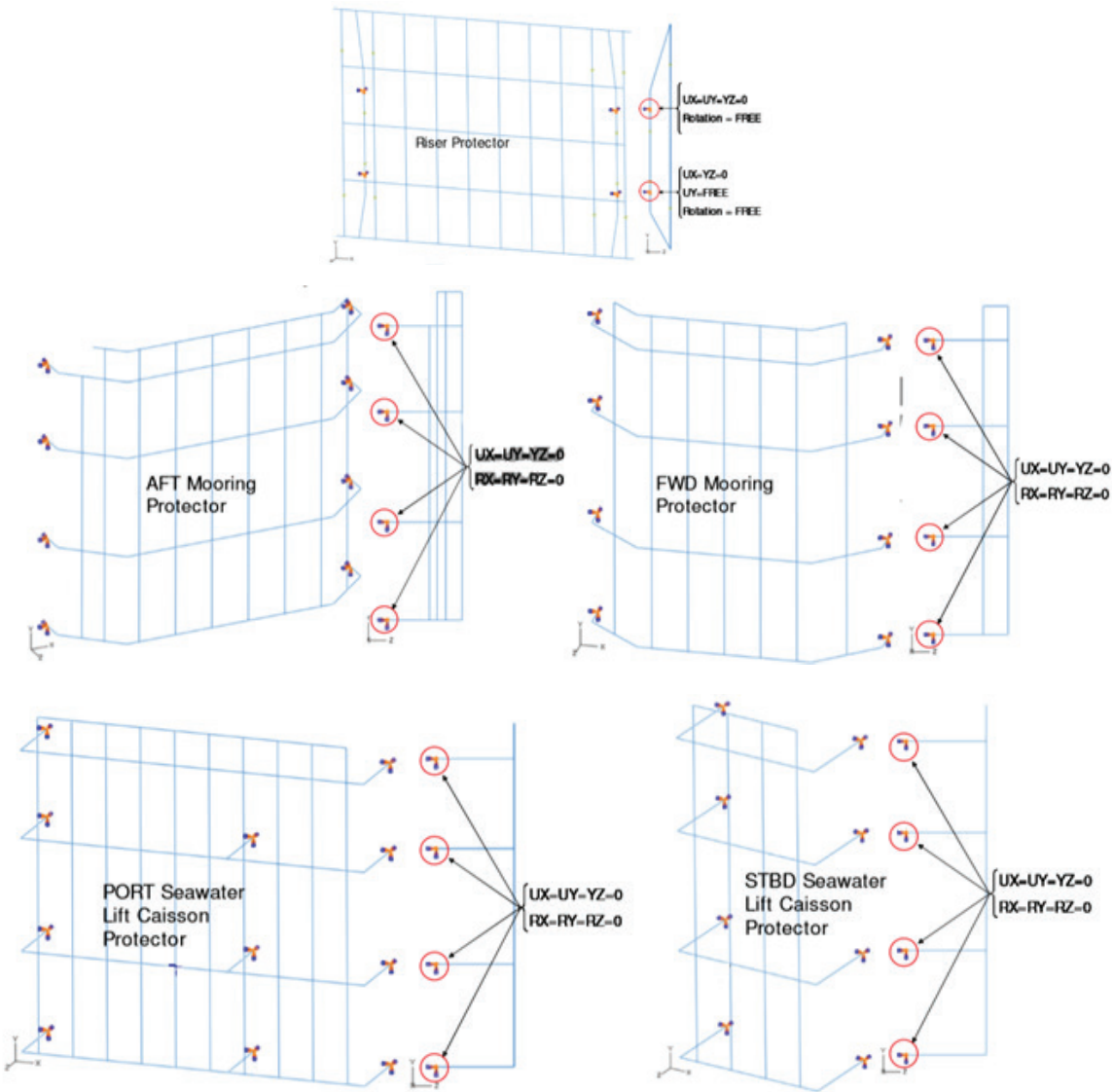


Figure 18.
Boundary conditions of protectors.

9. FINITE ELEMENT SIMULATION

Collision events are simulated by giving initial speed of 1.0 m/s to the rigid body, which represents colliding supply vessel. The mass of the rigid body varies according to the colliding directions (bow/side-on) with corresponding added mass coefficients.

During the collision the surface contact between the supply vessel and the protector is taken into consideration. An infinite coefficient of friction is used during contact phenomenon because it is considered a conservative approach to allow no slip at the contact point. The contact was defined by beam-to-surface in ABAQUS. Self-contact which may occur due to large deformation of protector is allowed, but no self-contact occurred.

10. LOCAL DENTING EFFECT

For local denting on the pipe surface due to the ship collision, it may be necessary to estimate the reaction force from the striking vessel (NORSOK standard N-004). The response of a beam subjected to a collision load is initially governed by bending, which is affected by and interacts with local denting under the load. The bending capacity is also reduced if local buckling takes place on the compression side. As the beam undergoes finite deformations, the load carrying capacity may increase considerably due to the development of membrane tension forces. This depends upon the ability of adjacent structure to restrain the connections at the member ends to inward displacements. Provided that the connections do not fail, the energy dissipation capacity is either limited by tension failure of the member or rupture of the connection.

Obviously, the bow collision might affect more the denting phenomenon on the surface rather than side directional collision. The local denting was looked into by considering a collision on the middle of the span of riser protector, which was chosen as an example for knowing how a certain level of denting may take place on the tube. Load Condition (LC2) is accounted for a colliding event by supply vessel's bow.

From the FE results, the reaction force of 342 kN was calculated and compared to the critical resistance as per NORSOK Standard "N-004, Design of Steel Structures".

The critical resistance can be calculated to 279 kN, so the ratio of resistances is 1.22 (=342kN / 279kN). In accordance with the NORSOK N-004 code, the denting depth due to bow collision is required to be no more than 0.01D. Thus, considering the outer diameter of 450 mm, the denting depth is merely 4.5 mm, which would be negligible in the reduction of moment capacity due to local denting, which is referred to in Figures 19 and 20, according to NORSOK N-004. Finally, the effect of local denting from ship collision is not taken into account here.

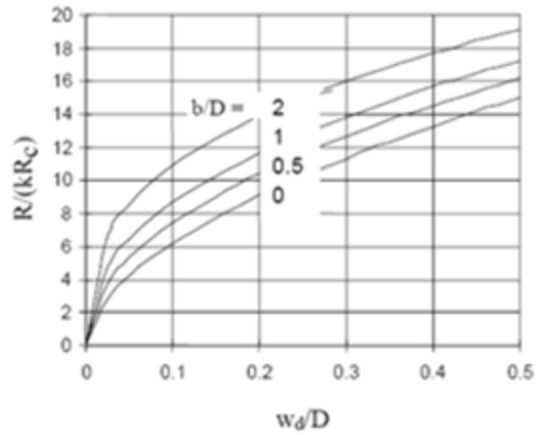


Figure 19.
Resistance curve for local denting.

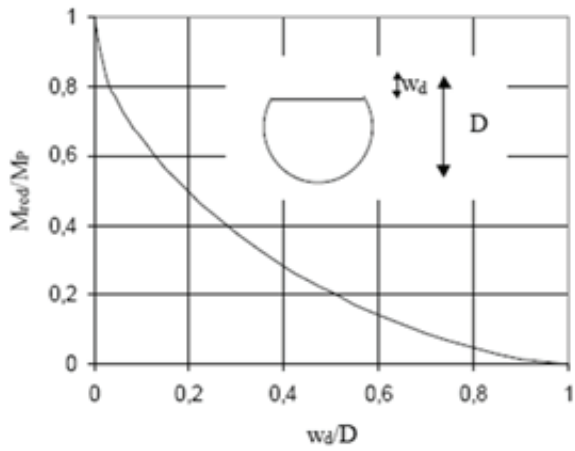


Figure 20.
Reduction of Moment Capacity due to local dent.

11. FINITE ELEMENT (FE) RESULTS

For all the impact load cases, the following results are provided:

- The maximum plastic strain and the maximum deflection,
- The maximum/minimum reactions at supports,
- Estimated acceleration of FPSO due to collision events on riser protector,
- Plots of deformed shape and plastic strain contour,
- graph containing kinetic energy and absorbed internal energy.

The maximum plastic strain and deflection results are summarized in Table 8.

Table 8.
Summary of result data on maximum plastic strain and deflection.

Protectors type	Plastic strain (%)		Deflection (meters)		
	Max. Results	Criteria	Max. Results	Criteria	Margin**
Riser	4.12	15	2.124	300 mm clearance to risers	0.321
AFT mooring	5.95	15	1.282	Not to contact with protected structures	0.559
			0.644 *		0.649
FWD mooring	7.75	15	1.341		0.500
			1.102 *		0.176
PORT caisson	7.82	15	1.051		1.524
STBD caisson	7.99	15	1.049		1.574

The results show that all the protectors sustain plastic strain of less than 8 %, which is about half of the critical plastic strain. This means that all the protectors sustain excessive stress of yield and deform permanently due to the accidental collision events by a supply vessel; however, they do not fail. The maximum deflection of the riser protector is 2.124 m, which is a sufficient margin considering the design criteria of 300 mm clearance to the risers.

The mooring protectors deform up to 1.282 m and 1.341 m at the parallel part of AFT and FWD mooring protector respectively. The results also show that the slanted parts of protectors in the way of No.3 stringer have not been contacted by mooring chain stoppers including related structures.

The maximum deflections of 1.051 m and 1.049 m for each PORT and STBD caisson protector show that collision events due to a supply vessel do not cause any contact between protectors and seawater lift caissons. Table 9 gives the summarized maximum deflections for each protector.

Reactions on the supports are obtained to be used as design loads of supporting structures of the appurtenances. To check whether the resultant acceleration of the FPSO due to the collision events on riser protector by a supply vessel affects the design basis of topside structures, the resultant translational acceleration of FPSO is estimated as following way:

Step 1. The maximum sum of reactions at the supports due to the collision on riser protector is calculated as 5,990 kN.

Table 9.
Summary of maximum deflection for protectors.

Protector	Colliding	Load Case	Deflection [m]
Risers	Bow	LC1	1.682
	Side	LC10	1.071
AFT Mooring	Bow	LC1	1.110
	Side	LC9	1.282
FWD Mooring	Bow	LC1	1.206
	Side	LC9	1.341
PORT Caisson	Bow	LC6	0.933
	Side	LC13	1.051
STBD Caisson	Bow	LC3	0.968
	Side	LC9	1.049

Step 2. The minimum displacement of FPSO is 147,825 tons at the loading No. 1101 – normal towing condition.

Step 3. The lateral acceleration is estimated with the assumption that the FPSO will behave as a rigid body: F/m = 5,990 kN / 147,825 = 0.0405 m/s = 0.004g.

Finally, there is no need for concern about the additional effect of topsides due to the ship's collision-induced inertia because the induced inertia is too low in comparison with the design lateral acceleration.

Buckling may be concerned at the ship collision in the way of the support member giving very high reaction into the hull structure; so, LC10 of the protector of PORT Seawater Lift Caisson was chosen as a critical loading case.

From the FE results, the member in the way of the impact had the sectional force of 140 kN and the bending moment of 640KN-m at the load case. The evaluation was done based on AISC Code (2001). Boundary condition was assumed to both ends fixed. Considering the scantling of member of Outer Diameter (OD) 550 x 30, the permissible force was calculated to around 1,000 kN, in which the unity check value was only 0.32 (i.e. <1.0) for accidental design factor of 1.0 (i.e. σall = 1.0 σ_y). Finally, the buckling is not the matter of concern. The collision was a side-on event, which concerns only two (2) members.

12. KINETIC ENERGY AND INTERNAL ENERGY

To check whether the collision simulations are carried out properly, the kinetic energy of the supply vessel and the absorbed internal energy of the protectors are plotted based on time. Most cases show that the kinetic energy starts from the required energy level, and the internal energy increases up to the required energy level. These results reveal that the loadings are properly applied and the simulations are carried out reasonably.

Some cases show that the kinetic energy is not reduced to zero and, hence, the internal energy does not absorb the required energy level. The reason may be that the structure is so stiff that the striking body is bounded before its kinetic energy is consumed. The crew boat collision events show this phenomenon.

The detailed results about the energy level change for all the load cases are shown in Figures 21 to 26. Design loads for the foundation of protectors are summarized in Table 10.

Table 10.
Summary of design loads for protector's foundation.

Item	Fx		Fy		Fz		Rx		Ry		Rz	
	min	max	min	max	min	max	min	max	min	max	min	max
Risers	-2,640	2,630	-4,010	813	-2,220	5,700	-	-	-	-	-	-
AFT Mooring	-3,280	4,340	-1,370	1,180	-1,220	9,950	-2,320	2,860	-5,800	4,900	-1,790	1,710
FWD Mooring	-2,610	2,610	-1,070	1,110	-6,530	4,610	-2,460	2,520	-4,090	4,330	-9,450	6,540
PORT Caisson	-5,120	1,770	-1,070	1,030	-1,610	13,400	-3,030	3,080	-8,570	4,730	-289	348
STBD Caisson	-3,540	1,360	-696	619	-1,190	5,830	-1,500	1,530	-6,150	3,850	-203	253
(Unit : kN, kN-m)												

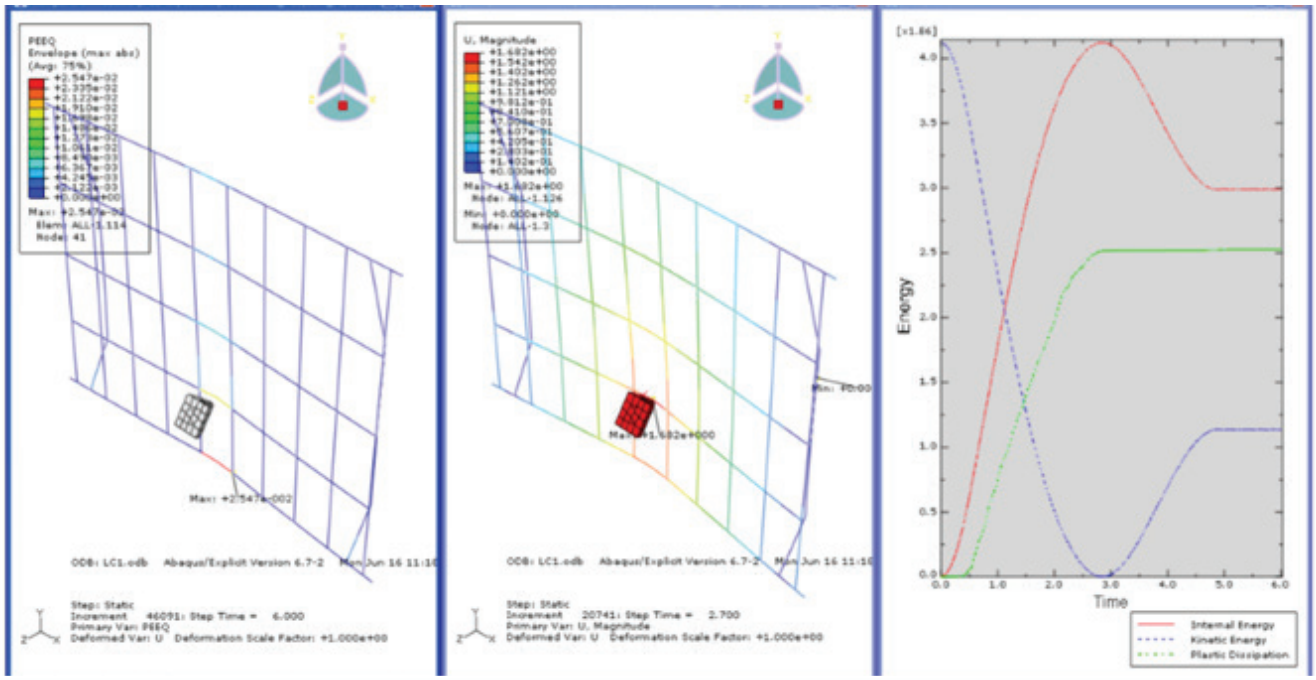


Figure 21.
Results of LC 1 of riser protector (plastic strain, deflection, energy levels).

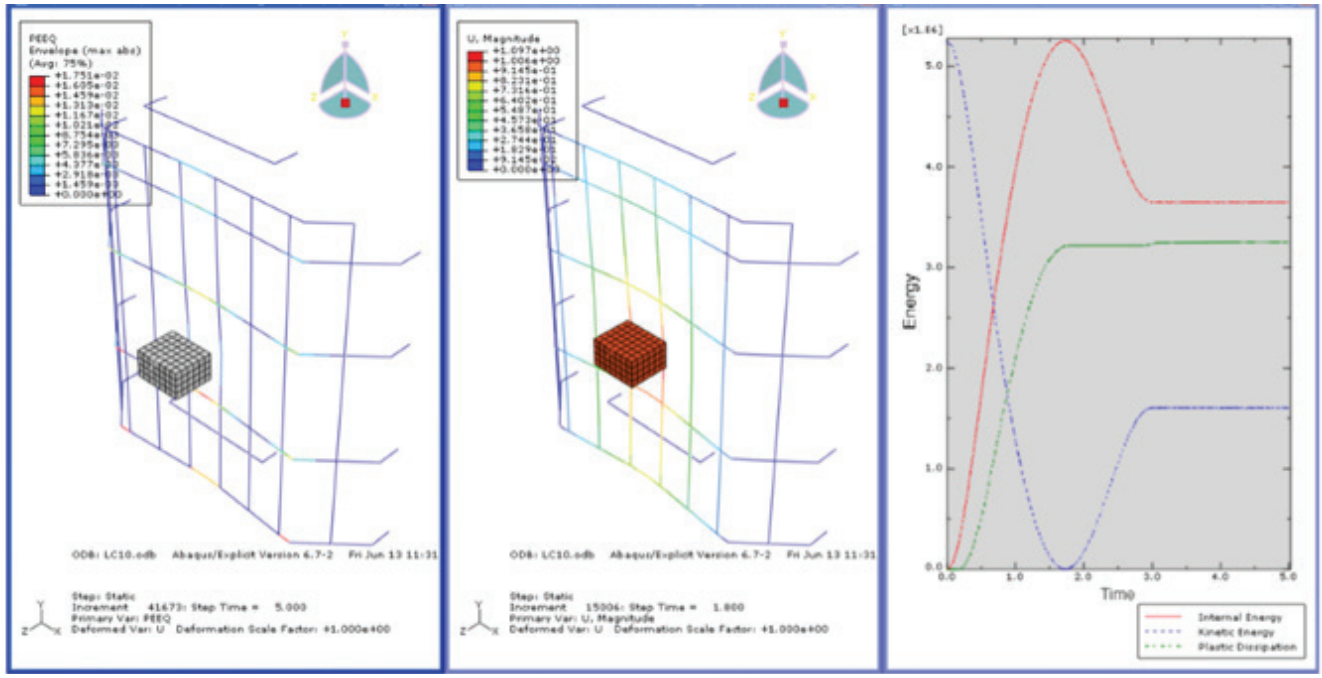


Figure 22.
Results of LC 10 of riser protector (plastic strain, deflection, energy levels).

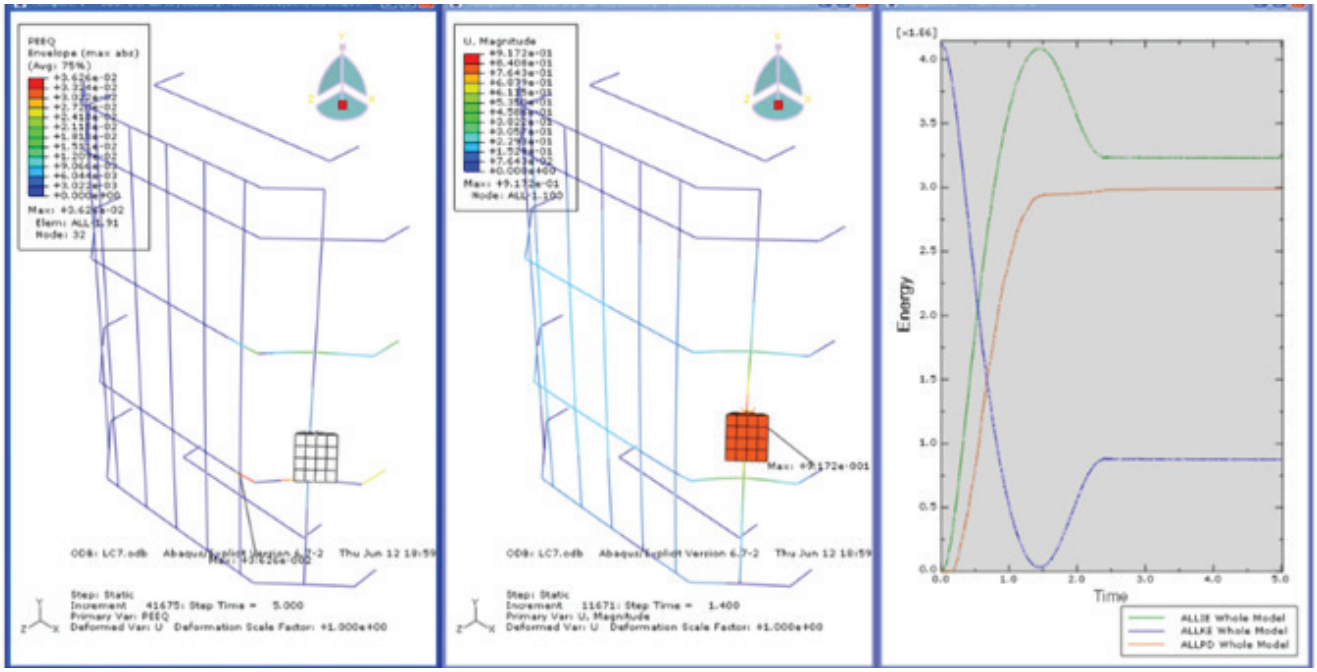


Figure 23.
Results of LC 7 of FWD mooring protector (plastic strain, deflection, energy levels).

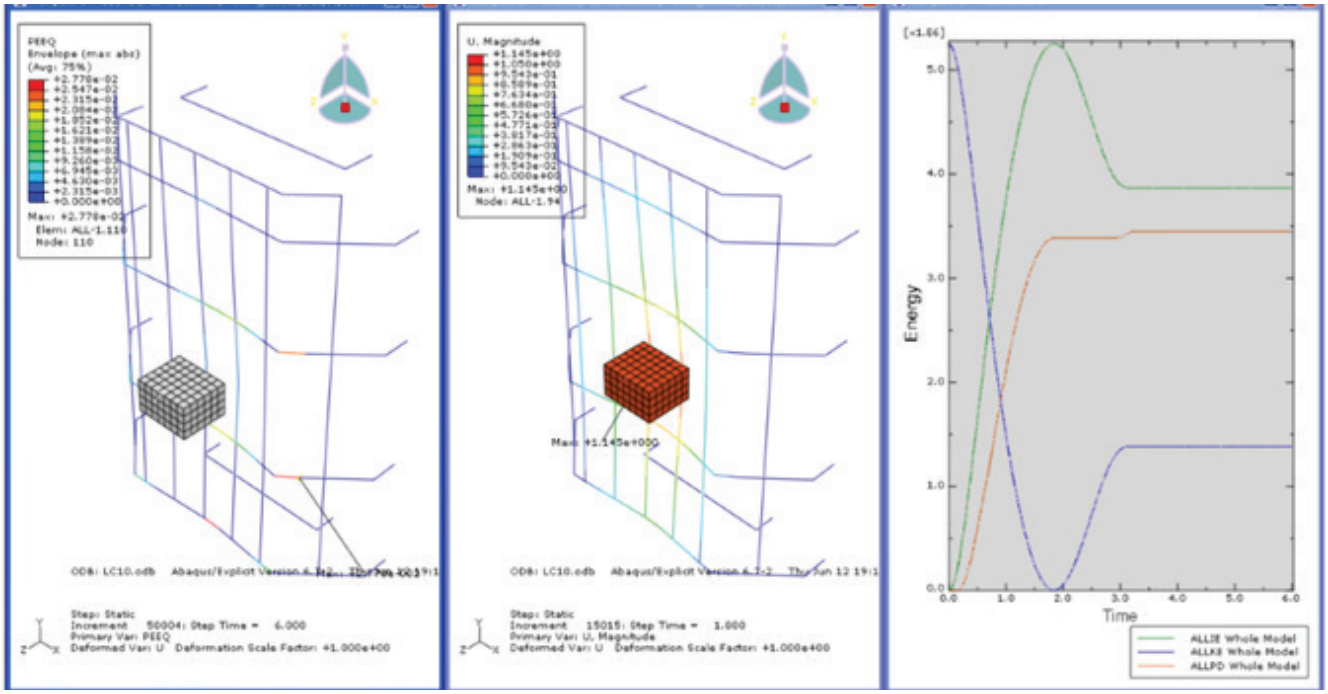


Figure 24.
Results of LC 10 of FWD mooring protector (plastic strain, deflection, energy levels).

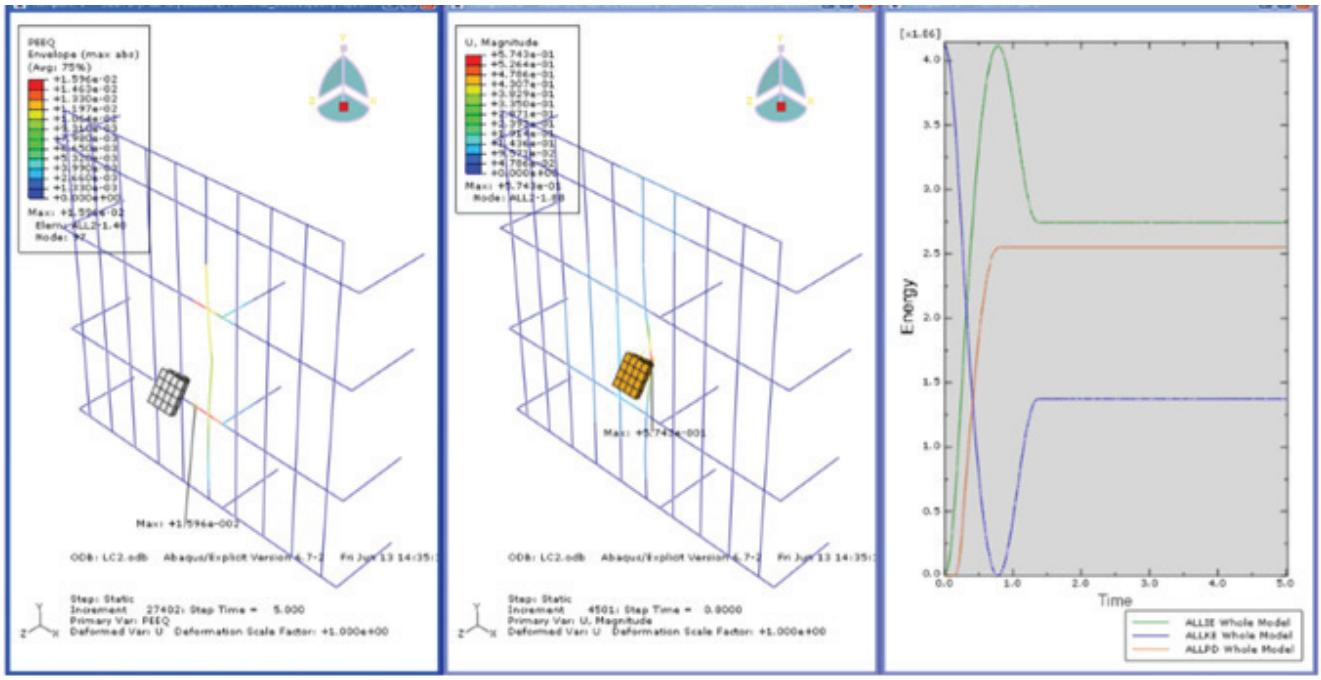


Figure 25.
Results of LC 2 of PORT seawater lift caisson protector (plastic strain, deflection, energy levels).

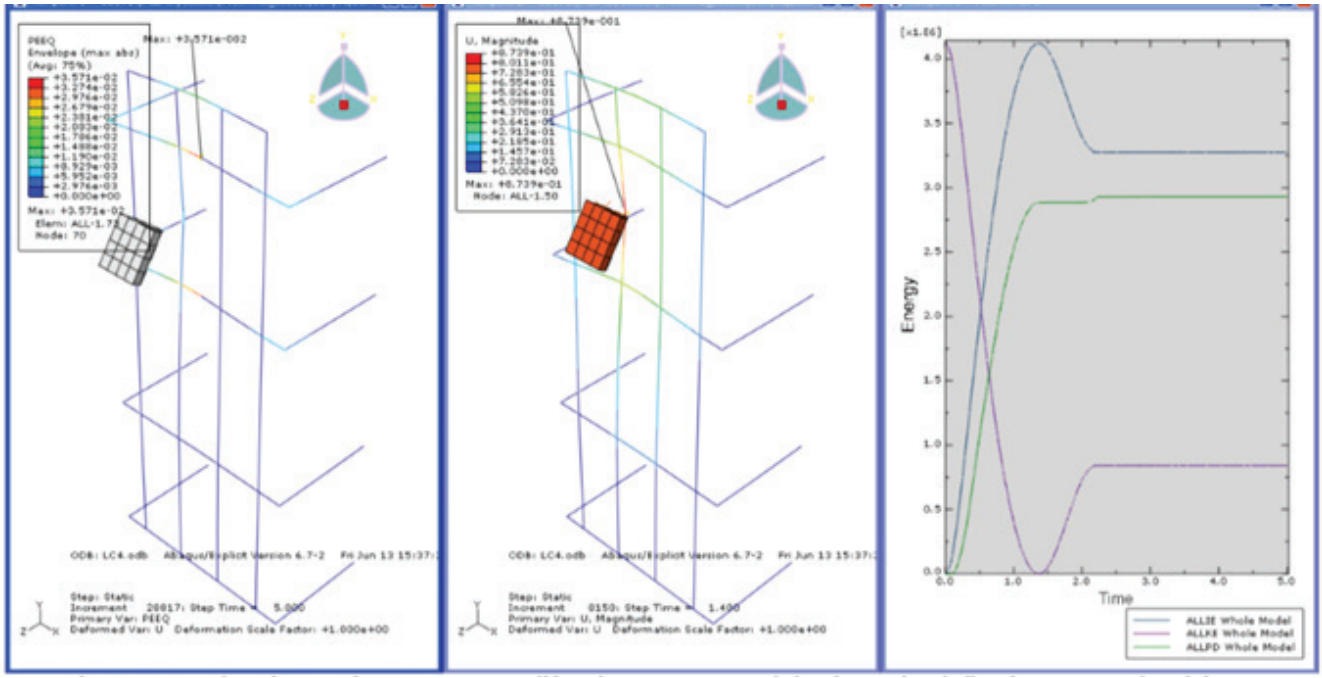


Figure 26.
Results of LC 4 of STBD seawater lift caisson protector (plastic strain, deflection, energy levels).

13. CONCLUSION

Caissons for seawater lift and discharge are normally positioned on the side shell structure. The design should consider the handling requirements for installation, and on-site deployment and maintenance. On the other hand, external vertical caissons fitted with strainer and submerged lift pump for seawater intake, running along the side shell are used. These external vertical caissons should be protected against collision and designed for an easy maintenance.

The collision impact analysis shows that while some parts of the protective parts are permanently deformed by collision events, there is no failure based on the NORSOK standard plastic strain criteria in which the critical plastic strain for HT36 steel grade is specified as 15%.

Bow collision is being simulated by one (1) contact point instead of a surface area, which might produce severer results since it is certain that the bow of the striking vessel is blunt. Furthermore, even though the supply vessel has a beam of over 90m, only two (2) vertical beams are taken into consideration, which is also very conservative.

The maximum deflections were checked, and no contact was found between the protectors and the protected structures. To verify if the collision simulations are performed correctly, the supply vessel's kinetic energy and the protector's absorbed internal energy were tested during collision events. In most cases, the absorbed internal energy arises to the required energy level, but in some cases all the kinetic energies are not consumed during collision events due to the relatively high protector rigidity.

The maximum deflection of the riser protector is 2.124 m, which is aa sufficient margin considering the design criteria of 300 mm clearance to the risers.

The mooring protectors deform up to 1.282 m and 1.341 m at the parallel part of AFT and FWD mooring protectors respectively. The results also show that the slanted parts of protectors in the way of No.3 stringer have not been contacted with mooring chain stoppers including related structures.

The maximum deflections of 1.051 m and 1.049 m for each PORT and STBD caisson protector show that the collision events due to the supply vessel do not cause any contact between protectors and seawater lift caissons.

These results show that the loadings have been properly applied and the simulations have been carried out reasonably. As such, the findings of this research should be informative in the safe design of FPSO units.

REFERENCES

ABAQUS, 2013. 6.13. User Guide Documentation, Dassault Systems, 2013.

AISC, 2001. Manual of Steel Construction, Load and Resistance Factor Design, Part 16 Specifications and Codes, 3rd Ed.

Cho, S.-R. et al., 2017. Development of simple design-oriented procedure for predicting the collision damage of FPSO caisson protection structures. Ocean Engineering, 142, pp.458–469. Available at: http://dx.doi.org/10.1016/j.oceaneng.2017.07.036.

DNV GL Rules for Classification, 2019. Hull Structural Design Ships with Length 100 meters and Above, Part 3, Chapter 1.

DNVGL-OS-C102, 2019. DNVGL Offshore Standard, Høvik, Det Norske Veritas, Norway.

DNVGL-RP-C208, 2019. Determination of Structural Capacity by Non-linear FE Analysis Methods, Recommended Practice, Høvik, Det Norske Veritas, Norway.

Hagen SA., 2018. Damage Assessment of Sevan 1000 FPSO Subjected to Impacts from Shuttle Tankers, Master thesis, Norwegian University of Science and Technology, Norway.

Ju, H.-B. & Jang, B.-S., 2019. A simplified method for assessing safety of ship collision event. Trends in the Analysis and Design of Marine Structures, pp.218–224. Available at: http://dx.doi.org/10.1201/9780429298875-25.

Ning, X., Zhang, B.L. & Tallavajhula, S., 2013. Structural Integrity of a Spar in Collision With a Large Supply Vessel. Volume 2A: Structures, Safety and Reliability. Available at: http://dx.doi.org/10.1115/omae2013-10213.

NORSOK Standard, 2004a. Design of Steel Structure N-004, Rev.2 October 2004

NORSOK Standard, 2004b. Materials selections M-001, Rev.4 August 2004

Ozguc, O., 2015. Vessel Impact Analysis for Riser Protection Frame and Protection Net Supports on Semi-submersible Offshore Structures, Journal of GIDB, 3, pp. 3-22.

Ozguc, O., 2017. Structural damage of ship–FPSO collisions. Journal of Marine Engineering & Technology, 18(1), pp.1–35. Available at: http://dx.doi.org/10.1080/20464177.2017.1359387.

The 20th International Ship and Offshore Structures Congress – ISSC, 2018. Committee V.1 Accidental Limit States, Proceedings of the 20th International Ship and Offshore Structures Congress Volume II – M.L.

Wang, G. & Pedersen, P.T., 2007. A Literature Review of Risk Assessment of Ship-FPSO Collisions. Volume 2: Structures, Safety and Reliability; Petroleum Technology Symposium. Available at: http://dx.doi.org/10.1115/omae2007-29760.

Zhang, S., 1999. The Mechanics of Ship Collision (PhD Thesis). Technical University of Denmark, Lyngby.

Assessment of the Stability of Passenger Ships in Coastal Navigation in Case of Lacking Ship Geometry Data

Kristofor Lapa

Ships should ensure safe navigation by meeting the stability norms defined by the International Maritime Organization (IMO) and determined by national maritime administrations. The fulfillment of these norms is becoming increasingly important, especially for passenger ships used for tourist excursions. Recently, the development of maritime tourism has greatly increased the demand for these ships most of which are converted fishing vessels. The situation described in this paper pertains to Albania and most probably differs in other countries in the region and the wider area. Ships rarely have adequate technical documentation. The Albanian Register of Shipping requires the performance of stability tests, the results of which are entered in the amended stability book to ensure the vessels' compliance with the norms following modifications undergone and guarantee safe navigation for tourists. An examination of a variety of ship design papers helped us identify various methods and methodologies for determining approximate geometric ship elements with an acceptable degree of reliability. However, their use should be limited and reliability proven by calculating parameters such as lightship VCG, number of passengers per m2, assessing the possible range and area of navigation and weather conditions (mainly wind speed and wave forces). The calculations based on stability testing and the use of highly reliable software such as MaxSurf - Integrated Naval Architecture Software, Napa - Naval Architectural Package, Autoship - Systems Operation, Orca3D – Naval Architecture Software delivered fast and reliable stability assessment results and verified conformance with the norms prescribed by the Albanian Register of Shipping.

KEY WORDS
~ Ship geometry measurements
~ MaxSurf software
~ Ship stability
~ Ship's VCG
~ GM
~ Inclining experiment

University of Vlora, Albania
e-mail: kristoforlapa@gmail.com

doi: 10.7225/toms.v09.n02.002

1. INTRODUCTION

Recently, maritime tourism in the bay of Vlora saw rapid development and the consequently increasing demand for passenger ships, especially those suitable for one day excursions (Rexhepaj, 2019).

Field observations and contacts with the Albanian port authorities and maritime administration suggest that these ships have major safety standard and service issues.

Tourist boats operate mainly in the bays of Vlora and Saranda, at short distances (1-2 hours) and inland, such as on Koman and Vau i Dejes lakes on the Drin River or artificial lakes such as Belsh lake in Elbasan. The problems faced by the owners of these ships are associated with the coastal infrastructure required for periodic and instantaneous technical repair and maintenance. The only repair shipyard is the Pashaliman Shipyard, which is still under the jurisdiction of the Ministry of Defense, but lacks the tools and specialists needed to meet all ship repair, maintenance and construction requirements. In these conditions, lacking the required safety-related technical data, these ships fail to meet the safety standards applicable at sea and geometric and stability calculations are not made. As the Albanian Register of Shipping

Table 1.
Number and transport capacity of ships in the bay of Vlora.

Year	2016	2017	2018	2019
Number of ships	3	4	10	15
Daily transport capacity	295	342	1198	1350
Number of pax	9150	14546	30843	51815

(ARS) (AMA, 2009) set a series of safety norms that must be taken into consideration, we attempted to conduct an in-depth analysis of IMO norms and requirements implemented by other European registers having similar coastal conditions with respect to tourist services, mainly of the Croatian Register of Shipping (Shipping, 2002).

We consulted several bibliographies because:

- these ships are rather old and have been in operation for a great number of years;
- these ships underwent structural modifications, in the course of which they were examined for potential damage that may have occurred during the provision of technical support;
- some ships have undergone structural modifications without the supervision of a specialist or an engineer.

Most ships have been completely repurposed and converted from service ships into one-day passenger transport ships. Thus, to meet the prescribed requirements and norms, these ships must first meet some other preconditions.

As almost no ship has the requisite documentation, such as technical documentation, general layout and structural drawings, the development of a ship lines plan requires their size and respective structural elements to be physically measured.

2. THE TRIM AND STABILITY BOOKLET

All relevant calculations for ships in lightweight and other loading conditions should be made both at departure and upon arrival to determine their displacement and coordinates of their center of gravity. Hydrostatic data facilitate the identification of the vertical center of the metacenter, KM. Hydrostatic and dynamic stability curves are then calculated and designed by drawing up stability booklets (Biran, Ship Hydrostatic and Stability, Stability booklet, 2003), (IMO, Resolution MSC.267(85) - International Code on Intact Stability, 2008) containing calculations and stability curves for anticipated loading conditions.

The following ship stability rules have been set in accordance with the safe navigation norms (Biran, Ship Hydrostatic and Stability, Stability booklet, 2003), (IMO, Resolution MSC.267(85) - International Code on Intact Stability, 2008):

- ship name, number in the register, harbor of registry, gross/net tonnage, ship dimensions, number of passengers and draft must be indicated;
- general layout with all compartments, tanks, storage, crew and passenger accommodation and amidships positions must be available;
- capacity and center of gravity (longitudinal and particularly vertical) of each load such as fuel, stores, fresh or ballast water, vertical center of gravity of vehicles must be calculated;
- weight of passengers and crew, their effects and centers of gravity must be calculated. The hydrostatic data of the ship, the heights of the transverse metacenter and the time to change the trim by one centimeter;
- the effect of free surfaces on the stability of tanks containing liquids must be determined;
- a diagram of cross curves of stability indicating the height of the assumed axis from which the righting levers are measured and the trim assumed must be drawn up;
- superstructures, deckhouses, hatchway structures on or above the freeboard deck may be taken into account in the curves;
- the diagram and statements are required to be provided separately for the light, ballast and service loaded conditions at departure and upon arrival, provided that consumables are reduced to 10% of their capacity. A statement indicating lightweight, deadweight, displacement, their center of gravity, metacenter and metacentric height (GM). The curve of Righting Levers (GZ). These are corrected for a liquid free surface.
- The inclining test and appropriate lightship calculations must be made.

3. SHIP HULL 3D-CAD MODELLING

The physically measured point coordinates were used to obtain hull lines and surfaces. Then, the faired model of the hull was developed by interpolation and optimization processes. The hull was reconstructed using the Maxsurf software. All surfaces were checked to ensure the observance of the geometric boundary conditions and recreate surfaces belonging to any of the three main groups: the bow, the stern and the central regions (C, 2006).

The following steps need to be taken to reconstruct a 3D ship hull model based on physically measured point coordinates (al X. B., 2008):

- Necessary measurements of keel line, extreme parts of the hull and its sections were taken. Based on the condition of a particular ship and international guidelines, we intended to measure as many sections as we could. Although it is generally recommended to measure physical frames every 50 cm, that depends on the length of a given ship. In this case, ship length was sixteen (16) meters. A total of 20 measurements were taken.

- Surfaces were built individually for each part of the hull (bow, stern, central body).
- Individual surfaces were assembled and the hull assumed its preliminary form.
- The hull was double checked. Initially based on previously designed geometric data and subsequently on physical measurement. This approach was adopted to avoid systematic and chance errors.
- The surface of the CAD model was smoothed until the required level of compliance with hydrostatic characteristics was achieved.
- The drawing of the CAD model of the modelled hull was carried out. (al K. L., 2016)

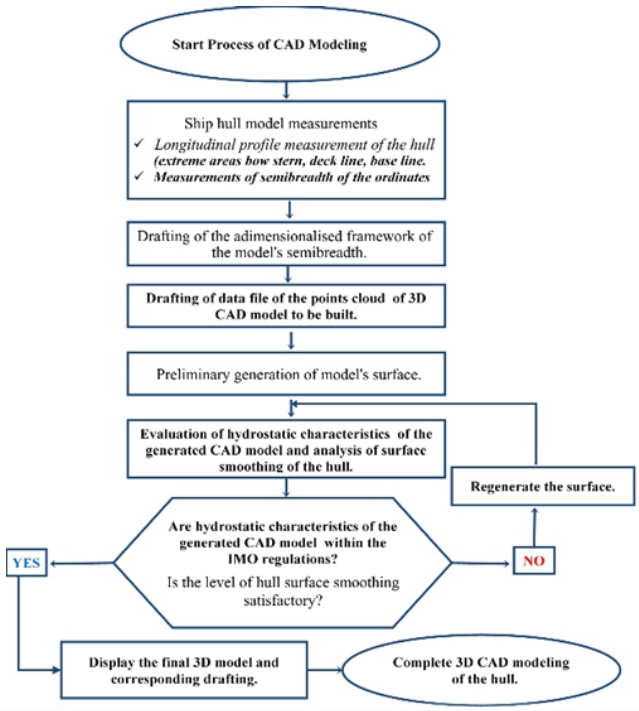


Figure 1.
General flow chart of the hull recreation process.

Since measurements are highly important and have a significant effect on the viewing of ship stability assessment results, they deserve special attention.

Traditional measuring requires simple measuring tools such as: plumb line, measuring tape and digital meter, batten, 90 degree measuring tool, spirit level, marker, and tensioned rope. Using the data obtained, the lines were initially modeled in AutoCAD, potential measurement errors were corrected and the lines plan for the ship drawn up.

There are two problems:

- The ship is on the ground. In this case the positioning of the ship against the horizontal and diametric plane must be well-controlled, and some corrections may be required.
- The ship is in the water. In this case the measurements should be made directly on and inside the ship, beginning with the physical frames and proceeding to the lines plan.
- Other digital methods using 3D scanning of the hull surface are not applicable, as they take longer and do not have very high measurement accuracy requirements.

The following example illustrates traditional vessel positioning and measurement:

- putting the vessel in the right position, just as it would be free in the water;
- positioning two horizontal tensioned ropes to determine the middle line plane;
- determining the main dimensions of the vessel (LOA and BOA);
- choosing an external reference system for the vessel;
- choosing half-breath along which the transverse sections (De_Ruyter, 2012) will be drawn.

4. THE NUMBER OF PASSENGERS PERMITTED AND THEIR ACCOMMODATION

Ship owners seek to increase the number of passengers onboard tourist vessels operating in Albanian bays, sometimes even beyond the norms or requirements of the International Convention for the Safety of Life at Sea (SOLAS, 1974/1980), which is detrimental to vessel stability and passenger safety. We have issued some recommendations in response to the norms (Shipping, 2002):

For passenger ships not engaged on international voyages

Passenger cabins must not be located in front of the fore nor behind the aft collision bulkhead, nor where clear headroom is less than 2.0 m;

4.1. Permitted Number of Passengers on Exposed Parts of the Deck

In case of day trips, the number of passengers allowed to stay on the exposed deck during transportation is determined by dividing the free space available to passengers by 0.7. In no case should the number of passengers exceed the number of the seats provided.

4. 2. Seats Dimensions Should Be as Follows

The seats should be at least 0.45 m wide, seats on the deck should be 400-480 mm high. Rear seat backrest must be at least 400 mm high. When the seats are grouped in transverse or longitudinal rows, the crossings between these groups must be at least 0.75 m wide. The distance between two adjacent rows must not be less than 0.80 m.

5. PRELIMINARY DETERMINATION OF LIGHTSHIP AND VCG

Lightship (Biran, Ship Hydrostatic and Stability, Stability booklet, 2003) is the weight of an empty ship (hull, outfit, and weights of machinery including liquids in various systems). The concept of marginal weight, which should be slightly higher, is used to identify inaccuracies in lightship assessment in naval architecture. R – reserve (tolerance/margin of uncertainty) is 2–3% (up to 6% according to Schneekluth) to compensate for potentially inaccurate weight group estimates.

Lightship weight (WL) approximately corresponds to the weight of the ship upon its delivery from the shipyard to the ship owner.

It is defined as:

$$W_L = W_H + W_M + R \quad (1)$$

where:

W_H – weight of hull

$W_H = W_{ST} + W_{OT}$

W_{ST} - weight of steel structure

W_{OT} – weight of outfitting

W_M – weight of machinery

$W_M = W_{MM} + W_{MS} + W_{MR}$

W_{MM} – weight of main machinery

W_{MS} – weight of shaft and propeller

W_{MR} – weight of remaining machinery

R – reserve (tolerance/margin of uncertainty) is 2–3% (up to 6% according to Schneekluth) to compensate for potentially inaccurate weight group estimates.

As for the initial estimation of the VCG of a fully loaded ship, the relationship between KG and depth D is illustrated as:

$$KG = C \cdot D_S \quad (2)$$

where modified depth D_S is defined as:

$$D_S = D + \nabla_{SS} / (L_{PP} \cdot B) \quad (3)$$

and ∇_{SS} – volume of superstructures and deckhouses.

Coefficient C is taken from Dudszus and Danckwardt (1982) as in the following table.

Table 2.
C coefficient for KG estimation (Bertram, 1998).

Passengers ships	0.67-0.72
Fishing vessels	0.66-0.75

Based on the Estimation of Ship Weights study, page 177 Papanikolaou, A. (2014), Ship Design (pp. 268, 262-263), the vertical position of the weight center of R was assumed to be located 20% higher than the estimated KG of the vessel.

5.1. Evaluation of Vertical Center of Gravity

In our case study, based on the above recommendations, the vertical center of gravity of the ship with 30 passengers on main deck and 50 passengers on upper deck was calculated as shown in Table 4 based on the following assumptions:

- that the maximum number of crew was 3 people on board. The average weight of each individual was estimated at 75 kg,
- that the center of gravity of a seated passenger was 0.3 m above the seat and the center of gravity of a standing passenger 1 m,
- that the lightweight is determined based on real measurement of the draft. The measured draft of the vessel was 1.10 m and the hydrostatic data indicated that the ship's lightweight was 32 tons,
- the vertical center of "Other" group weight was taken [0,5*(Depth of Ship)] .

Table 3.
Weights on the vessel.

Nr	Weight Items	Weight (t)	VCG of weights Zi (m)
1	Lightship	32,00	1.27
2	Passenger and crew members Main deck (33 = 30+3)	2.64	3,30
3	Passenger on upper deck (50)	4,00	5,30
4	Fuel	5,00	0,35
5	Water	2,00	0,35
6	Other	3,00	1,35
	Total Weight	48,64	1,58

The vessel's vertical center of gravity:

$$KG = \frac{\Sigma_2}{\Sigma_1} = \frac{76,89}{48,64} = 1,58\ m \quad (4)$$

6. TYPICAL METACENTRIC HEIGHT VALUES

The evaluation of the initial stability of the vessel in the preliminary design stage usually only requires the comparison of the obtained GM value with values typical for similar ship types, as shown in the following table (Papanikolaou, Typical Values of Metacentric Height, 2014):

Table 4.
Typical GM values per passenger ship upon departure and in fully loaded condition.

Passengers ships (oceangoing)	1.0-2.5 m
Passengers ships (limited waters)	0.5-1.5 m
Passengers ships CATAMARAN	> 10m

High GM values paired with the sufficient range of positive restoring arm curves ensure satisfactory stability and safety of the ship against capsizing at high inclination angles.

High GM values trigger intense rolling motion and transverse acceleration on the ship's deck, in view of the relationship (Papanikolaou, Typical Values of Metacentric Height, 2014):

$$T_{ROLL} \infty B / (GM)^{1/2} \quad (5)$$

where T_{ROLL} – natural roll period of the ship.

GM ≥ 0.30–0.35 m is recommended upon departure and in design loading condition. (Papanikolaou, Typical Values of Metacentric Height, 2014).

7. SPECIAL CRITERIA FOR THE CROWDING OF PASSENGERS ON ONE SIDE AND DURING THE TURNING MANEUVER

The angle of heel during the crowding of passengers on one side and the turning maneuver, must not exceed 10° (Papanikolaou, Special Criteria for Certain Types of Ships, 2014):

$$M_R = 0.200 \cdot \frac{V_o^2}{L_{WL}} \cdot \Delta \cdot (KG - \frac{d}{2}) \quad (6)$$

where:

M_R = heeling moment (kN· m)
V_o = service speed (m/s)
L_{WL} = waterline length (m)
Δ = displacement (t)
D = mean draught (m)
KG = height of center of gravity above baseline (m).

8. SPECIAL FREEBOARD CRITERIA

Large freeboard provides large reserve buoyancy, increases a ship's survivability in case of hull damage and additionally improves ship stability at large inclination angles. Sufficient freeboard improves the ship's behavior in seaways. According to the data in the following figure, small ship (L ≤ 65 m) freeboard is less than/equal to 1% L, while the corresponding required height of ships with approximate L ≥ 120 m is more than 1.5% L (Papanikolaou, Freeboard, 2014).

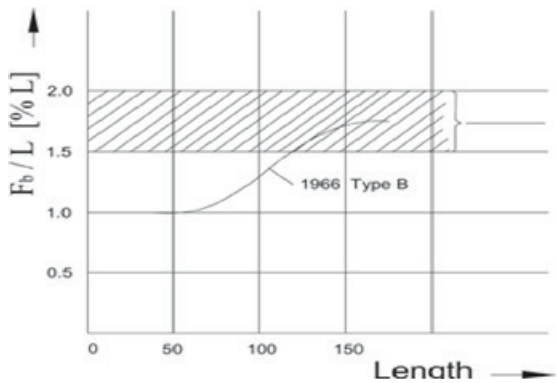


Figure 2.
Basic ship freeboard relative to their length, according to ICLL 1966.

9. CASE STUDY - EVALUATION OF STABILITY OF VESSEL "ESPERANZA"

As required by the Albanian Register of Shipping, calculations have been made to verify the stability of tourist ships that operate in the Vlora and Saranda bays, as well as in inland waters such as Koman and Vau i Dejes lakes.

The methods of calculation presented in this paper have been used. Most of the ships lack the necessary technical documentation, some are very old and have undergone structural modifications to be repurposed and converted into tourist ships (Albanian Shipping Register, 2019).

Table 5.
Data on ships for tourist transport in Albania.

Name	Year of construction/reconstruction	Built in	GT	NT
DRAGOBIA, Koman	1982/2013	Durres	24	15
BERISHA 01, Koman	N/A/2015	Koman	57	18
BERISHA 03, Koman	N/A/2015	Koman	64	19
TEUTA	1976/2015	Italy	9	3
Black Pearl	2012/2015	Marmaris, Turkey	99	53
Teuta I	1980/2018	Italy	9	6
SARDA, Vau i Dejes	N/A	N/A	NA	NA
JULKA UNIQUE	2018/N/A	Vlore	142	64
TINA TOURIST	1984/2018	Greece	44	26
ESPERANZA	1990/2018	SCILLA RC, Italy	43	13
ROZAFA	N/A/2018	N/A	42	23
AQUAMARINE	1997/N/A	Marmaris, Turkey	N/A	N/A
DELFINI 23	1980/N/A	Kalymnos, Greece	15	9
LIBURNA	1963/2019	Greece	77	34
SEASTAR	2017/N/A	Italy	7	2.1
AVVENTURA II	1991/N/A	Peschici FG, Italy	7.27	4.94
ANNA ST	1984/2019	Durres, Alb	13	6
MOGILA	1955/2002/2019	Montenegro	132	40
PADAJ	1989/2020	Bellaria, Italy	8	3

Name	Number of passengers	Lightship	VCG Lightship	VCG Fully loaded	LOA	B	D	T
DRAGOBIA, Koman	46 pax	22.40	1.27	1.45	12.90	4.50	1.85	1.25
BERISHA 01, Koman	80 pax + 10 cars	32.8	1.20	1.588	24.60	6.40		0.55
BERISHA 03, Koman	100 pax + 12 cars	49.81	1.20	1.55	29.80	7.40	1.30	0.65
TEUTA	30 pax	8.99	0.88	1.175	12.75	3.70	1.90	1.20
Black Pearl	180 pax	91.31	1.75	2.088	21.35	6.90	2.75	1.43
Teuta I	50 pax	9.58	0.82	1.31	13.60	3.80	1.50	0.92
SARDA, Vau i Dejes	40 pax	N/A	N/A	0.96	14.50	4.00	1.60	1.00
JULKA UNIQUE	200 pax	31	2.66	3.12	24.00	9.00	1.65	0.98
TINA TOURIST	150 pax	30.5	1.49	1.648	22.50	4.80	2.85	1.255
ESPERANZA	80 pax	32	1.27	1.58	16.60	4.60	2.45	1.46
ROZAFA	30 pax + 10 cars	29.6	0.99	1.7	20.40	7.40	1.80	1.33
AQUAMARINE	225 pax	127.8	1.67	2.09	30.50	8.00	3.50	2.10
DELFINI 23	48 pax	12.19	1.54	1.52	11.90	3.30	1.28	0.79
LIBURNA	120 pax	145.74	2.06	2.21	23.75	6.25	3.40	2.40
SEASTAR	50 pax	2.97	1.13	1.67	12.00	5.00	1.70	0.40
AVVENTURA II	45 pax	11.45	1.2	1.3	11.96	2.72	2.00	0.95
ANNA ST	33 pax	18	1.056	1.30	13.22	3.58	1.90	1.26
MOGILA	286 pax	159.7	1.69	1.79	25.50	13.70	2.15	1.142
PADAJ	20 pax	12.35	0.82	1.02	11.00	2.82	1.50	1.00

9.1. Basic Steps to Model the Ship Hull of the "Esperanza"

The development of a 3D-CAD model of a real ship requires the obtainment of vessel hull dimensions. The main dimensions of the vessel are shown in Table 2 and general layout in Figure 2. The measurement process was carried out on physical bulkheads and on 10 or 20 theoretical ordinates of the ship. Following measurement completion and the obtainment of ordinates, profile line and extreme parts required to draw up a database in MS Excel, the set up of the half-breadths of the model to be build was created (al X. B., 2008).

Table 6.
Main dimensions of the ship "Esperanza".

Length overall	LOA = 16.60 m
Length between perpendiculars	LBP = 15.60 m
Breadth overall	BOA = 4.60 m
Depth	D = 2.45 m
Draft	T = 1.46 m
Passengers + Crew	80+3
Main engine:	2x177 HP
Construction material:	Wood
Year of reconstruction:	1990
Place of construction:	Italy

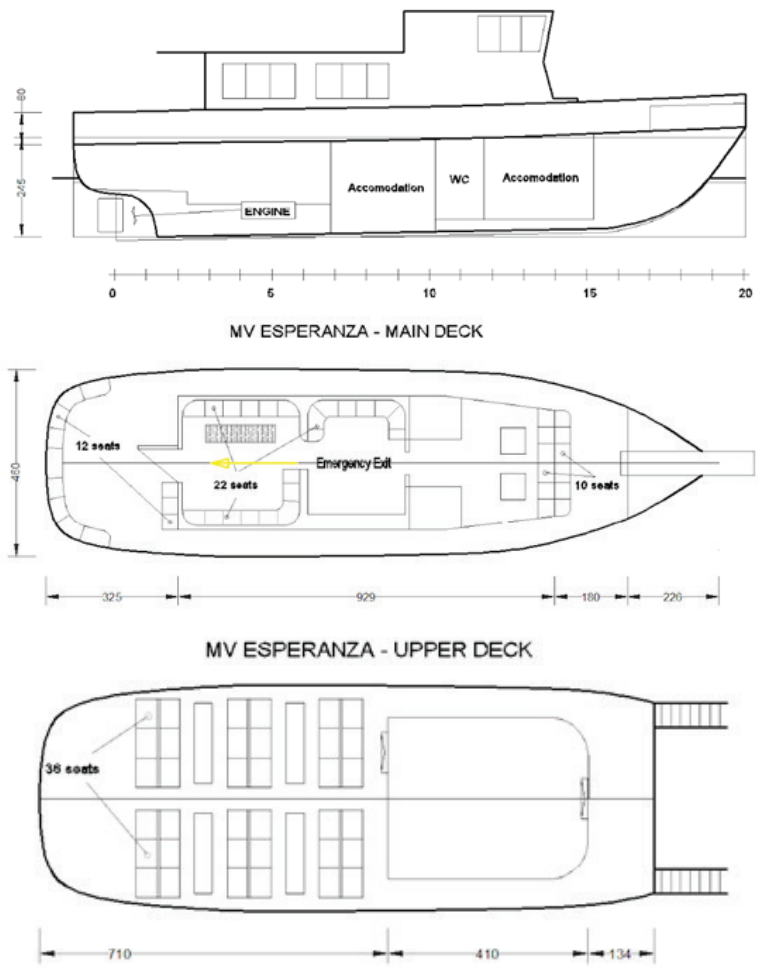


Figure 3.
General layout of tourist ship "ESPERANZA".

After database creation in MS Excel, the 3D model of the vessel was created using the MaxSurf software.

The hull surface design process was conducted in three stages:

1. Modelling of initial hull curves
2. Building of the hull surface
3. Smoothing of the hull surface

After visualization, potential errors occurring during coordinate insertion were corrected, appropriate modifications were made and record file containing all coordinates of the points needed to generate the hull were created (Systems, 2009).

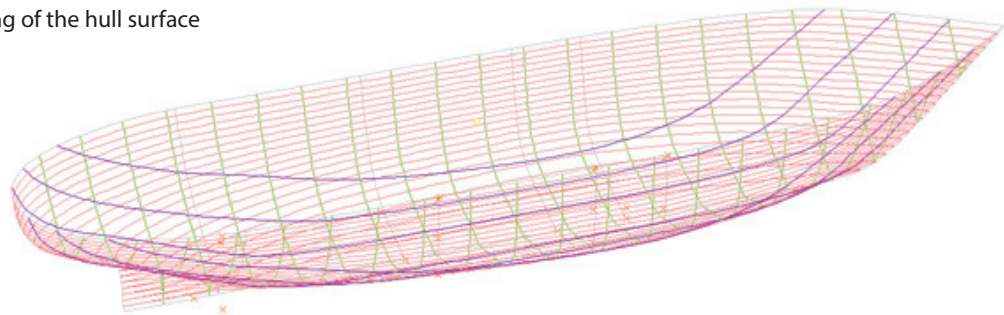


Figure 4.
Model - final form of the hull after consecutive encore. 3D Lines Plan of 'ESPERANZA'.

9.2. Generation of Hydrostatic Curves

Hydrostatic curves were calculated (Biran, Ship Hydrostatic and Stability, Stability booklet, 2003) (Figure 3) using the Hydromax Software. Table 2 presents data for the fully loaded vessel, corresponding to waterline DWL=1.46m.

Table 7.
Hydrostatic DATA of vessel "ESPERANZA".

Draft Amidsh. M	DWL=1.46	Block Coeff.	0.53
Displacement tonne	48.5	Midship Area Coeff.	0.78
Draft at FP m	1.46	Waterpl. Area Coeff.	0.82
Draft at AP m	1.46	LCB from zero pt. (+ve fwd) m	8.36
Draft at LCF m	1.46	LCF from zero pt. (+ve fwd) m	7.95
WL Length m	15.6	KB m	0.90
WL Beam m	4.20	BMt m	1.23
AWL (m2)	51	Immersion (TPc) tonne/cm	0.515
Prismatic Coeff.	0.68	MTc tonne.m	0.51

9.3. Stability Data Calculations

Stability data were calculated using the MAXSURF Naval Architecture Software (Hydromax).

The following diagram shows the static stability curve of the vessel.

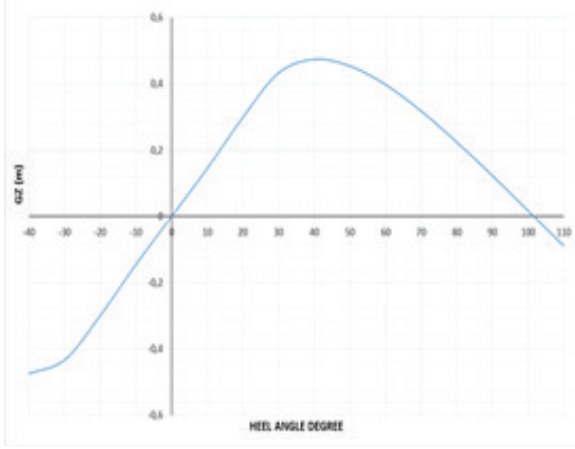


Figure 5.
GZ diagram vs heeling angle.

Table 8.
Stability data according to Hydromax Software calculations.

Heel to starboard (degrees)	10	20	30	40	50	60	70	80	90
GZ (m)	0,15	0,30	0,43	0,47	0,45	0,40	0,32	0,22	0,12
Displacement (mt)	48,40	48,40	48,40	48,40	48,40	48,40	48,40	48,40	48,40
Wetted area (m^2)	69,58	70,38	74,50	77,60	79,47	80,68	81,47	81,81	81,39
Water plane area (m^2)	51,36	53,05	47,91	41,27	36,93	34,23	32,80	32,49	32,23
Prismatic coefficient	0,68	0,68	0,70	0,71	0,72	0,73	0,74	0,75	0,75
Block coefficient	0,53	0,50	0,53	0,59	0,63	0,66	0,68	0,68	0,63

9.4. Criteria for Righting Lever Curve Properties

The assessment of the level to which the IMO stability criteria (IMO resolution A.167) (IMO, IMO stability Criteria (IMO resolution A.167)) have been met is conducted using the stability curve for the main loading condition/s in respect of the vessel's operation.

Table 9.
Verification of IMO stability criteria.

Code	Criteria	Value	Units	Actual	Status
A.749(18) Ch3 - Design criteria applicable to all vessels	3.1.2.1: Area 00 to 300	3.151	m.rad	6.65	Pass
	3.1.2.1: Area 00 to 400	5.157	m.rad	11.25	Pass
	3.1.2.1: Area 300 to 400	1.719	m.rad	4.60	Pass
	3.1.2.2: Max GZ at 300 or greater	0.200	m	0.47	Pass
	3.1.2.3: Angle of maximum GZ	25	degree	40.9	Pass
	3.1.2.4: Initial GMt	0.150	m	0.82	Pass

9.5. Weather Criteria (Wind and Rolling Criterion)

The ability of a vessel to withstand the combined effects of beam wind and rolling was demonstrated by reference to Figure 9 (al L. k., 2005).

Under these circumstances, area b is equal to or greater than area a, as indicated in the following table.

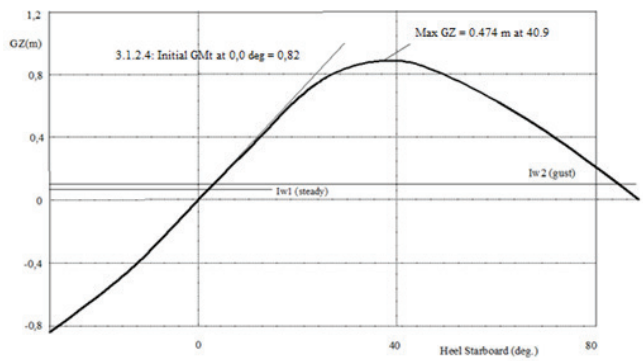


Figure 5.
Severe wind and rolling.

Table 10.
Verification of weather criteria.

Criteria	Value	Units	Actual	Status	Margin%
A.749(18) Ch3 - 3.2.2: Severe wind and rolling					
Angle of steady heel is not greater than	16.0	deg	4.6	Pass	+60
Angle of steady heel / Deck edge immersion angle is not greater than	80.000	%	28.59	Pass	+64
Area1 (b) / Area2(a) is not less than	100.000	%	231.14	Pass	+131
Area1 (under GZ), from 6.2 to 50.0 deg.		m.deg	15,28		
Area1 (under HA), from 6.2 to 50.0 deg.		m.deg	5,55		
Area1(b), from 6.2 to 50.0 deg.		m.deg	9,73		
Area2 (under GZ), from -16.4 to 9.5 deg.		m.deg	-0,91		
Area2 (under HA), from -16.4 to 6.2 deg.		m.deg	3,31		
Area2(a), from -16.4 to 6.2 deg.		m.deg	4,21		

10. CONCLUSIONS

The purpose of this study was to present the necessary stability procedure required by the Albanian Register of Shipping, which is of paramount importance for the safety of short distance passenger transport activities.

Consulting various authors and literature on ship design, methods and methodologies for preliminary determination or empirical formulas for calculating various technical elements of vessels, such as vertical center of gravity for lightship, minimum values for metacentric heights GM or others parameters, helped us create an excellent inventory to be used in ship calculations required to fill out the trim and stability booklet as described above.

Some technical recommendations with respect to the maximum number of passengers allowed were given to ensure safe navigation. The application of these recommendations to ship stability assessment required by the Albanian Register of Shipping was described. The procedure followed by actual measurement is helpful for 3D modelling of ship hulls and useful for creating models in similar cases.

The use of the naval computer package significantly contributed to the obtainment of improved hull surface and facilitated extremely tedious manual work.

The fulfillment of the stability criteria was verified in accordance with the criteria stipulated in the IMO stability code and the norms prescribed by Resolution MSC.267 (85).

REFERENCES

Al, X. B., 2008. Perdorimi i sistemeve te programeve Maxsurf per vleresimin e cilesive lundrimore te mjeteve te transportit detar shqiptar. Besueshmeria e Mjeteve te Transportit Detar, pp. 52–61.

Albanian Shipping Register, 2019. Data of touristic ships operating in Albanian Waters, 2015 – now. Durres.

AMA., 2009. Albanian Regulation for Ship Inspection. Durres.

Bertram, H. S., 1998. Ship Design for Efficiency and Economy. Butterworth-Heinemann.

Biran, A., 2003. Ship Hydrostatics and Stability. Available at: http://dx.doi.org/10.1016/b978-0-7506-4988-9.x5000-7.

C, G., (2006). Rilievo di carene navali mediante techniche di riverese engineering. Napoli: Tesi di Dottorato.

Croatian Register of Shipping, 2002. Passenger ships not engaged on international voyages. Rules for Technical Supervision of Sea-going Ships, pp. 7-11.

De Ruyter, 2012. Traditional Maritime Skills. Available at: http://www.boat-building.org/learn-skills/index.php/en/wood/measuring-a-boat-or-ship/.

Ibrahimi, K. & Lapa, K., 2006. The influence of Albanian sea winds on fishing-boat stability of FV 2 KP,Äi400 type. Maritime Transportation and Exploitation of Ocean and Coastal Resources, pp.1231–1237. Available at: http://dx.doi.org/10.1201/9781439833728.ch150.

IMO, (n.d.). IMO stability Criteria (IMO resolution A.167). London.

IMO, 2003. Stability Criteria. London.

IMO, 2008. Resolution MSC.267(85) - International Code on Intact Stability.

IMO. (n.d.). International Convention for the Safety of Life at Sea (SOLAS) - Chapter II-1 - Construction - Subdivision and stability, machinery and electrical installations.

Lapa, K. et al., 2016. Evaluation of stability for a passenger ship in inland water in Koman Lake in Albania. 7th International Conference on Maritime Transport, Barcelona: Universitat Politecnica de Catalunya - Barcelonatech, pp. 319-321.

Lapa, K., 2020. Project H, Vlore.

MaxSURF, 2009. Integrated Naval Architecture Software. Australia - Bentley Systems.

Papanikolaou, A., 2014. Ship Design. Available at: http://dx.doi.org/10.1007/978-94-017-8751-2.

Rexhepaj, L., 2019. Data on the number of vessels, capacity and number of passengers in the period, 2016-2019, Harbor of Vlora - Vlora Port Administration.

SOLAS, 1974/1980. International Convention for the Safety of Life at Sea.

Numerical Assessment of FPSO Platform Behaviour in Ship Collision

Ozgur Ozguc

Offshore platforms may potentially collide with vessels of various types, including visiting ships such as supply ships and passing ships. The most critical and relevant conditions, including the analysis and design approaches are introduced. Different ship types having different displacements and structural designs exert different vessel impact loads on impacted structures. This paper presents the findings of collision impact analyses of the side shell panel, bow and stern structures of Floating Production Storage Offloading (FPSO) platforms in case of impact, e.g. by a supply vessel or methanol tanker. As collision impact simulations continue to be conducted conservatively, the colliding positions of the striking vessel are presumed to be bow and stern only, with side force. In order to assess hull strength in collision events, non-linear FE simulations were performed by means of the MSC / DYTRAN tool, as these collision events result in more complex reactions. The degree of hull damage suffered by an FPSO vessel in different collision scenarios and at varying impact energy levels was determined in accordance with the NORSOK N-004 standard guidelines. Post-collision analyses were conducted to establish the structural integrity of the damaged hull after being exposed to environmental conditions for one year. The reduction of hull girder strength associated with the worst damage was evaluated and accounted for in the present study, providing no further damage occurs. Furthermore, the acceptance criteria for evaluation and corresponding consequences are calculated and discussed in detail. Finally, the findings from the present paper will help clarify the impact response of offshore structures and evaluation approaches and give valuable guidance for the design and operation of FPSO platforms.

KEY WORDS
~ Collision accident
~ Offshore facilities
~ Non-linear finite element simulation
~ Energy absorption
~ Post-collision analysis

Department of Naval Architecture and Ocean Engineering, Istanbul Technical University, Istanbul, Turkey

e-mail: ozguco@itu.edu.tr

doi: 10.7225/toms.v09.n02.003

1. INTRODUCTION

During operation, supply vessels are continuously servicing offshore production platforms and drilling rigs. Collisions between them are inevitable. Vessel impact with offshore facilities is one of the main issues to be considered in the design and evaluation of facility performance and safety, as a significant safety threat to ships and other offshore installations that can result in serious economic damage, environmental contamination and fatalities.

FPSO hull should be designed with due regard to potential loads caused by accidents such as collisions, dropped objects, fire, explosion and other abnormal events such as mooring line failures or broken risers. Structural improvements and/or protective structures ensuring that the consequences of accidental loads do not compromise installation safety will be considered.

Collision is a major hazard to the safety of ships and other offshore installations and may result in severe economic loss, environmental pollution and fatalities. Ship collision accidents can be divided into approximately four categories, such as ship-ship, ship-offshore structure, ship-bridge and ship-iceberg collisions (ISSC, 2018).

You and Rhee (2016) conducted a study in an attempt to solve the intrinsic problem of critical collisions, inter alia considering the dilemma of slower ship's manoeuvrability, and the International Regulations for Preventing Collisions at Sea

(COLREGs). They developed a collision ratio that can be used to determine the right moment to initiate collision avoidance manoeuvres.

Szlapczynski and Szlapczynska (2016) developed analytic formulas for domain-based collision risk parameters: degree of domain violation (DDV) and time to domain violation (TDV), to overcome the drawbacks of DCPA and TCPA, which lack efficient analytical solutions in real-time systems where computational time is essential. Zhang et al. (2016) proposed a novel method for detecting potential near-miss ship–ship collisions based on AIS data and discussed how near-miss data can be used to gain further insight into the safety of maritime transportation. Zhang et al. (2015) studied a multi-ship anti-collision decision support formula in distributed and real time. The formula was proven effective in helping avoid collisions when all ships act in accordance with COLREGs, as well as when some of them do not take action. Research on internal and external mechanisms gives us an understanding of responses in different ship collision scenarios.

Zhang et al. (2017) further analysed the validity and robustness of closed-form analytical methods they proposed in 1998 and further improved the accuracy of some parameters, obtaining 60 experimental results. A simple way of accounting for the effective mass of free surface liquids carried on board a ship was also introduced, and it was proved that the analytical procedure can be expanded to take into account the effect of ship roll on energy released by impact. By using nonlinear finite element code LSDYNA, Yu and Amdahl (2016a) first proposed a new coupled approach allowing the simultaneous calculation of structural damage and 6DOF ship motion during ship collision. The proposed method is particularly useful for design purposes as detailed knowledge of ship hull shape is not required. In addition, Yu et al. (2016b) upgraded the approach taking into consideration the hydrodynamic loads, based on linear potential-flow theory in the LS-DYNA code. The approach facilitates a fully coupled six degrees of freedom (6DOF) dynamic simulation of ship collision and grounding accidents, in contrast to previous studies that neglected ship motion and hydrodynamic loads.

Liu et al. (2015a and 2015b) proposed a simplified analytical method for examining energy absorption mechanisms of small-scale stiffened plate specimens, quasi-statically punched in the midspan by a hard indenter with a knife or a blunt edge. Both experiments and numerical simulations were carried out to validate the analytical method.

Calle et al. (2017) summarised a series of experiments including scaled collision tests of a T cross-section beam, frontal collision of an oil tanker with a rigid wall, ship grounding and collision between two oil tankers, to validate their finite element analysis. They indicated that the mechanical properties of materials, slight misalignments in test arrangements, failure criteria, weld joints and sloshing effect of ship cargo all influence differences between numerical and experimental results.

The public concern about ship collisions with offshore structures mainly focuses on the consequences. Since the costs of repair of offshore structures exceed the costs of repair of the striking ship, many researchers focus on improving the crashworthiness of offshore structures in accidental collision scenarios.

Zhang and Terndrup Pedersen (2015) conducted an analysis of collision energy and structural damage in ship - offshore platform collisions in various scenarios. They considered ship collision with offshore installations one of the key concerns in the design and assessment of platform performances and safety. An example of an ice-strengthened supply vessel colliding with a jack-up rig was analysed and the crushing resistance of the colliding thin-walled structures evaluated.

Travanca and Hao (2015) analysed energy dissipation in high-energy ship-offshore jacket collisions, to gain a clearer understanding of the strain-energy dissipation phenomenon, particularly with respect to the ship-structure interaction. Vinnem et al. (2015) discussed the need for online decision support reduce the risk of FPSO–shuttle tanker collisions.

The characteristics of accidental loads and various methods of their calculation, theoretical and empirical formulae such as FEA (Finite Element Analysis) were well described in International Ship and Offshore Structures Congress (ISSC) reports. Collision and grounding accidents of ship structures are found in ISSC (2006).

The Association of Structural Improvement of Shipbuilding Industry of Japan conducted extensive collision and grounding tests (ISSC, 2003). One of the collision test models was a double side structure model made of mild steel. In the dynamics test, the bow model fell freely from the height of 4.8 m above the initial position of the outer hull, with the impact velocity of approx..9.7 m/sec. Ozguc et al., 2005 performed a LS-DYNA validation study using ISSC benchmark collision test. The force-penetration curve was calculated from the finite element simulation of the dynamics test and good correlation with the experimental result was achieved.

Storheim and Amdahl (2017) investigated the effect of various features of the complete stress–strain curve on anticipated outcomes of collision simulations. The effect of the assumed stress–strain curve was determined through nonlinear finite element analysis simulations of a full-scale impact scenario. The influence of strain-rate effects was investigated. The findings revealed that the slope of the stress–strain curve determines strain localisation, and thereby when and where the fracture propagates. The slope was strongly dependent on the yield ratio, yield plateau and the fracture elongation, parameters having significant statistical variation within a material grade.

Depending on the size and speed of the impacting ship, anything from damage to hull rupture, oil pollution, flooding, and loss of buoyancy, capsizing, and sinking may occur. As supply vessels and tankers frequently visit FPSOs to transport consumables and chemicals, there is a risk of collision between two structures. Hence, during structural design, special attention needs to be paid to the minimization of damage from such accidents (Ozguc, 2018).

The main concern regarding vessel impacts with offshore platforms are the consequences. Since the costs of repair and maintenance of offshore facilities are higher than those of the striking vessel, several studies focused on the method of improving the crashworthiness of offshore structures in unintentional collision scenarios. In addition, as the number of offshore wind turbines along the coastlines increases, collisions between trading vessels and offshore wind turbines become more common (ISSC, 2018).

The outcome of a vessel-platform collision depends on the kinetic energy, carrying weight and speed of the ship, as well as on the deformation capacity of both the structure and the vessel. When two bodies collide, the rigidity of their deformation can result in different outcomes, such as a near-elastic collision (where both bodies travel in opposite directions after collision), a perfectly inelastic collision (both bodies travel together) or an in-between situation. NORSOK N-004 codes include three separate design scenarios, such as the strength design, where energy is dissipated by vessel, the ductile design, where energy is dissipated by the structure, and the halfway compromised shared-energy design, which is very difficult to measure.

The purpose of the research was to carry out a sensitive numerical study of offshore unit actions in case of impact by a hard and soft 5000 ton vessel, moving at the speeds of 0.5 m/s and 2 m/s as specified in the Standards. ABAQUS finite element tool was employed to assess the deformation and dissipation of energy in both vessel and platform structure during local collision (Rigueiro et al. 2017).

FPSOs take on oil and gas through the riser system, process it and store it in vessel tanks which are kept in place by a mooring or a dynamic positioning system as defined by Moan et al. (2003). In accordance with the HSE (2000) study, during operation they may be struck by a) supply vessels approaching or leaving the installation, b) tankers while refuelling, c) ships and fishing vessels passing by the installation, and d) floating installations, such as flotels. A part of collision energy may be dissipated as strain energy in both FPSO and the striking vessel, likely contributing to a significant amount of plastic tension.

Zhang et al. (2015) conducted a research using a numerical simulation method to analyse crashworthiness of Floating Liquefied Natural Gas (FLNG) side structures during side by side offloading process in case of collision. Two typical collision scenarios have been described, based on the parameters obtained from the model test. Instead, the LS-DYNA code simulated collision scenarios. A special limit collision condition was suggested based on the structural response of LNG CCS (cargo containment system). The structural response of the CCS was given considerable attention to determine the level of protection of FLNG side structures.

Ning et al. (2013) developed numerical methods to assess the structural integrity of a generic Spar hull in collision with a large supply ship and explain the progressive nature of collision damage suffered. The analysis of dynamic and nonlinear finite elements was carried out for two collision scenarios using ABAQUS / Explicit tool, respectively. One was a practical simulation where kinetic energy of the impact dependent upon initial impact velocity and ship's total mass during collision was slowly depleted. The other was a simpler theoretical approach where a ship bow's impact velocity was constant during the collision, or the total impact energy was infinite. Progressive impact damage to hull structures was correctly recorded for purposes of structural integrity evaluation, using a combination of optimized progressive material damage models and Mises plasticity, which is a part of the plasticity theory best suited to ductile materials, such as some metals. Prior to yield, material response can be assumed to be nonlinear elastic, viscoelastic, or linear elastic.

Zhang et al. (2015) gave an overview of colliding energy and structural damage in vessel - offshore structure collisions in various collision scenarios. The facility was either viewed as rigid or flexible, and its response to collision energy and structural damage was examined. An example of a collision of an ice-strengthened supply ship with a jack-up structure, and crushing resistance of the thin-walled structures involved was explored.

Wang and Pedersen (2007) reviewed the work and analyses relating to ship-FPSO collision risk assessment. The emphasis was on current requirements, FPSO collision occurrence, FPSO collision design scenarios, collision dynamics, impacts and acceptance requirements. There have been some developments in the study of ship collision and grounding since the 1990s. Issues unique to vessel-FPSO collisions meriting further attention have been addressed.

Amdahl et al. (2012) investigated large vessel-vessel collisions with jacket legs, with specific focus on NORSOK N-004 recommended analysis procedure. A jacket leg and the shipside of a typical supply vessel were modelled, and LS-DYNA software ran impact simulations. The denting resistance of the jacket leg and shipside indentation resistance were compared with NORSOK guidelines. The distribution of energy dissipation and ship and leg damage were analysed for legs of different thicknesses and two contact positions.

Yu and Amdahl (2018) reviewed state-of-the-art response dynamics and mechanics of offshore tubular structures subject to mass impacts, including material modelling, ship impact loading, ship and platform energy absorption, global and local response of tubular structures, residual strengths of damaged tubular members, and design considerations to mitigate impacts. Literature provided a wealth of material, with priority given to recent discoveries and broadly influential classical sources. The findings were compared and discussed. Potential directions of study that would improve our understanding of impact dynamics and accurate and effective design equations have been proposed.

Mujeeb-Ahmed et al. (2018) used an automatic identification system (AIS) database to conduct a probabilistic collision-risk analysis for offshore platforms exposed to controlled collisions with passing ships. The study first defined the statistical distribution of vessel traffic analysed, and then discussed how these findings could be effectively used to predict collision frequency and impact energy for different vessel categories, based on a simple probabilistic approach. Frequency calculations took into account the effects of different collision avoidance measures such as improved collision warning systems, and the ability of platforms to rotate using thrusters. This risk approach could be applied to both new and existing platforms in the design and development stage.

Amante and Estefen (2018) published an accident analysis that included accidents between ships and offshore platforms. The study documented few existing publications that addressed this issue in Brazilian waters and presented the effects of 11 years of collecting collision data on Petrobras platforms.

Pedersen (2015) outlined some of the available analytical elements for collision frequency and response estimates for different types of offshore installations and explained how these methods could be used to identify appropriate risk management options.

Moan (2019) focused on design to improve robustness or damage tolerance and ensure structural integrity during service life. A simple definition of robustness is that it is "the ability of a structure to limit the escalation of accident scenarios into accidental conditions with a magnitude disproportionate to the original cause." Robustness requirements apply to different failure modes that can ultimately result in fatalities, pollution or property loss. Structures supported on the seafloor can experience structural, foundation or soil failures, while buoyant structures can capsize, sink, or suffer hull or mooring system failure.

Ozguc (2019) focused on the general approach and design of FPSO accident scenarios, using advanced methods such as nonlinear finite element method used to provide structural responses during and after impact. As varying collision scenarios and impact energy levels were simulated, the degree of FPSO hull damage was assessed using the criteria defined in the NORSOK standard. The accident case of 5 years on-site setting accounted for the Accidental Limit State (ALS). Different collision scenarios were described as supply ship collision bow on, supply ship collision side on, supply ship collision stern on, and tanker collision bow on off. Conservatively, the impacting vessel was deemed not to deform during collision. Damage to FPSO hull, including flare tower foundations, aft muster station, offloading reel and piping, and safety of green water above cargo deck, was assessed.

This paper incorporates the findings of impact analyses of collision of a striking ship, e.g. supply ship and methanol oil tanker, with FPSO side hull, bow and stern structures. Collision impact analyses were performed conservatively and the presumed collision path of the struck vessel was only bow and stern with side energy. Non-linear FE analyses were performed using the MSC/DYTRAN code to test the strength of the hull structure in case of collision events, as collision accidents require more complex responses. The extent of FPSO hull damage in various collision scenarios and at different impact energy levels was computed in keeping with the guidelines from the NORSOK code. The reduction of a ship's longitudinal strength after collision damage was also calculated. The residual strength of damaged structures must be kept at a certain level to avoid potentially catastrophic consequences.

2. FPSO VESSEL DESIGN

Single bottom and double side hull was designed as shown in Figure1, with topsides weighing 32,300 tons. The FPSO is moored in a fixed position and the suction piles and ground chain are linked. FPSO facilities have been designed for a 20-year service life. FPSO's topside control system was designed to accommodate 21 wells and a fourth subsea separation unit. Subsea production lines, injection lines and risers for spread moored FPSO.

FPSO characteristics are as follows;

- Overall length (L): 325.05 m
- Length between perpendiculars (L_{bp}): 325.00 m
- Breadth (B): 61.00 m
- Depth (D): 32.00 m
- Design draft (T_d): 24.56 m
- Scantling draft (T_s): 25.55 m
- Block coefficient for scantling (C_b): 0.983

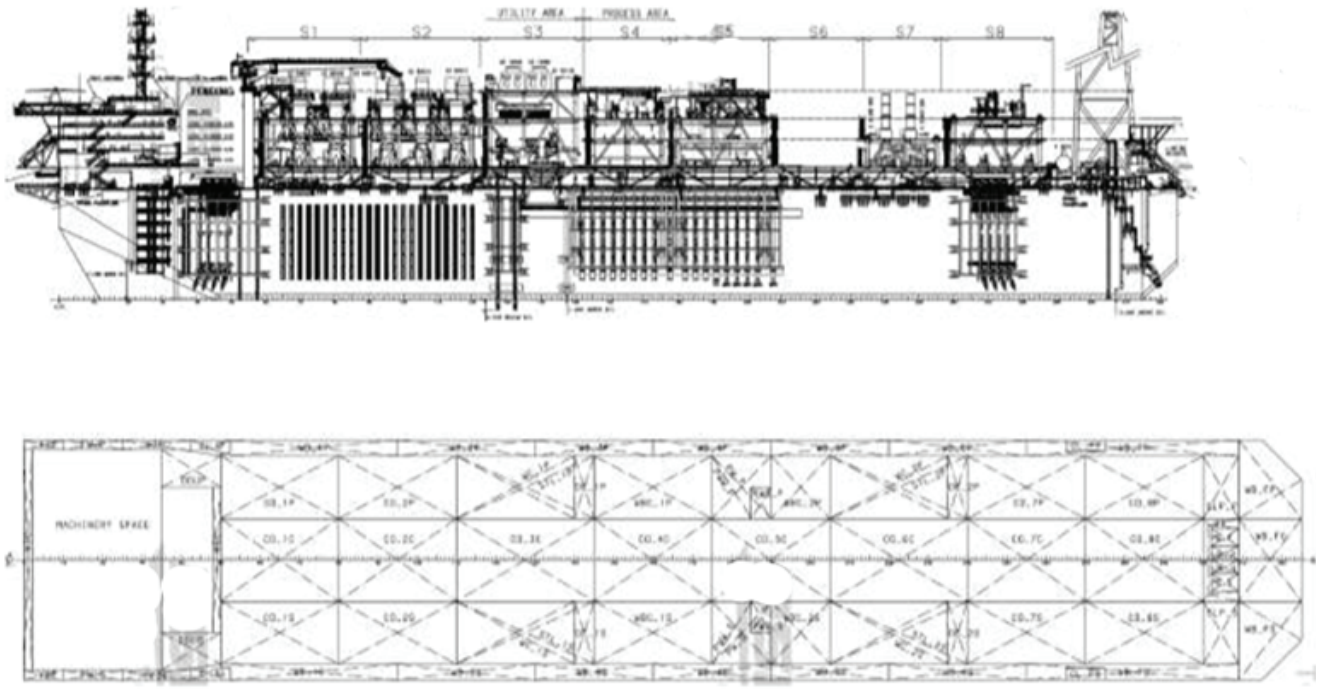


Figure 1.
General layout of a FPSO vessel.

3. COLLISION IMPACT ANALYSIS SCENARIOS

Ship collision analysis is often conducted in displacement controlled manner, i.e. the analysis of external motion dynamics is separate from the evaluation of structural consequences. Such analysis assumes a certain prescribed penetration path. This assumption was found to be valid in case of symmetric right angle collisions, while in non-symmetric collisions penetration depth depends on the structural configuration and mass of the ship, collision location, etc. Differences in damage description and penetration depth can be significant.

Brown (2002) compared the coupled SIMCOL model with the decoupled model of Pedersen and Zhang (1998) and concluded that, while total energy was similar in both approaches, the decomposition of the total energy into transverse and longitudinal energy was significantly different. Tabri and Broekhuijsen (2011) came to the same conclusion in their coupled and decoupled finite element simulation. They found that decoupled simulation could give an erroneous description of penetration depth in oblique angle collisions. With respect to ship collisions, prescriptive scenarios exist for ship-platform or ship-FPSO collisions; see for example recent guidelines by LR (2014).

In offshore ship collision studies conducted in the design stage, the speed of the striking vessel must not to be less than 2.0 m/s and the most probable impact location should be determined by risk analysis, taking into account factors that affect the exact location, such as tidal changes and vessel motion due to conditions at sea (NORSOK-N-003, 2007). In the absence of specific impact zone information, values between 10 m below LAT and 13m above HAT ((NORSOK-N-003, 2007) are to be considered. Force-indentation, energy-deformation and force-deformation curves are available in DNV-RP-C204 (2010) for different ship sizes and impact locations (bow, stern, broad side). Should a more detailed investigation be required than provided in the guidelines defined in classification rules, a local explicit FE analysis should be considered, with emphasis on material properties and failure criteria.

Impact energies for collision analyses are provided in Table 1. Collision locations used in the analyses are shown in Figure 2. Only one draft for each hull plating and the collision angle of 90 degrees between striking vessel and FPSO (that is, perpendicular to FPSO) are taken into account in hull plating evaluation, as this is where the most severe damage could occur. Especially for operational collisions with the side shell structure, in real life simulations the collision direction of the supply ship is not bow but stern. Hull plating locations considered in collision impact analyses are shown in Figures 3-5. The main dimensions of typical supply ship and methanol tanker are summarized in Table 2 and Table 3.

Table 1.
Ship collision scenarios for nonlinear FE analyses.

Collision location	Loading	Acceptance criteria	Collision direction	Speed	Colliding vessel	Displacement	Impact energy
Side shell	Operational	Energy absorbed by elastic deformation	Bow	0.64 m/s	Supply ship	7,500 t	1.7 MJ
			Side				2.2 MJ
	Accidental	Energy absorbed by plastic deformation (no breach)	Bow	1.7 m/s			11.9 MJ
			Side				15.2 MJ
	Critical	Breach of shell up to contact with inner hull	Bow	3.48 m/s			50 MJ
Bow (Tandem end)	Accidental	Energy absorbed by plastic deformation (no breach)	Bow	1.7 m/s	Methanol tanker	10,000 t	16 MJ
			Side				20.5 MJ
	Critical	Breach of shell up to contact with inner hull	Bow	4.35 m/s			104 MJ
Stern	Accidental	Energy absorbed by plastic deformation (no breach)	Bow	1.7 m/s	Supply ship	7,500 t	11.9 MJ
			Side				15.2 MJ
	Critical	Breach of shell up to contact with inner hull	Bow	3.48 m/s			50 MJ

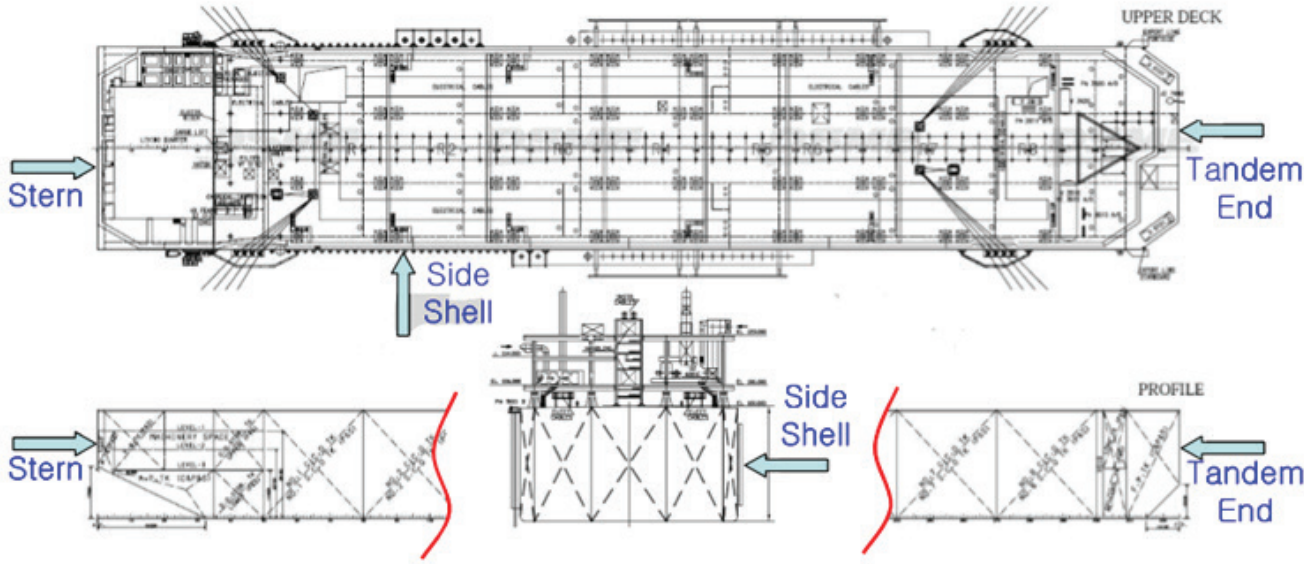


Figure 2.
Colliding position and collision direction for collision analyses.

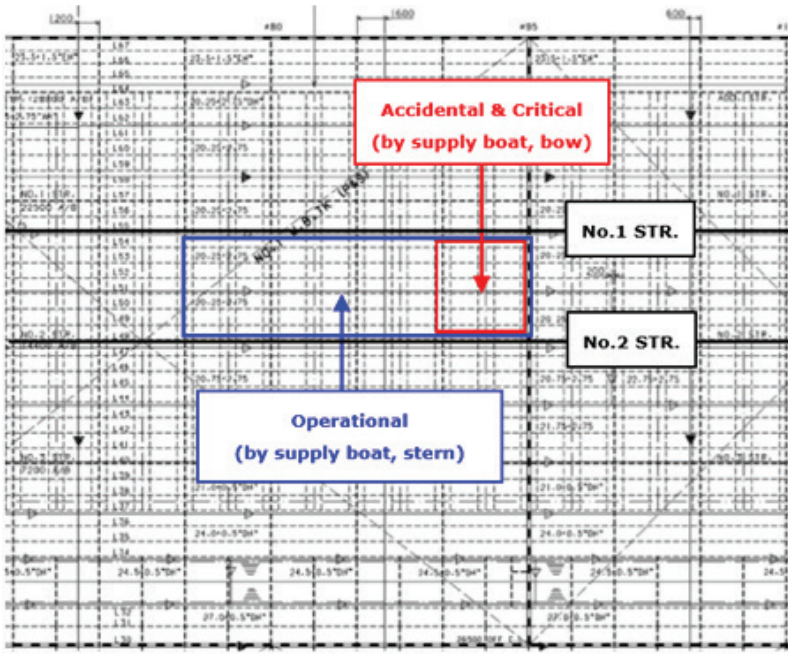


Figure 3.
Vertical striking position on FPSO side shell for collision analyses.

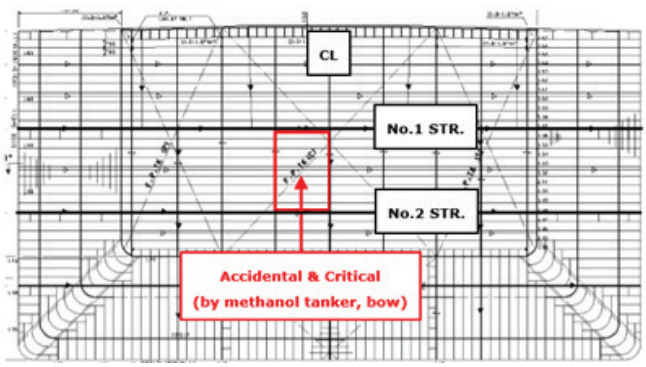


Figure 4.
Vertical striking position on FPSO bow for collision analyses.

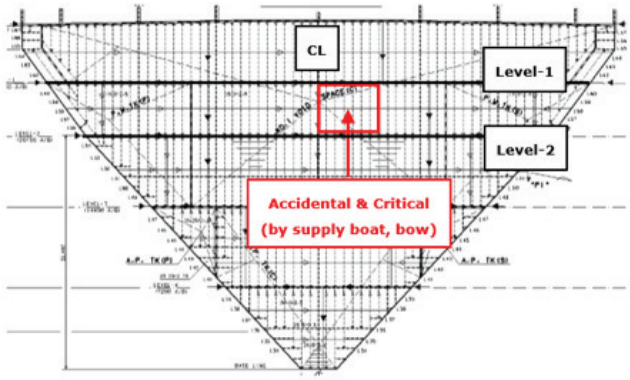


Figure 5.
Vertical striking position on FPSO stern for collision analyses.t

Impact velocities are calculated as in Eq.1.

$$E = 0.5\,(M + A_d)\,V^2 \quad (1)$$

M = striking ship displacement (t)
A_d = added mass (t)
V = collision speed (m/s)

Acceptance criteria allow severe plastic deformation of hull plating, providing there is no oil leakage and the integrity of vessel hull strength is not compromised.

Table 2.
Main dimensions of typical supply ship.

Overall length	90.00 m
Overall beam	19.00 m
Depth	8.00 m
Draught	6.50 m
Max. dead weight	3,800 t
Light displacement	3,700 t
Loaded displacement	7,500 t
Cruise speed	12 knots
Max. speed	16 knots

Table 3.
Main dimensions of typical methanol tanker.

Overall length	126.95 m
Length perpendicular	121.40 m
Overall beam	19.60 m
Moulded depth	9.35 m
Draught	6.80 m
Deadweight at design	10,000 t
Tonnage	6,688 GT
Max. speed	13.5 knots

5. BOW HULL PLATING

Impact on bow hull plating is assumed to be caused by a 10,000t methanol tanker.

The accidental impact of methanol tanker at the speed of 1.7 m/s generates kinetic energy of 16 MJ in a bow/stern impact and 20.5 MJ in a side-on impact with added mass factors. The hull plating may suffer significant plastic deformations but no leak is accepted.

Collision impact analysis of critical case on tandem end hull plating is carried out for verification purposes. Calculated ship impact speed is 4.35 m/s, required to generate the kinetic energy of 104 MJ. The maintenance of inner collision bulkhead structure integrity in case of breached outer shell structure is examined at impact locations.

The striking vessel is presumed to be a hard body, which assumption is considered to produce conservative results with respect to safety. Additionally, the FPSO vessel is presumed to stay in its position during collision events.

6. RUPTURE STRAIN AND MATERIAL PROPERTY

The amount of kinetic energy absorbed as strain energy must be calculated in accordance with the NORSOK standard. However, all kinetic energy is assumed to be consumed in a conservative way to strain water. The percentage of rupture strain is also determined depending on the grade of steel as shown in Table 4 below, in accordance with the NORSOK standard. The percentage of rupture strain for the grade of steel that is not specified in the table is calculated in the interpolation. In addition, material properties used in impact analysis are indicated in Table 5.

Table 4.
Suggested ε_{cr} values for various steel grades under NORSOK.

Steel grade	**Critical strain (ε_{cr})**
Mild	20%
HT 32	16.7%
HT 36	15%

Table 5.
Material properties to be used in nonlinear finite element simulations (DNVGL-RP-C208).

Steel grade	Mild	HT-32	HT-36
Yield stress	235 MPa	315 MPa	355 MPa
Elastic strain	0.20%	0.20%	0.20%
Ultimate tensile stress	450 MPa	530 MPa	560 MPa
Critical failure strain	20.0%	16.7%	15.0%
Density	7850 kg/m3	7850 kg/m3	7850 kg/m3
Young's modulus	2.06e+11 N/m2	2.06e+11 N/m2	2.06e+11 N/m2
Poison's ratio	0.3	0.3	0.3
Tangent modulus	1085 MPa	1303 MPa	1385 MPa
Hardening parameter	1.0	1.0	1.0
Strain rate (C)	40.4	3200	3200
Strain rate (P)	5.0	5.0	5.0

7. ASSESSMENT METHOD

In this study, FE analyses focus on a multitude of potential ship collision scenarios and structural configurations to be analysed. FE analysis is the most flexible method that can be used to account for possible effects and evaluate the relevant factors such as impact energy, boundary conditions, material, discrete indenter shape, rigidity and indentation location. Assessing non-linear material behaviour is essential for determining the response of a structure. The properties of elastic-plastic materials should be described by application;

- initial yield criterion;
- hardening rule where yield condition is modified due to the history of plastic flow;
- flow rule that updates plastic rigidity using an incremental stress-strain relationship.

The explicit method of FE analysis has the following characteristics:

- capability to manage very low dynamic response times, allowing highly discontinuous processes for large models;
- tolerance to large deformations and rotations;
- capability to analyse assembled parts with very general contact definitions;
- allows for the use of linear geometrical deformation theory if small deformations and rotations are presumed;
- allows for the use of adiabatic stress analysis if heat generation is assumed to be associated with inelastic dissipation;
- permits the quasi-static analysis of models with complex contact definitions;
- permits the deletion of the element to the rupture model.

Explicit nonlinear FE simulations were carried out to examine the strength of structures against collision impact, including the large deformation of structures and the properties of elasto-plastic material. In non-linear FE analysis, the strain hardening effect together with ultimate stress are presented as a bi-linear strain-stress curve based on material grades as depicted in Figure 6 and Figure 7. Fracture was determined on the basis of the critical plastic strain of material utilized in accordance with the NORSOK N-004 standard. Figure 8 shows the properties of the material employed in the nonlinear simulation. Ultimate stress data are average values and critical strain data are in accordance with the NORSOK N-004 standard. The Cowper-Symonds rate enhancement formula is employed to account for the effect of strain rate on material properties as provided by (2), (3) and (4) presented in Figure 6 and Figure 7.

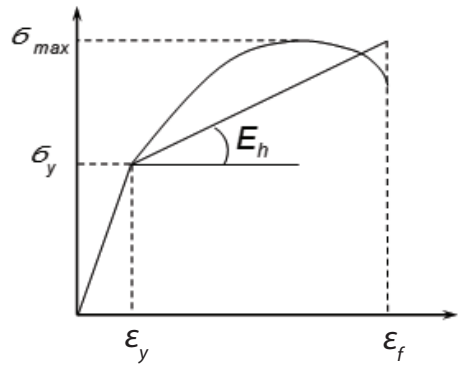


Figure 6.
Stress-strain curve for bilinear material.

$$\sigma_p = \sigma_y + \frac{EE_h}{E-E_h}\varepsilon_p \quad (2)$$

$$E_h = \frac{\sigma_{ymax} - \sigma_y}{\varepsilon_f - \varepsilon_y} \quad (3)$$

σ_y = Yield stress
E_h = Hardening modulus
σ_p, ε_p = Plastic stress and Plastic strain
E = Young's modulus

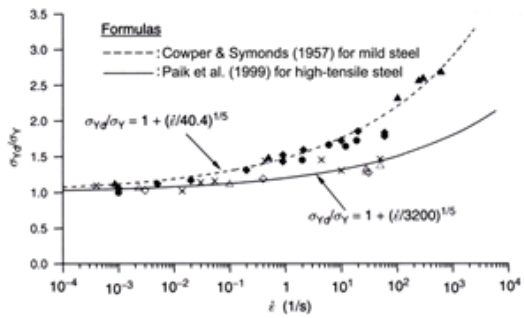


Figure 7.
Strain rate effect.

$$\frac{\sigma_{yd}}{\sigma_y} = 1 + \left\{\frac{\varepsilon}{D}\right\}^{1/q} \quad (4)$$

Mild steel:	D=40.4,	q=5
HT steel	D=3200,	q=5

σ_{yd} is dynamic yield stress; σ_y is static yield stress. The material properties of the initial configuration are in accordance with the steel quality used for the FPSO vessel, i.e. steel grades Mild, HT32 and HT36 as per DNVGL-RP-C208 (2019).

Collision simulation, including material and geometric nonlinearities, was performed using MSC/DYTRAN tool. To determine the strength capacity of supply ship and oil carrier hull plating in collision events, advanced nonlinear FE simulation was performed, as collision events cause complex responses. The properties of elements used in the FE models were obtained by deducting the DNVGL rule corrosion addition from the rule gross scantling in accordance with DNVGL Class.

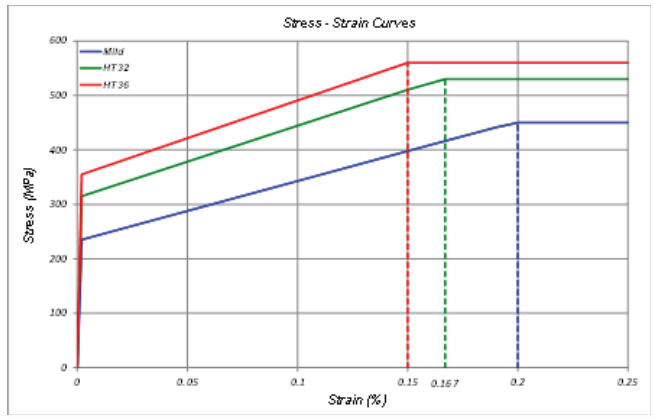


Figure 8.
Stress-strain curves for different steel grades.

8. FINITE ELEMENT MODEL

MSC/PATRAN was used to generate the FE models. The FE models were generated by using only shell elements, and the areas concerned were modelled using a mesh scale of about 100 mm x 100 mm. Taking the DNVGL rule into account, the corrosion effects were reflected. The striking ships were presumed to be infinitely rigid and FPSO's hull structure was thus presumed to absorb all energy. However, their rigidity should be taken with caution as energy dissipation in the bow is not taken into consideration. Figures 9 and 19 show FE models of FPSO hull structure with striking rigid ship in case of side collision, and FE model in case of bow and stern collision.

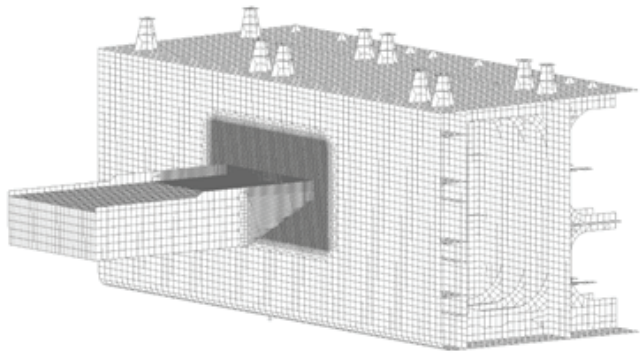


Figure 9.
FE model for impact analysis of side shell collisions – operational event.

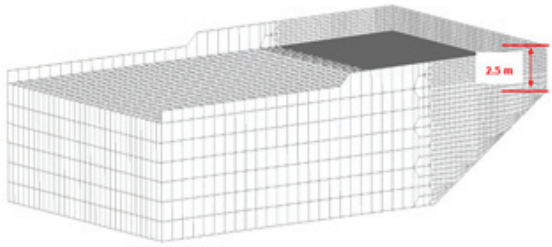


Figure 10.
FE model of supply ship (stern).

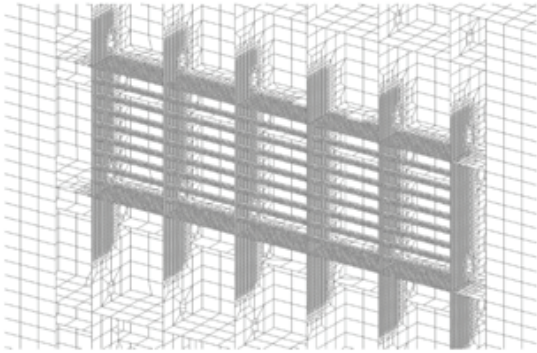


Figure 11.
FE model of side shell structure.

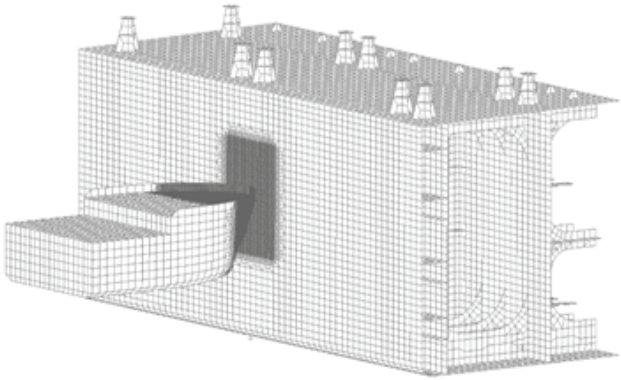


Figure 11.
FE model for side shell collision impact analysis –accidental / critical events.

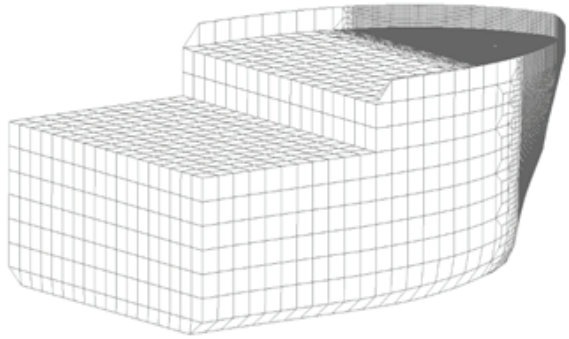


Figure 13.
FE model of supply ship (bow).

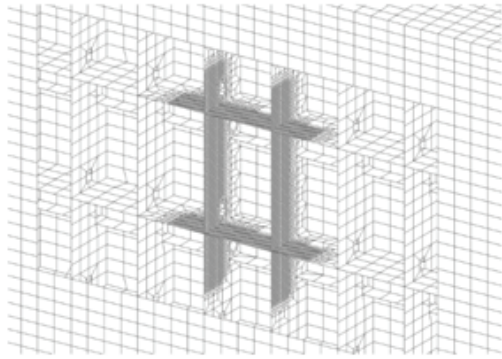


Figure 14.
FE model of side shell structure.

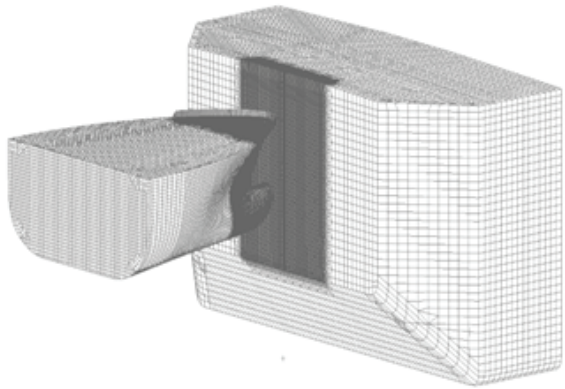


Figure 15.
FE model for impact analysis of bow collisions.

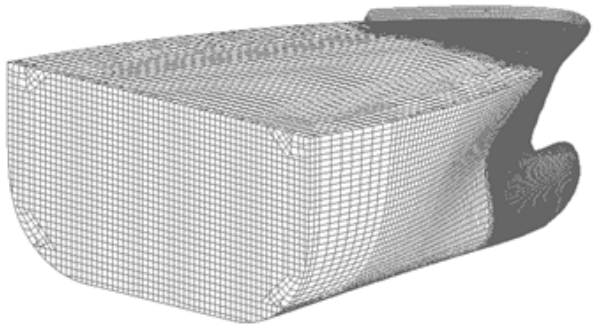


Figure 16.
FE model of methanol tanker (bow).

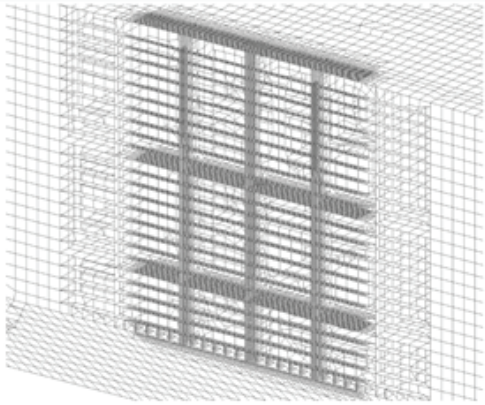


Figure 17.
FE model of bow structure.

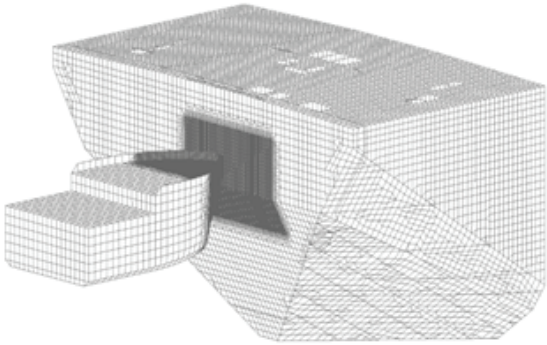


Figure 18.
FE model for stern collision impact analysis.

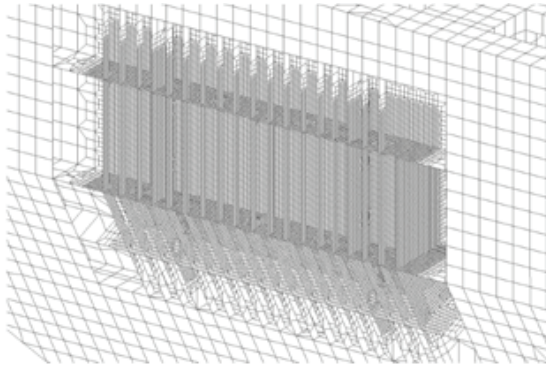


Figure 19.
FE model of stern structure.

9. APPLIED BOUNDARY CONDITIONS

The struck vessel is presumed to remain in place during impact. The assumption gives conservative results in terms of safety. Hence, boundary condition of FPSO hull structure has been implemented as fully fixed. Figure 20 depicts FE model with boundary plots for the side shell collision analysis.

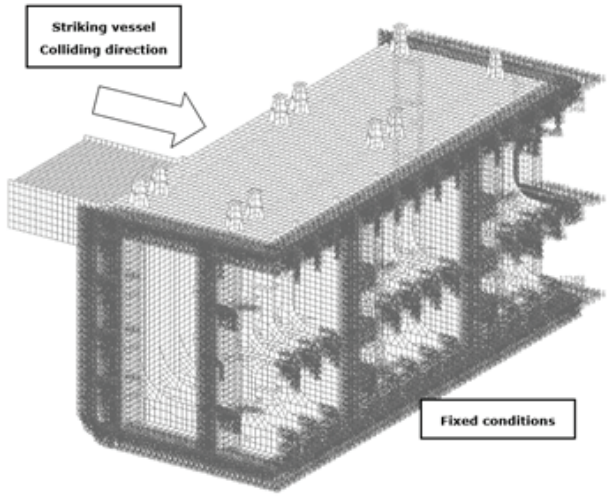


Figure 20.
Boundary conditions for FPSO (fixed).

10. FINITE ELEMENT ANALYSIS

Collision events were simulated by assigning the rigid body various initial speeds to represent a colliding ship, such as a supply vessel or a methanol oil tanker. The mass of the rigid body varies depending on collision direction with the corresponding added mass coefficients.

The surface contact between the impacting ship and the FPSO hull structure during collision was calculated. During the impact phenomenon, an infinite friction coefficient was employed, as it is known for preventing slipping at the contact point in the conservative method. In the MSC/DYTRAN tool, surface to surface contact was established. Self-contact due to great FPSO vessel hull deformation was frequent.

11. THE RESULTS OF FINITE ELEMENT ANALYSIS

In all impact load cases, nonlinear FE analyses have been performed to validate and check structural capacity in ship collision events.

- Deformed shape plots and plastic strain contour,
- Deformed shape plots and equivalent stress contour,
- Graphics illustrating kinetic energy and internally consumed energy,
- Graphics illustrating penetration depth and striking ship velocity.

Maximum plastic strains and equivalent stresses for each collision event are summarized in Table 6. Equivalent stresses are evaluated in accordance with the NORSOK code, taking into account the strain rate enhancement formula. Strain rate is determined as 0.2, a value normally used in ship collision events to determine stress limit. The details of plastic strain, equivalent stress and energy level change for all load cases are shown in Figures 21 to 71.

12. FE RESULTS OF SIDE SHELL COLLISION IMPACT ANALYSIS – OPERATIONAL EVENT

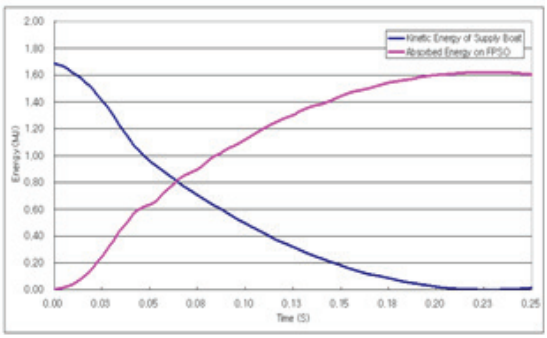


Figure 21.
Time history of kinetic and absorbed energy.

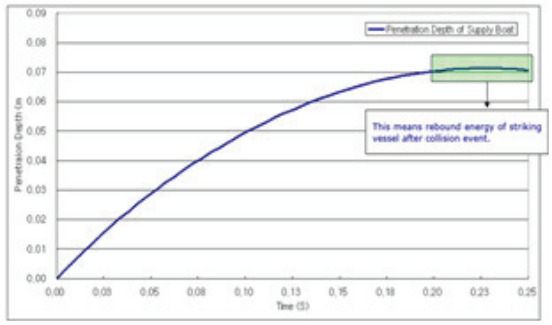


Figure 22.
Time history of supply ship penetration depth.

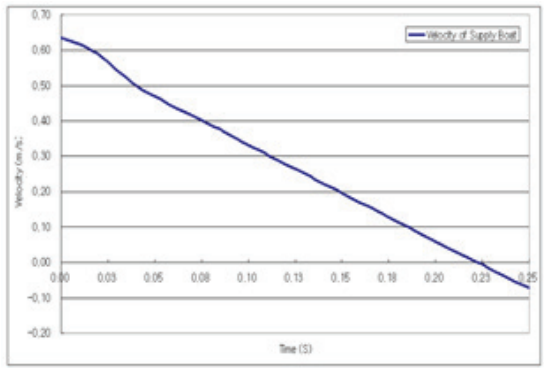


Figure 23.
Time history of supply ship velocity.

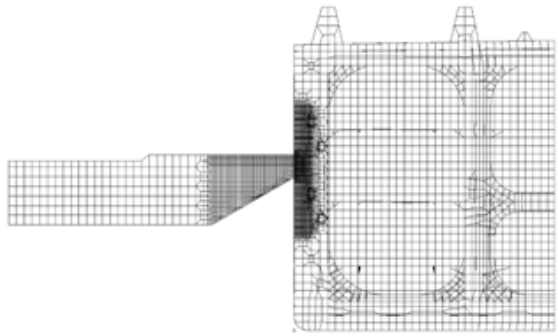


Figure 24.
Deformed shape at time = 0.25 sec.

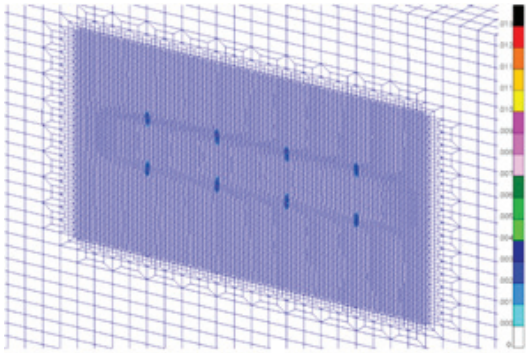


Figure 25.
Deformed shape and plastic strain contour of side shell plating at time = 0.25 sec.

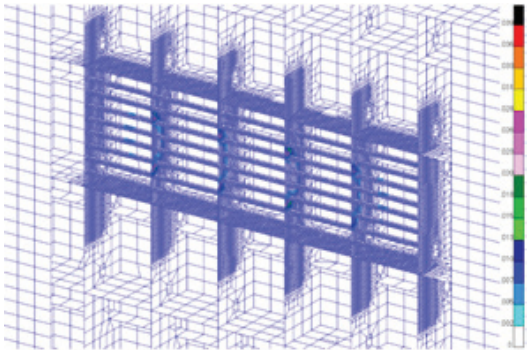


Figure 26.
Deformed shape and plastic strain contour of inner hull structure at time = 0.25 sec.

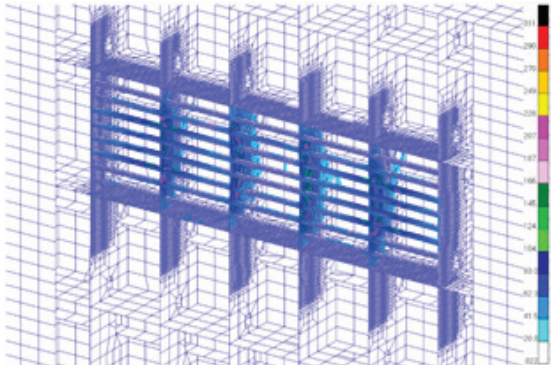


Figure 27.
Deformed shape and equivalent stress contour of inner hull structure at the end of collision.

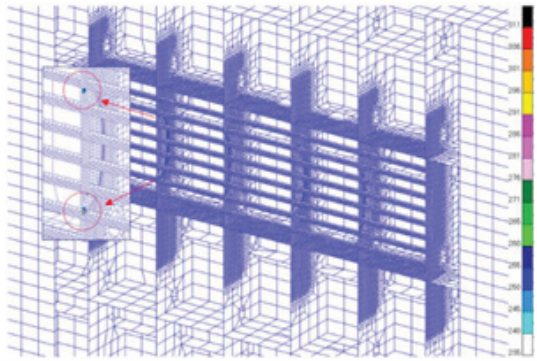


Figure 28.
Deformed shape and equivalent stress contour over yielding.

13. FE RESULTS OF SIDE SHELL IMPACT ANALYSIS – ACCIDENTAL EVENT

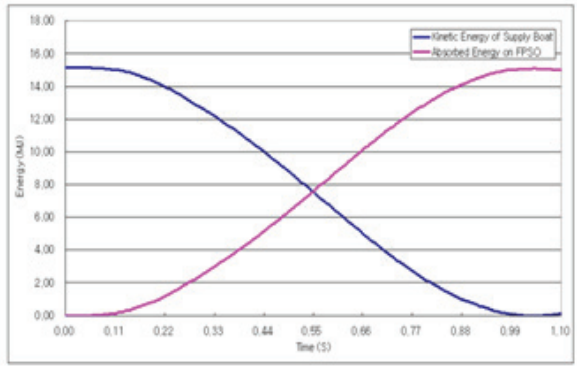


Figure 29.
Time history of kinetic and absorbed energy.

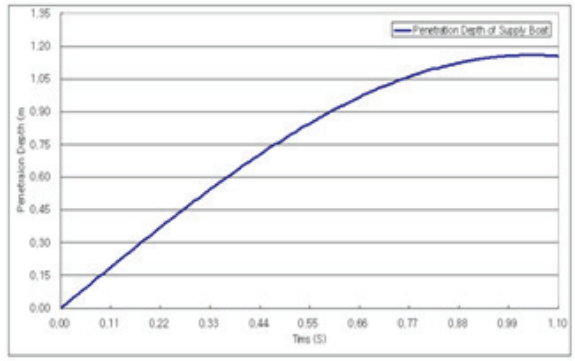


Figure 30.
Time history for supply ship penetration depth.

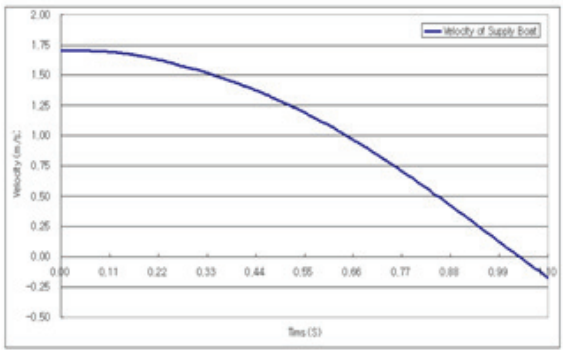


Figure 31.
Time history for supply ship velocity.

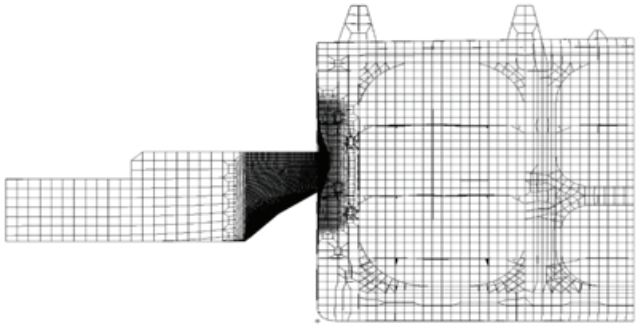


Figure 32.
Deformed shape at time = 1.10 sec.

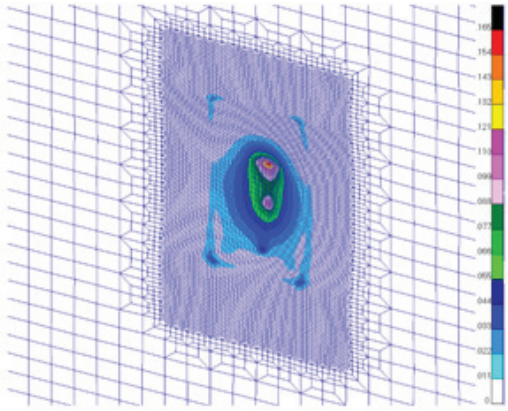


Figure 33.
Deformed shape and plastic strain contour of side shell plating at time = 1.10 sec.

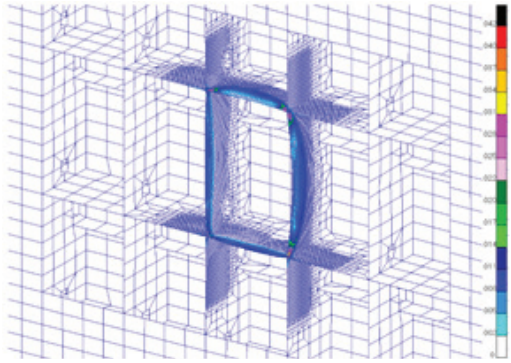


Figure 34.
Deformed shape and plastic strain contour of inner hull structure at time = 1.10 sec.

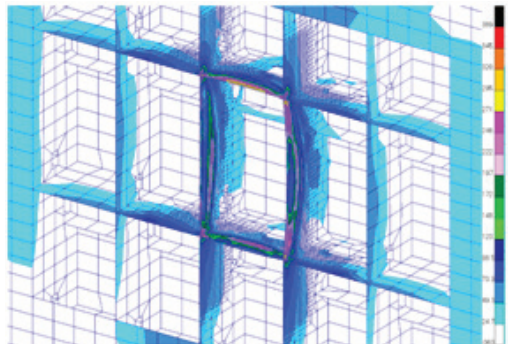


Figure 35.
Deformed shape and equivalent stress contour of inner hull structure at the end of collision.

14. FE RESULTS OF SIDE SHELL IMPACT ANALYSIS – CRITICAL EVENT

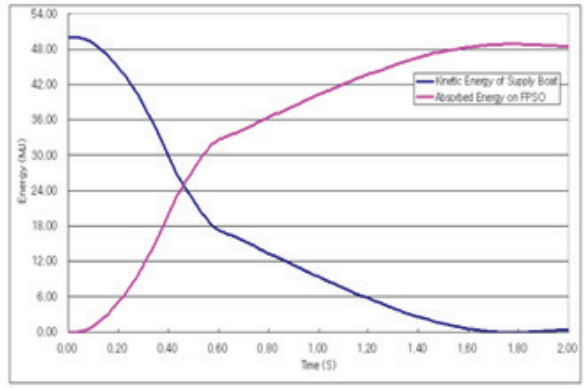


Figure 36.
Time history for kinetic and absorbed energy.

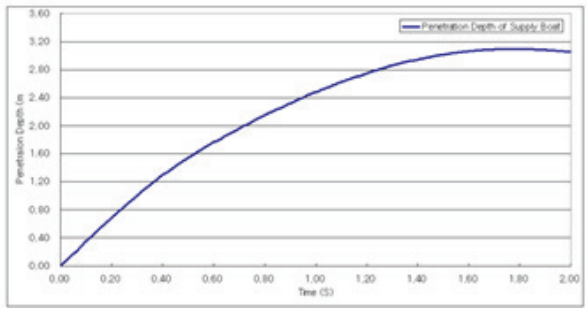


Figure 37.
Time history for supply ship penetration depth.

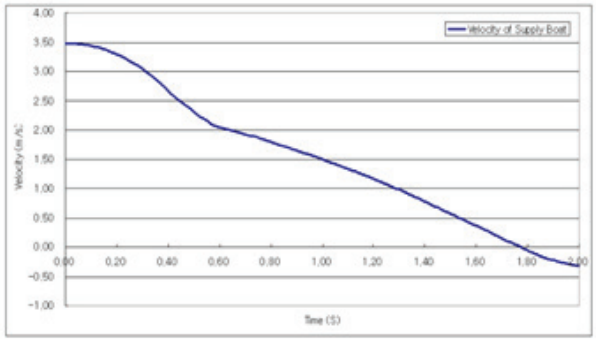


Figure 38.
Time history for supply ship velocity.

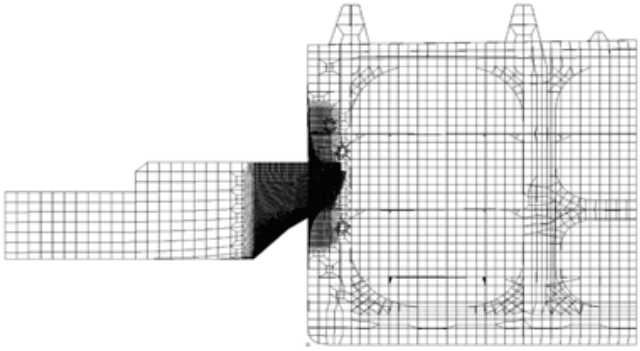


Figure 39.
Deformed shape at time = 2.00 sec.

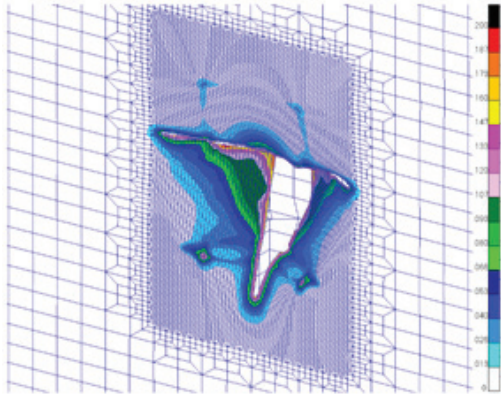


Figure 40.
Deformed shape and plastic strain contour of side shell plating at time = 2.00 sec. Deformed shape at time = 2.00 sec.

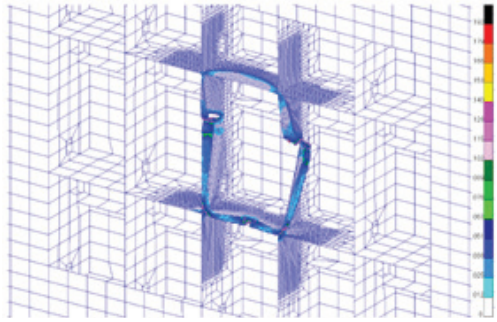


Figure 41.
Deformed shape and plastic strain contour of inner hull structure at time = 2.00 sec.

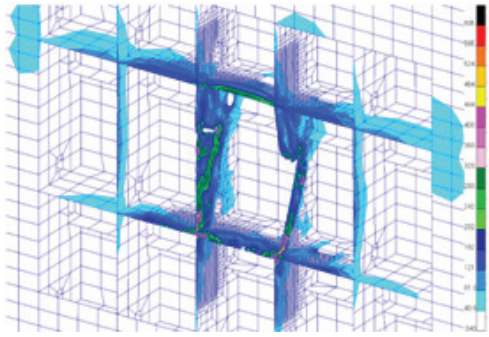


Figure 42.
Deformed shape and equivalent stress contour of inner hull structure at the end of collision.

15. FE RESULTS OF BOW IMPACT ANALYSIS – ACCIDENTAL EVENT

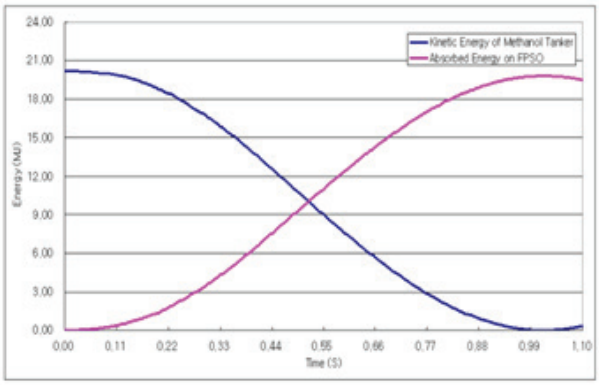


Figure 43.
Time history for kinetic and absorbed energy.

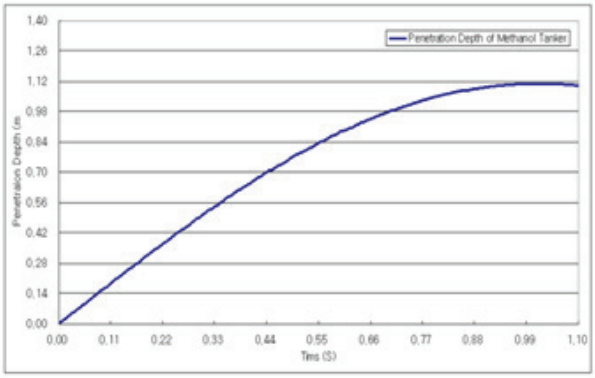


Figure 44.
Time history for methanol tanker penetration depth.

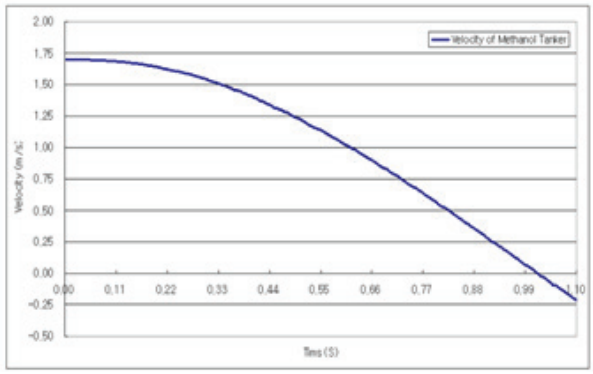


Figure 45.
Time history for methanol tanker velocity.

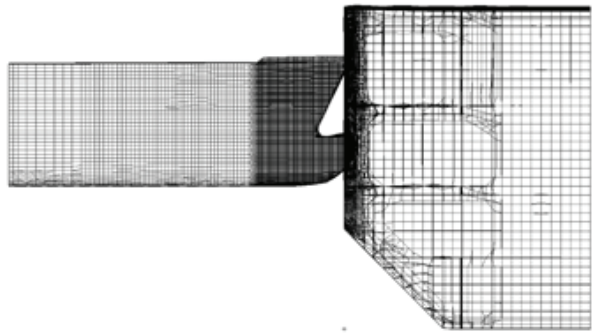


Figure 46.
Deformed shape at time = 1.10 sec.

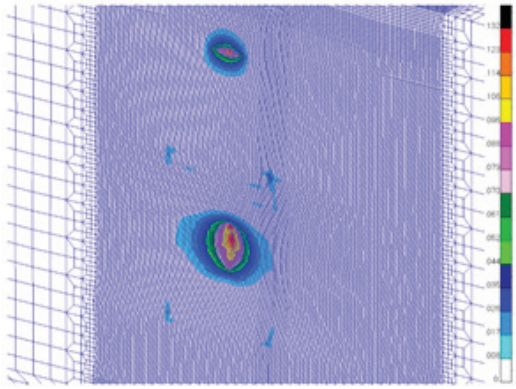


Figure 47.
Deformed shape and plastic strain contour of side shell plating at time = 1.10 sec.

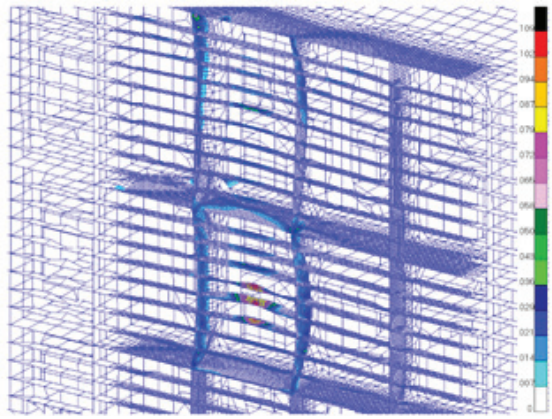


Figure 48.
Deformed shape and plastic strain contour of inner hull structure at time = 1.10 sec.

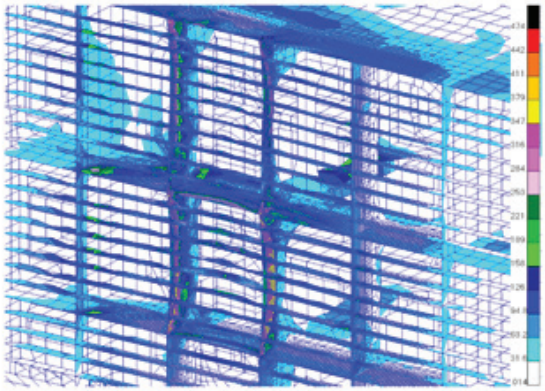


Figure 49.
Deformed shape and equivalent stress contour of inner hull structure at the end of collision.

16. FE RESULTS OF BOW IMPACT ANALYSIS – CRITICAL EVENT

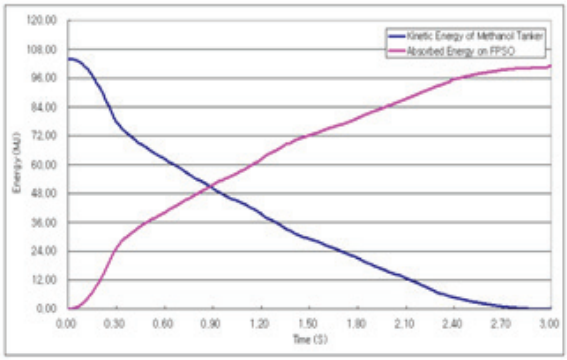


Figure 50.
Time history for kinetic and absorbed energy.

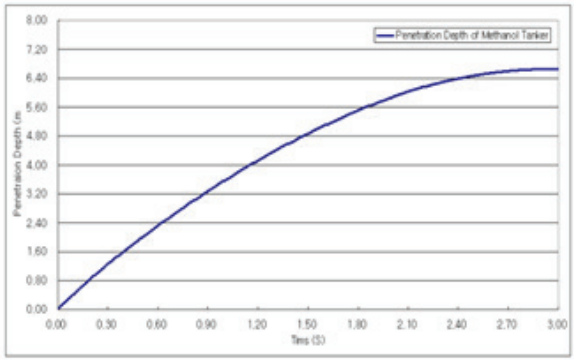


Figure 51.
Time history for methanol tanker penetration depth.

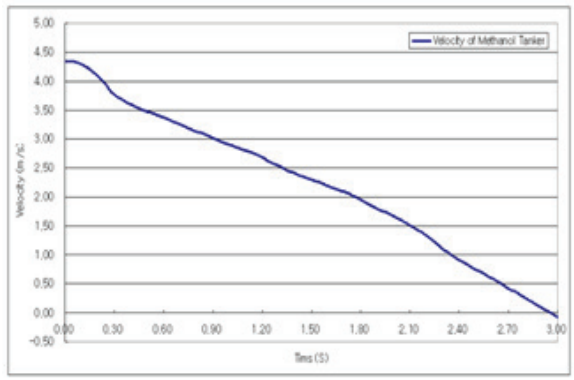


Figure 52.
Time history for methanol tanker velocity.

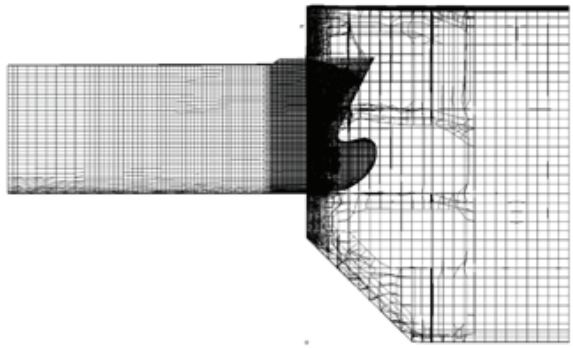


Figure 53.
Deformed shape at time = 3.00 sec.

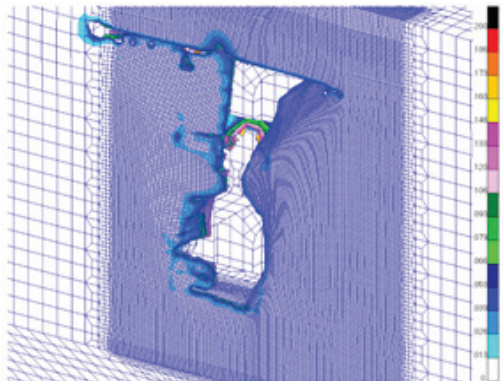


Figure 54.
Deformed shape and plastic strain contour of side shell plating at time = 3.00 sec.

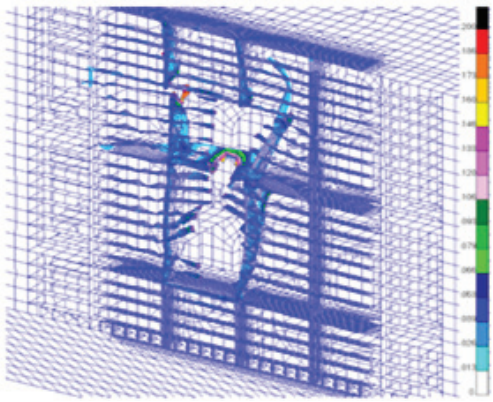


Figure 55.
Deformed shape and plastic strain contour of inner hull structure at time = 3.00 sec.

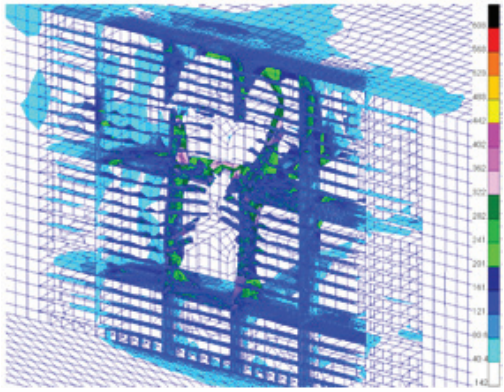


Figure 56.
Deformed shape and equivalent stress contour of inner hull structure at the end of collision.

17. FE RESULTS FOR STERN IMPACT ANALYSIS – ACCIDENTAL EVENT

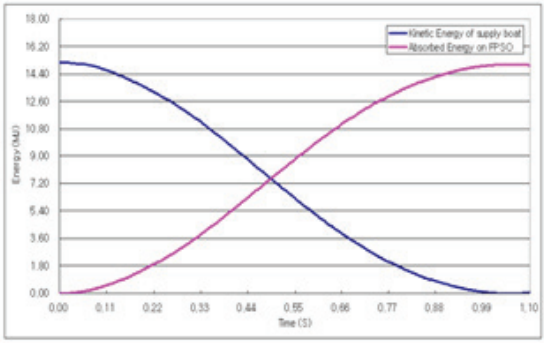


Figure 57.
Time history for kinetic and absorbed energy.

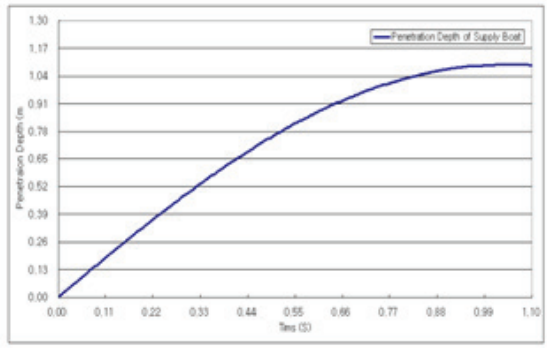


Figure 58.
Time history for supply ship penetration depth.

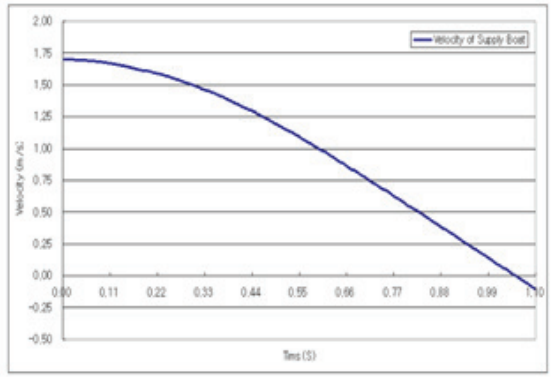


Figure 59.
Time history for supply ship velocity.

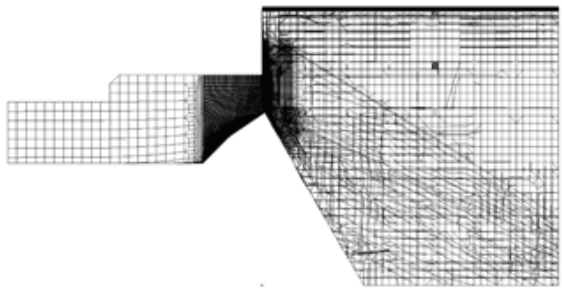


Figure 60.
Deformed shape at time = 1.10 sec.

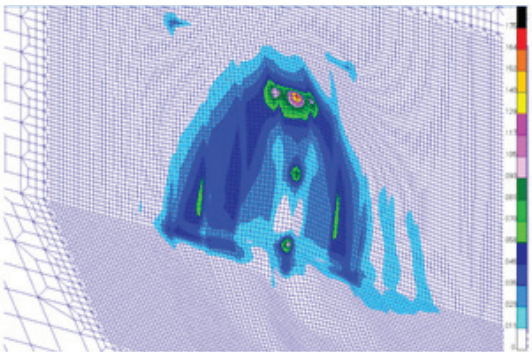


Figure 61.
Deformed shape and plastic strain contour of side shell plating at time = 1.10 sec.

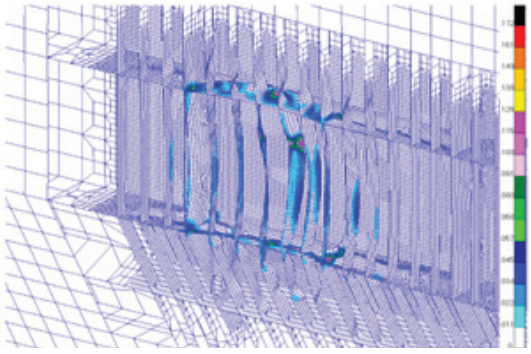


Figure 62.
Deformed shape and plastic strain contour of inner hull structure at time = 1.10 sec.

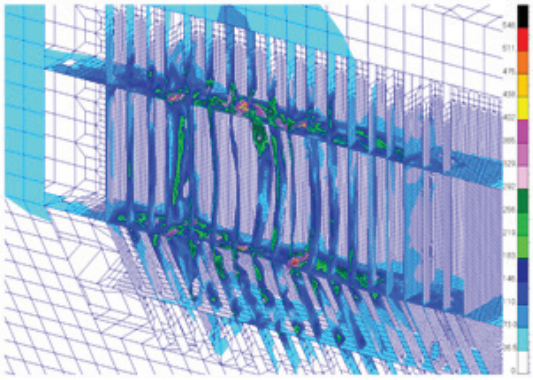


Figure 63.
Deformed shape and equivalent stress contour of inner hull structure at the end of collision.

18. FE RESULTS FOR STERN IMPACT ANALYSIS – CRITICAL EVENT

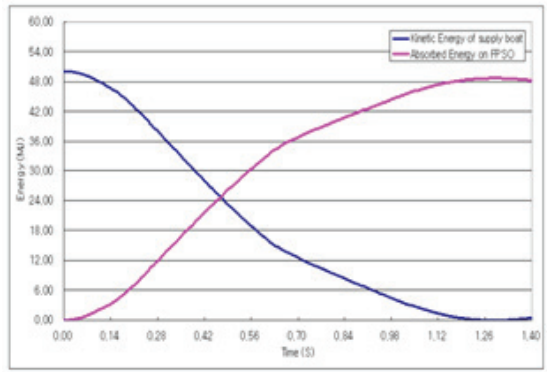


Figure 64.
Time history for kinetic and absorbed energy.

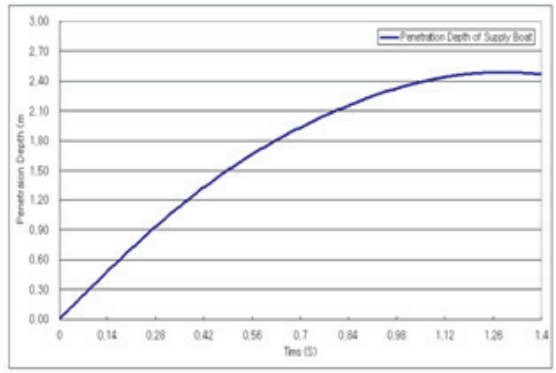


Figure 65.
Time history for supply ship penetration depth.

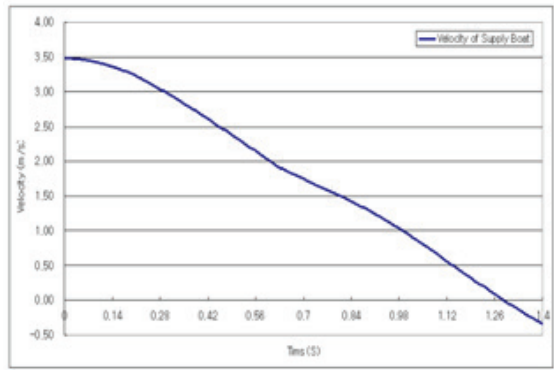


Figure 66.
Time history for supply ship velocity.

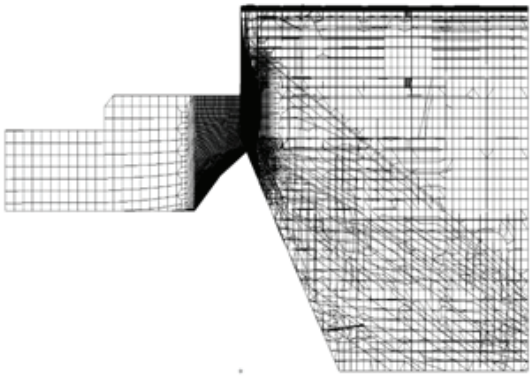


Figure 67.
Deformed shape at time = 1.40 sec.

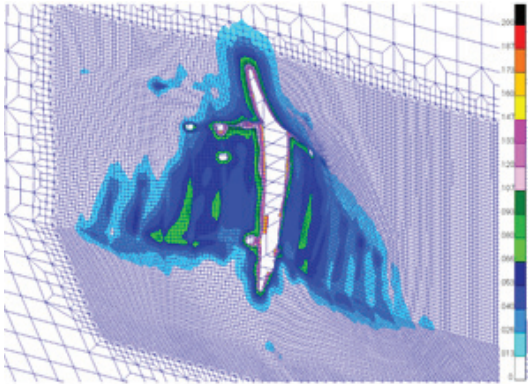


Figure 68.
Deformed shape and plastic strain contour of side shell plating at time = 1.40 sec.

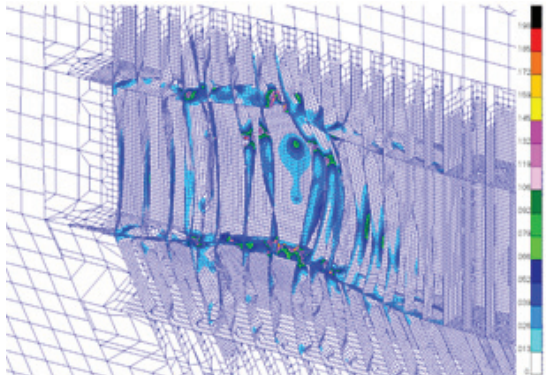


Figure 69.
Deformed shape and plastic strain contour of inner hull structure at time = 1.40 sec.

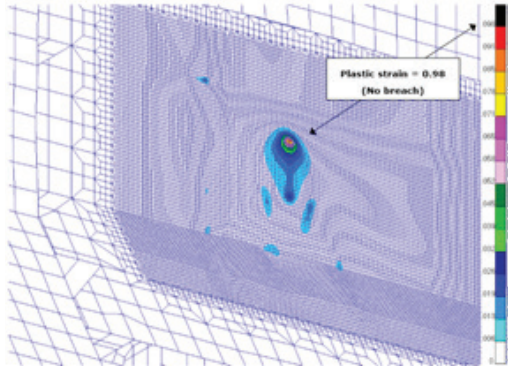


Figure 70.
Deformed shape and plastic strain contour of inner shell at time = 1.40 sec.

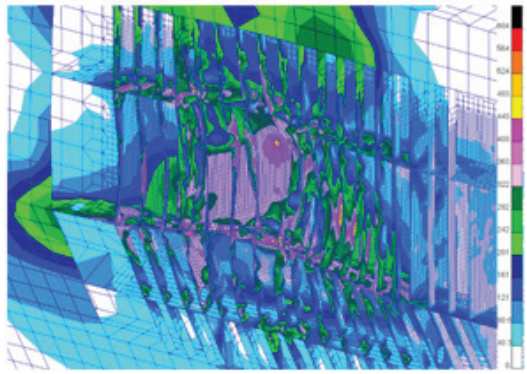


Figure 71.
Deformed shape and equivalent stress contour of inner hull structure at the end of collision.

To ensure that the collision simulations are conducted correctly, both the striking vessel's kinetic energy and the FPSO hull structure's absorbed internal energy were plotted based on the time history. In all cases, kinetic energy started from the required energy level and the internal energy was equal to the initial kinetic energy of the impacting vessel. The results of analyses indicated in Table 6 show that collision loads were correctly distributed and that simulations were reasonably performed. Structural strength was estimated by comparing the maximum stress obtained by collision analysis with the stress limit stipulated in the NORSOK code, taking into account the increase in strain rate.

Table 6.
Results of collision impact analyses.

Collision location	Loading and energy	Collison direction	Material	Plastic strain (%)		Equiv. stress(MPa)		Result
				Max. result	Criteria	Max. stress	Stresslimit	
Side Shell	Operational 1.7 MJ	Stern	Mild	3.9	20.0	311	316	Satisfactory
	Accidental 15.2 MJ	Bow	Mild	16.5	20.0	369	606	Satisfactory
	Critical 50 MJ	Bow	Mild	Over criteria	20.0	Over stress limit	606	No contact inner hull
Bow	Accidental 20.5 MJ	Bow	HT-32	13.2	16.7	474	606	Satisfactory
	Critical 104 MJ	Bow	HT-32	Over criteria	16.7	Over stress limit	606	No contact inner bulkhead
Stern	Accidental 15.2 MJ	Bow	Mild	17.5	20.0	548	606	Satisfactory
	Critical 50 MJ	Bow	Mild	Over criteria	20.0	Over stress limit	606	Contact inner hull but no breach

19. ACCEPTANCE CRITERIA AND CONSEQUENCE EVALUATION

Structural damage caused by ship collision accidents can have serious consequences. For example, the reduction of a ship's longitudinal strength may induce global hull collapse. The assessment of global strength after collision damage is thus a necessary step in design. Furthermore, other consequences, such as oil spills, consequent salvage flooding and riser collision consequences have all attracted much attention by the scholars. Global strength has always been a key concern for damaged ships after collision accidents (ISSC 2018).

Obisesan et al. (2016) proposed a framework for reliability assessment of ship hull damage in the event of bow impact. They used reliability computations to show that the probability of hull fracture increases as the hull deformation progresses, with maximum value occurring at the onset of outer hull fracture. Youssef, Faisal et al. (2016) proposed a method for the assessment of risk of ship hull collapse following a collision. They used a probabilistic approach to establish a correlation between the exceedance probability of collision and the residual ultimate longitudinal strength index.

Begovic (2017) carried out an experimental study on hull girder loads on an intact and a damaged naval ship DTMB 5415 at zero speed. He found that moorings influence hull girder loads at some wave frequencies. The global responses of ships suffering impact during collision were investigated by Jia and Moan (2015), with emphasis on hydrodynamic effects. They found that equivalent added mass for sway motion depends not only on the duration of collision impact and impact force, but on collision location as well. Comparatively, the equivalent added mass for yaw motion could be assumed to be independent of collision location. Flooding in damaged ships has also been a matter of concern.

Afenyo et al. (2016) made a state-of the-art review of the fate and transport of oil spills in open and ice-covered water. The review identified the current knowledge gaps and future research directions.

Inadequate longitudinal strength may cause an FPSO to collapse after collision. The residual strength of damaged structures must be maintained at a certain level to avoid additional catastrophic consequences. A measure of residual bending capacity can be based on either the maximum elastic bending moment corresponding to occurrence of initial yielding (section modulus-based residual strength), or the maximum bending moment beyond which the ship will break its back due to extensive yielding and buckling (ultimate bending moment-based residual strength). Figure 72 presents the vertical extent of the damaged members in a critical collision event, which is the most dangerous scenario strength-wise. Figure 73 illustrates the moment of inertia of an intact structure, while Figure 74 shows the moment of inertia of a damaged structure in a critical collision event.

Ultimate hull girder bending capacity was calculated for undamaged and damaged mid-ship sections shown in Table 7 and Table 8. According to calculation, inertia moment reduction due to loss of side structural members is less than 1%.

Table 7.
Hull girder strength criteria for undamaged (intact).

Modulus at deck (m^3)	120.11
Modulus at bottom (m^3)	118.55
Inertia (m^4)	1909.11

Table 8.
Hull girder strength criteria for damaged section.

Modulus at deck (m^3)	119.88
Modulus at bottom (m^3)	118.22
Inertia (m^4)	1904.65

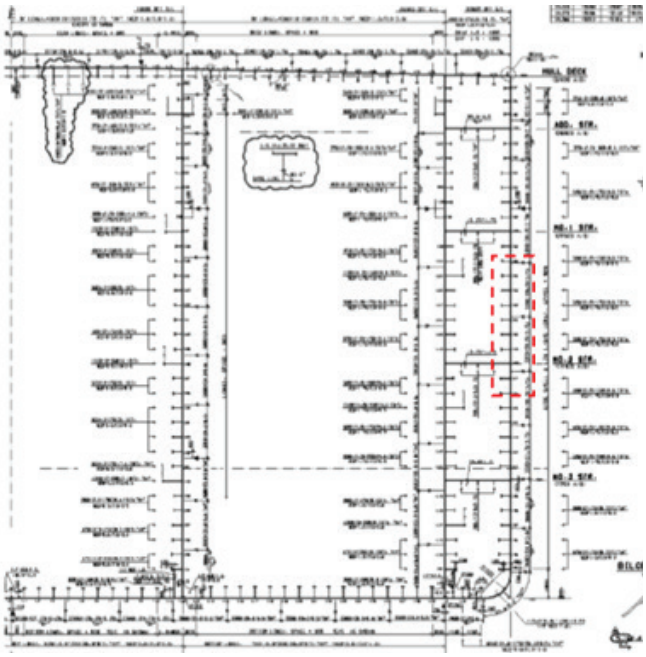


Figure 72.
Vertical extent of the damaged members in a critical collision event (the most dangerous case).

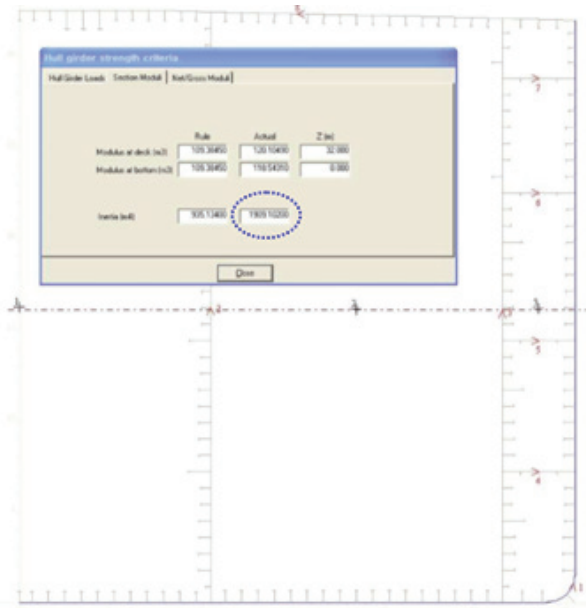


Figure 73.
Moment of inertia of intact structure.

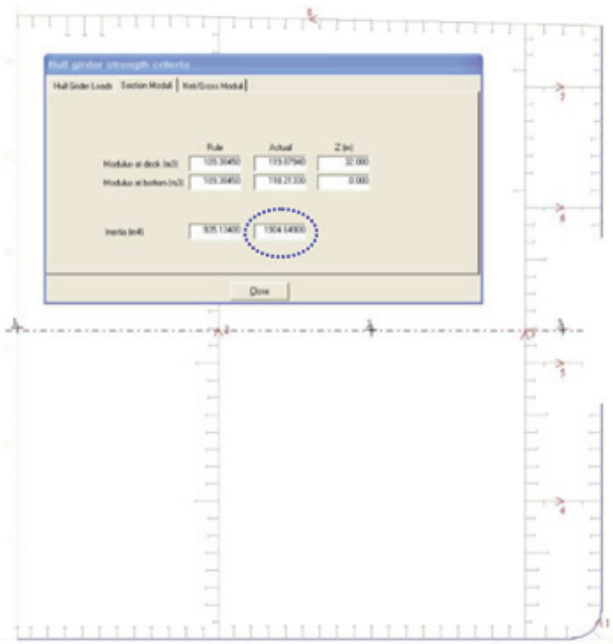


Figure 74.
Moment of inertia of damaged structure in a critical collision event.

20. CONCLUSION

Offshore platforms operating at sea are at risk of impacts with ships. Potential impacts can range from minor local structural deformations to significant threats to structural integrity, resulting in major economic losses, serious environmental contamination, and fatalities. Accidental loads can, under severe circumstances, result in the global collapse of whole structures and put people's lives at risk.

Collision impact analyses based on numerical impact simulations were conducted to examine the protection of FPSO vessel's hull during collision accidents with striking ships. In the side shell structure operational scenario, the impact analysis of collision indicates that certain elements surpass yield stress, but the damage is minor. In this case, as impact energy is primarily absorbed by elastic deformation of hull structure, slight plastic deformation occurred. Damage sustained by hull plating in this type of collision event was minor.

Rupture strain percentage by steel grade, the extent of hull damage in different collision scenarios and impact energy levels are determined using the guidelines contained in the NORSOK code "Design of steel structure N-004".

In all accidental collisions kinetic energy was absorbed by plastic deformation and there were no failures. Though hull structure sustained significant plastic deformations, there were no leakages.

In the event of a critical collision, for verification purposes only, the intactness of inner hull structure at impact locations in case of breach of the outer shell structure was checked. Several elements of the hull structure exceeded the fracture strain for vital collision of side shell and bow structures, but the striking ship did not strike the inner hull collision bulkhead. Supply ship collided with the inner hull in critical collisions with stern structures, but without breaching the internal hull plating.

Flare tower should be positioned so as to minimise the risk of ignition of a gas-cloud coming from the process installation. If an over water cantilevered solution is considered, it should be positioned at a height sufficient to avoid collision with passing vessels, including export tankers.

The offloading and mooring points should be positioned so as to minimise the risk of collision with export tanker or risk of offloading hose rupture. Their position needs to be checked under various environmental conditions and in different FPSO's positions.

Location of risers is determined with consideration of the risk of damage due to events such as collision by external vessels (including export tanker).

Supply ship operations must therefore be carried out carefully at the stern part of the FPSO. In accordance with the acceptance criteria, the FPSO hull structure was confirmed to have adequate structural strength to meet the design criteria for collision occurrences. Furthermore, an ultimate hull girder bending capacity was tested for intact and damaged conditions at mid-ship sections. According to simulations, inertia moment reduction due to loss of side structural members was less than 1%.

Due to the short duration of events, collision analyses are usually conducted using explicit solvers in which the kinetic energy of a dropped object is converted to strain energy of the struck and the striking body. Material failure is also considered in studies in which implicit element formulations are inadequate. Special attention should be paid to enforced boundary conditions; fixed conditions of the struck body often applied at a distance away from the striking point are typical. The striking body can be modelled wholly or partially. In the latter case, the initial velocity of the entire body should be used.

The usual output of concern is force deflection, i.e. energy dissipation-deflection curve. The greatest attention should be paid to the establishment of credible failure criteria and creating mesh size based on recommended practices where applicable. Most commercial codes nowadays support a series of failure criteria that remove elements as soon as certain limits are exceeded. Typical failure criteria are based on geometric strain, plastic strain, element distortion or time step.

Finally, the findings of the present study will improve our understanding of the collision response of offshore platforms and evaluation procedures and provide efficient guidance for the design and operation of FPSOs.

REFERENCES

Afenyo, M., Veitch, B. & Khan, F., 2016. A state-of-the-art review of fate and transport of oil spills in open and ice-covered water. Ocean Engineering, 119, pp.233–248. Available at: http://dx.doi.org/10.1016/j.oceaneng.2015.10.014.

Amante, D. do A.M. & Estefen, S.F., 2018. Collisions Between Ships and Platforms in Brazilian Waters. Volume 3: Structures, Safety, and Reliability. Available at: http://dx.doi.org/10.1115/omae2018-78199.

Amdahl, J. et al., 2012. Broad Side Ship Collision With Jacket Legs: Examination of NORSOK N-004 Analysis Procedure. Volume 2: Structures, Safety and Reliability. Available at: http://dx.doi.org/10.1115/omae2012-84266.

Begovic, E., Day, A.H. & Incecik, A., 2017. An experimental study of hull girder loads on an intact and damaged naval ship. Ocean Engineering, 133, pp.47–65. Available at: http://dx.doi.org/10.1016/j.oceaneng.2017.02.001.

Brown, A.J., 2002. Collision scenarios and probabilistic collision damage. Marine Structures, 15(4-5), pp.335–364. Available at: http://dx.doi.org/10.1016/s0951-8339(02)00007-2.

Calle, M.A.G., Oshiro, R.E. & Alves, M., 2017. Ship collision and grounding: Scaled experiments and numerical analysis. International Journal of Impact Engineering, 103, pp.195–210. Available at: http://dx.doi.org/10.1016/j.ijimpeng.2017.01.021.

Det Norske Veritas Offshore Standard, 2019. DNVGL-OS-C102. Høvik, Norway.

DNVGL-RP-C204, 2010. Design against Accidental Loads, Det Norske Veritas, Høvik, Norway.

DNVGL-RP-C208, 2019. Determination of Structural Capacity by Non-linear FE Analysis Methods, Recommended Practice, Det Norske Veritas, Høvik, Norway.

Health and Safety Executive (HSE), 2000. Collision resistance of ship-based structures to side impact, OTO 053/2000.

ISSC 2018, Proceedings of the 20th International Ship and Offshore Structures Congress (ISSC 2018) Volume II – M.L. Kaminski and P. Rigo (Eds.), Committee V.1 Accidental Limit States.

ISSC, 2003. Committee V.3 Collision and Grounding. The 15th International Ship and Offshore Structures Congress (ISSC), San Diego, USA.

ISSC, 2006. V.1. Collision and Grounding. The 16th Int. Ship and Offshore Structures Congress 2, Southampton, UK.

Jia, H. & Moan, T., 2015. Global Responses of Struck Ships in Collision With Emphasis on Hydrodynamic Effects. Journal of Offshore Mechanics and Arctic Engineering, 137(4). Available at: http://dx.doi.org/10.1115/1.4030343.

Liu, B., Villavicencio, R. & Guedes Soares, C., 2015a. Simplified method for quasi-static collision assessment of a damaged tanker side panel. Marine Structures, 40, pp.267–288. Available at: http://dx.doi.org/10.1016/j.marstruc.2014.11.006.

Liu, B., Villavicencio, R. & Guedes Soares, C., 2015b. Simplified analytical method to evaluate tanker side panels during minor collision incidents. International Journal of Impact Engineering, 78, pp.20–33. Available at: http://dx.doi.org/10.1016/j.ijimpeng.2014.11.021.

LR, 2014. Guidance notes for collision analysis. Lloyd's Register of Shipping.

Moan, T., 2019. Integrity Management of Offshore Structures With Emphasis on Design for Structural Damage Tolerance. Journal of Offshore Mechanics and Arctic Engineering, 142(3). Available at: http://dx.doi.org/10.1115/1.4045373.

Moan, T., Amdahl, J., Wang, X.Z. & Spencer, J., 2003. Risk Assessment of FPSOs with Emphasis on Collision, SNAME Transactions, 110, pp. 307-339.

Mujeeb-Ahmed, M.P., Seo, J.K. & Paik, J.K., 2018. Probabilistic approach for collision risk analysis of powered vessel with offshore platforms. Ocean Engineering, 151, pp.206–221. Available at: http://dx.doi.org/10.1016/j.oceaneng.2018.01.008.

Ning, X., Zhang, B.L. & Tallavajhula, S., 2013. Structural Integrity of a Spar in Collision With a Large Supply Vessel. Volume 2A: Structures, Safety and Reliability. Available at: http://dx.doi.org/10.1115/omae2013-10213.

NORSOK Standard, 2004a. Design of steel structure N-004, Rev.2 October 2004.

NORSOK Standard, 2004b. Materials selections M-001, Rev.4 August 2004.

NORSOK-N-003, 2017. Action and Action Effects. Edition 3. Standard Norway.

Obisesan, A., Sriramula, S. & Harrigan, J., 2015. A framework for reliability assessment of ship hull damage under ship bow impact. Ships and Offshore Structures, 11(7), pp.700–719. Available at: http://dx.doi.org/10.1080/17445302.2015.1051281.

Ozguc, O., 2017. Structural damage of ship–FPSO collisions. Journal of Marine Engineering & Technology, 18(1), pp.1–35. Available at: http://dx.doi.org/10.1080/20464177.2017.1359387.

Ozguc, O., 2018. Consideration of Collision Damage in FPSO Structural Design. Journal of Offshore Structure and Technology, 5(2), pp. 1–21.

Ozguc, O., Das, P.K. & Barltrop, N., 2005. A comparative study on the structural integrity of single and double side skin bulk carriers under collision damage. Marine Structures, 18(7-8), pp.511–547. Available at: http://dx.doi.org/10.1016/j.marstruc.2006.01.004.

Pedersen, P., 2014. Risk assessment for ship collisions against offshore structures. Maritime Technology and Engineering, pp.11–21. Available at: http://dx.doi.org/10.1201/b17494-4.

Rigueiro, C., Ribeiro, J. & Santiago, A., 2017. Numerical assessment of the behaviour of a fixed offshore platform subjected to ship collision. Procedia Engineering, 199, pp.2494–2499. Available at: http://dx.doi.org/10.1016/j.proeng.2017.09.415.

Storheim, M. & Amdahl, J., 2015. On the sensitivity to work hardening and strain-rate effects in nonlinear FEM analysis of ship collisions. Ships and Offshore Structures, 12(1), pp.100–115. Available at: http://dx.doi.org/10.1080/17445302.2015.1115181.

Szlapczynski, R. & Szlapczynska, J., 2016. An analysis of domain-based ship collision risk parameters. Ocean Engineering, 126, pp.47–56. Available at: http://dx.doi.org/10.1016/j.oceaneng.2016.08.030.

Tabri, K. & Broekhuijsen, J., 2011. Influence of ship motions in the numerical prediction of ship collision damage. Advances in Marine Structures, pp.391–397. Available at: http://dx.doi.org/10.1201/b10771-48.

Terndrup Pedersen, P. & Zhang, S., 1998. On Impact mechanics in ship collisions. Marine Structures, 11(10), pp.429–449. Available at: http://dx.doi.org/10.1016/s0951-8339(99)00002-7.

The 20th International Ship and Offshore Structures Congress, 2018. COMMITTEE V.1 Accidental Limit States, Proceedings of the 20th International Ship and Offshore Structures Congress (ISSC 2018) Volume II.

Travanca, J. & Hao, H., 2015. Energy dissipation in high-energy ship-offshore jacket platform collisions. Marine Structures, 40, pp.1–37. Available at: http://dx.doi.org/10.1016/j.marstruc.2014.10.008.

Vinnem, J.E., Utne, I.B. & Schjølberg, I., 2015. On the need for online decision support in FPSO–shuttle tanker collision risk reduction. Ocean Engineering, 101, pp.109–117. Available at: http://dx.doi.org/10.1016/j.oceaneng.2015.04.008.

Wang, G. & Pedersen, P.T., 2007. A Literature Review of Risk Assessment of Ship-FPSO Collisions. Volume 2: Structures, Safety and Reliability; Petroleum Technology Symposium. Available at: http://dx.doi.org/10.1115/omae2007-29760.

You, Y. & Rhee, K., 2016. Development of the collision ratio to infer the time at which to begin a collision avoidance of a ship. Applied Ocean Research, 60, pp.164–175. Available at: http://dx.doi.org/10.1016/j.apor.2016.09.005.

Youssef, S.A.M. et al., 2015. Assessing the risk of ship hull collapse due to collision. Ships and Offshore Structures, 11(4), pp.335–350. Available at: http://dx.doi.org/10.1080/17445302.2014.993110.

Yu, Z. & Amdahl, J., 2016a. Full six degrees of freedom coupled dynamic simulation of ship collision and grounding accidents. Marine Structures, 47, pp.1–22. Available at: http://dx.doi.org/10.1016/j.marstruc.2016.03.001.

Yu, Z. & Amdahl, J., 2016b. Influence of 6 DOF ship motions in the damage prediction of ship collision and grounding accidents, 7th International Conference on Collision and Grounding of Ships and Offshore Structures, Ships and Offshore Structures, pp. 199–205.

Yu, Z. & Amdahl, J., 2018. A review of structural responses and design of offshore tubular structures subjected to ship impacts. Ocean Engineering, 154, pp.177–203. Available at: http://dx.doi.org/10.1016/j.oceaneng.2018.02.009.

Zhang, D., Hu, Z. & Chen, G., 2015. Research on the Crashworthiness of FLNG Side Structures in the Side-by-Side Offloading Operation With LNGC. Volume 3: Structures, Safety and Reliability. Available at: http://dx.doi.org/10.1115/omae2015-41363.

Zhang, J. et al., 2015. A distributed anti-collision decision support formulation in multi-ship encounter situations under COLREGs. Ocean Engineering, 105, pp.336–348. Available at: http://dx.doi.org/10.1016/j.oceaneng.2015.06.054.

Zhang, S. et al., 2017. Impact mechanics of ship collisions and validations with experimental results. Marine Structures, 52, pp.69–81. Available at: http://dx.doi.org/10.1016/j.marstruc.2016.12.003.

Zhang, S., Pedersen, P.T. & Ocakli, H., 2015. Collisions damage assessment of ships and jack-up rigs. Ships and Offshore Structures, pp.1–9. Available at: http://dx.doi.org/10.1080/17445302.2014.1003173.

Zhang, W. et al., 2015. A method for detecting possible near miss ship collisions from AIS data. Ocean Engineering, 107, pp.60–69. Available at: http://dx.doi.org/10.1016/j.oceaneng.2015.07.046.

Space Remote Sensing and Detecting Systems of Oceangoing Ships

Dimov Stojce Ilcev

This paper introduces the implementation of space remote sensing and detecting systems of oceangoing ships as an alternative to the Radio – Automatic Identification System (R-AIS), Satellite – Automatic Identification System (S-AIS), Long Range Identification and Tracking (LRIT), and other current vessel tracking systems. In this paper will be not included a new project known as a Global Ship Tracking (GST) as an autonomous and discrete satellite network designed by the Space Science Centre (SSC) for research and postgraduate studies in Satellite Communication, Navigation and Surveillance (CNS) at Durban University of Technology (DUT). The ship detection from satellite remote sensing imagery system is a crucial application for maritime safety and security, which includes among others ship tracking, detecting and traffic surveillance, oil spill detection service, and discharge control, sea pollution monitoring, sea ice monitoring service, and protection against illegal fisheries activities. The establishment of a modern sea surface and ships monitoring system needs enhancement of the Satellite Synthetic Aperture Radar (SSAR) that is here discussed as a modern observation infrastructure integrated with Ships Surveillance and Detecting via SSAR TerraSAR-X Spacecraft, Ships Surveillance and Detecting via SSAR Radarsat Spacecraft and Vessels Detecting System (VDS) via SSAR.

KEY WORDS
~ R-AIS
~ LRIT
~ GST
~ CNS
~ SSAR
~ VDS
~ SRSS
~ GEO
~ EOSS
~ SPS
~ UAV
~ SAR
~ LEO
~ MEO
~ TerraSAR-X

Durban University of Technogy, Space Science Center, Durban, South Africa
e-mail: ilcev@dut.ac.za

doi: 10.7225/toms.v09.n02.004

1. INTRODUCTION

Space remote sensing and detecting systems of oceangoing vessels are very important applications for their tracking, positioning and control. In fact, these applications have been developed and deployed as a potential systems implementing satellite remote sensing since its earliest days. Remote sensing images of the sea surface immediately reveal that ships can be seen from space with radar, optical sensors and especially via a Satellite Synthetic Aperture Radars (SSAR) onboard Geostationary Earth Orbit (GEO) spacecraft.

Space Remote Sensing System (SRSS) technology is providing surveillance and detecting of ships via SSAR, Ladar, Lidar, and Electro-Optical Space Surveillance (EOSS) using existing facilities of the GEO and Non-GEO satellite constellations including Stratospheric Platform Systems (SPS) or Unmanned Aerial Vehicles (UAV) stations. The oceanic surface vastness with all moving objects is globally observed by the remote sensing facilities, which space, ground and users segments are shown in Figure 1.

Therefore, in the development of satellite remote sensing technology, significant attention has been paid to the remote

sensing images production of oceangoing ships from the space. Ship detection has been playing an important role in the field of remote sensing for a long time and can promote enhanced safety and security, port management, cargo transportation, and maritime Search and Rescue (SAR) solutions. Although many ship detection methods have been proposed in past, additional applications will be described in this context (Richards, 2009; Ilcev, 2016).

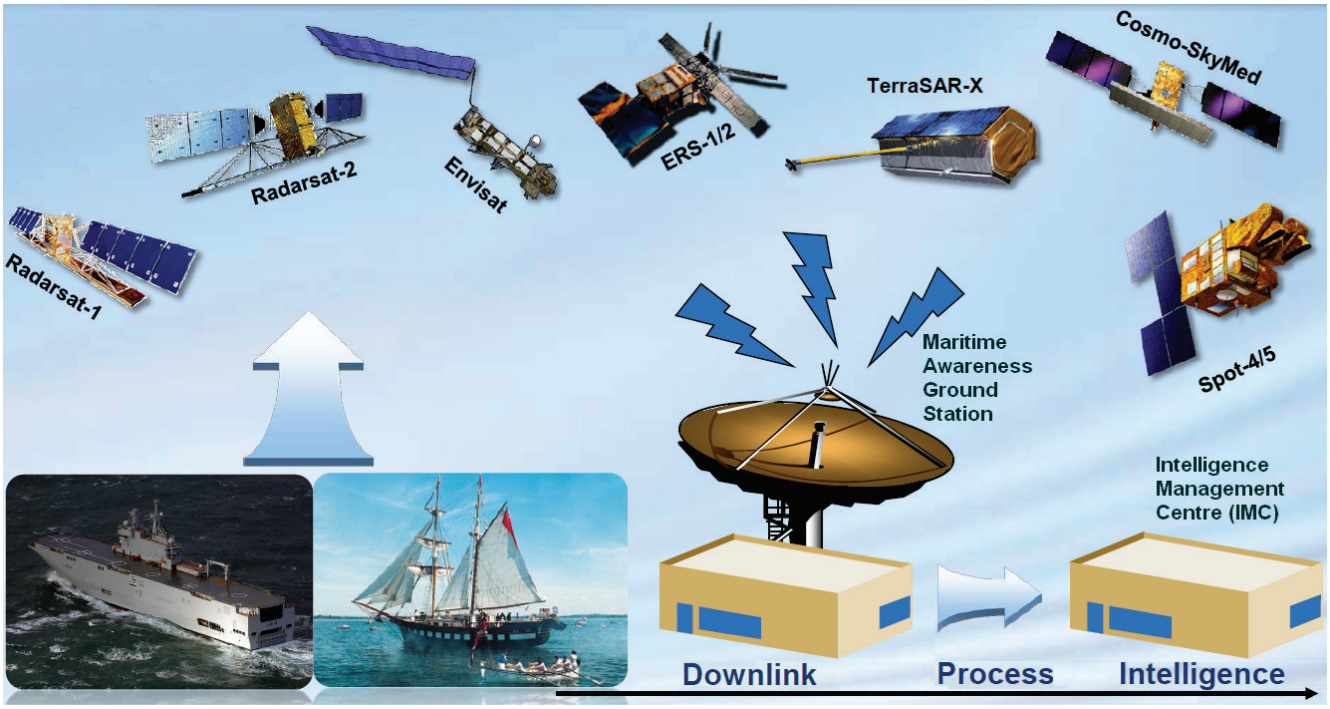


Figure 1.
Remote Sensing Solutions of Ships via Satellites – Source: Ilcev (2016).

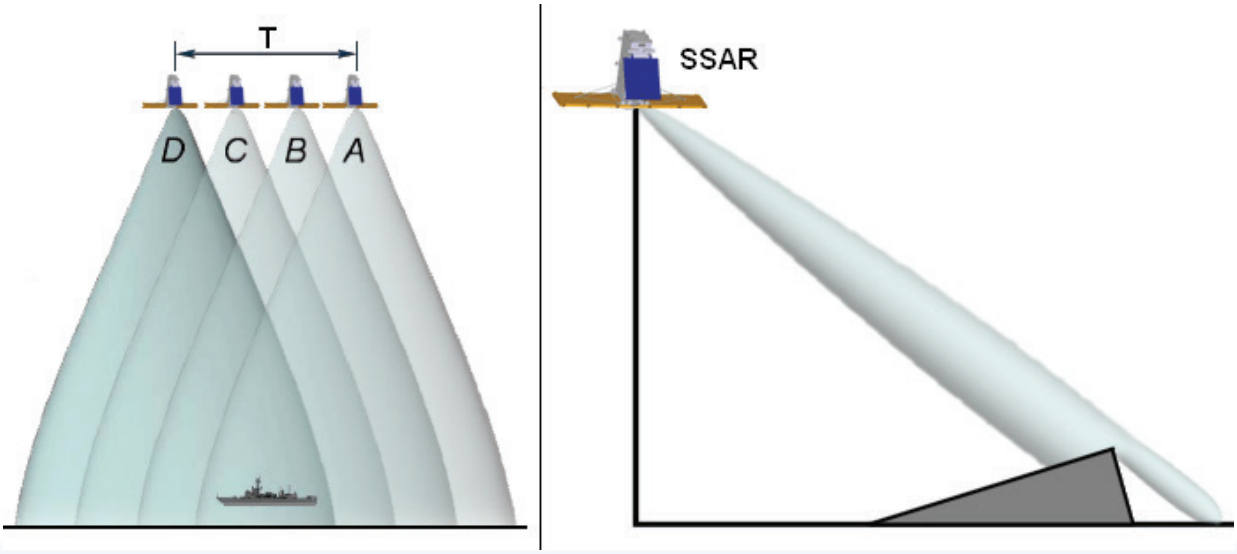


Figure 2.
Synthesized Expanding Beamwidth and Shadowing – Source: Wolff [3].

2. SATELLITE SYNTHETIC APERTURE RADAR (SSAR) SENSORS

Satellite Synthetic Aperture Radar (SSAR) as onboard spacecraft instruments or sensors can provide an efficient way of detecting ships in the open sea and through the wake and Doppler displacement measures their movement, speed, and direction. Request for maritime surveillance with new high-resolution sensors has been increased, particularly in the field of the ships safety and security demand. Coastal surveillance systems are widely used but are limited in their coverage, while satellite imagery gives the possibility to overcome these limits. The possibility to provide efficient ship surveillance over wide regions and all weather conditions make SSAR a very well suited instrument for this application. Different satellite images at a variety of modes are available and can be selected depending on the extent of the area in order to monitor the different target sizes of interest. Repeated SSAR observation can contribute to a ships surveillance system, complementing information on routes from High Frequency (HF) coastal radars and shipboard R-AIS or S-AIS and other tracking systems.

The area accessible from SSAR generally increases with the elevation of the GEO satellites, while the map coverage rate is a more complicated function of platform velocity and beam agility. The Low Earth Orbit (LEO) satellite coverage is basically given by the ground velocity times of the relatively narrow swath width. The instantaneously accessible area will be limited to some hundreds of miles away from the sub-satellite point.

On the other extreme, the subsatellite point of GEO SSAR will move relatively slowly, while the area that can be accessed at any given time is very large, reaching thousands of miles from the subsatellite point. Thus, to effectively use the accessibility provided by a high vantage point, very large antennas with electronically steered array beams are required. Interestingly, Medium Earth Orbit (MEO) satellite constellations will enable powerful observational systems that provide large instantaneous reach and high mapping rates, while pushing technology less than alternative systems at higher altitudes. In Fact, using interferometric SSAR techniques that can reveal centimeter-level (potentially sub-centimeter) surface displacements and frequent including targeted observations might be a key factor in developing such elusive applications as earthquake forecasting.

Although not strictly environmental measurements like the other parameters, ship signatures are found in ocean imagery made by many SSAR system operators. These significant signatures can provide information useful to environmental scientists, coastal and fishery managers, and law enforcement agencies. Characteristics such as high resolution (10 to 100 m), sensitivity to small variations in surface roughness (on the order of centimeters), and especially the strong signal return from hard targets like ships make SSAR systems particularly adept at detecting vessels at sea. Ships may be detected via three main mechanisms: a) Identification of radar energy reflected directly from the vessel, b) Detecting of wake patterns and c) Identification of slicks on the ocean surface resulting from the release of engine or fish oils.

The SSAR application is coherent mostly spaceborne or airborne side-looking radar system which utilizes the flight path of the space platform to simulate an extremely large phase antenna or aperture electronically and that generates high-resolution remote sensing imagery. The individual transmit/receive Pulse Repetition Time (PRT) cycles are completed with the data from each cycle being stored electronically. The signal processing uses magnitude and phase of the received signals over successive pulses from elements of synthetic aperture radar.

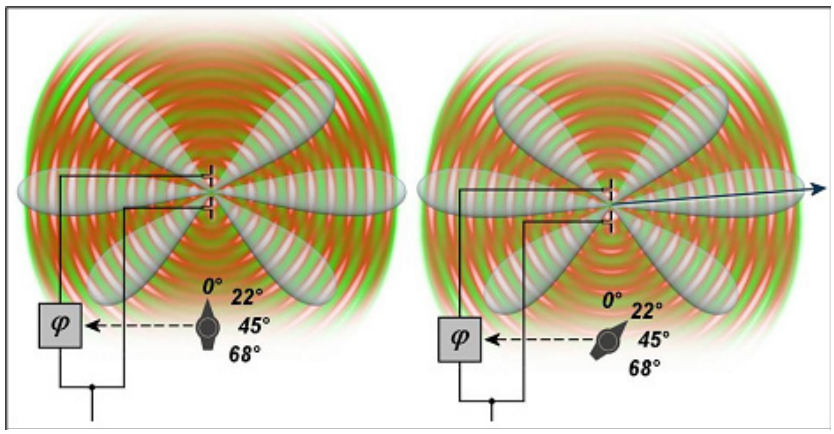


Figure 3.
SSAR Phase Array Antenna – Source: Wolff (2015).

After a given number of cycles, the stored surveillance data is recombined (taking into account the Doppler effects inherent in the different transmitter to target geometry in each succeeding cycle) to create a high-resolution image of the land or sea surface being overflown. The SSAR-processor stores all the radar returned signals, as amplitudes and phases, for the time period T (Synthetic Length of SSAR coming from Imagine Phased Array) and from position A to D, the Synthesized Expanding Beamwidth is shown in Figure 2 (Left). The accessible area of the SSAR radiating antenna sometimes decreases or even it suppresses, because a slope away from the radar illumination with an angle that is steeper than the sensor depression angle provokes radar shadows, which scenario is shown in Figure 2 (Right) (Ilcev, 2016; Wolff, 2015).

The shadowing effect increases with a greater incident or looks angle (θ_o), just as these shadows lengthen as the Sunsets. Thus, it should be also noted that the radar shadows of two objects of the same height are longer in the far range than in the near range. Shadow regions appear as dark (zero signal) with any changes due solely to system noise, sidelobes, and other effects normally of small importance.

Therefore, the SSAR system works similarly to a phased array, but the contrary to a large number of the parallel antenna elements of a phased array, SSAR uses one antenna in time-multiplex, which is shown in Figure 3. The different geometric positions of the SSAR antenna elements are the result of the moving platform in progress.

The Pulse Repetition Frequency (PRF) value of the radar system is the number of pulses that are transmitted per second, is shown in Figure 4 (Left), and the principle of SSAR operation is shown in Figure 4 (Right). Radar systems radiate each pulse at the carrier frequency during transmit time or Pulse Width (PW), wait for returning echoes during listening or rest time, and then radiate the next pulse, as shown in the above figure. The time between the beginning of one pulse and the start of the next pulse is already stated PRT and is equal to the reciprocal of PRF and is defined as follows:

$$PRT = 1 / PRF \tag{1}$$

The surveillance radar system pulse repetition frequency determines its ability to unambiguously measure target range and range rate in a single coherent processing interval as well as determining the inherent clutter rejection capabilities of the radar system.

In order to obtain an unambiguous measurement of the target range, the interval between radar pulses must be greater than the time required for a single pulse to propagate to a target at a given range and back. The maximum unambiguous range (R_{un}) in relation to the velocity of electromagnetic propagation or speed of light (c_o) is then given by the equation:

$$R_{un} = c_o / 2 \cdot PRF = c_o \cdot PRT / 2 \tag{2}$$

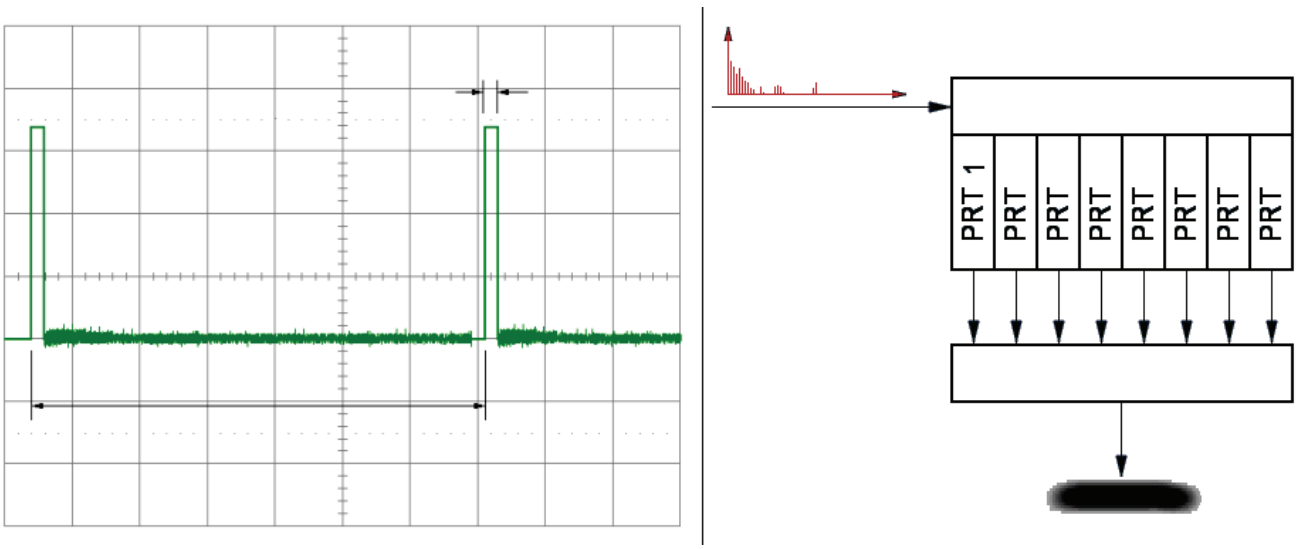


Figure 4.
Value of PRF and Principle of SSAR Operation – Source: Wolff (2015).

The SSAR processor stores all the radar returned signals, as amplitudes and phases, for the time period (T) from position A to D. Thus, now it is possible to reconstruct the signal that would have been obtained by the geometric length of the antenna (L) with the following equation:

$$L = v \cdot T = R_{o\lambda} / D \sin \theta_o \quad (3)$$

where v = speed of the platform, R_o = slant range from the antenna to the midpoint of the swath, λ = wavelength of the transmitted pulses (transmitted signal), D = distance, and θ_o = look angle (Wolff, 2015; Chen 2014).

As the Line of Sight (LOS) direction changes along the space radar platform trajectory, a synthetic aperture is produced by signal processing that has the effect of lengthening the antenna. Presenting T large makes the „synthetic aperture" enlarged and hence a higher resolution can be achieved. As a target (like a ship) first enters the radar antenna beam then the backscattered echoes from each transmitted pulse begin to be recorded. As the platform continues to move forward, all echoes from the target (ship) for each pulse are recorded during the entire time that it is within the beam. The point at which the target leaves the view of the radar beam sometime later determines the length of the simulated or synthesized antenna. The synthesized expanding beamwidth, combined with the increased time a target is within the array beam as ground range increases, balance each other, such that the resolution remains constant across the entire swath. The achievable azimuth resolution of an SSAR is approximately equal to one-half the length of the actual antenna and does not depend on platform altitude (distance).

The platform (aircraft or satellite) of a Side-Looking Airborne Radar (SLAR) travels forward in the flight direction with the nadir directly beneath the platform. The microwave beam is transmitted obliquely at right angles to the direction of flight illuminating a swath. Range refers to the across-track dimension perpendicular to the flight direction, while azimuth refers to the along-track dimension parallel to the flight direction. Swath width refers to the strip of the Earth's surface from which data are collected by side-looking airborne radar. It is the width of the imaged scene in the range dimension.

The longitudinal extent of the swath is defined by the motion of the aircraft with respect to the surface, whereas the swath width is measured perpendicularly to the longitudinal extent of the swath. The SLAR is a real aperture radar primarily, which requires a reasonable large antenna for adequately angular resolution. The azimuth resolution (R_a) is defined as:

$$R_a = H \cdot \lambda / L \cdot \cos \theta \quad (4)$$

where H = height of the antenna (height of the spacecraft/airplane), λ = wavelength of the transmitted pulses, L = geometric length of the antenna, and θ = incidence angle (Wolff, 2015; Ilcev, 2018).

The equation shows that with increasing altitude decreases the azimuthal resolution of SLAR and very long antenna (i.e., large L) would be required to achieve a good resolution from a satellite. The SSAR system is used to acquire higher resolution. The size of the ground resolution cell increases on the side of the nadir as the distance between the radar platform and the ground resolution cell increases. This means that the ground resolution cells are larger towards the edge of the image than near the middle. This causes a scale distortion, which must be accounted for.

At all ranges, the radar antenna measures the radial line of sight distance between the radar and each target on the surface. This is the slant range distance. The ground range distance is the true horizontal distance with the ground corresponding to each point measured in the slant range. The cross-track resolution (R_r) is defined as:

$$R_r = c_o \cdot t_p / 2 \cos \theta \quad (5)$$

where c_o = speed of light and t_p = pulse duration of the transmitter.

The practical example is given for the SLAR applications with the following characteristics: λ = 1 cm, L = 3 m, H = 6000 m, θ = 60° and t_p = 100 ns. It has got a resolution of R_a = 40 m and R_r = 17.3 m. The same SLAR on a platform in a height of 600 Km would achieve an azimuth-resolution of R_a = 4000 m.

The requirements of SSAR are: Stable, full-coherent transmitter, an efficient and powerful SSAR processor and exact knowledge of the flight path and the velocity of the platform. Using such a technique, radar designers, are able to achieve demanded resolutions, which would require real aperture antennas so large as to be impractical with arrays ranging in size up to 10 m. The SSAR radar can be partnered by what is termed Inverse SAR (abbreviated to ISAR) technology, which in the broadest terms utilizes the movement of the target rather than the emitter to create the synthetic aperture. The ISAR radars have a significant role aboard maritime patrol aircraft to provide them with a radar image of sufficient quality that allows it to be used for target recognition purposes. The slant-range distortion occurs because the radar is measuring the distance to features in slant-range rather than the true horizontal distance along the ground. This results in a varying image scale, moving from near to far range.

The foreshortening of the SSAR system occurs when the radar beam reaches the base of a tall feature tilted towards the radar (e.g. a mountain) before it reaches the top. Because the

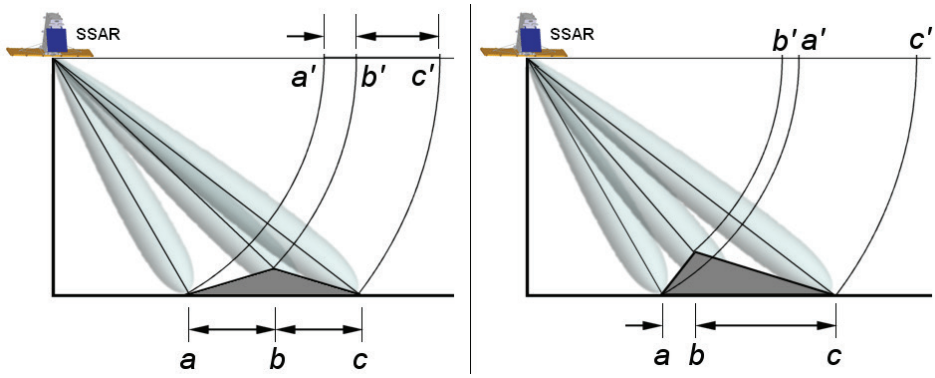


Figure 5.
SSAR Foreshortening and Layover – Source: Wolff (2015).

radar measures distance in slant-range, the slope (from point a to point (b) will appear compressed and the length of the slope will be represented incorrectly (a' to b') at the image plane, which system is shown in Figure 5 (Left).

Layover of the SSAR system occurs when the radar beam reaches the top of a tall feature (b) before it reaches the base (a). The return signal from the top of the feature will be received before the signal from the bottom. As a result, the top of the feature is displaced towards the radar from its true position on the ground, and „lays over" the base of the feature (b' to a'), shown in Figure 5 (Right) (Wolff, 2015, DLR, 2002)

3. Ships Surveillance and Detecting via SSAR TerraSAR-X Spacecraft

Ship surveillance and detecting is an important application of global Earth environment and surface monitoring for ecological, safety, and security purposes. In order to overcome the limitations by other systems, surveillance with SSAR is used because of its possibility to provide ship detecting at high resolution over wide swaths and in all weather conditions. During the last years, the demand for vessel surveillance has increased both for fisheries control and for maritime transport security and safety.

In order to overcome the limitations posed by conventional systems, surveillance with SSAR is being adopted more frequently because of its possibility to provide ship detecting over wide swaths and under many weather and environmental conditions. Up to now, different satellite sensors have been deployed for vessel surveillance, which additional availability in the future will be of great interest. Considering revisit and reliable coverage requirements of different SSAR operators, here is chosen and introduced TerraSAR-X (ScanSAR mode) onboard TerraSAR-X spacecraft, which gives a preliminary impression about its

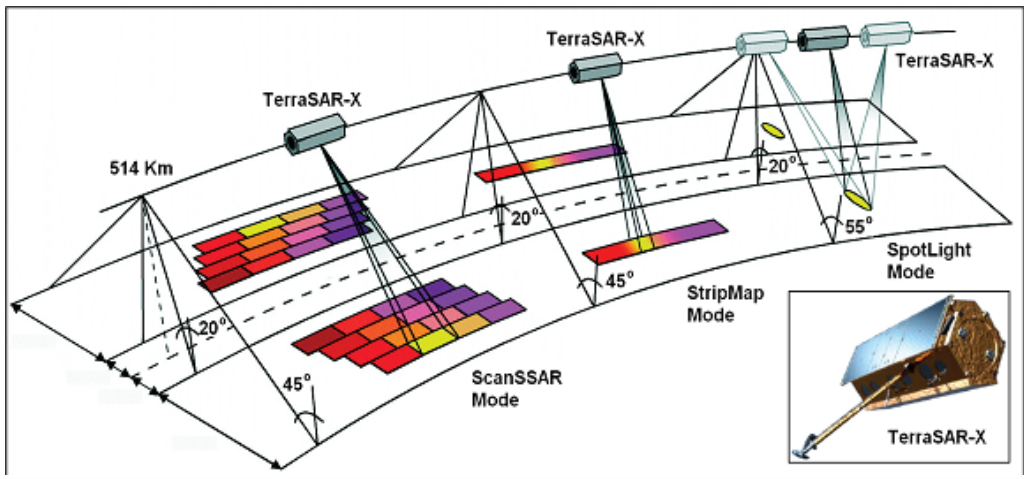


Figure 6.
TerraSAR-X Spacecraft and Operational Parameters – Source: Airbus (2020).

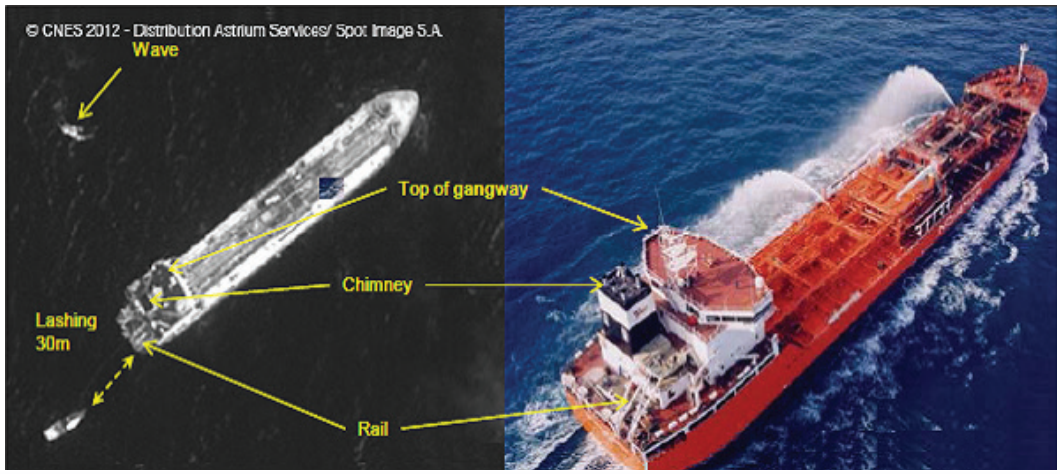


Figure 7.
Image of Captured Ship by Pirates – Source: Bosk (2014).

performance for vessel detecting and which includes the pirate boats activities and movements as well. The new X-band SSAR imager gives access to spatial resolution as fine as 1 m, which orbital parameters with three scanning modes and TerraSAR-X satellite constellations are shown in Figure 6.

TerraSAR-X as a radar SSAR Earth observation satellite is a joint venture being carried out under a public-private-partnership between the German Aerospace Center (DLR) and EADS Astrium provider. The exclusive commercial exploitation rights of TerraSAR-X are held by the geo-information service provider Astrium. TerraSAR-X was launched on 15 June 2007 and has been in operational service since January 2008. With its twin satellite TanDEM-X launched on 21 June 2010, so in such a way, TerraSAR-X (TS-X) acquires the data basis available from 2014.

The quality of TS-X images with respect to ship detecting is important together with the first assessment of its performance. Therefore, the velocity of a moving ship globally is estimated using complex TS-X data. As test cases, images were acquired over the North Sea, Baltic Sea, Atlantic Ocean, and the Pacific Ocean in Stripmap mode with a resolution of 3 m at the coverage of 30 x 100 km. With its active phased array X-band SSAR antenna (wavelength 31 mm, frequency 9.6 GHz), TerraSAR-X acquires new high-quality radar images of the entire planet whilst circling Earth in a polar orbit at 514 km altitude.

The satellite orbit is selected such that the satellite flies in a sun-synchronous dusk-dawn orbit, which means that it moves along the day-night boundary of the Earth and always presents the same face to the Sun, ensuring an optimum energy supply via the solar cells. TerraSAR-X satellite is designed to carry out its task for five years, independent of weather conditions and illumination, and reliably provides radar images with a resolution of up to 1m.

Features of the TerraSAR-X satellite are: the resolution of up to 1 m, excellent radiometric accuracy and geometric accuracy unrivaled by any other commercial spaceborne sensor, the quick site access time of 2.5 days maximum (2 days at 95% probability) to any point on Earth, unique agility (rapid switches between imaging modes and polarization). TerraSAR-X acquires radar data in the following three main imaging modes:

1. SpotLight provide up to 1 m resolution, scene size 10 km (width) x 5 km (length);
2. StripMap provides up to 3 m resolution, scene size 30 km (width) x 50 km (length); and
3. ScanSAR provides up to 18 m resolution, scene size 100 km (width) x 150 km (length).

However, StripMap and ScanSAR: acquisition length extendable to up to 1,650 km.

In addition, the unique design of the TerraSAR-X's SSAR satellite antenna allows a variety of polarimetric combinations: single or dual polarization and even full polarimetric data take, are possible. Otherwise, depending on the desired application, one of four different product types (processing levels) can be selected: Single-look Slant-range Complex (SSC); Multi-look Ground-range Detected (MGD); Geocoded Ellipsoid Corrected (GEC), and Enhanced Ellipsoid Corrected (EEC).

TerraSAR-X will exhibit some technical-industrial novelties. One of these innovations is a kind of zoom shot, with the resolution and scanning field vice versa changeable in a 1:10 relationship, either a larger area to grasp or a small area with the highest possible resolution. Furthermore, the antenna can be aligned by electronics within an angle range so that the point of view is adjustable. Earlier radar satellites could radiate the antenna only in one direction. Except for other SSAR applications,

TerraSAR-X serves for different purpose vessel tracking and detecting in normal situations and for anti-piracy activities.

Thus, identification of oil spills and leakages caused by vessels and also the characterization of typical drift behavior of icebergs in certain areas and times have a significant impact by using TerraSAR sensors and service. In Figure 7 is shown SSAR ship identification of hijacked by pirates Italian tanker m/t Enrico Iveoli with Pleiades-1A in March 2012. The TerraSAR-X sensors can be employed for the identification of starting points of ships and destinations, typical traveling routes, contraband, smuggling and pirate activities (Airbus, 2020; Bosk, 2014).

In such a way, this ship is easily detected and identified by aid of TerraSAR-X SSAR with the following size characteristics at position: Latitude = 07°13′29″N. Longitude = 049°35′11″E, Length

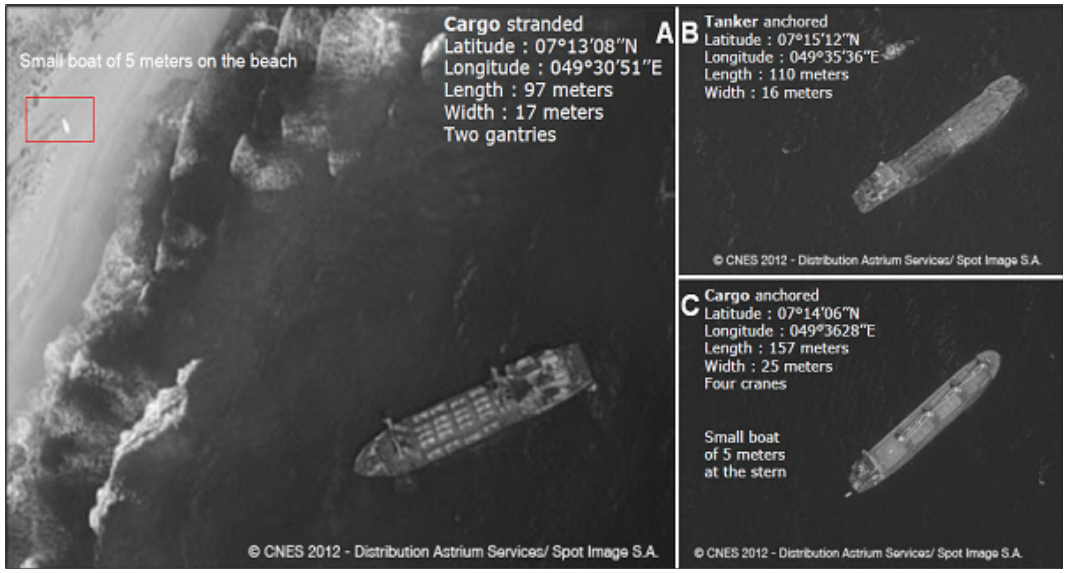


Figure 8.
Localization of other Ships in the area of m/t Enrico Iveoli – Source: Dearden (2020).

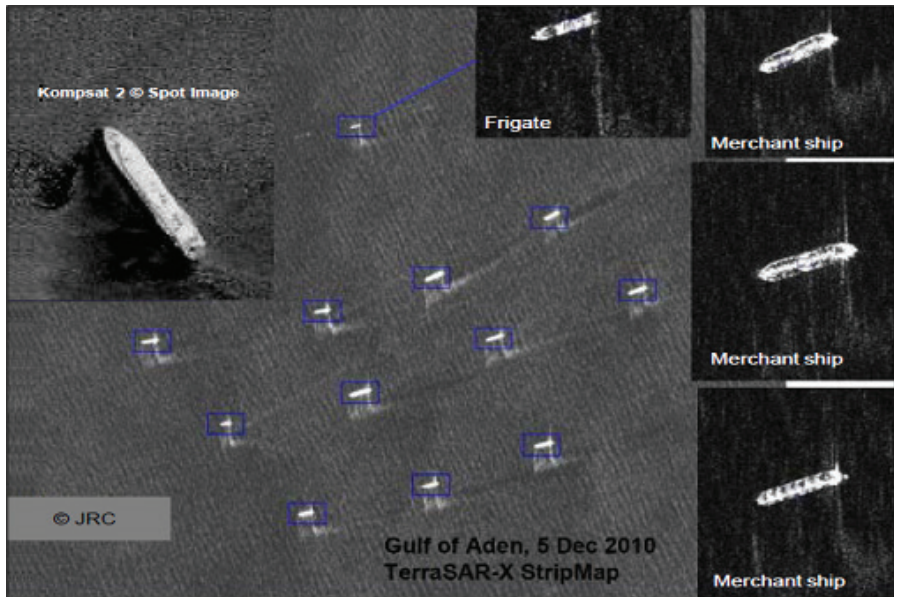


Figure 9.
Ships Tracking and Detecting Service – Source: Airbus (2020).

= 138 m, Width = 22 m, Dhow = 17 meters and Course = 053°. All these particulars are enough to find out and trace and assist the ship.

In Figure 8 is illustrated an example of localization of further vessels in the area of m/t Enrico Iveoli for possible immediate assistance in SAR and to released activities.

Integrated Maritime Security and Safety Services provide a full range of information for enhanced security, safe shipping, and sustainable resources exploitation on a modular basis, benefiting from complementary capabilities of space SSAR sensors known as: Ships Tracking and Detecting Service, Oil Spill Detecting Service, and Sea Ice Monitoring Service.

Traffic monitoring from space, day and night, from more than 500 kilometers up above are the service solutions for ships tracking and positioning, oil spill location and sea ice observation, as very important parameters for enhanced safety and security of ships. In Figure 9 is illustrated an example of ships tracking and detecting service via TerraSAR sensors in the Gulf of Aden as the hottest sea area in the world.

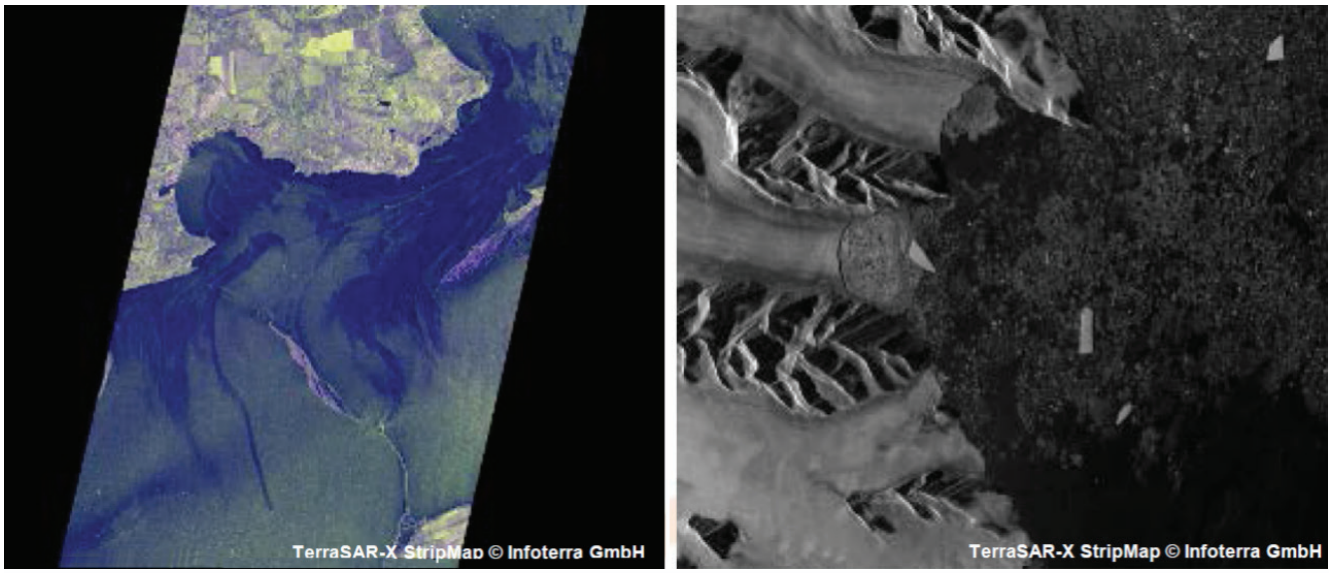


Figure 10.
Oil Spill Detecting and Sea Ice Monitoring Service – Source: Baltay (2010).

In Figure 10 (Left) is illustrated example of oil spill detecting service, and Figure 10 (Right) is illustrated example of sea ice monitoring service, both by aid of TerraSAR sensors for enhanced ecological and safety solutions at sea. The orbital parameters of TerraSAR-X spacecraft are: type of orbit circular, sun-synchronous and with orbit altitude of 514 Km, orbit period is 95 min, the inclination angle is 97.40, period repeat cycle is 11 days, imaging frequency in 95% cases – 2 days, maximum – 4 days, and lifetime is 5 years (Airbus, 2020; Bosk, 2014; Dearden, 2020).

Therefore, TerraSAR sensors can be used for detecting of all kind of ships including small and non-metal boats (what Radar cannot provide), identification and detailed information gathering on identified suspicious vessels and pirate activities, such as images with the provision of high resolution: ship position, dimension, heading and even with R-AIS cooperativeness. Then, the system is providing accurate identification of oil spills, small scaled-leakages at oil rigs, and natural oil seeps. Finally, the important impact of the TerraSAR sensors is tactical support to ships and oil rigs operating in ice waters, which delivery detailed information on ice objects and conditions, route optimization and navigation safety of ships, enhanced coordination of ice breakers (ICEMAR project), and early warning and protection of oil rigs.

The TerraSAR-X spacecraft is equipped with an active synthetic aperture radar. Active in this context means that the beam can be aligned in a slewing range of 20 to 60o. This is not done by mechanically moving the antenna or the complete satellite, but by superimposing many individual radar beams. The SSAR radar operated in the so-called X-band spectrum. The radio signals emitted in this spectrum have a frequency of 9.65 GHz, which corresponds to a wavelength of about 3 cm, thus allowing for such an extremely high image resolution.

With the adjustable angle radar sensor - along with other course refinements (precession by the Earth flattening) any place on Earth can be observed preferentially within 1–3 days. For a specific point on the equator, TerraSAR X has a revisit cycle of 11 days. The revisit time decreases towards the poles, e.g. northern Europe has a revisit time of typically 3–4 days.

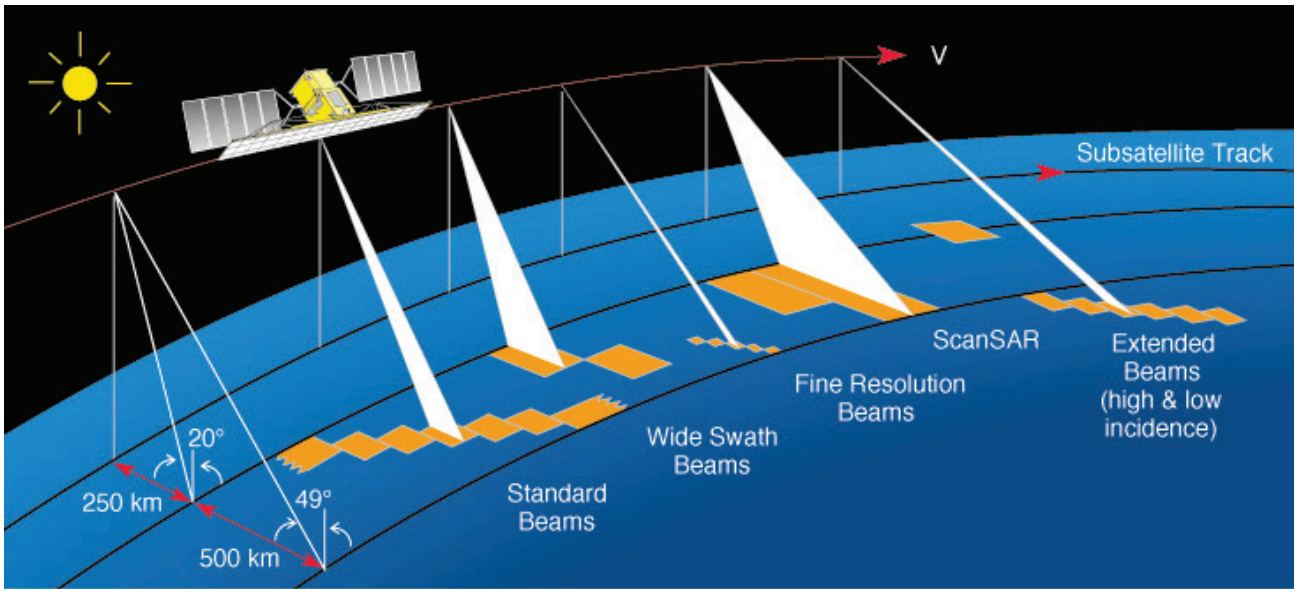


Figure 11.
Radarsat Spacecraft and Operational Parameters – Source: CSA (2020).

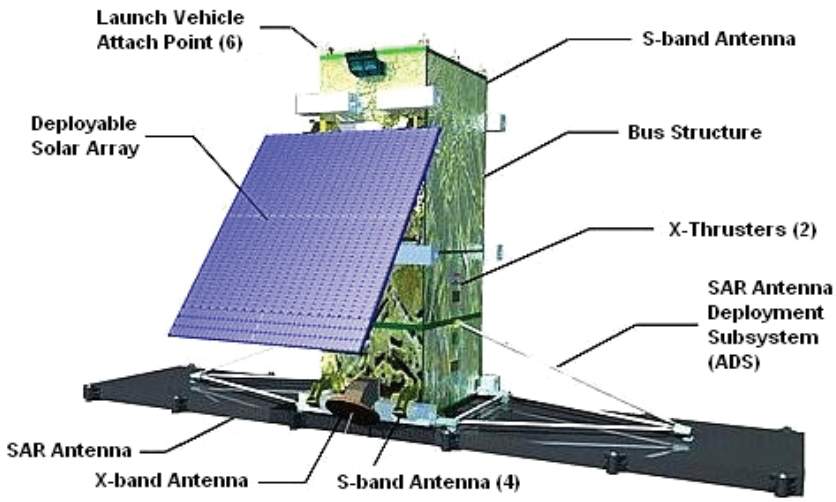


Figure 12.
Radarsat-2 Spacecraft – Source: ESA (2020).

The ground operating mechanism and controls for the TerraSAR X is developed by the DLR institute in Oberpfaffenhofen. It consists of mission operating equipment, payload ground segment with instrument operation, and calibration segment. At the base of the ground segment lies the German Space Operation Center (GSOC), the German Remote Sensing Datum Center (DFD) as well as Institutes for Methodology of Remote Sensing (MF) and the Institute for High-Frequency Engineering and Radar Systems (HR) which are all part of the DLR (Baltay, 2010; CSA, 2020; ESA, 2020).

4. SHIPS SURVEILLANCE AND DETECTING VIA SSAR RADARSAT SPACECRAFT

The satellite Radarsat SSAR system is an innovative Earth observation satellite program developed by Canada to monitor

environmental conditions and natural resources of the country's vast landmass and its territorial waters. Since its launch in November 1995, the versatile SSAR instrument aboard Radarsat-1 has also acquired, on-demand, large amounts of data in many other parts of the globe.

Moreover, the suite of high and low-resolution imaging modes and data products has become a reliable source of geospatial information, which Spacecraft and Operational Parameters with rages are shown in Figure 11. The Radarsat-2 SSAR illustrated in Figure 12 is an Earth observation satellite that was successfully launched on 14 December 2007 for the Canadian Space Agency by Starsem, using a Soyuz FG launch vehicle, from Kazakhstan's Baikonur Cosmodrome.

The Radarsat-2 spacecraft was previously assembled, integrated, and tested at the David Florida Laboratory near Ottawa, Ontario before the start of its launch campaign. The end of the spacecraft and ground segment commissioning period was declared on 27 April 2008 after which routine commercial operation started. Hence, SSAR satellite images were delivered not only to Canadian customers but also to a multitude of scientific institutions, government agencies, and commercial clients worldwide. It has proven itself infrequently cloud-covered tropical regions, in cases of environmental emergencies, ocean and ships surveillance.

This satellite has an SSAR sensors with multiple polarization modes, including a fully polarimetric mode in which different polarized data are acquired. Its highest resolution is 1 m in Spotlight mode (3 m in Ultra-Fine mode) with 100 m positional accuracy requirement. In ScanSAR Wide Beam mode the SSAR sensor has a nominal swath width of 500 Km and an imaging resolution of 100 m. Its left-looking capability allows the unique capability to image the Antarctic on a routine basis providing data in support of scientific research.

The prime contractor on the project is MacDonald Dettwiler (MDA), and other collaborating companies included EMS Technologies and Alenia. The Radarsat-2 spacecraft is owned and operated by MDA and is a follow-on to Radarsat-1. It has the same sun-synchronous at 798 Km altitude with 6 PM ascending node and 6 AM descending node. Radarsat-2 is separated by half an orbit period of ~50 min from Radarsat-1 in terms of ground or subsatellite track it would represent ~12 days ground track separation.

Some of the orbit characteristics are 24 days repeat cycle of 343 orbits, 14.29 orbits per day, each orbit being 100.75 minutes duration. It is filling a wide variety of roles, including sea ice mapping and ship routing, iceberg detecting, marine surveillance for ship and pollution detecting, terrestrial defense surveillance and target identification, geological mapping, land use mapping, agricultural crop monitoring, wetlands mapping, and topographic mapping.

As of January 2013, Radarsat-2 is entering its 5th operational service year. In such a way, the numerous enhancements have been added to the original capabilities both on the ground and space segments. The operational performance is well within the specification with an acquisition success rate above 98%. Moreover, the usage of SSAR data has been steadily growing from an average of 3.5 minutes per orbit in 2008 to an average of 9.0 minutes per orbit in 2012.

The many advances in Radarstat-2 satellite technology were developed to respond to specific requirements for radar data in hundreds of environmental monitoring applications in Canada and around the world. Through different programs, conferences, and funding opportunities, applications are being developed all the time. This is an overview of the important maritime Radarsat-2 Earth observation data applications:

1. Ice and Oil Spill Monitoring – The Radarsat program was born out the need for effective monitoring, so Canada is one of world leaders in the operational use of space radar for sea ice and oil spill monitoring. Satellites operate day and night in all weather conditions covering timely coverage of vast areas.

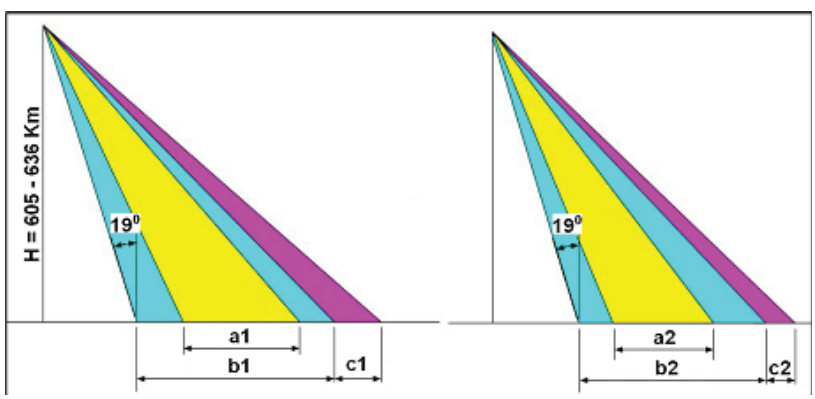


Figure 13.
ScanSAR and Stripmap Beam Modes – Source: ESA (2020).

Some Radarsat-2 capabilities that benefit sea and river-ice applications are the multi-polarization options that improve ice-edge detecting, ice-type discrimination and ice topography and structure information. Earth observation satellites have an advantage over aerial surveillance, because clouds cannot affect SSAR surveillance.

2. Marine Surveillance - Worldwide offshore resource-based operations such as fishing and oil and gas exploration and production have intensified over the past few decades. Thus, to monitor the world's oceans, Canada has provided radar data for operational applications such as ship detecting and tracking including pirate activities, oil spill monitoring at sea and wind and surface-wave field estimation. The Radarsat-2 SSAR sensors improves ship detecting and monitoring with its Ultra-Fine beam mode using three-metre resolution and offers the potential for ship classification and enhanced safety. In addition, it can provide surveillance of pirate boats and captured ships by pirates. Government and industry require powerful solutions for assessing the resources and risks associated with the ocean environment.

The Canadian Space Agency (CSA) is currently conducting a feasibility study on the development of a C-band SAR satellite constellation referred to as Radarsat Constellation Mission (RCM). The current mission concept considers a three-satellite constellation that covers Canadian territory and waters on average once daily by combining ScanSAR data with a 50 resolution, acquired from ascending and descending orbits. The low-cost SSAR concept requires that the design of the SSAR system is in terms of mass, power consumption, volume, and antenna size in compliance with the constrains imposed by using a low-cost launch vehicle and a small satellite bus. In this regard, a two-panel deployable SSAR antenna was selected with the dimensions of 1.375 m x 6.88 m. Thus, full implementation of the constellation is planned for 2014/15. The challenge for maritime surveillance is to achieve wide-area SSAR data coverage at a resolution that suitable for ship detecting. Two principal imaging modes are considered: (1) a wide-area medium-resolution ScanSAR and (2) a high-resolution Stripmap mode.

The ScanSAR mode is designed to have a swath width of 350 Km with a 500 Km accessible region, shown in Figure 13 (Left). Using 4-looks in range and one look in azimuth, this ScanSAR mode provides a medium resolution of 50 m. Thus, the trade-off is that 8 ScanSAR subbeams will be necessary to achieve the desired swath width. In this respect, however, other parameters are currently being analyzed, involving variations of the Noise Equivalent Sigma Zero (NESZ) and resolution across the swath. Regarding image quality assurance, there is a requirement on the ScanSAR beam to provide a mean NESZ of –22 dB with an acceptable radiometric variation of 0.2 dB at the beam boundaries. Additionally, no nadir returns shall be visible in the ScanSAR image. The high-resolution Stripmap, shown in Figure 13 (Right) beam modes with a spatial resolution of 5 m and a swath width of 20 km is intended for specific on-demand image acquisitions. The RCM key system parameters or Radarsat-2 are summarized in Table 1 (Kramer, 2002).

Table 1.
Key System Parameters of RCM.

Characteristics	Values
Radar Frequesncy	C-band: 5.405 GHz
Chirp Bandwidth	100 Mhz
Swath Width	20-350 km
Accessible Swath Width	500 km
Spatial Resolution (1-look)	5-50 m
Orbital Altitude	~500 km
Imaging Time	12 min per Orbit
Repeat Orbit Circle	12 Days
Polarization	HH or Dual-pol (HH-VV)

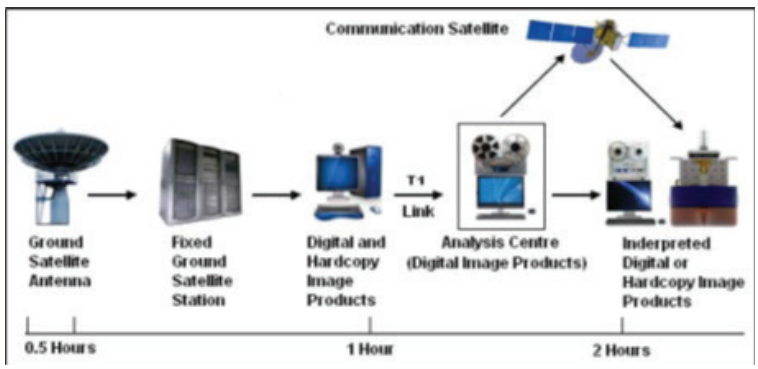


Figure 14.
Radarsat Ground Segment and Processing Facilities – Source: Ilcev (2016).

The Radarsat-2 ground segment has been designed based on the need to support the advanced capabilities of the Radarsat-2 spacecraft, the need to support a commercial mission with increased data and order volumes, and the body of experience and lessons learned from the operation of the Radarsat-1 mission, which architectural design is illustrated in Figure 14. The design of the Radarsat-2 network was produced in consultation with the key organizations and agencies that will be critical to the success of the mission. The ground segment is responsible for operating the Radarsat-2 spacecraft, accepting and implementing orders, planning and tasking for image acquisition, product processing, distribution, and image quality control. In Figure 15 is depicted the Radarsat-2 spacecraft coverage map of ground stations (Ilcev, 2016).

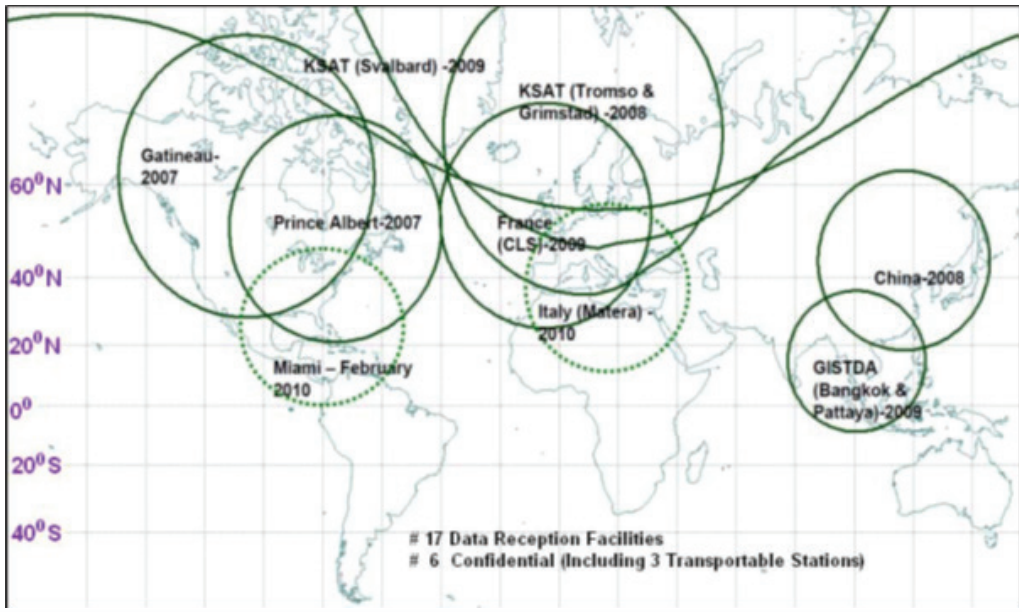


Figure 15.
Radarsat-2 Reception Coverage – Source: Ilcev (2018).

Figure 16.
Radarsat SAR Ships Monitoring and Detecting – Source: ESA (2020).

The ground support is provided for the addition of external network stations via a complete set of interfaces and the ability to reuse ground segment building block components. In Table 2 is presented comparison particulars of Radarsat-1 and Radarsat-2 Spacecraft (Ilcev, 2018; ESA, 2020; Kramer, 2002).

Table 2.
Comparison of Radarsat-1 and Radarsat-2 Spacecraft.

	RADARSAT-1	RADARSAT-2
Launch	November 1995	December 2007
Owner	Canadian Space Agency	MDA
Design life	5 years (now @ +14)	7 years
Imaging Frequency	C-Band; 5.3 GHz	C-Band; 5.405 GHz
Spatial Resolution	8 to 100 meters	1 to 100 meters
Beam Modes	7	12
Polarization Channels	HH	HH, VV, HV, VH
Look Direction	Right	Right and Left

In Figure 16 (Left) is shown detecting of ship wake and speed dome by Radarsat-1 sensors acquired on 28 February 1998 with a location in Arabian Gulf via beam in wide 2, resolution 27 m and bow wake scene size of 8.5 x 8.5 Km. In Figure 16 (Middle) is illustrated image acquired also by Radarsat-1 on 8 January 1996 in Singapore using beam fine 2 and resolutions 27 m and in Figure 16 (Right) is shown the same image in resolution of 8 m. In Figure 17 (A) is illustrated the SSAR image acquired by Radarsat-1 sensors on 20 February 1998 at 1929 UTC on C-band, HH ScanSAR wide B indicating US trawler fleet vessels (circled) anchored under very low wind conditions in Dutch Harbor, Alaska. In such a way, all vessels are easy to detect since their large backscatter makes them stand out against the calm waters of the harbor.

However, outside the protection of the harbor where the wind is much higher and therefore the ship and sea contrast is reduced on the upper part of the image. In Figure 17 (B-Left) is shown image also acquired by Radarsat-1 on 5 July 2004 at 0411 UTC on C-band HH standard mode image showing small fishing vessels with approximately 10 m in length in the Egegik Bay salmon fishery in Bristol Bay, Alaska at position 58.2N and

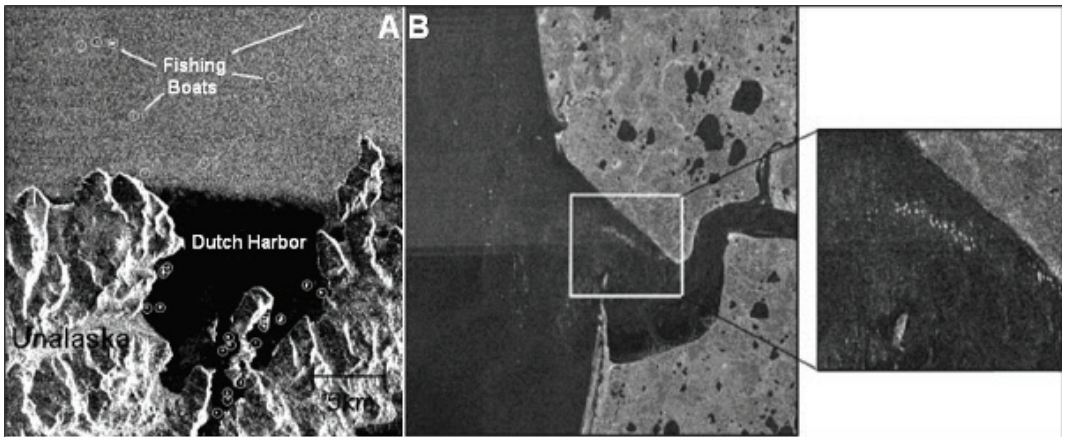


Figure 17.
Radarsat SSAR Fishing Vessels Monitoring and Detecting – Source: Pichel et al. (2005).

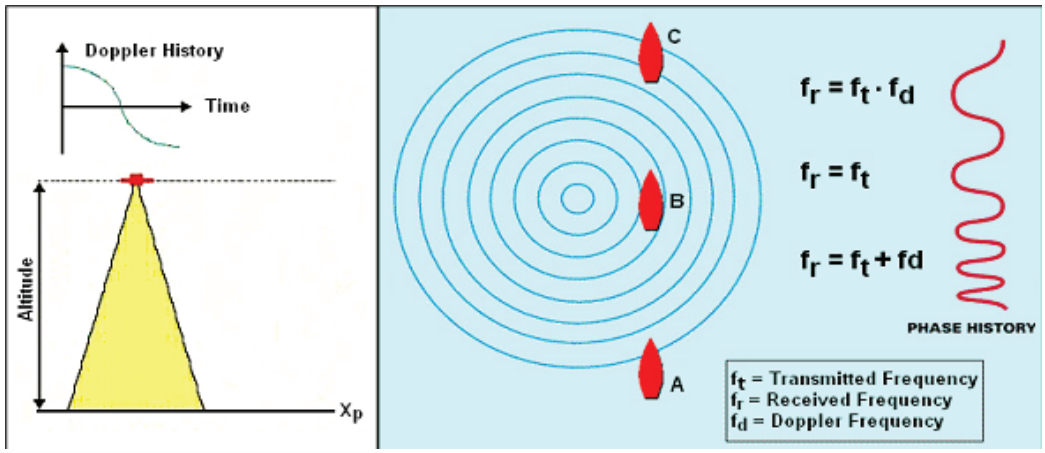


Figure 18.
SSAR Doppler and Phase History – Source: ESA (2020).

157.5W. In Figure 17 (B-Right) is illustrated the same image of a big ship and group of fishing vessels in a higher resolution of 8 m (Pichel et al., 2005; ESA, 2020).

5. VESSELS DETECTING SYSTEM (VDS) VIA SSAR IMAGERY SYSTEM

The SSAR systems were developed as a means of overcoming the limitations of real aperture radars, what is significant for VDS service. These systems achieve good azimuth resolution that is independent of the slant range to the target, yet use small antennae and relatively long wavelengths to do it. A synthetic aperture is produced by using the forward motion of the radar. As it passes a given scatterer, many pulses are reflected in sequence. By recording and then combining these individuals signals, a "synthetic aperture" is created in the computer providing a much-improved azimuth resolution. It is important to note that some details of the structure of the echoes produced by a given target change during the time the radar passes by. This change is explained also by the Doppler Effect, which among others is used to focus the signals in the azimuth processor, which can illustrate this point with an analogy.

The SSAR radar sensors are usually divided into two groups according to their modes of operation. Active sensors are those that provide their own illumination and therefore contain a transmitter and a receiver, while passive sensors are simply receivers that measure the radiation emanating from the scene under observation. To provide ships surveillance and detecting is SSAR maritime CNS specialists have to be interested in radar imaging systems.

The basic principle of the SSAR system is transmission and reception of pulses, so short (microsecond) high energy pulses are emitted and the returning echoes recorded, providing information on: Magnitude; Phase; Time interval between pulse emission and return from the object; Polarization; and Doppler frequency.

The same antenna is often used for transmission and reception of signals. This animation presents the basic elements of an imaging radar system. The two types of imaging radars most commonly used are: Satellite Real Aperture Radar (SRAR) and Satellite Synthetic Aperture Radar (SSAR). In fact, Real Aperture radars are often called SLAR (Side Looking Airborne Radar). Both Real Aperture and Synthetic Aperture Radar are side-looking systems with an illumination direction usually perpendicular to the flight line. The difference lies in the resolution of the along-track or azimuth direction. Real Aperture Radars have azimuth resolution determined by the antenna beamwidth so that it is proportional to the distance between the radar and the target (slant-range).

Thus, Synthetic Aperture Radar uses signal processing to synthesize an aperture that is hundreds of times longer than the actual antenna by operating on a sequence of signals recorded in the system memory. These systems have azimuth resolution (along-track resolution) that is independent of the distance between the antenna and the target. The nominal azimuth resolution for an SSAR is half of the real antenna size, although a larger resolution may be selected so that other aspects of image quality may be improved. Generally, depending on the processing, resolutions achieved are of the order of 1-2 meters for airborne radars and 5-50 meters for spaceborne radars. Let to consider, as in the case shown in Figure 18 (Left) is illustrating Doppler History determined in time of SSAR at certain altitudes. In Figure 18 (Right) is shown Phase History, where a plunger going up and down in the water, producing circles of radiating waves, each with a constant frequency (f) (ESA, 2020).

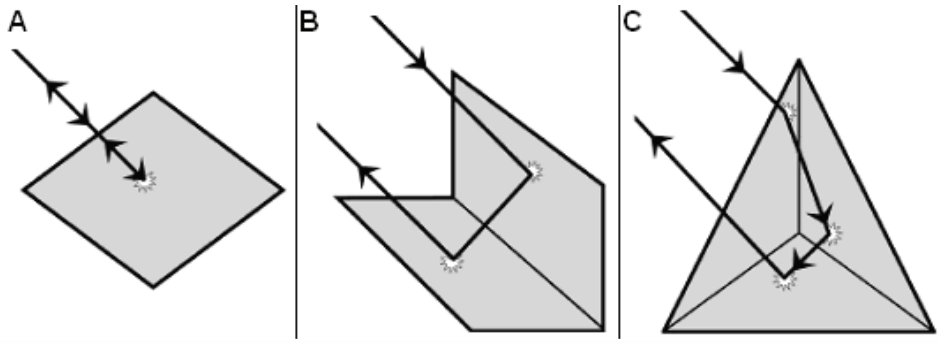


Figure 19.
SSAR Doppler and Phase History – Source: Pichel et al. (2005).

These waves travel at a known speed and the plunger is a source of waves analogous to those from radar. Observers are interested in the appearance of this wavefield at a certain distance, considering that ship is moving along the line. At position B, an operator on the ship would count the same wavenumber as emitted, since he is moving neither toward nor away from the waves (source). However, at position A, the ship is moving towards the waves and the operator will count a higher number of waves. The traveling speed of the waves is slightly increased by the speed of the ship. Thus, on the contrary, at position C, the ship is moving away from the buoy and the apparent frequency is lower, so the waves are moving in the same direction as the ship. Doppler frequency is the difference between received and emitted frequencies where the difference is caused by relative motion between the source and the observer.

Equivalently, the relative spacing between crests of the wavefield could be recorded along with the line AC, measured as if the wavefield were motionless. This leads to a phase model of the signals that is equivalent to the Doppler model. During the movement of the ship from position A to position C, the recording by the observer of the number of waves would look like the curve at the right of Figure 18. Instead of a plunger, let's now consider a spacecraft or aircraft emitting a radar signal. The ship corresponds to a target appearing to move through the antenna beam as the radar moves past. The record of the signals backscattered by the target and received would be similar to the record of the operator on the ship. Such a record is called the Doppler history (or phase history) of the returned signals. When the target is entering the beam, the Doppler shift is positive because the source to target distance is decreasing. The phase history is then stored to be used during the SSAR processing. By the time the antenna is abeam relative to the target, the received frequency is nominal, with the Doppler frequency being zero. Late it decreases as the satellite moves away and the phase history is then stored to be used during the SSAR processing.

The VDS service uses the detecting of ships from acquired SSAR imagery. The advantage of such a system is the all-weather and day or night vision capability as well as its noncooperative nature (meaning that vessels are imaged regardless of their actions). These features make VDS an ideal source of data to combine with other cooperative sources such as R-AIS, LRIT, and noncooperative VMS for its use in Maritime Surveillance and Fisheries Enforcement (ESA, 2020; Heng, 2012).

For realization of ships and wake detecting is important as follows:

1. SSAR Physical Process – Spaceborne instruments send out pulses of electromagnetic radiation and then measure the amplitude and phase of reflected radiation from the ocean, the land or man-made objects (referred to as hard targets such as ships and sea platform). Strong radar returns result from direct reflection from objects with high dielectric constant, namely conductors such as steel and even wood, oriented so that large surfaces are perpendicular to the incoming satellite radar beam or arranged in angular corner-shaped structures, namely corner reflectors. Corner reflectors have the property of returning radiation back to the source, parallel to its incoming direction. Ships constructions often contain superstructure or deck configurations that act as direct reflectors or corner reflectors. In addition, under the right orientation with respect to the satellite radar beam, the hull and ocean together can, through a double reflection, return significant energy back to the satellite SSAR antennas, which shapes are illustrated in Figure 19. Radar pulses from a satellite can be reflected back to the detector by: (A) direct reflection, e.g. from portions of the ship perpendicular to the radar beam, (B) a double bounce off a dihedral reflector, e.g. the ocean and then the ship or vice versa, or (C) a corner reflection (triple bounce) e.g. from the ship superstructure.

2. SSAR Imaging Characteristics – The direct radar return from a ship is the most common ship signature in SSAR imagery. Depending on the SSAR sensor resolution, the SSAR image

signature of a ship direct return may simply be a single pixel with significantly greater normalized radar cross-section (i.e. large backscatter and therefore brighter) than surrounding pixels or, at a higher resolution (e.g. 30 m or better), an elongated series of brighter pixels. Thus, at the highest resolutions (10 m, 8 m or less), details of the ship superstructure may become distinguishable. As long as the ship has good radar backscatter characteristics, even ships smaller than the SSAR pixel resolution can be easily detected under a fairly wide range of wind and wave conditions (Pichel et al., 2005).

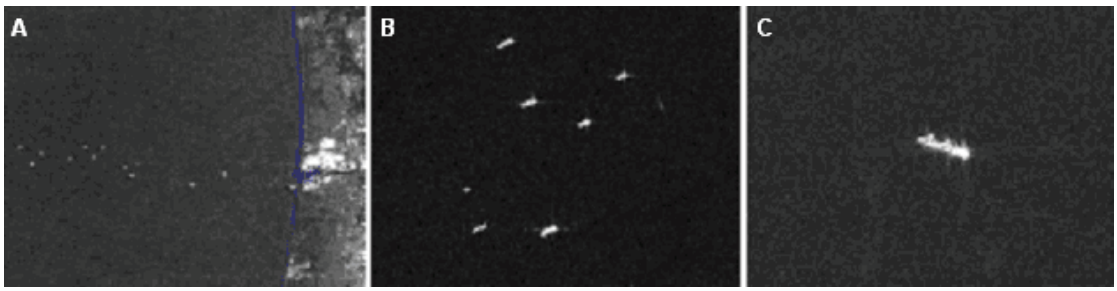


Figure 20.
SSAR 50, 25 and 8 m Resolutions of Ships Images – Source: Ilcev (2016).

The direct return from the ship is often the only ship signature, particularly (1) when the ship is not underway, (2) when higher winds or waves quickly destroy wake and slick signatures, or (3) when lower resolution modes, such as ScanSAR, are employed.

In Figure 20 are illustrated collections of ship direct return signatures. Automated ship detecting algorithms generally look for a statistically significant contrast between the ship and the local ocean background. However, a single detecting threshold cannot be used for the whole image since the background backscatter changes substantially with the SSAR angle of incidence, wind speed, and sea state. At this point, various algorithm approaches have been developed which automatically adapt to changing background backscatter during the search for targets.

Limitations to the success of direct detecting of ships and wakes with SSAR sensor systems can be grouped into the following five categories: (1) ship characteristics, (2) environmental conditions, (3) radar characteristics, (4) image quality, (5) image resolution and (6) wakes (Ilcev, 2016; Schott, 1997)

1. Ship Characteristics – Structural ship configuration with respect to the radar reflection, ship size, and structural material have a highly significant effect on the ability of SSAR systems to detect a particular vessel. In fact, a ship made from materials with high dielectric constant such as steel is a better radar reflector than a vessel made of non-conducting materials such as fiberglass or wood. A vessel with a substantial superstructure consisting of natural corner reflectors is a particularly good target. Also, a ship traveling perpendicular to the radar beam, in the same direction as the satellite is flying, generally, North or South presents as a larger target and has the possibility of a greater double reflection return.

2. Environmental Conditions – Environmental characteristics such as sea state, wind speed, proximity to land, and presence of ice affect the ability to distinguish SSAR ship signatures from the ocean background return. Thus, the greater the wind speed or the higher the waves, the greater the environmental contribution to the radar return signal, and thus the weaker the contrast between the vessel and the ocean background.

3. Radar Characteristics – Characteristics of the radar instrument (sensors) such as the angle of incidence (i.e. the angle between lines connecting the radar with the reflecting surface being viewed and the local normal to the surface), polarization, resolution, and sensitivity affect the ability to detect vessels with an SSAR system. The signal return from the ocean's surface is a function of angle of incidence with the return falling off as the angle of incidence increases. A ship return does not change as dramatically with the angle of incidence, but at higher angles of incidence, there is improved contrast between the ship and the ocean background.

4. Image Quality – The SSAR image processing errors and the inherent speckle noise in SSAR imagery can interfere with vessel detecting algorithms. The effect of speckle is noise in the image manifesting as random pixels that are much brighter or darker than the average of surrounding pixels. The speckle noise is a result of constructive or destructive interference during the coherent addition of backscatter from many different scatterers within a resolution cell of the SSAR image during the image integration time. Speckle noise in low-backscatter regions of an image where the surface return is below the noise floor of the SSAR instrument can appear as small vessels to a ship-detecting algorithm. The speckle noise of an SSAR image will also ultimately limit the minimum vessel size that can be detected since smaller vessels will become indistinguishable from speckle. Processing

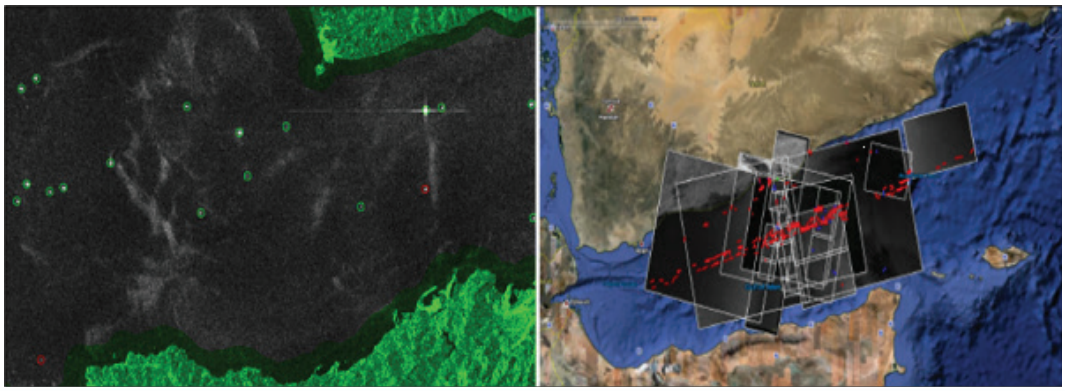


Figure 21.
SSAR Identification of Suspicious and Pirated Vessels – Source: Ilcev (2016).

problems such as obvious seam boundaries between beams in ScanSAR imagery, nadir ambiguities (an along-track bright-line resulting from the timing of the direct return from the Earth surface immediately below the satellite), scalloping in ScanSAR imagery (a cyclic banding pattern caused by errors in Doppler processing) and cross-track noise lines caused by processing errors can all be problematic, mainly by masking hardship targets within erroneous high backscatter anomalies. It should be noted that these processing problems are processor dependent on different SSAR processors will produce slightly different SSAR images when attempting to handle difficulties encountered during processing. Finally, image Earth location errors can interfere with the correct discrimination between small coastal islands and coastal vessels.

5. Image Resolution – Although all the different modes (specific resolution and swath width characteristics) of available satellite SSAR imagery are useful for detecting of ships, particularly larger ships, some modes are better than others. The highest resolution of radar images is 1m and going up to weakest one as 10 m (Ulaby et al., 2014; Chuvieco and Huete, 2009).

6. Wakes – The track left in the water by a moving vessel, the wake, is an important clue in the detecting of ships. Wake structures fall into four categories: (1) turbulent wakes stretched out directly behind the vessel, (2) Kelvin wake formed by decameter-scale surface gravity waves generated by the passage of the vessel and propagating outward from the vessel track, (3) narrow-V wakes visible through Bragg scattering from short centimeter-scale waves generated by hydrodynamic processes along the ship's hull, and (4) internal wave wakes generated under conditions of shallow stratification.

As new SSAR satellites are becoming available, the VDS solutions should evolve in order to cope with the enhanced capabilities of the sensors, especially higher resolution. Namely, the intention of VDS developments and improvements is VDS evolution in higher resolution of images, which will be used for enhanced tracking and detecting of vessels. In Figure 20 is shown that three SSAR images with a resolution of 50 m (A), 25 m (B), and 8 m (C). Namely, as resolution increases new details from the vessels are revealed.

The significant tracking and detecting at sea is identification and flagging of Suspicious Vessels from SSAR imagery in integration and correlation with other similar systems such as R-AIS/Satellite and AIS/LRIT/VMS data. This tracking and detecting integration is shown in Figure 21 (Left), which illustrate the image of all ships passing in the area of Gibraltar.

Satellite acquired SSAR vessel detecting (VDS) provides the position of vessel targets during the image acquisition time. In such a way, these vessels position can be confirmed by other systems, so if some image of the ship is not matching with shore data means that is suspicious. In most cases, it is impossible to identify the vessel from its SSAR signature therefore fusion with other positional data (namely R-AIS, LRIT, VMS tracks) is essential, which integration system for anti-pirate actions is shown in Figure 21 (Right).

Therefore, correlation methodologies use the prediction of the position at the time of the image together with the size information (obtained from both registry and radar signature) to find the best match and make possible the identification of the vessels on the image and flagging of suspicious vessels (Ilcev, 2016; Baltay, 2010).

6. CONCLUSION

In this paper is proposed the space remote sensing and detecting systems of the oceangoing ships as an alternative to current applications used in the maritime transportation industry. Thus, ships detection from space SSAR imagery system is an operational application that can be performed in near-real space and time, with detection real and false alarm rates that are sufficient for some users and scenarios that need to be improved

for shipping service. The values of the SSAR system for vessel tracking can be only reached when their detection data, as an alternative, is integrated with the current vessel data tracking from other sources, and especially for detecting ships in a distress situations. Although the SSAR data imaginary system for maritime applications is increasingly being done, classification of the vessel from SSAR data is still difficult and automatic algorithms do not yet always provide a reliable size of estimates.

Accordingly, researchers and developers of the SSAR tracking data system have to enhance integration parts of space and ground segments as new shipborne project and to improve their subsystems and products. Although detection of oceangoing ships from SSAR images can be hindered by clouds or poor illuminations, using accurate sensing techniques during favorable observation conditions gives very good and valuable results. Therefore, to obtain optimal or even desirable space remote surveillance and observational results an automatic shipping surveillance system should combine data from a number of different sensors. In fact, the SSAR space imagery, which is unaffected by cloud cover or illumination, would be used as complementary solutions. Demanding applications will enable it to be combined with the increased availability of space systems under operationally and commercially attractive conditions.

REFERENCES

Airbus, 2020. TerraSAR-X Image Product Guide, Airbus Defence and Space.

Baltay S., 2010. Astrium Services Solutions for Risks and Crises Management, Infoterra, Farnborough, UK.

Baltay, S., 2010. Astrium Services Solutions for Risks and Crises Management, Infoterra, Farnborough, UK.

Bosc, P.-A., 2014. Earth Observation for Security and Dual Use. Handbook of Space Security, pp.555–579. Available at: http://dx.doi.org/10.1007/978-1-4614-2029-3_7.

Chen, H.S., 2014. Space Remote Sensing Systems, Academic Press, Washington DC.

Chuvieco, E., 2009. Fundamentals of Satellite Remote Sensing. Available at: http://dx.doi.org/10.1201/b18954.

CSA, 2020. Components and Specifications, Canadian Space Agency, Quebec, Canada.

Dearden, L., 2020. Daily Press and Media Panorama with Maritime Thematic, GeoGarage Blog.

DLR, 2002. TerraSAR-X (TSX) Mission, German Aerospace Centre, Cologne, Germany

ESA, 2020. RADARSAT Constellation Mission (RCM), Paris, France.

ESA, 2020. Synthetic Aperture Radar (SAR), Earth Online, European Space Agency, Paris, France.

Heng, O., 2012. An Introduction to Contemporary Remote Sensing, McGraw-Hill, New York.

Ilcev, D.S., 2016. Global Satellite Ship Tracking and Surveillance Systems, DUT, Durban, South Africa.

Ilčev, D.S., 2018. Global Satellite Meteorological Observation (GSMO) Theory. Available at: http://dx.doi.org/10.1007/978-3-319-67119-2.

Kramer, H.J., 2002. Earth Observation/Monitoring Missions. Observation of the Earth and Its Environment, pp.329–553. Available at: http://dx.doi.org/10.1007/978-3-642-56294-5_5.

Pichel, W.G. et al., 2005. Ship and Wake Detection, Chapter 12, Office of Research and Applications, NOAA/NESDIS, Camp Springs, USA.

Richards, J.A., 2009. Remote Sensing with Imaging Radar, Springer, Boston.

Schott, J.R., 1997. Remote Sensing, Oxford University Press, Oxford.

Ulaby, F. & Long, D., 2014. Microwave Radar and Radiometric Remote Sensing. Available at: http://dx.doi.org/10.3998/0472119356.

Wolff, C., 2015. Synthetic Aperture Radar - Radartutorial, Cologne, Germany.

Evaluation of Montenegrin Seafarers' Awareness of Cyber Security

Ivan Mraković, Ranko Vojinović

Topics on maritime cyber security have undoubtedly been attracting great public attention in recent days. The reasons are rapidly evolving computing technologies and digitalization in maritime sector. A successful cyber-attack may have catastrophic consequences and a harmful impact on people, properties or marine environment. In addition to numerous factors that pave the way for a successful cyber-attack on ships, human errors are also in the limelight as they are notorious sources of cyber-attacks today. In this research paper, the authors examine Montenegrin seafarers' level of familiarisation with current cyber-security risks by conducting a structured survey questionnaire. After thoroughly analysing the collected answers, the authors realise that the respondents have an insufficient level of cyber-security knowledge and awareness. Lastly, using the quantitative risk assessment method, the authors propose the best practices for maritime cyber security in the form of implementation of mandatory training course.

KEY WORDS
~ Cyber security
~ Maritime
~ Risk assessment
~ Seafarer
~ Education
~ Cyber-security awareness

Mediterranean University, Faculty of Information Technologies, Podgorica, Montenegro
e-mail: iwanmrak@gmail.com

doi: 10.7225/toms.v09n02.005

1. INTRODUCTION

A successful cyber-attack may be an important issue from the safety, environmental, and commercial standpoints. Cyber security at sea is largely related to critical infrastructures and, therefore, there is an urgent need to do the revaluation of the current awareness and preparedness of crews to adequately respond to maritime cyber risks.

"Maritime cyber risk refers to a measure of the extent to which a technology asset is threatened by a potential circumstance or event, which may result in shipping-related operational, safety, or security failures as a consequence of information or systems being corrupted, lost or compromised" (International Maritime Organization, 2017a). As a matter of fact, modern vessels rely heavily on remote monitoring and automation that can provide porous holes to hackers and cybercriminals, resulting in a compromise of vessel's key components such as ECDIS, VDR, RADAR/ARPA, GNSS, ballast/cargo/engine control systems, which are operated and controlled by the crew. Skills of a crew define how efficiently the systems will work (Yousefi and Seyedjavadin, 2012).

In order to mitigate cyber-security risks and reduce the level of their human dependency, several leading maritime organizations such as e.g. IMO, BIMCO, International Chamber of Shipping developed a set of guidelines. Their purpose is to assist shipowners and vessel operators in reducing the chance of a successful cyber incident, and to recover from it.

BIMCO Guidelines on Cyber Security On board Ships (BIMCO, 2017), EU Regulation 2016/679 (The European parliament and the Council of the European Union, 2016), IMO MSC-FAL.1/Circ.3 (International Maritime Organization, 2017a), ISO 27032:2012, which will be soon replaced by ISO/IEC WD 27032 (ISO, no date),

USCG Policy Letter No. 08-16 (USCG, 2016), TMSA Cyber security guidelines for vessels (TMSA, 2019), UK Department of Transport Code of Practice Cyber Security for Ships (Boyes and Isbell, 2017), USCG Cyber Security Strategy (USCG, 2015) are the most important sources for raising cybersecurity awareness at sea.

Various internationally required training courses, such as Security Awareness Training for all Seafarers or the Marine Environmental Awareness, have already been established. IMO "encourages Administrations to ensure that cyber risks are appropriately addressed in safety management systems no later than the first annual verification of the company's Document of Compliance after 1 January 2021" (International Maritime Organization, 2017b: 1) which is a great step forward towards achieving global shipping goals.

This research paper sheds a light on why the cyber risks at sea are still not adequately treated from the seafarer-education point of view, even after some very significant events such as hacking of Maersk's assets.

In fact, the hacking of Maersk occurred back in June 2017. At that time, due to successful NotPetya malware attack, the giant company lost between USD 250-300 million, and was forced to reinstall more than 4,000 servers and 45,000 PCs (A.P. Moller - Maersk, 2017; Cimpanu, 2018). Up to date, this has been the most serious attack of its kind, once again confirming that shipping companies are not prepared to respond to cyber risks adequately.

The largest number of safety incidents at sea occur due to human error (Yousefi and Seyedjavadin, 2012). It is no different in cyber security either. Overall situational awareness of the navigator while performing his duties on the navigation bridge consists of spatial, task, and system awareness, including cyber security awareness as well (Hareide et al., 2018). Research (Svilicic, Rudan, et al., 2019) explores cyber-security threatening Integrated Navigational System, stating that cyber-security awareness of crew is satisfying. However, another study (Svilicic, Kamahara, et al., 2019: 10) states that "crew is not familiar with cybersecurity policies, procedures and agreements, and practice insufficient cyber hygiene". More articles assess the IT infrastructure and on-board policies related to cyber-security protection, but only few of them are aimed at defining seafarers' level of awareness and knowledge of cyber threats (Bolat, Yüksel and Yüksel, 2016).

Is the awareness of Montenegrin seafarers of cyber-security high enough to make them a reliable part of the defensive shield to prevent malicious attacks on board vessel? To that end, this research paper carries out the analysis of seafarers' awareness and their knowledge of basic cyber-security aspects, and further weights the findings on a risk scale.

This paper is organised as follows: Section 2 provides an overview of common cyber-security threats at sea and users' best practices. Section 3 deals with current education process of seafarers in Montenegro. Section 4 explains the method of obtaining survey responses, which are assessed in Section 5. Section 6 elaborates the problem solutions. The findings are discussed in Section 7.

2. COMMON CYBER-SECURITY THREATS TO SHIPS AND USER BEST PRACTICES

There is a difference between general maritime security and maritime cyber security. While the topic of the former has been widely explored since the implementation of ISPS Code in 2003, the latter requires further attention.

Various studies have been done to clarify and explore cyber-security risks and threats on vessels. The most important ones are: Witherby Publishing Group, BIMCO, and the International Chamber of Shipping (ICS), 2019.

a. Malware – a malicious piece of code that is utilised by cyber pests to carry out a cyber-attack. The example of malware incorporates viruses, worms, Trojan horses, ransomware, spyware, bots, etc. The malware can steal, delete, encrypt or damage sensitive data without knowledge of the victim. "Malware often infects ship's computers through the crew's use of memory sticks". (Riviera, 2020);

b. Social engineering - technique that manipulates human psychology to get sensitive data. The victim makes mistakes that lead to data breaches. According to the Korean Register of Shipping, "social engineering means to secure access rights to systems, data, and buildings by exploiting human psychology instead of a technical hacking technique to steal into the system". There are different types of social engineering such as:

   a. *Phishing* - combines social engineering and technical methods to trick victims into divulging sensitive information such as identity and financial-related data or anything else that attackers perceive to have value (Furnell, Millet and Papadaki, 2019). Successful phishing attack can create extreme harm, e.g. in case of steeling sensitive information about the ship or itinerary details;

   b. *Spear phishing* - yet another form of phishing. Clicking on the link may cause installation of malicious software, trackers, loss of credentials, personal data or valuable shipping details. Spear phishing is sophisticated and difficult to detect;

   c. The so-called *e-mail spoofing*, still a surprisingly easy technique used for distribution of forged electronic documents that attempt to mislead the recipient about the origin of the message (Hu, Peng and Wang, 2018). Following of e-mail instructions or requests may lead to the loss of sensitive information, e.g. ship's schedule, data on nationality of the crew, etc.;

c. *Distributed denial of service* (DDoS) attack is a kind of cooperative attack model where attackers use many machines to simultaneously launch DoS attacks causing the target's resources

or network band-width to become exhausted or to collapse (Li et al., 2018). On board ship, it can lead to failure of navigational, engineering, and other system.

By conducting a literature research, two main types of best practices for reducing cyber-threat at sea are identified. The first is related to the network arrangement and implementation of various software and hardware solutions, while the second is focused on asset management and user best practices. For the purpose of this research, the authors have identified widely accepted cyber-security best practices whose level of success depends on user behaviour:

a. Use a strong password - Using a strong password can create the main barrier against cybercriminals. A weak password can be guessed within hours. Hackers compromise seafarers' passwords using various techniques such as a Brute-force attack, dictionary attack, and phishing attack. This type of attack can have devastating consequences;

b. Stay vigilant against phishing emails – The seafarer should avoid clicking on any attachment or link from suspicious emails, especially when working on a ship's system or a network;

c. Avoid using removable media - Removable media such as flash drive or smartphone memory card are vulnerable devices and can pose a serious challenge to ship's systems or/and network. Therefore, a seafarer must avoid using flash drives. They should save essential ship-related documents into the cloud drive or a soft copy into a secure personal computer or a laptop;

d. Stay vigilant against SMS attacks - Seafarers often prefer using SIM cards that offer cheap rates and data plans. Today's hackers better understand human psychology and know how to manipulate it. To this end, they send a phishing SMS with a link that involves the cheapest offers on calling and data plans. As soon as the seafarer opens the link, malware is installed on his/her phone. To avoid this nightmare, the seafarer must disregard such SMS or avoid opening unknown links inside it;

e. Avoid using free Wi-Fi - Free offers and gifts often grab everyone's attention, but they can prove detrimental to Seafarer's digital property. Threat actors often cleverly provide free Wi-Fi at ports or its suburbs. The seafarer must not access a free public Wi-Fi hotspot and must avoid putting sensitive credentials;

f. Patching - All the ship's systems should be regularly patched and updated. A patch can fix a security vulnerability and bugs in the software application as well as improve its performance. For example, if an ECDIS is not stable upon installation of new charts, a new patch can resolve the issue.

3. CURRENT EDUCATION PROCESS RELATED TO CYBER SECURITY AT SEA

How does the current educational process in Montenegro look like and is it good enough to suit the needs of today's market?

The education of seafarers in Montenegro is organised in two levels. The first is secondary education, which lasts for 4 years. Upon completion of Maritime High School, a person can choose between two paths - joining a vessel and starting a professional career or enrolling one of the accredited Maritime Faculties in order to get a higher education degree. Enrolment to a university study programme is allowed to anyone who has completed secondary education, even if it is not through Maritime High School. Upon completion of 3-year studies, students get the Bachelor's degree and are allowed to start their seafarer career.

In 2010, Maritime High School in Kotor started carrying out re-qualification courses for all those who had previously obtained a non-maritime high school diploma. Their purpose is to offer an alternative to people who are not interested in higher education and at the same time have no will to study the complete maritime-high-school programme for another 4 years. The re-qualification course plan has been done in accordance

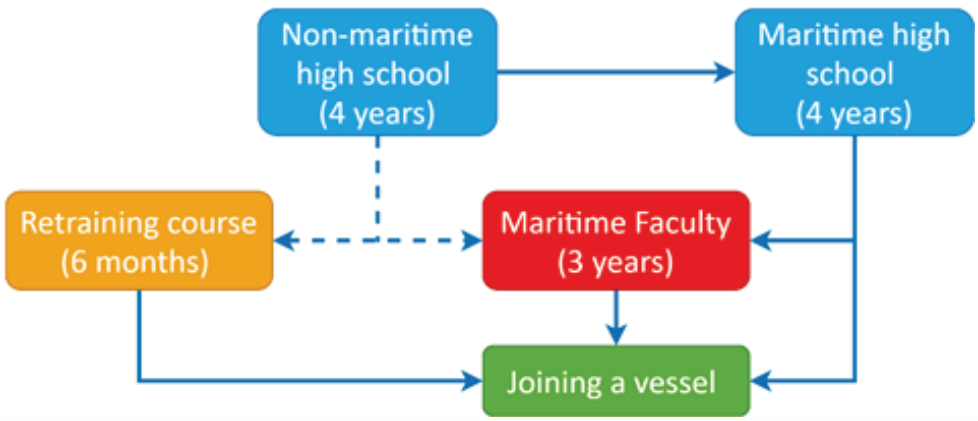


Figure 1.
Education road-map for becoming a seafarer in Montenegro.

with IMO model courses 7.03 - Officer in Charge of Navigational Watch and 7.04 - Officer in Charge of Engineering Watch, and are popular among elder population.

To better demonstrate the official educational path of seafarers in Montenegro, the following scheme has been created (Figure 1). Of course, seafarer education process does not end on finishing Maritime Faculty studies, Maritime High School or a re-qualification course, or on joining a vessel for the first time.

"The Standards of Training, Certification and Watch keeping (STCW) regulations developed by the International Maritime Organization (IMO) lists down the competencies and skills the seafarer should possess"(Sharma et al., 2019: 4). According to legislation in the Republic of Montenegro (The government of Montenegro, 2013, 2017; Ministry of Transport and Maritime Affairs, 2015, 2018), anyone who wants to be a seafarer is required to continue the education process by attending and completing various courses and passing related examinations in front of the Harbour Master's Commission. That is the case in all other countries that ratified the STCW convention.

Besides the previously mentioned IMO model courses 7.03 and 7.04, education plans and programmes of Maritime Faculties are also in line with the IMO model courses 7.01 - Master and Chief Mate and 7.02 - Chief Engineer Officer and Second Engineer Officer. On analysing these model courses, it is clear that the IMO does not require a seafarer to have any knowledge either about IT/OT topics or about cyber security. However, the world leading classification societies DNVGL and Lloyd's Register organise the *E-learning Maritime Cyber Security Course* (DNV GL, no date) and *Cyber and Data Protection Awareness Training* (Lloyd's Register, no date) respectively.

Exploring the current curricula of the above-mentioned educational institutions in Montenegro, one finds that each of them is exploring specific IT fields, most notably the application of software programmes from MS Office – Word and Excel. The use of the Internet and modern maritime technologies such as Radio Frequency Identification (RFID) is addressed to a lesser extent. The Faculty of Maritime Studies of Kotor goes a step further by providing students with an education in the basics of computer networks and network protocols. A deeper study of computer networks as well as their protection has not been addressed so far.

The following sections present a survey done among active seafarers in order to scale their level of awareness of cyber security.

4. SURVEY METHOD

Taking into consideration common cyber threats and best practices presented in Section 2 of this paper, the authors created a structured survey questionnaire. Its purpose is to find out the level of Montenegrin seafarers' awareness and their potential ability to adequately respond to cyber threats.

The total number of active seafarers licensed in Montenegro is 3,000 (official data not published). The research population consists of 429 participants sailing in the rank of deck/engine officer or Master on ocean-going vessels operated by various worldwide reputable companies, including Mediterranean Shipping Company – MSC, Mitsui Ocean Line – MOL, Eastern Mediterranean Maritime, Dabinović, Reederei Nord, Crnogorska Plovidba, Bernhard Schulte Ship Management, CMA CGM, Subsea 7, and others. Even though all the previously mentioned companies employ multinational crews, the conducted survey was limited to seafarers of Montenegrin nationality whose names are undisclosed due to privacy.

The survey questionnaire consists of a total of 18 questions which are presented in Table 3. They are structured in a comprehensive way to enable quantitative research as plausible and affordable method for gathering information from seafarers. The respondents were asked to choose only one answer for each question.

5. RISK ASSESSMENT AND SURVEY RESULTS

To carry out risk assessment, it is necessary to define the key terms at the very beginning: risk, hazard, harm (impact), likelihood, severity, and risk assessment.

There are several definitions of risk. A commonly-used glossary (Committee on Foundations of Risk Analysis, 2015) offers 7 definitions of risk while ISO (ISO, 2009) shortly defines it as the "effect of uncertainty on objectives". "Information security risk comprises the impacts on an organization and its stakeholders that could occur due to the threats and vulnerabilities associated with the operation and use of information systems and the environments in which those systems operate" (Gantz and Philpott, 2013).

"A hazard is a source of potential injury, harm or damage. It may come from many sources, e.g. situations, the environment or a human element."(Maritime and Coastguard Agency, 2019, p. 37)

Harm or impact can be defined as the degree of damage or harm caused to the organisation or an asset.

The likelihood of occurrence is the probability that a cybercriminal will initiate a threat or the probability that a threat could successfully exploit the given vulnerability (ISO, 2009).

Both likelihood and impact can be viewed in either objective or subjective terms. In an objective expression, likelihood and impact could be expressed in terms of numerical values. On the other hand, subjectively, both elements are termed qualitatively or utilizing a range of descriptions on a scale.

Severity is the amount of damage that a hazard could create. For example, the severity of harm can be slight, moderate or extreme.

Risk assessment is a systematic process of determining the number of hazards or threats that could occur in a given amount of time to your computer systems and networks (Prowse, 2017). "The purpose of risk assessment is primarily to support decision-making, including decisions on risk-reducing measures in the context of a structured, systematic and documented process" (Vinnem and Røed, 2020, p. 78). There are two types of risk assessment – i.e. "Quantitative Risk Assessment" and "Qualitative Risk Assessment."

Quantitative risk assessment is a systematic risk-analysis technique used to quantify the risks associated with the IT infrastructure of an organization. It helps in understanding the exposure to risk of the IT environment, employees (or seafarers), corporate assets and its reputation. As said before, this technique involves numerical values. Though Quantitative Risk Assessment is easier, cheaper, and quicker, it cannot give a total asset value for a potential monetary loss. For instance, using this approach we can assign the ranges from 1 to 50 or 1 to 100. If the number is high, the likelihood of occurrence is high. For example, the computer having no firewall or antivirus programme has a high probability of risk.

"Risk analysis methods that use intensive quantitative measures are not suitable for today's information security risk analysis" (Karabacak and Sogukpinar, 2005, p. 148). However, to measure cyber security awareness of Montenegrin seafarers, the authors implemented ISRAM (Karabacak and Sogukpinar, 2005) quantitative risk assessment method as the second most useful in comparison with *SANS, OA, Mehari*, *COBRA* and *FAIR* (Svensson, 2017).

The risk model of *ISRAM* is based on the following formula:

$$Risk = \left(\frac{\Sigma_m[T_1(\Sigma_i w_i p_i)]}{m}\right) x \left(\frac{\Sigma_m[T_2(\Sigma_j w_j p_j)]}{n}\right) \quad (1)$$

where:

i: the number of questions for the survey of probability of occurrence;

j: the number of questions for the survey of consequences of occurrence;

m: the number of participants who participated in the survey of probability of occurrence;

n: the number of participants who participated in the survey of consequences of occurrence;

w_i ; w_j: weight of the question i ; j;

p_i ; p_j: numerical value of the selected answer choice for question i / j;

T_1: the risk table for the survey of probability of occurrence;

T_2: the risk table for the survey of consequences of occurrence;

Risk: a single numeric value for representing the risk.

Note: All the survey participants answered all the questions from the questionnaire. Therefore, *m* is equal to *n*.

On completion of the questionnaire, but before conducting the survey, the authors "weighted" each question to scale their importance in assessing final risk. In other words, not all questions contribute equally to the conclusion of this research. Weight scale is shown in Table 1 for both probability and consequence of cyber-attack.

Table 1.
Weight (importance) of each question for final risk assessment,

Weight value	Probability of occurrence	Seriousness of consequence
3		Severe
2		Normal
1		Low

After designation of answer choices, they are converted into numerical values as shown in Table 2 in order to scale probability and/or consequence of potential cyber accident.

Table 2.
Numerical values of answer choices.

Weight value	Probability of occurrence	Seriousness of consequence
0	Answer has no effect on probability and/or consequence of cyber accident.	
1	Answer is slightly effective to probability and/or consequence of cyber accident.	
2	Answer is considerably effective to probability and/or consequence of cyber accident.	
3	Answer is highly effective to probability and/or consequence of cyber accident.	
4	Answer is extremely effective to probability and/or consequence of cyber accident.	

Further in-depth scaling of questionnaire with probability and consequence weights included is shown in Table 3.

Table 3.
Questions valued for probability and/or consequence, with their respective answer choice.

	Question Weight value of Probability (P); Consequence (C)	Answer choice / Numerical value of answer choice
Q1	Have you ever shared your personal passwords with a colleague? P=3 ; C=3	Yes / 4 No / 0
Q2	Did you know that emails containing attachments are the most common way of cyber-attack? P=3 ; C=3	Yes / 0 No / 4
Q3	Did you know that a displayed web address in an email could be different from the underlying link that it will direct to? P=2 ; C=3	Yes / 0 No / 4
Q4	Did you know that "From" field in an email can be manipulated to show any trusted email address? P=2 ; C=2	Yes / 0 No / 4
Q5	Did you know that NMEA 0183 protocol has no encryption? P=2 ; C=3	Yes / 0 No / 4
Q6	Is it safe to open any email while anti-virus is running? P=2 ; C=3	Yes / 4 No / 0
Q7	Do you know what DDoS attack is and how it can disrupt or slow down ship's IT systems or network services? P=2 ; C=3	Yes / 4 No / 0
Q8	In your opinion, are crew members an important factor in terms of cyber-security vulnerabilities of on-board systems? P=N/A ; C=2	Yes / 0 No / 4
Q9	Have you ever heard about the social engineering attacks on seafarers and about their ways of manipulation of seafarers to break the vessel's security procedures to gain access to critical systems or networks? P=2 ; C=3	Yes / 0 No / 4
Q10	How do threat actors use a Short Messaging Service (SMS) to infect the mobile device of seafarers? P=1 ; C=2	By sending fake links / 0 By sending suspicious attachments / 0 I do not know / 4
Q11	Usually, how many different sites do you visit while browsing web when you are off duty? P=1 ; C=N/A	More than 10 / 4 Between 6-9 / 3 Between 3-5 / 2 Less than 3 / 1
Q12	How much time do you spend connected on ship's WI-FI network, daily? P=2 ; C=2	More than 6 hours / 4 Between 3-5 hours / 3 Between 1-3 hours / 2 Less than 1 hour / 1
Q13	Are you using Administrator or Normal user account to log on into ship's PC? P=2 ; C=3	Administrator / 4 Normal user / 1
Q14	Do you regularly update PC? P=2 ; C=3	Yes / 0 No / 4
Q15	Do you know the adverse effects of seafarers' Bring-Your-Own-Device (BYOD) on board? P=2 ; C=2	Yes / 0 No / 4

Q16	Patching, updating and maintaining of ship's navigation system (e.g. ECDIS) is always crucial. Does your company have these security controls in its cyber-risk assessment plan? P=2 ; C=3	Yes / 0 No / 4
Q17	Is it true that a cyber-incident can go unnoticed for a substantial period and does not have to involve an obvious system fault or alarming ransomware messages? P=2 ; C=3	Yes / 0 No / 4
Q18	What is the typical sign that your vessel's IT/OT infrastructure is cyber-attacked? P=2 ; C=3	System is slow or unresponsive / 0 System displays warnings and alarms to inform the user about an on-going cyber-attack / 4 I do not know / 4

The minimum and maximum probability of cyber incident can be scaled based on survey results by using the equation (2):

$$\sum_i w_i p_i \tag{2}$$

Calculations are presented in Table 4, where possible survey values are grouped evenly and scaled to represent the probability level of risk parameter.

Table 4 is the risk table constructed for the probability of cyber-security incident parameter. As per Table 4, maximum possible value for survey result is 136, while minimum value is 5. For the purpose of this research, the interval of 'very high probability' is set to 27, while for other scales it is set to 25.

Using the same principle and replacing *i* with *j* in equation (2), the authors obtained the minimum and maximum values of the survey output to measure the consequences of cyber incident (Table 5).

Table 4.
Risk table representing probability of cyber incident upon survey results.

Survey result	Qualitative scale	Quantitative scale [T1]
5-30	Very low probability	1
31-56	Low probability	2
57-82	Medium probability	3
83-108	High probability	4
109-136	Very high probability	5

Table 5.
Risk table representing consequences of cyber incident upon survey results.

Survey result	Qualitative scale	Quantitative scale [T2]
2-37	Negligible consequences	1
38-73	Minor consequences	2
74-109	Important consequences	3
110-145	Serious consequences	4
146-184	Very serious consequences	5

Table 5 is the risk table constructed for the consequence of cyber-security incident parameter. As per Table 5, the maximum possible value for the survey result is 184, while the minimum value is 2. For the purpose of this research, the interval of 'very high probability' is set to 38, while for other scales it is set to 35.

Quantitative risk matrix used for this research is presented in Table 6. It is a modified version of the risk matrix which is frequently seen on board merchant vessels and is widely used for risk assessment of daily tasks (Maritime and Coastguard Agency, 2019). Multiplying quantitative values of probability and consequences, the final value of the risk is obtained.

Table 6.
Risk matrix.

Likelihood of harm (probability - P)	**Severity of harm (consequences - C)**				
	1 = Negligible	2 = Minor	3 = Important	4 = Serious	5 = Very serious
1 = Very low	1 = Very low risk	2 = Very low risk	3 = Very low risk	4 = Low risk	5 = Low risk
2 = Low	2 = Very low risk	4 = Low risk	6 = Low risk	8 = Medium risk	10 = Medium risk
3 = Medium	3 = Very low risk	6 = Low risk	9 = Medium risk	12 = Medium risk	15 = High risk
4 = High	4 = Low risk	8 = Medium risk	12 = Medium risk	16 = High risk	20 = Very high risk
5 = Very high	5 = Low risk	10 = Medium risk	15 = High risk	20 = Very high risk	25 = Very high risk

Once the previous steps were completed, questions were distributed to 638 people who are active seafarers. Out of that number, 429 people fully responded to the questionnaire. Due to space constraints, Table 7 represents an extract of all the collected data, with average calculated probability [T1] and consequences [T2] of risk.

Calculated risk based on the conducted-survey questionnaire, by application of fundamental risk equation (1) is 11.18, which can be described as medium level risk.

Table 7.
Survey results.

Respondent # m *[m=n]*	Probability of cyber incident $\sum_i w_i p_i$, where $i = 429$	T1	Consequences of cyber incident $\sum_j w_j p_j$, where $j = 429$	T2
Respondent # 1	88	4	88	3
Respondent # 2	96	4	128	4
Respondent # 3	80	3	116	4
Respondent # 4	48	2	68	2
Respondent # 5	80	3	80	3
…	…	…	…	…
Respondent # m	…	…	…	…
…	…	…	…	…
Respondent # 429	72	3	76	3
	$\left(\frac{(\sum_m [T_1 (\sum_i w_i p_i)])}{m}\right)$ =	3.26	$\left(\frac{(\sum_m [T_2 (\sum_j w_j p_j)])}{n}\right)$ =	3.43

6. SOLUTIONS

Maritime industry is being rapidly digitalised, and IT is playing a crucial role in this regard. Before knowing how to prevent cyber-attacks, it is essential to know how these attacks are detected. Typically, seafarers are unaware of the attack and remain oblivious until a real loss occurs. It is indispensable for seafarers not only to adopt and understand new technologies, but also to keep themselves abreast of threats and attacks in the face of the ship's IT infrastructure.

Based on the conducted quantitative survey and ISRAM risk assessment methodology, authors measured the risk level of cyber-security awareness of Montenegrin seafarers. Rated as a medium-level risk, it can be treated as a clear indicator of necessity of urgent actions.

The human factor is always crucial when it comes to the cyber security of a ship, and this is also an important subject of this research paper. To that end, the authors proposed a model of the training course that should be set as mandatory for all crewmembers. The model course is presented in Table 8. The proposed training course should be set mandatory for all crewmembers, and it should continue in form of refresh courses on a regular 5-year basis. Implementation into the existing IMO model course 3.27 – Security awareness training for all seafarers, is also possible.

As per Table 8, the course should consist of 8 topics and should last for 8 hours, out of which 2.5 hrs are dedicated to demonstration purposes.

Table 8.
Proposed model course for cyber-security awareness.

	Topic	Duration in hrs	
		Theory	Demonstration
1.	Introduction to cyber security	0.5	
2.	SMS vs. cyber security – IMO requirements and legal framework	0.5	
3.	Identification of threats – Types of cyber-attack (DDoS, Phishing, etc.)	1.0	1.0
4.	Identification of vulnerable shipboard systems (IBS, engine/cargo/ballast control systems and NMEA 0183 standard)	1.0	
5.	Cyber-security risk assessment	0.5	0.5
6.	Measures for prevention and detection of cyber-attack – technological and behavioural	1.0	1.0
7.	Reporting cyber attacks	0.5	
8.	Conclusion	0.5	
	TOTAL	8,0 hrs	

Proposed training would educate Montenegrin Seafarers about ship's IT security policies, procedures, and best practices that are required to better work in a ship's IT environment.

Security familiarisation training is also essential before joining the ship's duties. The Shipboard familiarisation checklist should be expanded to include cyber-security related training, which should be performed by the Ship Security Officer or an equally qualified seafarer. Familiarisation process should be adequately structured to guide a newly joining seafarer how to report a security incident, how to act in IT security-related emergencies and to explain which security solution is required in the event of a cyber-security incident.

7. CONCLUSION

In the world of digital warfare, the global shipping community including vessels, ports, terminals and various other facilities are relying heavily on the Internet to establish connectivity. Automated equipment, GNSS, ECDIS, AIS, engine/ballast/cargo control systems, and consignment tracking systems are just some of the items dependent on adequate cyber security.

Policies and procedures on board ships should be structured and planned, accompanied by an appropriate IT infrastructure including firewalls, anti-malwares, etc. Ship's IT infrastructure is vulnerable to cyber-attacks, and human error can play its part in

this regard. Therefore, achieving the overall cyber security of the ship is out of the question without a proper and effective training of seafarers. The conducted risk assessment based on survey questionnaire implicitly shows that human resources are a hot topic in terms of cyber security on board ships.

Montenegrin seafarers are mostly novices with regard to IT and cyber security. In addition, they have not acquired any IT and cyber-security related education from shore-based institutions either. For example, neither Maritime High Schools nor Maritime Faculties in Montenegro are providing any sort of education about cyber security at sea. Thus, maritime cyber security of Montenegrin seafarers is not up to the mark and needs urgent attention.

Therefore, a holistic approach to cyber security should start with the increase of people's awareness and focusing of knowledge on the mindset with appropriate training. If their training is planned to make them aware and ready to act on any threat, there is no doubt that the overall risk will be significantly reduced.

Implementation of the authors' proposed training course would set a milestone on security at sea. The proposed model course in cyber-security awareness would help in protecting confidentiality, integrity, and accessibility of information through various measures relating to people, processes, and IT systems on board ships.

Further research should focus on developing unique teaching syllabus of cyber security that will suit the needs of both Montenegrin seafarers and their employers.

REFERENCE

A.P. Moller - Maersk, 2017. Interim Report Q3 2017. Available at: https://investor.maersk.com/static-files/1226cd7b-d1b4-4281-b42c-5f032b0e1595.

BIMCO, 2017. The guidelines on cyber security onboard ships, Version 3, available at: http://www.ics-shipping.org/docs/default-source/resources/safety-security-and-operations/guidelines-on-cyber-security-onboard-ships.pdf?sfvrsn=16.

Bolat, P., Yüksel, G. & Yüksel, S., 2016. A Study For Understanding Cyber Security Awareness Among Turkish Seafarers. The Second Global Conference on Innovation in Marine Technology and the Future of Maritime Transportation. Bodrum: Union of Chambers of Turkish Engineers and Architects – The Chamber of Marine Engineers of Turkey, pp. 278–279.

Boyes, H. and Isbell, R., 2017. Code of Practice Cyber Security for Ships. London: Institution of Engineering and Technology.

Cimpanu, C., 2018. Maersk Reinstalled 45,000 PCs and 4,000 Servers to Recover From NotPetya Attack, Bleeping Computer. Available at: https://www.bleepingcomputer.com/news/security/maersk-reinstalled-45-000-pcs-and-4-000-servers-to-recover-from-notpetya-attack/, accessed on: 7 December 2018.

Committee on Foundations of Risk Analysis, 2015. Society for Risk Analysis Glossary. Available at: https://www.sra.org/sites/default/files/pdf/SRA_glossary_20150622.pdf.

DNV GL (no date) Maritime Cyber Security Awareness E-learning. Available at: https://www.dnvgl.com/maritime/maritime-academy/cyber-security-elearning.html, accessed on: 23 February 2020.

Furnell, S., Millet, K. & Papadaki, M., 2019. Fifteen years of phishing: can technology save us? Computer Fraud & Security, 2019(7), pp.11–16. Available at: http://dx.doi.org/10.1016/s1361-3723(19)30074-0.

Gantz, S. D. and Philpott, D. R., 2013. FISMA and the Risk Management Framework. Available at: http://dx.doi.org/10.1016/c2010-0-66566-7.

Hareide, O.S. et al., 2018. Enhancing Navigator Competence by Demonstrating Maritime Cyber Security. Journal of Navigation, 71(5), pp.1025–1039. Available at: http://dx.doi.org/10.1017/s0373463318000164.

Hu, H., Peng, P. & Wang, G., 2018. Towards Understanding the Adoption of Anti-Spoofing Protocols in Email Systems. 2018 IEEE Cybersecurity Development (SecDev). Available at: http://dx.doi.org/10.1109/secdev.2018.00020.

International Maritime Organization , 2017a. MSC-FAL.1/Circ.3: Guidelines on maritime cyber risk management. Available at: http://www.imo.org/en/OurWork/Security/Guide_to_Maritime_Security/Documents/MSC-FAL.1-Circ.3 - Guidelines On Maritime Cyber Risk Management (Secretariat).pdf.

International Maritime Organization, 2017b. MSC.428(98): Maritime cyber risk management in safety management systems. Available at: http://www.imo.org/en/OurWork/Security/Guide_to_Maritime_Security/Documents/Resolution MSC.428(98).pdf.

ISO, 2009. ISO/Guide 73:2009 Risk management — Vocabulary. Available at: https://www.iso.org/obp/ui/#iso:std:iso:guide:73:ed-1:v1:en, accessed on: 20 February 2020.

ISO, no date. ISO/IEC 27032:2012 Information technology — Security techniques — Guidelines for cybersecurity, 2012. Available at: https://www.iso.org/standard/44375.html, accessed on: 24 February 2020.

Karabacak, B. & Sogukpinar, I., 2005. ISRAM: information security risk analysis method. Computers & Security, 24(2), pp.147–159. Available at: http://dx.doi.org/10.1016/j.cose.2004.07.004.

Li, C. et al., 2018. Detection and defense of DDoS attack-based on deep learning in OpenFlow-based SDN. International Journal of Communication Systems, 31(5), p.e3497. Available at: http://dx.doi.org/10.1002/dac.3497.

Lloyd's Register, no date. Cyber and data protection awareness training. Available at: https://www.lr.org/en/training/cyber-security-training/, accessed on: 23 February 2020.

Maritime and Coastguard Agency, 2019. Code of Safe Working Practices for Merchant Seafarers. London: TSO. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/848506/Code_of_safe_working_practices_for_merchant_seafarers_COSWP_2019.pdf.

Ministry of Transport and Maritime Affairs, 2015. Rulebook on the types of ranks and competencies, requirements for obtaining ranks and issuing certificates of competencies for crew members of seagoing ships. Official Gazette of the Republic of Montenegro, 15(51).

Ministry of Transport and Maritime Affairs, 2018. Rulebook amending the Rulebook on the types of ranks and competencies, requirements for obtaining ranks and issuing certificates of competencies for crew members of seagoing ships. Official Gazette of the Republic of Montenegro, 15(51), 16(44), 63

NIST, 2018. Framework for Improving Critical Infrastructure Cybersecurity, Version 1.1. Available at: http://dx.doi.org/10.6028/nist.cswp.04162018.

Prowse, D. L., 2017. CompTIA Security+ SY0-501 Cert Guide, Pearson Education.

Riviera, 2020. Ships are riddled with malware. Available at: https://www.rivieramm.com/opinion/opinion/ships-are-riddled-with-malware-28356.

Sharma, A. et al., 2018. Computer Supported Collaborative Learning as an Intervention for Maritime Education and Training. Advances in Human Factors in Training, Education, and Learning Sciences, pp.3–12. Available at: http://dx.doi.org/10.1007/978-3-319-93882-0_1.

Svensson, L., 2017. Evaluation of quantitative assessment extensions to a qualitative risk analysis method. Linköping University. Available at: http://www.ep.liu.se/.

Svilicic et al., 2019. A Study on Cyber Security Threats in a Shipboard Integrated Navigational System. Journal of Marine Science and Engineering, 7(10), p.364. Available at: http://dx.doi.org/10.3390/jmse7100364.

Svilicic, B. et al., 2019. Maritime Cyber Risk Management: An Experimental Ship Assessment. Journal of Navigation, 72(5), pp.1108–1120. Available at: http://dx.doi.org/10.1017/s0373463318001157.

The European parliament and the Council of the European Union, 2016. Regulation (EU) 2016/679 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation). Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32016R0679&from=EN.

The government of Montenegro, 2013. Law on Safety of Navigation. Official Gazette of the Republic of Montenegro, 13(62).

The government of Montenegro, 2017. Law Amending the Law on safety of navigation. Official Gazette of the Republic of Montenegro, 13(62), 14(06), 15(47), 17(71).

TMSA, 2019. Cyber security guidelines for vessels. Available at: https://www.shipownersclub.com/media/2019/01/TMSA-3-Cyber-Security-On-board-ships-1217.pdf.

USCG, 2015. United States Coast Guard Cyber Strategy. Available at: https://www.work.uscg.mil/Portals/6/Documents/PDF/CG_Cyber_Strategy.pdf?ver=2016-10-13-122915-863.

USCG, 2016. CG-5P Policy letter No. 08-16: Reporting suspicious activity and breaches of security. Available at: https://homeport.uscg.mil/Lists/Content/Attachments/2676/CG-5P Policy Letter 08-16_3.pdf.

Vinnem, J.-E. & Røed, W., 2020. Offshore Risk Assessment Vol. 1. Springer Series in Reliability Engineering. Available at: http://dx.doi.org/10.1007/978-1-4471-7444-8.

Witherby Publishing Group, BIMCO and The International Chamber of Shipping (ICS), 2019. Cyber Security Workbook for On Board Ship Use (eBook). 1st Ed. Witherby Publishing Group.

Yousefi, H. & Seyedjavadin, R., 2012. Crew Resource Management: The Role of Human Factors and Bridge Resource Management in Reducing Maritime Casualties, TransNav, International Journal on Marine Navigation and Safety of Sea Transportation.

Prediction of Marine Traffic Density Using Different Time Series Model From AIS data of Port Klang and Straits of Malacca

Akim Ramin[a], Masnawi Mustaffa[b], Shaharudin Ahmad[a]

In the study of ocean engineering, marine traffic is referring to the study of the pattern of the density of ships within the particular boundaries at certain periods. The Port Klang and Straits of Malacca are known for one of the heaviest traffics in Malaysia and the world. The study of traffic within this area is important, because it enables ships to avoid traffic congestion that might happen. Thus, this study is mainly aimed at predicting or forecasting the density of the ships using the route through this waterway by using quantitative methods which are time-series models and the associative models from the Automatic Identification System (AIS) data. The moving averages, weight moving average, and exponential smoothing for the time series model and associative model have used multiple regression. The results show an exponential smoothing alpha 0.8 and give the lowest MAPE as 20.701%, thereby making this method to be the best in forecasting the future traffic density among the method categories.

KEY WORDS
~ AIS
~ Traffic density
~ Port Klang
~ Malaysia
~ Straits of Malacca
~ Navigation
~ Time series model

a. Universiti Teknologi MARA, Faculty of Mechanical Engineering
e-mail: akim.ramin@gmail.com
b. Universiti Tekologi MARA, Faculty of Applied Sciences
e-mail: masnawimustaffa@gmail.com

doi: 10.7225/toms.v09.n02.006

1. INTRODUCTION

A high traffic route is an alarming situation for any vessel using it as it is bound to have higher possibilities of accidents, causing financial loss, injury, or casualties, and damage to the environment. In this respect the shipping traffic at Strait of Malacca and Port Klang waterways is one of the highest traffic in Malaysia and the world for marine routes. The average statistic of Port Klang keeps increasing as, in 2013, the cargo and vessel statistics are 200,278,901 and 16,703 respectively (Mustaffa et al., 2019).

The AIS technology is mainly aimed at giving information in studying this field. In a brief explanation, the Automatic Identification System (AIS) technology is a system that enables a vessel to obtain about the encountered vessels, such as their position (Zaman et al., 2015), course, speed, and other parameters automatically by very high frequency (VHF) radio transmission (Kundakci et al., 2018). Using AIS (Wu et al., 2017; Kang et al., 2018) will improve and remedy the traffic congestion on open water as it gives required data for traffic analysis (Xiao et al., 2015; Zhang et al., 2019; Fiorini et al., 2016).

In studying the pattern of data, it always takes into consideration the affecting and responding variables and the season or weather that may affect the traffic congestion. Previous studies show that weather during storms or disasters affects the traffic or behaviour of ships in manoeuvres of vessels (Gao et al., 2017). Thus a seasonal pattern technique has been used in the analysis.

Several methods have been used for this study and the effectiveness of each method is measured by the percentage of error. It presents the graphs to show the pattern of the forecast and the actual situation. This is expected to improve the

effectiveness of predicting the overall density in the study area. Furthermore, the prediction or forecast may be useful for vessels in planning to use a route to avoid traffic congestion.

The scope of this research is the forecasting using time series and associative models. These methods are based on a set of data from July 2016 to December 2017. These data have been collected from our laboratory, using our own AIS receiver. These data do not represent real data of the whole Port Klang and Starits of Malacca. We are not using any data from related authorities in Malaysia. Rather, we are using our own data to study the pattern and measure the effectiveness of the methods.

1.1. Straits of Malacca

At the centre of one of the busiest shipping lanes that connect East and West, the Straits of Malacca play a vital role for the shipping industry (Cheng et al., 2019). The Straits of Malacca are located on the east coast of Indonesia's Sumatra Island and the west coast of the Malaysia Peninsula, and extend to the Straits of Singapore at its southeast end. Marine navigational hazards will emerge when using this straits due to the increasing amount of traffic, in addition to a geographically narrow straits (Mustaffa et al., 2019).

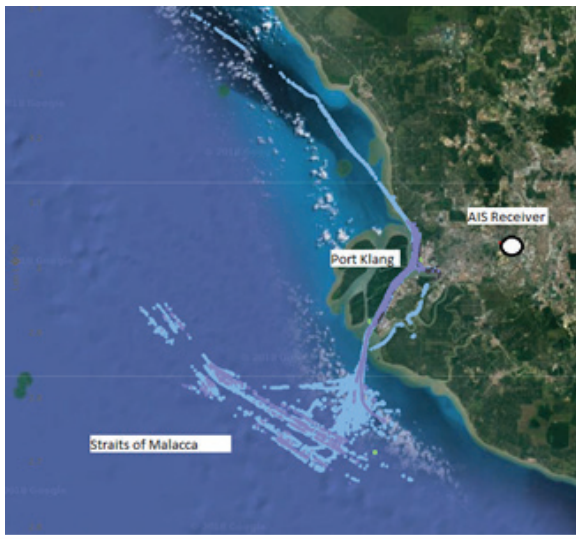


Figure 1.
Traffic density using Straits of Malacca and Port Klang, Malaysia (Mustaffa et al., 2019).

2. QUANTITATIVE FORECASTING

Forecasting is a science of predicting future events as it gives the good application in economic forecasting, technology forecasts and also demands forecasts which are a projection of a company's sales for each period in the planning horizon (Gao et al., 2017; Mustaffa et al., 2019). Furthermore, the main aim of time series modeling is to carefully collect and rigorously study the past observations of a time series to develop an appropriate model which describes the inherent structure of the series. This model is then used to generate future values for the series, time series forecasting can thus be termed as the act of predicting the future by understanding the past (Ratnadip et al., 2013).

A forecasting system should follow seven basic steps(Heizer, 2016):

1. Determine the use of the forecast
2. Select the items to be forecast
3. Determine the time needed to make a forecast
4. Select the forecasting models
5. Gather the data needed to make the forecast
6. Make the forecast
7. Validate and implement the results

The quantitative forecasting and qualitative forecasts are a general approach to forecast categorized into time-series models and the associative model.

2.1. Time-series Model

This type of model predicts the assumption that the future is a function of the past. By using this, the data will analyse the previous past data to make a forecast. In this study, the approach used is Moving Average, Weighted Moving Average and the Exponential Smoothing.

2.2. Associate Model

This model is like the linear regression. It incorporates the variables or factors that might influence the quality being forecast. The variables that give the effect of the forecast is the seasonal pattern and this study involves this variable. The Multiple-Regression approach is used in this study for this category.

3. METHODOLOGY

3.1. AIS Data

All collected data was encrypted, analyzed daily and stored in the database. This dataset contains all traffic in the area of study.

The scope of this study is obtaining the general equation or the pattern of the data distribution of traffic density. The dataset used contains the statistical data from July 2016 until December 2017.

The data are a collection of 499 day dataset, containing the total of ships. We categorized the data by the four seasonality

quarter of the year. Each season represents months from January to March, April to June, July to September, and October to December, denoted as 1 to 4 respectively.

3.2. Moving Average (MA)

A moving average forecast uses many historical actual data values to generate a forecast. A 4-month moving average is found by simply summing the demand during the past 4 months and dividing it by 4. The following is the formula for calculating the moving average:

$$MA = \frac{\sum \text{Num.of ships in previous n period}}{n} \quad (1)$$

Where n is the number of periods in the moving average.

3.3. Weighted Moving Average (WMA)

The trend of the pattern can be more emphasis on recent value when considering the weights. The following formula represents the weighted moving average:

$$WMA = \frac{\sum \text{(Total ships in previous n period) (weight for period)}}{\sum \text{Weight}} \quad (2)$$

The weight for each calculation represents ascending number of the number of ships in n period.

3.4. Exponential Smoothing

Exponential smoothing is also known as a weighted moving average as it involves very little record keeping of past data. The α is a weight or smoothing constant that has a value greater than or equal to 0 and less than or equal to 1. This study will show the results of different value α and obtain the best value α in this forecast. The following formula show the exponential smoothing:

$$F_t = F_{t-1} + \alpha (A_{t-1} + F_{t-1}) \quad (3)$$

Where:

F_t = new forecast

F_{t-1} = previous period's forecast

α = smoothing constant ($0 \le \alpha \le 1$)

A_{t-1} = previous period's actual number of ships

3.5. Multiple Regressions

Unlike time-series forecasting, associative forecasting models take into consideration several variables that are related to the quantity being predicted and make this method more reliable than others. Multiple regression analysis is a practical extension of the simple regression model, a straight-line mathematical model to describe the functional relationships between independent and dependent variables. It is represented by the following equation:

$$y = a + b_1 x_1 + b_2 x_2 \quad (4)$$

Where y is a dependent variable, a is a constant, x_1, and x_2 are values of two independent variables, seasonal b_1 and b_1 are coefficients for the two independent variables.

3.6. Computational Approach of Multiple Regressions

The least-square method has been used to compute the independent variables to the dependent variables which are the density of traffic.

3.7. Mean Absolute Percent Error(MAPE)

The average of the absolute differences between the forecast and actual values is expressed as a percent of actual values. The formula for this error is as follows:

$$MAPE = \frac{\sum_i^n \frac{100\,|Actual_i - Forecast_i|}{Actual_i}}{n} \quad (5)$$

Where n is a period for the forecast and actual values.

4. RESULTS AND DISCUSSION

4.1. Traffic Density Analysis

The statistical summary for all quarters of actual traffic within the study time frame of 499 day is tabulated in Table 1,

showing the trend line equation with maximum and minimum amount by quarter. The line graph of 6 quarter of years for July 2016 until December 2017, as shown in Figure 2-7, represents the distribution of daily traffic, which always fluctuates, and trend line of actual traffic density by each quarter.

4.2. Moving Average

For each group of four month data or seasonal group of data, the forecast for the consecutive days uses the first four days of the number of ships in each seasonal group. Based on the equation (1), a total of four days is divided by four and forecast value of the 5th day is obtained. This iteration is continuously being forecast until the 499th day. The MAPE was calculated for the comparison.

4.3. Weighted Moving Average

In this type of forecast, the more heavily weighted the latest days provide a more accurate projection. Weighted moving average for four days projection was calculated using the equation (2). The MAPE has been calculated for comparison with other methods.

4.4. Exponential Smoothing

The equation (3), applying the forecast as the initial forecast for the first day, is 205. This consecutive iteration continues until the 499th day. In obtaining the best smoothing constant, try-and-error technique has been used to calculate the best alpha value and MAPE each difference smoothing constant, α was calculated and tabulated as in Table 2.

From this table, the best value smoothing constant to match the forecasting or closest to the actual is α = 0.8.

Table 1.
Traffic distribution with trend line equation.

Quarter	Period (months)	Trend line equation	Max. amount (number of ships)	Min. amount (number of ships)
3rd	Jul - Sep 2016	y = -0.5609x + 213.23	285	103
4th	Oct - Dec 2016	y = -0.202x + 221.38	315	78
1st	Jan - Mar 2017	y = 0.7305x + 0.7559	339	72
2nd	Apr – Jun 2017	y = -0.3325x + 299.44	349	36
3rd	Jul – Sep 2017	y = 1.429x - 369.33	367	65
4th	Oct – Dec 2017	y = -0.0488x + 203.83	282	77

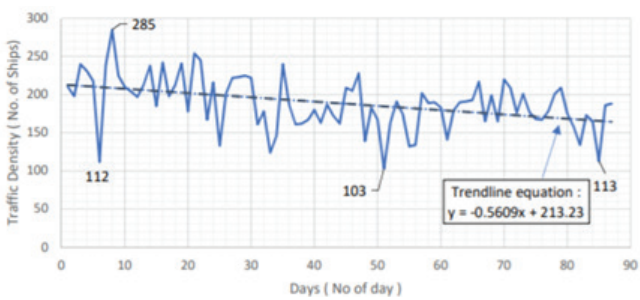


Figure 2.
The third quarter of 2016 traffic distribution from day 1 to day 87.

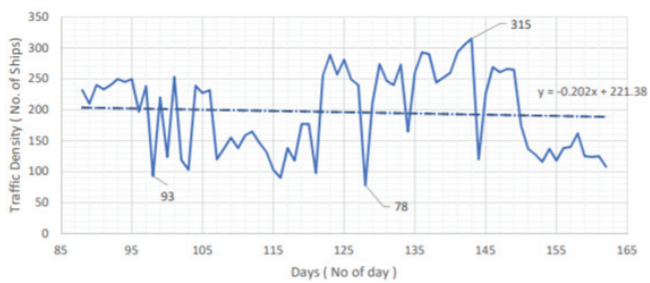


Figure 3.
The fourth quarter of 2016 traffic distribution from day 88 to day 162.

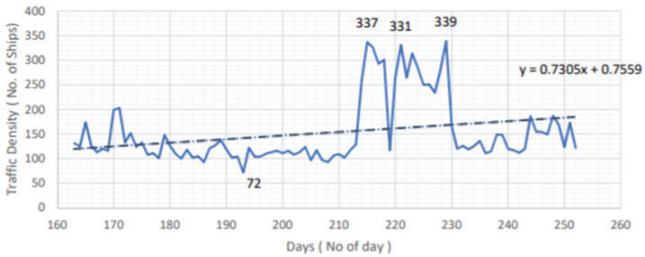


Figure 4.
The first quarter of 2017 traffic distribution from day 163 to day 252.

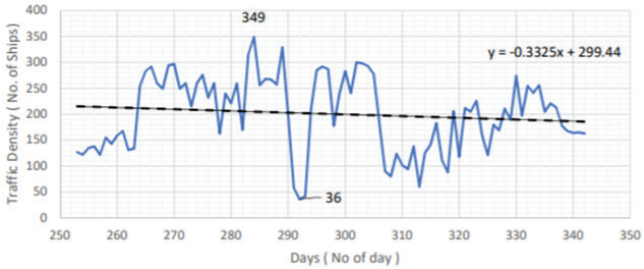


Figure 5.
The second quarter of 2016 traffic distribution from day 253 to day 342.

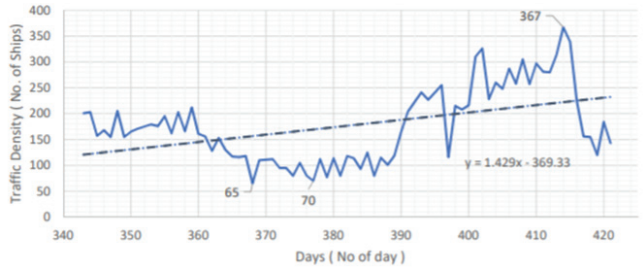


Figure 6.
The third quarter of 2017 traffic distribution from day 343 to day 421.

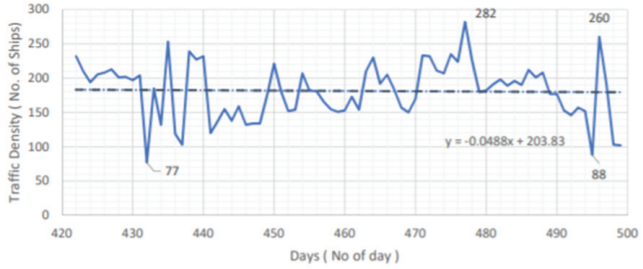


Figure 7.
The fourth quarter of 2016 of traffic distribution from day 422 to day 499.

Table 2.
MAPE for difference smoothing constant, *α*.

Method	MAPE
Exponential smoothing, α = 0.4	21.648
Exponential smoothing, α = 0.5	21.147
Exponential smoothing, α = 0.6	20.880
Exponential smoothing, α = 0.7	20.738
Exponential smoothing, α = 0.8	**20.701**
Exponential smoothing, α = 0.9	20.827

4.5. Associative Models

The multiple-regression is obtained as the equation considering the 4 variables, one variable representing the number of days, and the other 3 representing the set of seasonal variables. The following is the set of variables used. Table 3 shows the independent variable in which this density traffic is influenced by seasonal by quarter year.

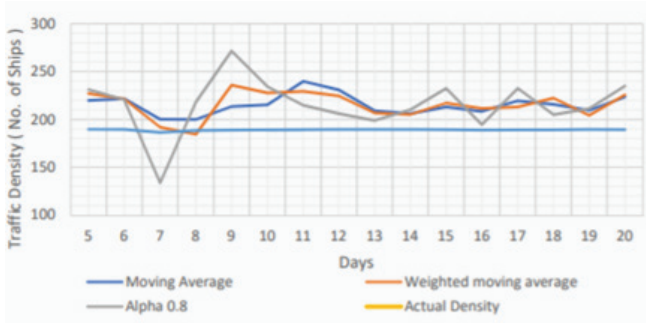


Figure 8.
Comparison of Time Series Forecasting of Day 5 to Day 20.

Table 3.
The variable represent the seasonal variables.

Seasonal	X1	X2	X3
1st quarter	0	0	0
2nd quarter	1	0	0
3rd quarter	0	1	0
4th quarter	0	0	1

From the general equation of Equation (4), applying the formula as the variables and the variables of x_1 = *days* number, $x_2 = X1$, $x_3 = X2$, $x_4 = X3$ yielding;

$$y = 159.327 - 0.0337x_1 + 51.211x_2 + 30.4209x_3 + 39.252x_4 \quad (6)$$

4.6. Comparison by Forecasting Method

Mean Absolute Percentage Error (MAPE) values were compared to measure the effectiveness of the actual value for each of the methods. Applying Equation (5), data iteration for 499 days from dataset gives the following value respectively to the method used in this project as in Table 4. Trend line for each method is shown in Figure 8.

Table 4.
Comparison Using Different Method and its MAPE.

Method	MAPE (%)
Moving average	30.834
Weighted moving average	22.134
Exponential smoothing, α = 0.8	20.701
Multiple regression	32.183

This comparison shows the exponential smoothing with alpha value 0.8 as the best method compared with other methods. The comparison by the plotting the graph for all method compared to actual data plotting is shown in Figure 9.

4.7. Forecasting Future Traffic Density

From the analysis overall method, the reliable method in this study is the exponential smoothing alpha 0.8, as to perform the forecasting the extrapolating of recent data is required for continuity of the data projection. For the case, the date required is the 1st January 2018 and iteration using equation (3) to obtain the traffic density for each consecutive day. The plotting graph pattern of the previous week and the predicted day is shown in Figure 9.

Table 5.
The iteration for the consecutive day in Jan 2018.

Date	Month	Num. of Days	Num. of Ship	Alpha=0.8	Absolute Error (%)
30	12	498	103	198.437	92.658
31	12	499	102	122.087	19.694
1	1	500		106.02	

5. CONCLUSION

In this study, the main objective of traffic forecasting analysis has been presented and discussed. The quantitative method has been used to forecast total density and by days as time horizon used to project the estimation density. The data are taken from July 2016 until December 2017, which only comprises 499 days as some of the data have not been completed due to some error in receiving the AIS signal. The quantitative method which is the time-series model; moving average, weighted moving average, exponential smoothing, and associative model; multiple-regression approach. These methods have been measured using the MAPE. The result showing the exponential smoothing alpha 0.8 gives the lowest MAPE as 20.701% and this will make this method reliable in terms of indicating or forecasting the future traffic density by the number of ships.

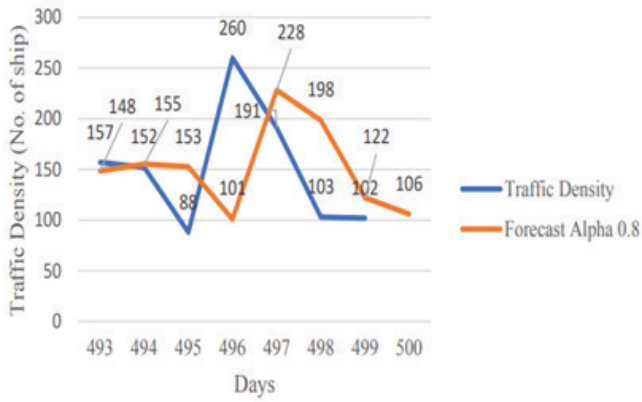


Figure 9.
Plotting of Forecasting using exponential smoothing alpha 0.8.

REFERENCES

Adhikari, R. & Agrawal, R.K., 2013. An Introductory Study on Time Series Modeling and Forecasting.

Cheng, L. et al., 2018. Using big data to track marine oil transportation along the 21st-century Maritime Silk Road. Science China Technological Sciences, 62(4), pp.677–686. Available at: http://dx.doi.org/10.1007/s11431-018-9335-1.

Fiorini, M., Capata, A. & Bloisi, D.D., 2016. AIS Data Visualization for Maritime Spatial Planning (MSP). International Journal of e-Navigation and Maritime Economy, 5, pp.45–60. Available at: http://dx.doi.org/10.1016/j.enavi.2016.12.004.

Gao, X. & Makino, H., 2017. Analysis of anchoring ships around coastal industrial complex in a natural disaster. Journal of Loss Prevention in the Process Industries, 50, pp.355–363. Available at: http://dx.doi.org/10.1016/j.jlp.2016.12.003.

Heizer, J., 2016. Operations Management : Sustainability and Supply Chain Management. Pearson.

Kang, L., Meng, Q. & Liu, Q., 2018. Fundamental diagram of ship traffic in the Singapore Strait. Ocean Engineering, 147, pp.340–354. Available at: http://dx.doi.org/10.1016/j.oceaneng.2017.10.051.

Kundakçi, B. & Nas, S., 2018. Mapping Marine Traffic Density by Using AIS Data: An Application in the Northern Aegean Sea. Polish Maritime Research, 25(4), pp.49–58. Available at: http://dx.doi.org/10.2478/pomr-2018-0131.

Mustaffa, M. et al., 2019. Data mining analysis on ships collision risk and marine traffic characteristic of Port Klang Malaysia waterways from automatic identification system (AIS) data, International Multi Conference of Engineers and Computer Scientists 2019 (IMECS 2019), 2019, vol. 2239, pp. 242–246.

Wu, L. et al., 2016. Mapping Global Shipping Density from AIS Data. Journal of Navigation, 70(1), pp.67–81. Available at: http://dx.doi.org/10.1017/s0373463316000345.

Xiao, F. et al., 2015. Comparison study on AIS data of ship traffic behavior. Ocean Engineering, 95, pp.84–93. Available at: http://dx.doi.org/10.1016/j.oceaneng.2014.11.020.

Zaman, M.B. et al., 2015. Risk of Navigation for Marine Traffic in the Malacca Strait Using AIS. Procedia Earth and Planetary Science, 14, pp.33–40. Available at: http://dx.doi.org/10.1016/j.proeps.2015.07.082.

Zhang, L., Meng, Q. & Fang Fwa, T., 2019. Big AIS data based spatial-temporal analyses of ship traffic in Singapore port waters. Transportation Research Part E: Logistics and Transportation Review, 129, pp.287–304. Available at: http://dx.doi.org/10.1016/j.tre.2017.07.011.

The Correlation Between Strong Wind and Leisure Craft Grounding in Croatian Waters

Ivan Toman[a], Đani Mohović[b], Mate Barić[a], Robert Mohović[b]

This paper examines the correlation between strong wind and the frequency of small leisure craft grounding by analysing the available data on maritime accidents in the Adriatic. The primary goal of this study was to verify the hypothesis from prior research that strong wind is the prime cause of groundings in certain areas of the Adriatic. Contrary to the conclusions of the prior research, the new analysis indicates a far more uniform spatial distribution of wind-caused grounding accidents across all the examined areas of Croatian Adriatic waters. Furthermore, the analysis indicates that most grounding accidents occur in light wind conditions, suggesting that groundings can predominantly be attributed to factors other than strong wind. Several important drawbacks of the analysis stemming from the lack of accurate data on accidents in Croatian waters are discussed and suggestions given for the improved collection thereof that would greatly contribute to the future research on this topic. The inability to determine the exact causes of particular accidents from available data makes it impossible to accurately establish the number of grounding accidents caused by strong wind. In the future, more detailed statistical data could improve our understanding of the correlation between adverse weather conditions and recreational vessel accidents in the Adriatic.

KEY WORDS
~ Grounding accidents
~ Strong wind
~ Leisure vessels
~ Meteorological risks to navigation
~ Adriatic sea

a. Univeristy of Zadar, Maritime Department, Croatia
e-mail: ivtoman@unizd.hr
b. University of Rijeka, Faculty of Maritime Studies, Croatia
e-mail: dmohovic@pfri.hr

doi: 10.7225/toms.v09.n02.007

1. INTRODUCTION

Nautical tourism is one of the main branches of tourism in Croatia (Favro, 2018). As the traffic of marine leisure vessels, sailboats and yachts significantly intensifies in the Adriatic during the summer, maritime accidents occur far more frequently in this than in other seasons (Mohović, 2013). The impact of unfavourable weather conditions on the safety of navigation tends to increase the risk of accidents especially of small leisure vessels (defined in the Croatian Maritime Code as vessels carrying maximum 12 people, 2.5-15 meters in length, with minimum 5kW engines). The main objective of this paper is to establish whether unfavourable weather conditions have an impact on the frequency of maritime accidents in the Adriatic. The correlation between strong wind and grounding accidents is of particular interest for this paper.

In (Frančić, 2009) authors analyse the common causes of maritime accidents in Croatian waters and give recommendations for the improvement of safety of navigation. In that paper, the authors identified grounding as the most common type of accident.

To date there has been no substantial research on the correlation between leisure craft accidents and weather conditions in Croatian scientific papers. The analysis of statistical data in (Mohović, 2013) has shown the number of days with strong wind (Beaufort scale 6 and more) to correlate with the number

of accidents in some, but not all parts of the Adriatic. (Mohović, 2013) hypothesizes that strong and gale force wind could be an important contributing factor to small craft grounding, but does not give a precise analysis. This paper is a follow-up of the research from (Mohović, 2013), using new statistical data from 2014 to verify its findings and hypothesis and better understand the correlation between strong wind and grounding accidents of small vessels in Croatian waters. Some methodological problems associated with analysis in that paper that might have influenced the conclusions given are identified and discussed at the end of the next chapter.

Many foreign authors have found the correlation between maritime accidents and unfavourable weather conditions. Canadian authors, for example, concluded that, among other conditions, wind speed is an important contributing factor to accidents in Canadian Atlantic waters (Razaee, 2018). In general, the number of maritime accidents increases as weather conditions deteriorate, as shown in (Wu, 2009). The analysis of data obtained from three US ports (Kite-Powell, 1999) showed that poor visibility (less than 2 km) increases the risk of grounding. The same study found that though strong wind increases the risk of grounding, but not as much as low visibility (Kite-Powell, 1999). Another paper concluded that human causalities in maritime accidents are higher in precipitation and poor visibility conditions (Talley, 2006).

(Otamendi, 2014) found different spatial distribution of accidents among Spanish regions, with the majority of small leisure craft accidents occurring in the north of Spain and the majority of larger leisure craft accidents occurring in the Mediterranean Sea. Authors pointed out the lack of passage planning as major root cause of accidents. Hazardous weather or sea conditions were listed as primary contributing factors to deaths on leisure vessels in the United States 2000-2011, according to (Ryan, 2016).

The primary types of accidents of fishing vessels, in size generally similar to leisure vessels, are foundering and flooding, followed by grounding. Authors indicate engine/gearbox failures, fouled propellers and navigation errors as common causes of fishing boat grounding accidents. Heavy weather damage, as accident type, accounted for less than one percent of all accidents in the UK (Wang, 2005). However, it is not entirely clear if in this paper, for example, grounding caused by strong wind was classified as grounding or a heavy weather accident. Likewise, authors state that smaller vessels are more vulnerable to difficult weather conditions.

This paper tested the hypothesis given in (Mohović, 2013) by comparing the results and conclusions of that study with results obtained by applying the same methodology to new, more detailed data, and identified important differences. Nevertheless, the research is still insufficiently accurate to establish the precise correlation between strong wind and groundings, mainly due to the uncertainty of some aspects of statistical data, as discussed later in this paper. In addition, more research is required to reach detailed conclusions about the statistical distribution of causes of groundings and other accidents in the area of interest.

2. ANALYSIS OF PREVIOUS RESEARCH

(Mohović, 2013) as the basis for the research presented in this paper, gives a statistical analysis of data from 2005-2011 for the Croatian part of the Adriatic Sea and the distribution of types and causes of maritime accidents involving leisure vessels. Certain accident reduction and consequence mitigation measures were proposed. For that purpose, the authors used the maritime accident database of the Croatian Maritime Rescue and Coordinating centre (MRCC) – the record of all reported accidents in the Adriatic Sea. The key findings from that research are presented in the following paragraphs along with some modifications to the original analysis made in an attempt to better understand the available data from that paper.

According to (Mohović, 2013), the increase in the number of accidents can be attributed to the increment in the number of leisure vessels. The analysis of accident types has shown the majority of leisure craft accidents to fall under the "Not under Command" and "Grounding" categories. Although the authors indicated various causes of "Not under Command" or "Grounding" accidents, they failed to identify the main causes of accidents from that category due to the limited details offered by the MRCC data obtained. However, as the authors indicated strong wind as one of the possible causes of grounding accidents, they collected data from the Meteorological and Hydrological Service of Croatia for a number of days with strong wind for the counties analysed, for period May to October 2005-2011, when the leisure craft traffic is at its peak, in order to determine whether there is any correlation between the frequency of strong wind and the number of accidents.

Authors of (Mohović et al., 2013) compared the number of recorded maritime accidents in each Croatian county against the estimated nautical tourism leisure craft traffic. As there is no small craft monitoring system in the Adriatic, such traffic can not be precisely quantified. Therefore, the authors of (Mohović et al., 2013) used a proxy measure obtained by adding the number of vessels at permanent berths in nautical ports and the number of recorded transits in ports in each county. Clearly, the figure obtained does not represent the actual number of leisure craft, but the authors surmised that it could be used as an approximation for the comparison of counties. As this paper's objective was to verify the findings of that study using more direct wind data, the methodology for leisure craft traffic estimation for each county used in the original study was duplicated.

The original results of analysis from the paper are presented in Figure 1.

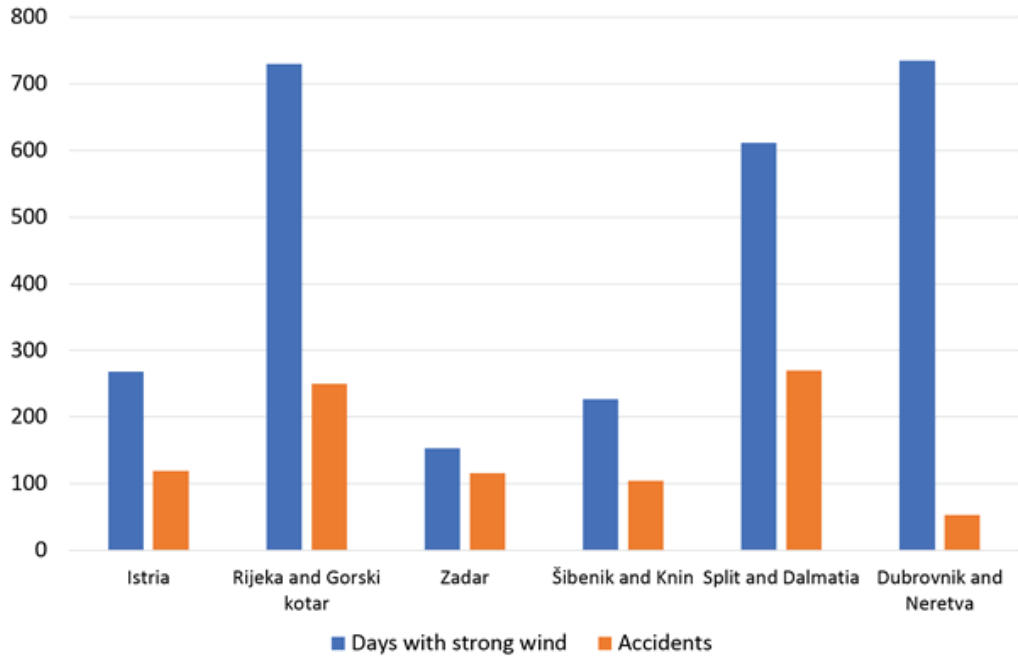


Figure 1.
Total number of accidents (all categories) and total number of days with strong wind, per county, 2005-2011.
Sources: (MRCC Rijeka, 2013; DHMZ, 2013), as adapted by (Mohović et al., 2013).

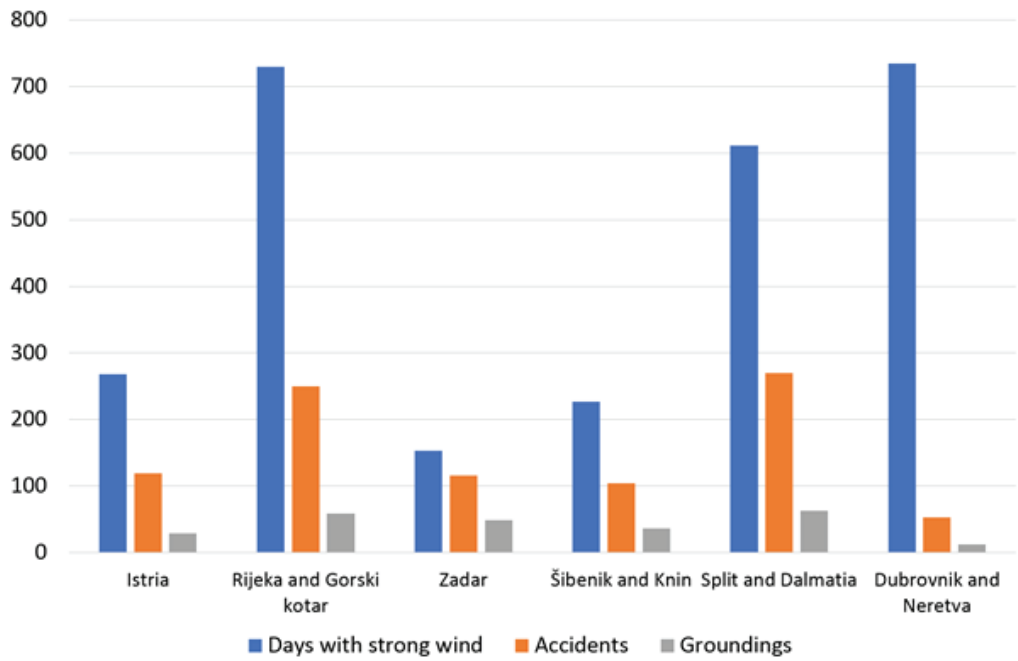


Figure 2.
Comparison of the number of all accidents against the number of groundings and number of days with strong wind, per county, in 2005-2011.
Sources: (MRCC Rijeka, 2013; DHMZ, 2013).

Though Figure 1 indicates a positive correlation between strong wind and the number of accidents in the Primorje-Gorski Kotar and Split-Dalmatia counties (large number of days with strong wind and large number of accidents), such correlation is not apparent in the Dubrovnik-Neretva County (large number of days with strong wind, but small number of accidents).

However, in the original paper, all accident types were combined and compared against the number of days with strong wind. In addition to such comparison, in order to facilitate a more direct identification of a possible causal relationship, grounding type accidents were separated from other accidents and compared against the numbers of days with strong wind. Figure 2 shows the "grounding" accidents category compared against the total number of accidents and number of days with strong wind in each county.

Figures 1 and 2 indicate a similar correlation between the number of days with strong wind and both the total number of accidents and the number of groundings in all counties. This modified analysis did not yield any new conclusions apart from those already given in the original paper.

However, owing to a huge difference in the number of leisure vessels from county to county, it would also be useful to normalize the number of accidents depending on the number of sailing leisure vessels in each county and then compare that number against the number of days with strong wind. Based on the data from (Mohović, 2013), the number of accidents per million vessels was calculated for each individual county and the results of this modified analysis are given in Table 1. The figures were calculated by dividing the number of accidents with the total number of vessels in the observed period multiplied by million. The "total number of vessels" is the sum of recorded vessels in transit and the number of vessels at permanent moorings, as calculated in (Mohović, 2013). The figure obtained is a proxy measure of traffic quantity for each county, and more data on this method and its shortcomings are provided and discussed later in Chapter 3.

Table 1.
Number of accidents per million vessels, per county, 2005-2011.
Source: (MRCC Rijeka, 2013).

County	Istria	Rijeka-Gorski Kotar	Zadar	Šibenik-Knin	Split-Dalmatia	Dubrovnik-Neretva
No. of days with strong wind	268	730	153	227	612	735
No. of accidents	119	250	116	104	270	53
No. of groundings	29	59	49	36	63	12
Total number of leisure vessels	231367	191889	387324	340769	260434	122059
Groundings per million vessels	125.3	307.5	126.5	105.6	241.9	98.3

The calculated number of groundings per million vessels for each county (Table 1) compared against the number of days with strong wind is given in Figure 3.

Figure 3. Number of groundings per million vessels compared against the number of days with strong wind, for each county, 2005-2011. Sources: (MRCC Rijeka, 2013; DHMZ, 2013).

Figure 3 clearly shows that the variables recorded in the Dubrovnik-Neretva County still significantly deviate from those recorded in other counties.

At the moment, the analysis cannot prove the correlation between the number of days with strong wind and the frequency of leisure vessel groundings, either in absolute or relative terms. The hypothesis is that the correlation found to exist in some counties can be attributed either to chance or increased navigational risks in adverse weather conditions. Further analysis should be performed using different datasets to get a better insight into these correlations.

It should be noted that the analysis of available data on accidents and days with strong wind presented to this point has several important drawbacks that could affect conclusions, and will be discussed in the following paragraphs.

1) The wind data for each county have been obtained by direct measurement at the weather stations of the Croatian Meteorological and Hydrological Service. Each provides data for a single location in the relative vicinity of a navigational area of interest. Currently, there are just a few or only one measurement location per county. More often than not, these single measurement locations do not cover the entire navigational area of the respective county. Due to the local nature of some winds, especially Bora, this is a serious objection to the analysis

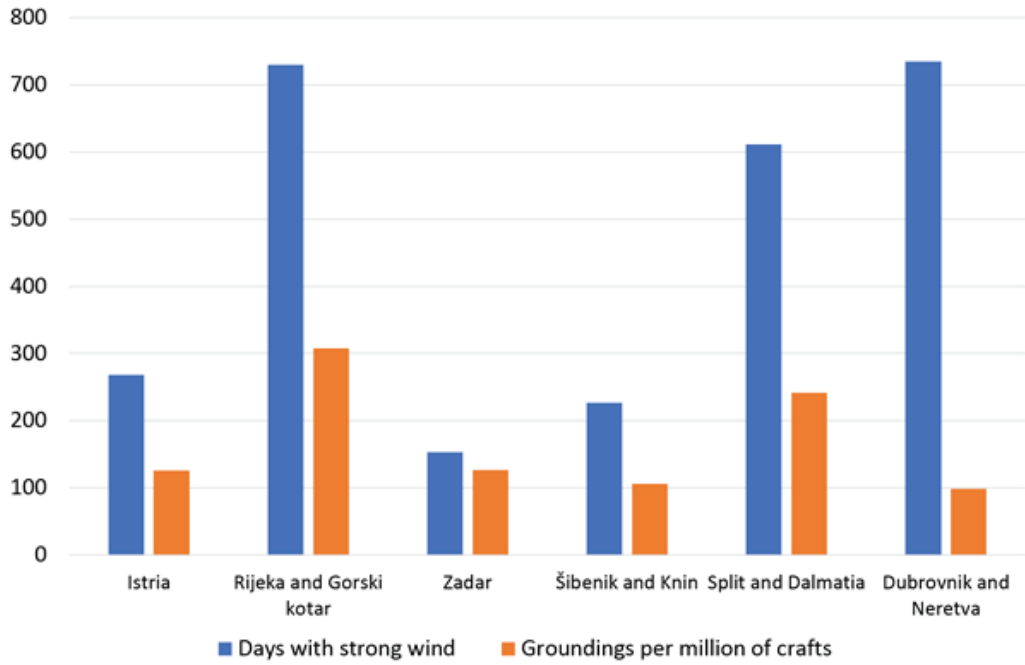


Figure 3.
Number of groundings per million vessels compared against the number of days with strong wind, for each county, 2005-2011.
Sources: (MRCC Rijeka, 2013; DHMZ, 2013).

performed. For example, one of weather stations in the Primorje-Gorski Kotar County is located in the town of Senj, notorious for strong Bora wind. Frequently when there is almost no wind in other parts of the county, that station registers Bora. This can be explained by local topographical properties, as the weather station is located under the low mountain pass Vratnik, that facilitates the unobstructed passage of cold air through the mountain barrier, even in the absence of a strong pressure gradient that would allow Bora to pass over considerably higher areas of Velebit and Kapela mountains. Therefore, significant Bora speeds are recorded only in the limited area around the town of Senj, where the mountain barrier is at its lowest, while the surrounding area has light or even no wind. This can easily corrupt the wind data presented since a false correlation is created due to more windy days being recorded than is realistic for the navigational area of the county as a whole.

2) Wind data are given in the form of the number of days with strong wind, without providing information on the time distribution of strong wind, neither by months nor by time of day, which may be relevant in some circumstances. As the Adriatic is a very large geographical area, similar wind distribution throughout the year or in different times of day cannot be generalized to exist in all of its counties.

3) Only the number of strong wind days is given, without indication of wind direction. As winds of the same speed but different direction are not equally dangerous for navigation, this omission makes the analysis problematic. Experience suggests that the north-easterly wind (Bora) is much more dangerous than the south-easterly wind (Jugo) due to its sudden and gusty nature, resulting in short/steep sea waves that are more dangerous to small vessels than the longer waves produced by the south-easterly or the north-westerly winds. Likewise, the north-easterly wind (more dangerous) is known to be far more common in the northern part of the Adriatic Sea, whereas the south-easterly wind (less dangerous) is more common in the southern parts of the Adriatic. This objection is recognized in the original paper by authors.

3. METHODS AND RESULTS OF NEW DATA ANALYSIS

Statistical data collected at MRCC Rijeka since 2014 contain a detailed description of every incident, including the type of accident, the type of the vessel involved, weather and sea conditions in the area. A new analysis was performed using these improved statistical data and compared with the results from (Mohović, 2013). Leisure vessel grounding accident data from

2014, 2015, 2016 and 2017 have been analysed and compared against weather conditions at the location of the recorded accident.

It is important to note that the weather conditions recorded in the MRCC database pertain to conditions at the time of arrival of the SAR unit to accident location, which reduces the reliability of data as there is no guarantee that weather conditions that led to vessel grounding were the same as conditions at the time of the arrival of the SAR vessel. Average times elapsed between a distress call and arrival at the location of the accident were 0.9 hours in 2014, 1.0 hours in 2015 and 0.66 hours in 2016, while such details were not processed for 2017. The total average time between accident reporting and arrival at the accident location (50 minutes) could mean some difference in weather conditions at the time of the accident and at the time of accident recording. (Pitman, 2019) discusses how weather conditions can impact the speed of deployment of rescue vessels or helicopters. In addition, weather data recorded in the MRCC database do not provide precise measurements, but are based on the subjective opinion of the SAR unit crew. It is also unknown whether due attention was given to the accurate estimation of weather conditions, especially in case of complex search and rescue operations. The above facts impose important limitations even on this new detailed method of accident data analysis.

Weather data collected in the 4-year period have been divided by Harbour Master's Office (HMO) responsibility areas and wind speed Beaufort categories. The number of groundings, respective wind speed category and accident location are shown in Table 2.

Table 2.
Number of groundings divided by wind speed data and HMO location, 2014-2017.
Source: (MRCC Rijeka, 2019).

Harbour Master's office	Calm	Light breeze	Moderate breeze	Strong breeze	Gale	Storm	Hurricane
Pula	2	7	6	1	0	0	0
Rijeka	1	5	11	4	0	0	0
Senj	0	1	1	1	1	0	0
Zadar	4	12	12	7	0	0	0
Šibenik	2	10	15	1	1	0	0
Split	3	18	14	4	1	1	0
Ploče	0	0	1	0	0	0	0
Dubrovnik	2	2	8	2	0	0	0

According to (Bilić, 1999), wind force over 5 Bf (Beaufort scale) is dangerous for small vessels. In Table 2, the groundings in each county are divided into categories depending on Beaufort wind force scale (Frampton, 1988). The groundings were then divided into two groups. The first group are accidents that occurred during level 5 or weaker winds on the Beaufort scale (light wind), and the second group accidents that occurred during level 6 or stronger (strong wind) winds on the Beaufort scale. The results are given in Table 3.

In Table 3, the light/strong ratio represents the number of accidents occurring during light wind (5 Bf or less), divided by the number of accidents occurring during strong wind (6 Bf or more). This ratio indicates the areas where a higher percentage of groundings occur during lighter wind (high ratio) and the areas in which the majority of accidents occur during stronger wind (low ratio). For example, 15 times more groundings occurred in winds of 5 Bf or less, than during winds of 6 Bf or more in the HMO Pula area. In contrast to Pula, in the HMO Senj area, the same number of groundings were recorded during 5 or less Beaufort winds and during 6 or more Beaufort wind.

The borders of Croatian Harbour Master's Offices responsibility areas correspond to the borders of Croatian counties, with the exception of the Dubrovnik-Neretva County, where the responsibility is shared between Ploče and Dubrovnik HMOs.

The best measurements of traffic density in individual counties would be monitoring systems covering all types of vessels in an area. If such data were available, traffic density would correspond to the total number of hours away from berth, as accident risk is proportional to time away from berth. However, such data are not available as no monitoring system currently tracks all leisure vessels. The AIS system is an excellent traffic monitoring tool, but is not compulsory on passenger vessels under 300 BT. Due to the unavailability of such data, the same

Table 3.
Number of grounding occurrences by HMO, during light and strong wind.
Source: taken over from (MRCC Rijeka, 2019) data.

Harbour Master's Office	Light wind	Strong wind	Ratio light/strong
Pula	15	1	15.0
Rijeka	17	4	4.3
Senj	2	2	1.0
Zadar	28	7	4.0
Šibenik	27	2	13.5
Split	35	6	5.8
Ploče	1	0	-
Dubrovnik	12	2	6.0
TOTAL	137	24	5.7

proxy measure for traffic density in individual areas was used in this paper and in (Mohović et al., 2013). It is the sum of vessels in transit and vessels permanently berthed in nautical tourism ports in a given county. This figure is not an accurate measure, but merely a figure used in calculations to compare counties in terms of groundings per million vessels in order to expand the analysis and verify the conclusions from (Mohović et al., 2013).

The numbers of permanently berthed vessels and vessels in transit in Croatian nautical ports were obtained from the database of the Croatian Bureau of Statistics (DZS, 2019). The data are given in Table 4. The source database does not contain data for the Lika-Senj County.

Table 4.
The total number of permanently berthed vessels and vessels in transit, by county, 2014-2017. Source: (DZS, 2019).

County	2014	2015	2016	2017	Total
Istria	25437	25416	26476	22285	99614
Primorje-Gorski Kotar	22435	23622	24978	23786	94821
Zadar	38301	44360	37266	40337	160264
Šibenik-Knin	44086	46375	50898	52883	194242
Split-Dalmatia	51097	52317	54945	57340	215699
Dubrovnik-Neretva	13759	14759	17010	18698	64226
Total	195115	206849	211573	215329	828866

As the Senj-Lika County is not included in the number of vessel statistics, further analysis is performed without that area.

The number of groundings per million leisure vessels for individual counties was calculated for period 2014-2017, regardless of wind conditions at accident location. Results are presented in Table 5.

Next, the number of groundings per million vessels was calculated for the same period, but this time the data were divided depending on wind force. Results are shown in Table 6 and Table 7.

Groundings per million vessels for each scenario (light wind and strong wind) are plotted in Figure 4.

Table 5.
Calculated total number of groundings per million vessels, by county, period 2014-2017.
Source: taken over from (MRCC Rijeka, 2019; DZS, 2019) data.

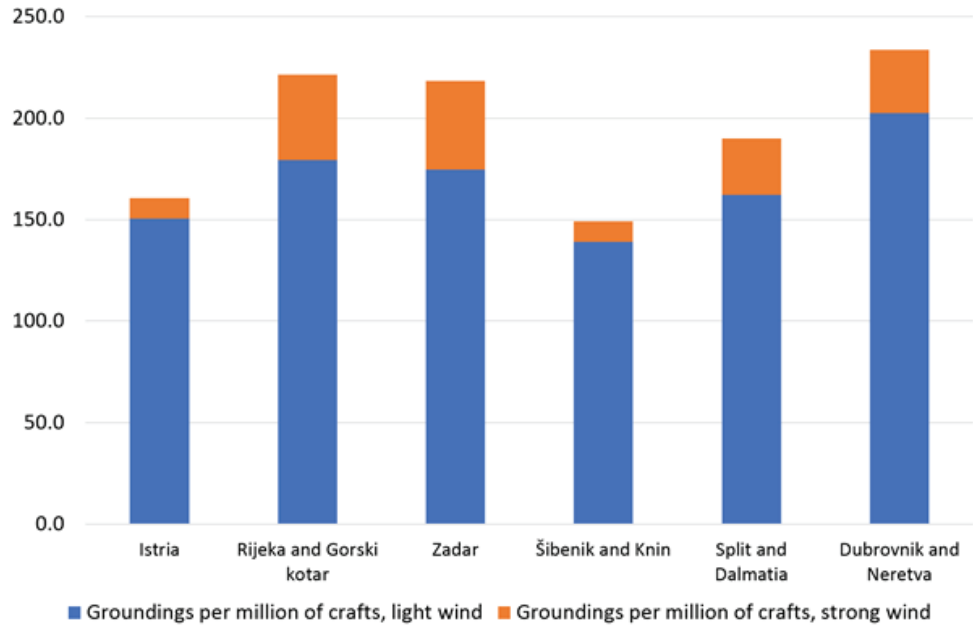
County	Istria	Rijeka-Gorski Kotar	Zadar	Šibenik-Knin	Split-Dalmatia	Dubrovnik-Neretva
No. of groundings	16	21	35	29	41	15
Total number of leisure vessels	99614	94821	160264	194242	215699	64226
No. of groundings per million vessels	160.6	221.5	218.4	149.3	190.1	233.6

Table 6.
Calculated number of groundings during light wind, per million vessels, by county, 2014-2017.
Source: taken over from (MRCC Rijeka, 2019; DHMZ, 2019; DZS, 2019) data.

County	Istria	Rijeka-Gorski Kotar	Zadar	Šibenik-Knin	Split-Dalmatia	Dubrovnik-Neretva
No. of groundings (light w.)	15	17	28	27	35	13
Total number of leisure vessels	99614	94821	160264	194242	215699	64226
No. of groundings per million vessels	150.6	179.3	174.7	139.0	162.3	202.4

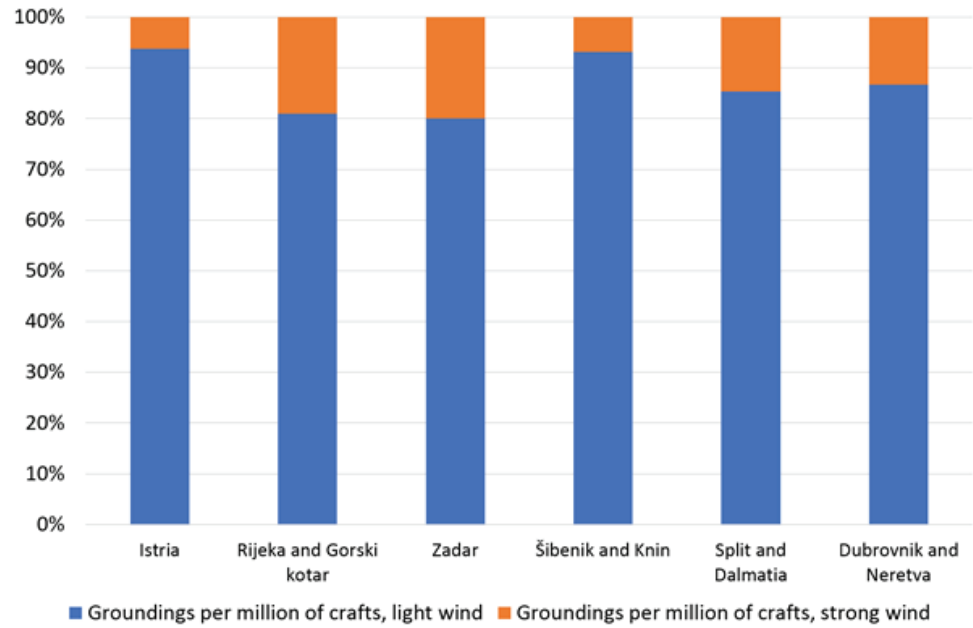
Table 7.
Calculated number of groundings during strong wind, per million vessels, by county, 2014-2017.
Source: taken over from (MRCC, 2019; DHMZ, 2019; DZS, 2019) data.

County	Istria	Rijeka-Gorski Kotar	Zadar	Šibenik-Knin	Split-Dalmatia	Dubrovnik-Neretva
No. of groundings (strong w.)	1	4	7	2	6	2
Total number of leisure vessels	99614	94821	160264	194242	215699	64226
No. of groundings per million vessels	10.0	42.2	43.7	10.3	27.8	31.1



*Groundings per million vessels

Figure 4.
Number of grounding accidents during light wind and strong wind per county, period 2014-2017.
Source: taken over from (MRCC Rijeka, 2019; DHMZ, 2019; DZS, 2019) data.



*Groundings per million vessels

Figure 5.
Number of grounding accidents during light wind and strong wind by county (stacked plot), period 2014-2017.
Source: taken over from (MRCC Rijeka, 2019; DHMZ, 2019; DZS, 2019) data.

Figure 4 indicates that normalized data (number of groundings per million vessels) are the lowest in the Šibenik-Knin County and the highest in the Dubrovnik-Neretva County. However, if the data are plotted as a percentage, the proper conclusion can be easily derived, as given in Figure 5.

The data presented in Tables 4, 5 and 6 and Figures 4 and 5 are derived from the total number of leisure vessels in the Croatian nautical ports, i.e. permanently berthed vessels and vessels in transit. As the number of permanently berthed vessels that got out of berth, but rather than reaching another port returned to their permanent berths is unknown, the exact number of vessels sailing in individual counties can not be established. However, as the number of permanently berthed vessels is relatively small compared to the number of vessels in transit (4-12% of total vessels have permanent berths, depending on county, details at the source (DZS, 2019)), the use of the total number of vessels in the calculations should not significantly affect the final conclusion.

4. DISCUSSION

The discrepancy between leisure vessel accidents and strong wind in the Dubrovnik-Neretva County established in (Mohović, 2013) cannot be verified by analysing the available data for 2014-2017. Figure 5 shows similar accident distribution across all counties, regardless of wind speed categories. The highest percentage of groundings during strong wind occurred in the Zadar County (20%), closely followed by the Rijeka-Gorski Kotar County (19%), Split-Dalmatia County (15%), Dubrovnik-Neretva County (13%), Šibenik-Knin County (7%) and finally Istria County (6%). The number of groundings during strong wind does not exceed the number of groundings during light wind in any county. Therefore, the analysis suggests that strong wind represents similar risk of grounding in every county and that differences between the counties are driven by other factors. This finding differs from the findings presented in (Mohović, 2013).

In the HMO Senj area, the low light/strong wind ratio could be attributed to the most dangerous Bora wind in the area. However, since only 4 groundings were recorded in the HMO Senj area during the observed 4-year period, which is statistically too small a sample, such low ratio could probably be attributed to a large statistical error. The same conclusion can be made in case of HMO Ploče, with only 1 recorded grounding in the 4-year period.

Similar numbers of groundings during light wind were recorded in the Zadar, Šibenik and Split HMOs (28, 27 and 35, respectively). However, only two groundings occurred in the Šibenik HMO during strong wind, compared to 7 in HMO Zadar and 6 in HMO Split. This suggests that factors other than strong wind have a much stronger influence on grounding risk in the Šibenik HMO than in the Zadar and Split HMOs. This is probably due to the fact that the navigational area of the Šibenik HMO is by far the most complex of all HMO areas, with a large number of navigational hazards like shallows and small scattered islands that make navigation challenging, especially to inexperienced leisure craft navigators. In (Belamarić, 2016), some of the risks encountered in the Šibenik area are discussed, particularly the complex navigation through St. Anthony channel. Similar navigational risk analysis was performed in (Đurđević-Tomaš, 2010) for the Dubrovnik area.

Our hypothesis is that most groundings in the Šibenik-Knin County, as the most complex area to navigate, can be attributed to navigational hazards other than strong wind. In contrast to the Šibenik-Knin County, the navigational area of the Istria County is not that complex (for example there aren't so many scattered islands), yet the ratio between groundings during light wind and during strong wind is similar as in the Šibenik-Knin County. Identification of the root cause of these results that would allow us to arrive at detailed conclusions about the causes of groundings and other accidents requires further research, preferably on a larger dataset. Strong wind should be one of the causes of groundings, but analysis to date, given all its limitations, suggests that it is not the prime cause of such incidents.

A very important factor to note is that the analysed period is short - only four years of data, with weather conditions recorded at accident locations. In the observed period, only a small number of groundings have been recorded during strong wind in most of the areas. In addition, since the reliability of weather data recorded at the site of the accidents is questionable, the possibility that such statistical analysis is not completely accurate and that conclusions derived therefrom should be taken with caution is greatly increased. Further research in the field is needed.

Due to the aforementioned limitations of research, the analysis should be repeated after several additional years of data collection, when larger data samples reduce statistical errors. In addition, it would be beneficial to unify and increase the quantity of data collected for individual accidents, as that would improve analysis and conclusion accuracy. Consequently, better accident prevention measures could be proposed that would reduce the number of future accidents.

One of the described limitations is the inability to determine the exact weather conditions at the time of the grounding, because conditions are collected upon the arrival of the SAR vessel at accident location and, as discussed, the average time between the distress call and arrival at the location was 50 minutes. This is not a problem in stable weather conditions, but when conditions change rapidly, the actual weather data may significantly differ from recorded data. For example, if a grounding occurs during a localized thunderstorm in the unstable summer conditions, the SAR vessel would very likely record calm or light wind upon its arrival at the location, although strong wind could have contributed to the grounding accident.

The above data issues make this type of analysis potentially inaccurate, preventing the researchers from reaching a decisive conclusion on the extent to which strong wind contributes to groundings or other accident types.

Another problem making this type of analysis problematic is that the number of leisure vessels sailing at sea during stable summer weather and during adverse weather conditions is unknown. In most cases, if weather conditions are not favourable, many skippers will decide not to sail out. Consequently, the number of vessels at sea must be much lower than the number of vessels sailing in stable summer weather conditions (Marvasti, 2017). Therefore, the number of accidents should also be lower during strong wind simply owing to a lower number of leisure vessels at sea. This further reduces the ability of researchers to accurately determine the risk of strong wind causing accidents from such statistical data.

In order to make statistical data more useful in the future, additional data for each accident could be collected by HMOs. More accurate data on weather conditions could be obtained and the causality of accidents better determined if following every accident, along with the data currently collected, a questionnaire is presented to the master involved in the accident. The questionnaire could include questions that would give more insight into the cause of the accident, which would greatly contribute to the analysis of statistical data and improve the accuracy of conclusions about the predominant causes of maritime accidents of leisure vessels. Questions that would yield useful data in this respect are what was the cause of the accident according to the master of the vessel, what were the weather conditions at time of the accident, what was the weather forecast prior to the accident and was it sufficiently accurate. Such data could give a much better insight into the causes of accidents and meteorological risks, and benefit future analysis of maritime accidents.

Finally, the traffic quantity/density is unknown as no existing monitoring system covers all leisure vessels. As current legislation does not require (passenger) vessels and yachts under 300 BT to carry an AIS transponder, there is no way to accurately determine the exact number of vessels sailing in the area of interest at any given time. This is yet another uncertainty in research that includes calculations based on traffic density. Another recommendation to the legislator is to extend the AIS carriage requirements to all vessels that can technically accommodate it.

5. CONCLUSION

Accidents of small leisure vessels in the summer season are a significant challenge to the safety of navigation in the Adriatic. On the other hand, unfavourable weather conditions could increase the risk of occurrence of leisure craft accidents, particularly grounding, which often results in human causalities, property loss, environmental incidents and puts challenges and inflicts the costs of search and rescue organization.

The analysis based on new data does not confirm the findings from (Mohović et al., 2013) that the correlation between strong wind and leisure vessel grounding differs in different parts of Croatian waters. Our analysis has shown this correlation to be similar in all the areas observed and failed to prove that strong wind is the primary cause of grounding accidents in any area of interest.

Although more detailed as of 2014, statistical data collected for individual accidents still do not give a clear insight into the causes of accidents. The correlation between groundings and strong wind could best be studied if weather conditions at the time of the accident were known. However, as this is not the case, the best the researchers can do is estimate the weather conditions based on the available data recorded upon the arrival of the SAR vessel at the scene of the accident.

The lack of accurate data precludes the clear establishment of the exact cause of grounding, consequently causing problems in the statistical analysis of accident causes. Based on incomplete data available at this point and a relatively small data sample, the analysis presented in this paper suggests that significantly more groundings occur during light than during strong wind in all Croatian Adriatic counties. However, as discussed in the paper, the conclusion that strong wind does not cause significant number of grounding accidents is difficult to prove without more accurate data about each recorded accident. Further research on this topic should focus on a longer time period with greater amount of data and if possible, more information about the causes of accidents should be recorded by the Search and Rescue organization and compulsory AIS carriage should be extended to apply to smaller vessels.

REFERENCES

Belamarić, G. et al., 2016. Marine Accident Risk Assessment for Port of Šibenik Area. Naše more, 63(4), pp.87–97. Available at: http://dx.doi.org/10.17818/nm/2016/4.7.

Bilić, M., Trošić, Ž., Kasum, J., (1999), Mobitel i sigurnost plovidbe brodica u hrvatskom obalnom moru. Naše more, 46(3-4), pp.119-124. Available at: https://hrcak.srce.hr/file/307260.

DHMZ (Croatian Meteorological and Hydrological Service) (2019). Official data. Courtesy of DHMZ. Zagreb, Croatia.

DZS (Croatian Bureau of Statistics). Official data. Available at: https://www.dzs.hr [accessed 6 October 2019].

Đurđević-Tomaš, I., Brajović, M. & Kurtela, Ž., (2010), Analiza rizika pomorskoga prometa u dubrovačkom akvatoriju. Naše more, 57(5-6), pp.215-225. Available at: https://hrcak.srce.hr/62166.

Favro, S., Kovačić, M., (2008), Nautičko gospodarstvo temelj sustavnog razvoja nautičkog turizma. Pomorstvo, 22(1), pp.31-51. Available at: https://hrcak.srce.hr/24797.

Frampton, M. & Uttridge, P.A., (1988), Meteorology for seafarers. Brown, Son & Ferguson LTD., Nautical Publishers, Glasgow, United Kingdom.

Frančić, V., Njegovan, M. & Maglić, L., (2009), Analiza sigurnosti putničkih brodova u nacionalnoj plovidbi. Pomorstvo, 23(2), pp.539-555. Available at: https://hrcak.srce.hr/45463.

Kite-Powell, H., Jin, D., Jebsen, J., Papakonstantinou, V. & Patrikalakis, N., (1999), Investigation of potential risk factors for groundings of commercial vessels in U.S. ports. International Journal of Offshore and Polar Engineering, 9. Available at: https://www.researchgate.net/publication/254509555_Investigation_of_Potential_Risk_Factors_For_Groundings_of_Commercial_Vessels_In_US_Ports.

Marvasti, A., 2017. Determinants of the risk of accidents in the Gulf of Mexico commercial fisheries. Ocean & Coastal Management, 148, pp.282–287. Available at: http://dx.doi.org/10.1016/j.ocecoaman.2017.08.018.

MRCC Rijeka (Maritime Rescue Co-ordination Centre Rijeka) (2019). Official data. Courtesy of MRCC. Rijeka, Croatia.

Ministry of the Sea, Transport and Infrastructure (MPPI): Harbormasters' offices. Available at: http://www.mppi.hr/default.aspx?id=667 [Accessed on: 7th December 2018].

Mohović, Đ., Barić, M., Itković, H., (2013), Contribution to the improvement of the safety of navigation of leisure vessels. Pomorstvo, 27 (1), pp.117-130. Available at: https://hrcak.srce.hr/104191.

Otamendi, F.J. & González de Vega, J.R., 2014. Recreational boating incidents based on marine surveyors reports: Economic, safety and prevention issues across Spain. Ocean & Coastal Management, 102, pp.65–71. Available at: http://dx.doi.org/10.1016/j.ocecoaman.2014.09.015.

Pomorski zakonik (Croatian maritime law book) (2020), Available at: https://www.zakon.hr/z/310/Pomorski-zakonik.

Pitman, S.J., Wright, M. & Hocken, R., 2019. An analysis of lifejacket wear, environmental factors, and casualty activity on marine accident fatality rates. Safety Science, 111, pp.234–242. Available at: http://dx.doi.org/10.1016/j.ssci.2018.07.016.

Rezaee, S., Pelot, R. & Finnis, J., 2016. The effect of extratropical cyclone weather conditions on fishing vessel incidents' severity level in Atlantic Canada. Safety Science, 85, pp.33–40. Available at: http://dx.doi.org/10.1016/j.ssci.2015.12.006.

Ryan, K.M. et al., 2016. Injuries and Fatalities on Sailboats in the United States 2000–2011: An Analysis of US Coast Guard Data. Wilderness & Environmental Medicine, 27(1), pp.10–18. Available at: http://dx.doi.org/10.1016/j.wem.2015.09.022.

Talley, W.K., Jin, D. & Kite-Powell, H., 2006. Determinants of the severity of passenger vessel accidents. Maritime Policy & Management, 33(2), pp.173–186. Available at: http://dx.doi.org/10.1080/03088830600612971.

Wang, J. et al., 2005. An analysis of fishing vessel accidents. Accident Analysis & Prevention, 37(6), pp.1019–1024. Available at:

http://dx.doi.org/10.1016/j.aap.2005.05.005.

Wu, Y., Pelot, R.P. & Hilliard, C., 2009. The Influence of Weather Conditions on the Relative Incident Rate of Fishing Vessels. Risk Analysis, 29(7), pp.985–999. Available at: http://dx.doi.org/10.1111/j.1539-6924.2009.01217.x.

Sea Level Rise Projections for Failaka Island in The State of Kuwait

Jasem A. Albanai

As a result of climate change, many lands are under risk due to the rising sea levels (RSL). Studies show that the mean sea level will likely rise by 0.16 to 0.63 metres before 2050, and 0.2 to 2.5 metres by 2100. Lower-lying islands are more endangered from RSL. One of such islands is Failaka, a small island in Kuwait lying at the entrance of Kuwait Bay, which is located on the north-western side of the Arabian Gulf (Also called the Persian Gulf). Most of Failaka Island is lower than three meters. The Governmental plans are to develop and populate the island. SLR should be considered in such planning. This study focuses particularly on detecting the areas of Failaka Island which are under high threat from the SLR. To detect these areas, spatial analysis of the Digital elevation model (DEM) are used. DEM is estimated for three SLR scenarios (1, 2 and 3 metres). It is expected that 31% of the island will be under sea level height for the SLR of 1 m; 54% for the SLR of 2 metres; and 87% for the SLR of 3 m. Coastal Vulnerability Index (CVI) is estimated as well. The CVI shows that the eastern coast is the most susceptible with regard to the SLR. The model was validated through using ground elevation points (n = 40), and a positive correlation was found with r^2 of 0.8019. Geographic Information System (GIS) and Remote sensing (RS) are confirmed to be effective tools for estimating spatial influence of the SLR.

KEY WORDS
~ Sea level rise
~ Failaka island
~ Kuwait
~ Geographic information system
~ Remote sensing
~ Coastal vulnerability index

Remote Sensing and GIS Analyst, Kuwait City, Kuwait
e-mail: albanay.com@gmail.com

doi: 10.7225/toms.v09.n02.008

1. INTRODUCTION

Scientists continue to confirm that the global sea level change is entirely related to climate change. The increased temperatures on the planet surface lead to thermal expansion in ocean waters, which further contributes to the rise in global sea levels (Titus, 1990). Furthermore, as increasing temperatures on the planet's surface dissolve the giant ice sheets in Greenland and Antarctica, this leading to the global SLR (Englander, 2015).

The SLR during the 20th century was estimated to be 20-25mm (J. A. Church et al., 2013; J. A. Church and White, 2011; Titus, 1990). Global SLR ranged between 0.3 and 3.2 mm per year (J. A. Church and White, 2006; 2011), to about 0.4 to 3.2mm per year (J. A. Church and White, 2011) (Figure 1). It is also worth noting that SLR varies spatially. For example, SLR in the Chesapeake Bay was 3.2mm per year during the last century (Stevenson et al., 2002). In the southern Netherlands, SLR was estimated at 1.7 - 2.7 m between 1940 and 2002 (Becker et al., 2009). The spatial variations in sea level changes are due to multiple natural factors (Nicholls and Mimura, 1998). The Arabian Gulf was exposed to sea level change during the geological timescale (Albanai, 2017). Studies estimate that the current flooding of the Arabian Gulf basin started 10,000 – 15,000 years ago (Holocene) (El-Enin, 1989). In the north-western part on the Arabian Gulf, Alothman, Bos, Fernandes, and Ayhan (2014) have estimated that the absolute sea level rise is 0.8-1.5 mm/year using all the available tide gauge data during 29 years study (1979 – 2007). The results are consistent with global SLR estimate of 0.1-1.9 mm/year (J. A. Church and White, 2011) for the same studied period.

SLR projections for the 21st century vary hugely. Overall, sea level is expected to rise from 0.16 to 0.63m by 2050, and from 0.2 to 2.5m by 2100 (Sweet et al., 2018). Englander (2015) pointed out that SLR is strongly dependant on the rate at which polar ice melts. It is expected that continuous SLR over the 21st century will cause many problems, such as population displacements,

Figure 1.
Nine different time projections of SLR at the end of this century, ranging from 0.2 to 2.1 m. The IPCC AR4 projection for 2007 does not include accelerated melting rates in Greenland and Antarctica (Englander, 2015; Rahmstorf, 2010; Moore, 2019).

the destruction of coastal infrastructure and coastal erosion. It should be noted that about 10% of the world's population lives within 10 kilometres from the coast (McGranahan, Balk, and Anderson, 2007; United Nations, 2017) and around 40% of the world's population lives within 100 Km of the coast (United Nations, 2017).

DEMs are often used in GIS and are the most common basis for digitally produced relief maps. There are two freely available DEMs for the area of this study: The Shuttle Radar Topography Mission (SRTM) and the Thermal Emission and Reflection Radiometer (ASTER). Both have a spatial resolution of around 30 m^2. Aster DEM is made from satellite stereo images while SRTM is made from RADAR data. Generally, there are three basic sources for the DEMs: (i) data from the topographic maps, which can be digitised; (ii) in-situ data collected with GPS; or (iii) aerial photographs or satellite images (Elkhrachy, 2017).

The integration of GIS and RS offers the possibility of calculating areas of land that may be flooded using DEMs, such as Malik and Abdalla's (2016) and Aleem and Aina's (2013) studies. However, CVI is widely used for spatial modelling of SLR. CVI was applied early by Gornitz et al. (1994). This indicator is calculated by introducing several variables that are believed to affect coastal zones in the event of SLR. Geo-technologies provide an approach to calculate and map this index (Reyes and Blanco, 2012). The variables calculated in CVI are divided into two groups: (i) a set of several physical variables such as slope, coastal erosion, elevations, geomorphology and hydrodynamics (Palmer et al., 2011; Shaw et al., 1998), (ii) human related variables, such as population affected, land use and transportation (Reyes and Blanco, 2012). CVI scores are classified usually into low, moderate and high, based on quantitative and qualitative analysis.

DEMs have horizontal and vertical accuracy. Statistical methods are needed to assess their accuracy. High-resolution DEMs are also subject to assessments of their accuracy (Cooper et al., 2013). Ground elevation points are used to validate DEMs. They could be taken from many sources, such as satellite images, aerial photography, topographic maps or field surveys. The coefficient of determination (r^2) and the Root Mean Square Error (RMSE) are widely used to validate spatial models (Aleem and Aina, 2013). Regression analysis could also be used to build a new empirical DEMs (Alimonte and Zibordi, 2003).

For SLR studies, Cooper et al., (2013) introduced a methodology for studying SLR using LIDAR data. Their study shows the importance of highly accurate data to support decisions. Kumar (2015) modelled future prospects for sea level rise in the Orissa region of India. He worked on the production of a high-resolution digital height model and analysed the model to visualize the impact of sea level rise. Malik and Abdalla (2016) modelled the expected losses of sea level rise on British Columbia. GIS was used to conceptualize the projections in different scenarios, ranging from one to three meters' rise in sea levels. At the regional level of the study area, Falour et al. (2013) modelled the vulnerability of the Syrian coasts to sea level rise and coastal hazards through GIS and remote sensing. CVI was computed to assess the coastal risk and several factors were taken to compute it, such as geomorphology, topography, coastal curvature, coastal erosion, sea level rise and hydrodynamics, as well as coastal erosion. Al-Jeneid et al. (2008) studied coastal hazards on the Bahrain Kingdom. The study found that 17% of the total area of the country may become below the main sea level if the sea level were to rise 1.5 meters.

In Kuwait, Alsahli and AlHasem (2016) studied the SLR impact on the Kuwaiti coasts, and the CVI was used to determine the impact of sea level rise, based on ground elevation points from a topographic map, and ASTER GDEM. The study showed that the northern coasts are likely to be the most affected by the sea level rise, while the southern coasts of Kuwait Bay (Doha) and Shuaibah port on the Southern coast are also affected. Another study by Neelamani and Al-Shatti (2014) discussed the sensitivity of the Kuwaiti coasts. The authors used a global model to show the SLR threats along Kuwait coasts. The study showed the rise effect on Bubyian Island, Failaka Island, Kuwait Bay and some Southern coasts. The current study aims to detect the areas of Failaka Island which are under threat from SLR through spatial analysis of DEM and CVI using six physical parameters (elevation, slope, geomorphology, maximum tidal height, maximum wave height and coastal erosion).

1.1. Study Area

Kuwait is a small country, lying on the north-western side of the Arabian Gulf. It is located between latitudes 28° 30′ and 30° 05′ North, and longitudes 47° 30′ and 48° 36′ East (Figure 2). There are nine islands in Kuwait, with Failaka Island the second in size. The total Kuwaiti land area is 17800 Km^2. Kuwait's coastline is more than 700 Km including the islands' maritime borders and new human-made coasts. The State of Kuwait has a desert climate and is affected by the tropical high-pressure region. Kuwait is considered to be a flat land. The surface geomorphology of the State of Kuwait reflects two important factors that govern it: the fluvial deposition in the delta environment and the historical deposition (El-Baz, and Al-Sarawi, 2000).

Failaka Island is located at the entrance of Kuwait Bay, and is at a distance of 20 Km from the coast. It has a total area of 46 Km^2, and coastline of approximately 38 Km. The island was inhabited up to the Gulf War in the 1990 (3500 citizens) with small urban area. The citizens left the island during the war due to the widespread destruction. There are currently two ports on the island, both lying in front of Kuwait City; with one of them working at the moment. Failaka is considered to be a flat land with a few small hills (Figure 3). The highest areas on Failaka reach 9 m above the mean sea level; these are located at the west and south-western parts of the island. Most of the island lands are lower than 2 m above mean sea level. The lower areas are mostly found in the Sabkha regions (Figure 2.). The Failaka coastal zone is affected by two forces: natural and anthropogenic. The tides and waves are the main natural forces controlling the coastal zone. The anthropogenic forces, meanwhile, can be seen clearly in the urban area and beaches. There are 16 different geomorphologic features which can be seen on the island, most important of which are Sabkha, wetland, sandy beach and hard rocks (Al-Sarawi, Marmoush, Lo, and Al-Salem, 1996). The Kuwaiti Government plans to develop and re-populate the island to achieve the Kuwait master plan 2035 (NewKuwait, 2018).

Figure 2.
The location of Failaka island in the State of Kuwait. The dark areas on Failaka Island represent the sabkhas.

Figure 3.
3D model shows Failaka Island elevations (SRTM DEM).

2. MATERIAL AND METHODS

2.1. Data Description

For mapping the shoreline, the study used satellite imaginary as the main source of data. Landsat 8 image, taken during high tide (10 - 11 AM GMT +3) on 25 August 2014, was used. The image was downloaded from the United States Geological Survey site (2018). To add more accuracy, high-resolution basemap images from the ArcGIS Online (2018), and Google Earth high-resolution database (2018) were used as a reference to validate and edit the shoreline.

Two sources were used to extract the elevations and validate the accuracy: (i) DEM layer from The Shuttle Radar Topography Mission (SRTM) done in 2000 and downloaded from the USGS site (2018). (ii) ground elevation points (n = 40) taken by GPS measurements on September 2018. The DEW was used to compute the SLR scenarios and the ground elevation points were used to validate the accuracy of the model.

The CVI map was prepared using six physical parameters: elevation, slope, geomorphology, maximum tidal height, maximum wave height and coastal erosion. The elevation and slope layers were extracted from the same DEM SRTM layer used to compute the SLR scenarios (USGS, 2018), while the geomorphologic, maximum tidal height and maximum wave height data were taken from Al-Sarawi et al.'s (1996) study of Failaka. The coastal erosion data of the island was obtained from Al-Mutari's (2017).

2.2. Shoreline Mapping

For mapping the shoreline, the Image was calibrated radiometrically using ENVI 5.2 software. The radiometric calibration process changes the pixel values from the digital numbers to radiances. This process helps in detecting the spectral signature of the land cover, which is necessary to class and analyse the Earth's features (Elrawy, 2015). Then, pan sharping technique has been applied using ArcGIS 10.4. The multispectral band of Landsat 8 has a low spatial resolution equal to 30 m^2, while the panchromatic band has 15 m^2 as a spatial resolution. The pan-sharping technique allows us to merge the two bands to benefit from the high spatial resolution of the panchromatic band and the high spectral resolution of the multispectral band. Moreover, a spectral index (band rationing) called the Normalized Difference Water Index was applied on the merged band of Landsat 8 using the band math tool on ENVI software. Several studies have used the spectral indices to map the shoreline and the most important indicator used for this purpose is the NDWI (McFeeters, 2013; Rokni et al., 2014; Al-Mutari, 2017). The NDWI is a related index to water stress and differences. It is calculated as the ratio between the refracted radiations of the near-infrared (NIR) and the short-wave infrared (SWIR) bands. Using more than one band increases the accuracy of shoreline mapping (Ryu et al., 2002). The band rationing method separates the land from the water in two clear colours in contrast to the natural colour, which is often show more gradual changes (Figure 4). The NDWI was applied to delineate the shoreline of Failaka Island using the following equation:

$$NDWI = \frac{(band_G - band_{NIR})}{(band_G + band_{NIR})} \quad (1)$$

Where *G* refers to the green band at 0.53 – 0.59 wavelength (*μm*) and *NIR* refers to the Near-Infrared band at 0.85 – 0.83 wavelength (*μm*) of Landsat 8.

After applying the NDWI, shoreline has been edited and validated manually. The manual mapping of shoreline shows good results (Ford, 2013; Meyer et al., 2016). The shoreline has been edited using the satellite basemap data on ArcGIS and Google

Figure 4 .
Using NDWI to separate the land from the water and delineate the shoreline.

Earth. It should be taken into account here that the basemap of the two sources were taken during different tidal conditions. The spatial resolution of available data reaches a few centimetres at some locations. The intertidal zone of Failaka coasts is narrower than the spatial resolution range of the merged band that used to map the shoreline. The final shoreline was projected on the coordinate system WGS_1984_UTM_Zone_39N.

2.3. SLR Scenarios

As for the SRTM DEM analysis, the DEM raster layer was corrected geometrically from the projected coordinate system GCS_WGC_1984 to WGS_1984_UTM_Zone_39N. The DEM layer was clipped using the final shoreline polyline layer. This procedure was done using "raster processing tool" on ArcGIS, allowing us to avoid any values outside the island in our analysis. Following that, the abnormal or outlier values were removed using the map algebra tool on ArcGIS. Out of the total DEM pixel values, 0.28% were classified as outliers and removed (Figure 5). Upon computing the upper and lower fences (quartiles method), the outliers have been removed. The following equations were used to compute the upper and lower fences:

$$Upper\ fence = Q_3 + 1.5*IQR \quad (2)$$

$$Lower\ fence = Q_1 - 1.5*IQR \quad (3)$$

Where $Q_1 = (n+2)/4$, $Q_3 = (3n+2)/4$ and $IQR = Q_3 - Q_1$. n is the samples total number.

The island total area was calculated using "calculate geometric tool" on ArcGIS. Following that, the statistical matrices were exported from the statistical report. This step was necessary to find the surface of areas that may be flooded according to the total island area. Using "map algebra tool" on ArcGIS, three hypothesis scenarios were calculated (1, 2 and 3 metre SLR). The values were chosen to reflect SLR projections for the 21st. The flooded unconnected areas to the shoreline were removed from the analysis using "select by location tool" on ArcGIS. This is due to the inability of the seawater to submerge the interior lowlands if the sea level rises (Figure 6). Figure 7. Shows the overall DEM processing and analysis.

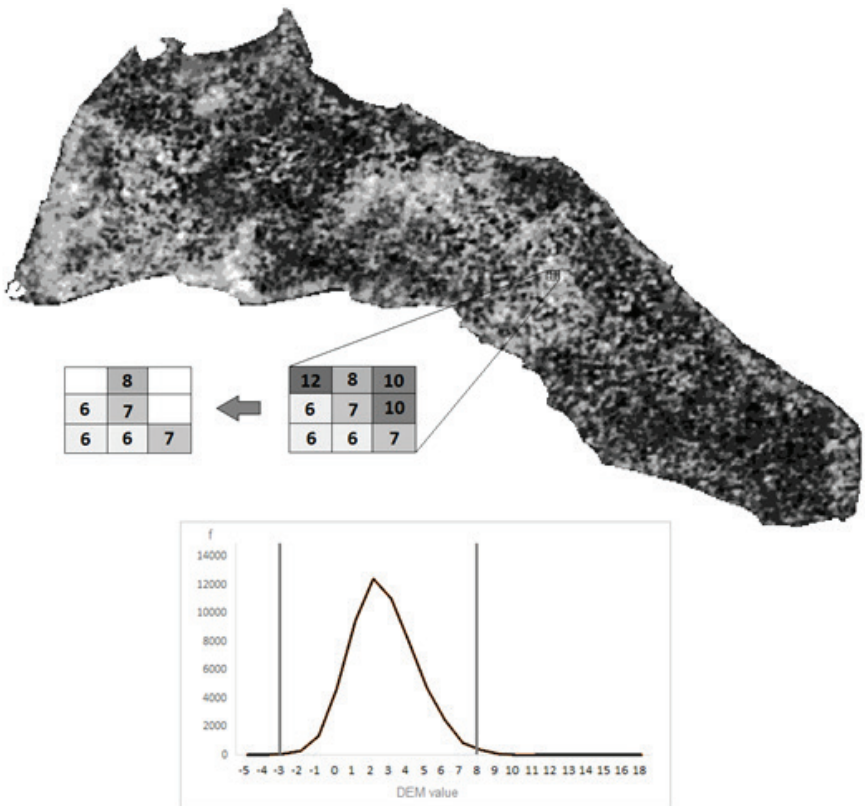


Figure 5.
Shows the DEM values distribution. Based on the DEM upper and lower fences, the outliers have been removed.

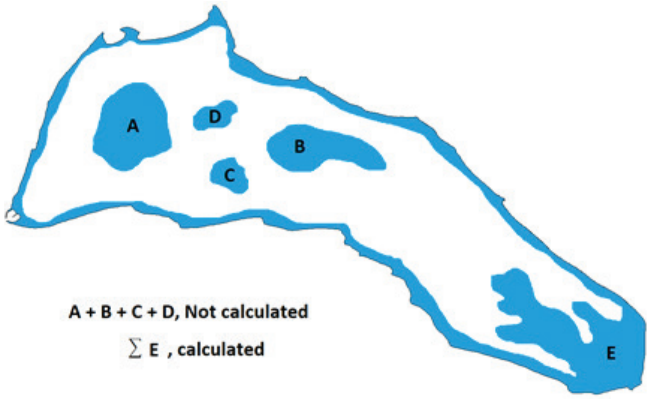


Figure 6.
An example of the calculated and avoided areas (not connected to the shoreline) on SLR scenarios.

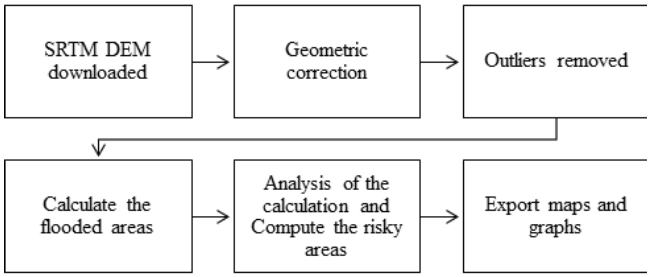


Figure 7.
DEM preparing and analysis methodology.

2.4. CVI Map

The CVI map was prepared using six physical parameters: elevation, slope, geomorphology, maximum tidal height, maximum wave height and coastal erosion (Table. 1). There were no relevant anthropogenic parameters since Failaka island is mostly uninhabited at the moment. The parameters were ranked from 1 (lowest vulnerability) to 3 (highest vulnerability) according to the estimated risks. These classes are similar to those used by Falour et al. (2013) and Gornitz et al. (1994), except for some differences due to the study area conditions. Topography (elevation and slope) is an important factor in coasts sensitivity. The low elevation areas with a gentle slope have Less sensitive to SLR. Geomorphology is an essential factor to assess the vulnerability to coastal erosion. Sabkhas (for example) has more sensitive to coastal erosion. The hydrodynamical factors such as the maximum tidal height and maximum wave height play a role in coastal erosion and vulnerability. The island coast was separated into four segments: the northern, southern, western and the eastern segment (Figure 8). The division was based on similarities of the coastal zones' characteristics. The CVI was computed and ranked based on 3 ranks (Table. 1.). The CVI was calculated using "calculate field tool" on ArcGIS, using the following equation:

$$CVI = \sqrt{\frac{x_1 \cdot x_2 \cdot x_3 \cdot x_4 \cdot x_5 \cdot x_6}{n}} \quad (4)$$

Where $x_{(1\ to\ 6)}$ are elevation, slope, geomorphology, maximum tidal height, maximum wave height and coastal erosion. n is the samples total number.

Figure 8.
Failaka Island segments.

Table 1.
The physical parameters used to compute the CVI and parameters ranks from 1 (lowest vulnerability) to 3 (highest vulnerability).

CVI variables	1	2	3
elevation (m)	1	-	-
Slope	<0.5	0.5 - 0.2	>0.2
Geomorphology	Hard Rocks, Cliff	Marine Deposition, Sand	Wetland, Sabkha
Maximum Tidal Spring Height (m)	>0.6	0.6 - 0.7	<0.7
Maximum Wave Height (m)	>2.5	2.5 - 3.0	<3.0
Coastal Erosion (m/y)	>- 0.5	- 0.5 – 0	< 0

2.5. Data Validation

Ground elevation points were used to validate the model accuracy. Several factors were considered during the sampling process. Each sample distanced is at least 50 metres from the closest different sample, and from the coast. Also, the urban areas, the vegetation areas, and hard-to-reach places have avoided, averting the DEM error. "Arc toolbox" and the statistical indicators have been used for matching. The following steps describe the analysis process:

1. A 3*3 pixels polygon was created around the ground elevation points to match with the DEM values. The pixel size is 30 m^2. The polygon size was specified as 3*3 pixels to encompass the horizontal accuracy of the DEM. Then, the mean and standard deviation were estimated for the polygon area.
2. The percent difference (PD) was calculated to validate the DEM accuracy; this formula is used to have a percentage number. The following equation is used to calculate the PD:

$$PD = \frac{DEM_i - GPS_i}{GPS_i} \quad 100 \tag{5}$$

where DEM is digital elevation model mean value at the polygon, and GPS is the ground elevation point.

3. The relationship between the two variables was examined and represented using the coefficient of determination (r^2). The coefficient is important as it shows the variance ratio between values. The following equation was used to calculate r^2:

$$r^2 = \left(\frac{\sum(GPS_i - \overline{GPS})(DEM_i - \overline{DEM})}{\sqrt{\sum(GPS_i - \overline{GPS})^2}\sqrt{\sum(DEM_i - \overline{DEM})^2}} \right)^2 \tag{6}$$

where GPS stands for ground elevation points and DEM for digital elevation model mean at the polygon.

The statistical measures indicate that there is a positive correlation between the corrected DEM and the ground elevation points (n = 40), with the $r^2 = 0.8019$ (Figure 9) and the *PD = 5.23%*.

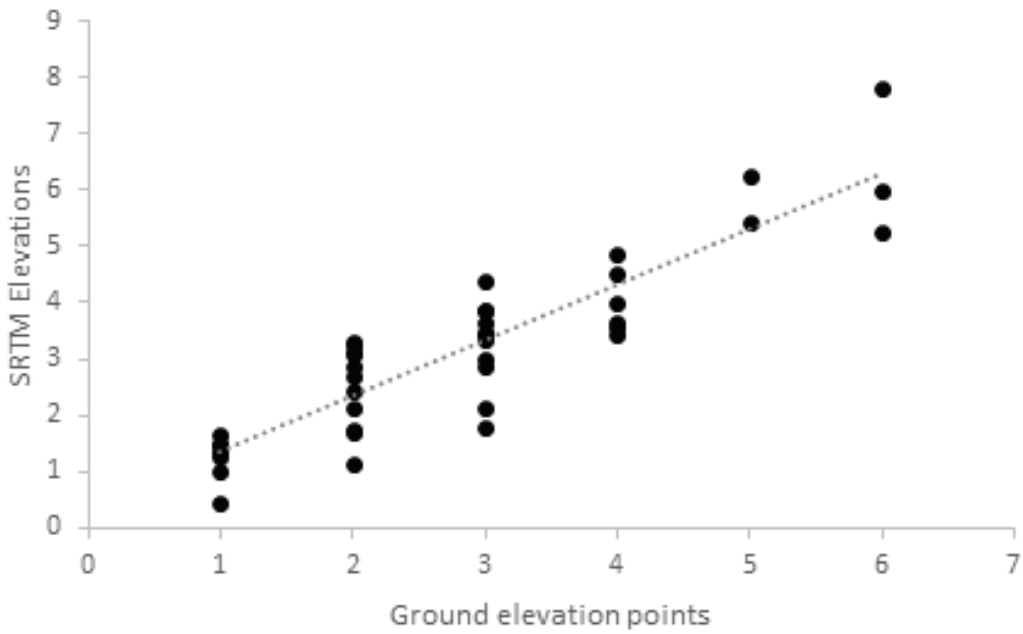


Figure 9.
The correlation between DEM and ground elevation points ($r^2 = 0.8019$, p-value = .000).

3. RESULTS

Estimates using SLR of 1 m, reveal that ~13% of the total island will be under present-day mean sea level (Table 2; Figure 10 and 11). Most of the island's coastlines will be affected with huge eastern parts of the island submerging below the mean sea level. This was to be expected given the geomorphology of the island. The wetlands cover most of the eastern part of the island. It can also be seen that the northern coasts of the island will be affected more than the southern. This is chiefly due to the depositions of the Shat-Al-Arab region north the island. The second scenario result shows that around 46% of the total island area may disappear underwater if sea-level rises for 2 metres (Table 2; Figure 10 and 11). Naturally, even more of the island coasts will be subject by the SLR. Most of the eastern part of the island will end up below mean sea level. In addition to the eastern region being flooded, we can see that the western part and the northern coasts will be affected strongly. The third scenario result shows that around 69% of the total island area may disappear if the sea-level rises for 3 metres. Nevertheless, two slightly elevated areas will remain above the mean sea level: (i) the first is in the middle of the island, while (ii) the second is at the south-western area of the island- close to the destroyed urban region. All of the island's coasts will be affected strongly in this scenario, and the island will likely separate into two smaller islands (Table 2; Figure 10 and 11) The CVI results reveal that the eastern coast part will be the most subjected areas of the Island. On the other hand, the southern coast will be moderately hit by the SLR, while the northern and western coasts show the lowest vulnerability to the SLR (Figure 20, Table 3).

Table 2.
SLR scenarios scores.

Scenario	Peer Metres	Losses	Area / Km²	Percentage
Current Situation	**Sea level**	**0**	**46.34**	**100%**
First Scenario	1 metre	6.14	40.2	86.75%
Second Scenario	2 metres	21.25	25.09	54.14%
Third Scenario	3 metres	31.91	14.43	31.14%

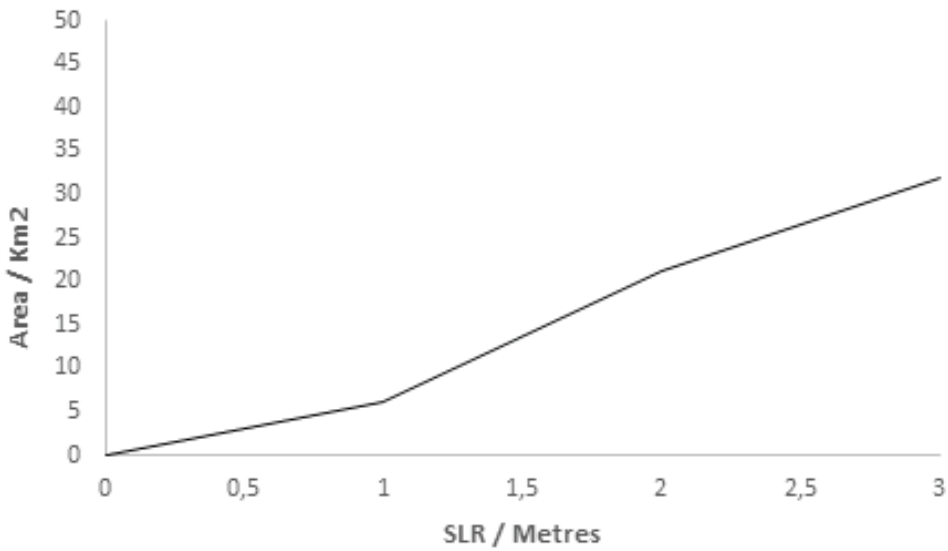


Figure 10.
Areas of Failaka Island that will be lower than mean sea level in case of realization of three different SLR scenarios (1, 2 and 3 metres).

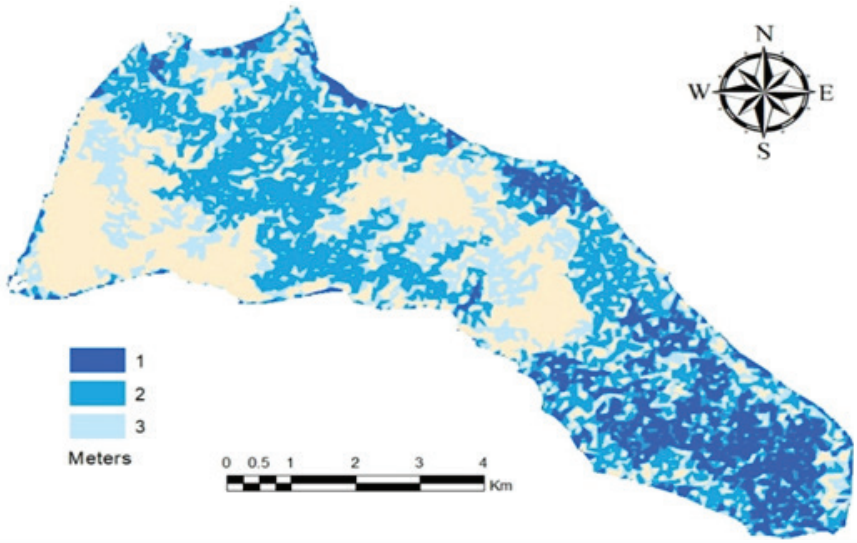


Figure 11.
SLR scenarios reflect Failaka island topography.

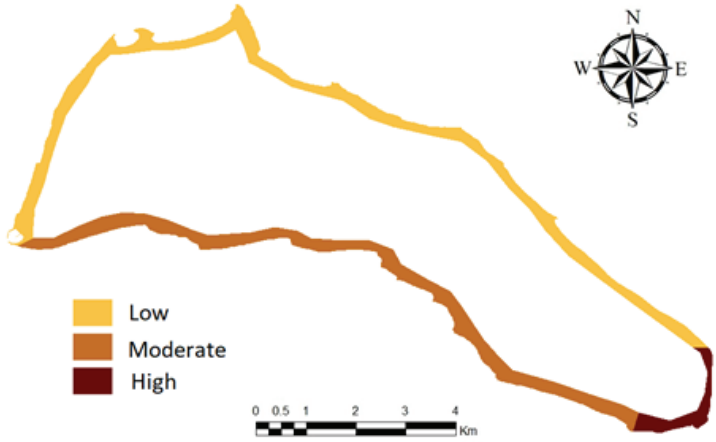


Figure 12.
The CVI map shows the geographical distribution of coasts vulnerability.

Table 3.
CVI results, estimated coastal length and percentage of the estimated coastal length from the total coastal length of the island.

Vulnerability	CVI result	Estimated coastal length (km)	Estimated CL from the total (%)
Low	0 - 0.58	21.8	47.1%
Moderate	0.58 – 1.16	13.7	29.6%
High	1.16 - 3	3.1	6.7%
Total	-	**46.3**	**100%**

4. DISCUSSION

The study results reveal the vulnerability of Failaka island to the SLR. The CVI analysis shows that the island's east coast and in general, the entire eastern part of the island, are most sensitive regarding the SLR. This is an expected result as it reflects geomorphology of the eastern part of the island. These results give us the initial idea of the island's future. Thus, they are important for the Kuwaiti government which plans to start developing and inhabiting the island. Despite the fact that the accuracy of the model used in this study appears to be high, more accurate data, such as LIDAR data is still needed for precise locations based further estimates. The SLR projection for the 21st century, vary widely, but all of without doubt of point to the fact that sea level is rising significantly, and will certainly continue to rise by the end of 21st century. One of the three scenarios analysed may be realised by the end of this century (like the 1st one). Any plans for the development of the island should take this consideration into account, since its long-term effects could cause many financial losses, or could require the adoption of engineering solutions related to coastal zone management, which are very expensive. Therefore, SLR should be considered in future planning.

Extreme raining in November 2018 has created some temporary lakes on the island, indicating the lowlands. The temporary lakes indicated the validity of the spatial models that can be obtained by analysing the geographical data, as it found a correspondence between the estimated 3 models and the sites of the temporary lakes. Moreover, the estimation results are similar to Neelamani and Al-Shatti (2014) results regarding Failaka Island. In particular, two peaks remain in the middle and the southwest in the 3 meters scenario for both studies. As for the Alsahli and AlHasem (2016) study, the SLR scenarios of Failaka do not agree with the two studies. Especially, for the lower scenarios. The Kuwait Government have to take solutions to face the SLR, such as natural structures (Mangrove, for example) along the coast of the island or raising the lowlands level. However, the study methodology can be used in further studies of SLR modelling for Kuwait and other similar coasts, taking into consideration all the physical and anthropogenic factors in calculating the CVI, and using more accurate data such as the in-situ data, Lidar data, high-resolution images, newer hydrodynamical and geomorphological maps and models. We strongly recommend that the result of this study taken as a preliminary result and that more detailed studies are being carried out.

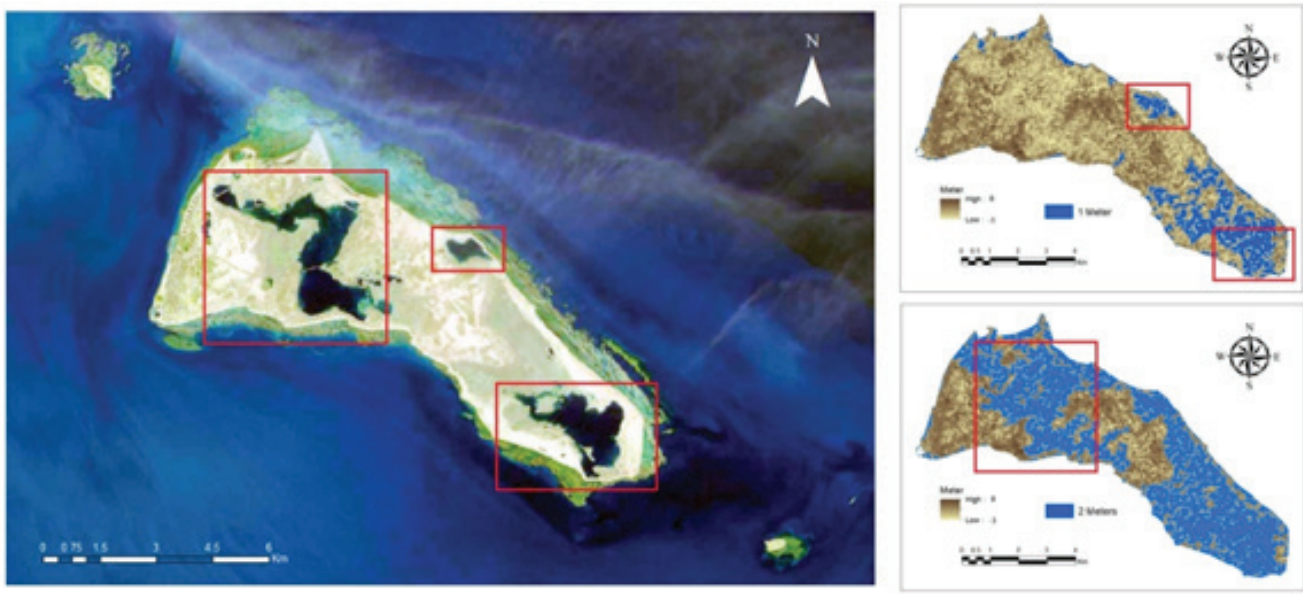


Figure 13.
On 27 November 2018 after extreme raining in Kuwait, Sentinel-2 captured this image which shows clearly the similarities between temporary lakes (low lands) locations and the estimated SLR 1st and 2nd scenarios. The biggest lake in the Westside was not obtained in the 1st scenario because it is not connected to the shoreline. On the other hand, the East Lake was obtained due to it is a connection with the shoreline in the high tide. The image is in real colours and was captured during the low tide time (USGS, 2018).

5. CONCLUSION

Results of analysis of the three SLR scenarios indicate that ~13% of the total island area may find itself below the mean sea level for the SLR of 1 m. Most of the island's coastal area will be affected. The eastern part of the island is the most vulnerable in regards to this scenario. For the SLR of 2 m ~46% of the total island area may disappear underwater. In addition to the eastern part, the western side will be affected noticeably too. Moreover, most of the island area will be end up underwater for the SLR of 3 m (around 69%). The CVI results reveal that the eastern part will be the most subjected areas of the Island. Studies show that the mean sea level will likely rise between 0.16 to 0.63m by 2050, and between 0.2 to 2.5 m by 2100.

ACKNOWLEDGEMENTS

The author would like to thank the ESRI, USGS, Google Earth, and the writers and institutions whose papers, websites and books were used in this study.

REFERENCES

Al-Jeneid, S. et al., 2007. Vulnerability assessment and adaptation to the impacts of sea level rise on the Kingdom of Bahrain. Mitigation and Adaptation Strategies for Global Change, 13(1), pp.87–104. Available at: http://dx.doi.org/10.1007/s11027-007-9083-8.

Al-Mutari, F., 2017. Detecting Shoreline Change of the State of Kuwait Using spatial data integration approach. Kuwait University.

Al-Sarawi, M.A. et al., 1996. Coastal Management of Failaka Island, Kuwait. Journal of Environmental Management, 47(4), pp.299–310. Available at: http://dx.doi.org/10.1006/jema.1996.0055.

Albanai, J. A., 2017. The Four Spheres "An Introduction To Physical Geography And Geosystem (2nd ed.). DAR KALEMAAT.

Aleem, K., & Aina, Y., 2013. The Use of SRTM in Assessing the Vulnerability to Predicted Sea Level Rise in Yanbu Industrial City, Saudi Arabia, (May 2013), pp. 6–10.

D'Alimonte, D. & Zibordi, G., 2003. Phytoplankton determination in an optically complex coastal region using a multilayer perceptron neural network. IEEE Transactions on Geoscience and Remote Sensing, 41(12), pp.2861–2868. Available at: http://dx.doi.org/10.1109/tgrs.2003.817682.

Alothman, A.O. et al., 2014. Sea level rise in the north-western part of the Arabian Gulf. Journal of Geodynamics, 81, pp.105–110. Available at: http://dx.doi.org/10.1016/j.jog.2014.09.002.

Alsahli, M.M.M. & AlHasem, A.M., 2016. Vulnerability of Kuwait coast to sea level rise. Geografisk Tidsskrift-Danish Journal of Geography, 116(1), pp.56–70. Available at: http://dx.doi.org/10.1080/00167223.2015.1121403.

ArcGIS Online, 2018. Basemap. Available at: http://arcgis.com.

Becker, M. et al., 2009. Impact of a shift in mean on the sea level rise: Application to the tide gauges in the Southern Netherlands. Continental Shelf Research, 29(4), pp.741–749. Available at: http://dx.doi.org/10.1016/j.csr.2008.12.005.

Intergovernmental Panel on Climate Change ed., Sea Level Change. Climate Change 2013 - The Physical Science Basis, pp.1137–1216. Available at: http://dx.doi.org/10.1017/cbo9781107415324.026.

Church, J.A. & White, N.J., 2006. A 20th century acceleration in global sea-level rise. Geophysical Research Letters, 33(1), p.n/a–n/a. Available at: http://dx.doi.org/10.1029/2005gl024826.

Church, J.A. & White, N.J., 2011. Sea-Level Rise from the Late 19th to the Early 21st Century. Surveys in Geophysics, 32(4-5), pp.585–602. Available at: http://dx.doi.org/10.1007/s10712-011-9119-1.

Cooper, H.M. et al., 2013. Sea-level rise vulnerability mapping for adaptation decisions using LiDAR DEMs. Progress in Physical Geography: Earth and Environment, 37(6), pp.745–766. Available at: http://dx.doi.org/10.1177/0309133313496835.

El-Baz, F., & Al-Sarawi, M., 2000. Atlas of State of Kuwait From Satellite Images (1st ed.). Kuwait Foundation for the Advancement of Sciences (KFAS).

El-Enin, H. A., 1989. Arabian Gulf - His bibliographic development, fluctuated sea level during the Pleistocene era. Kuwait Geographical Society, 125.

Elkhrachy, I., 2018. Vertical accuracy assessment for SRTM and ASTER Digital Elevation Models: A case study of Najran city, Saudi Arabia. Ain Shams Engineering Journal, 9(4), pp.1807–1817. Available at: http://dx.doi.org/10.1016/j.asej.2017.01.007.

Elrawy, M., 2015. Geomorphologic and Environmental Determinants for the Growth and Natural Vegetation in Kuwait. Kuwait Geographical Society, 427.

Englander, J., 2015. High Tide On Main Street (3rd ed.). Science Bookshelf.

Falour, G., Fayad, A. & Mhawej, M., 2013. GIS-Based Approach to the Assessment of Coastal Vulnerability to Sea Level Rise : Case Study on the Eastern Mediterranean. Journal of Surveying and Mapping Engineering, 1(1), pp. 41–48.

Ford, M., 2013. Shoreline changes interpreted from multi-temporal aerial photographs and high resolution satellite images: Wotje Atoll, Marshall Islands. Remote Sensing of Environment, 135, pp.130–140. Available at: http://dx.doi.org/10.1016/j.rse.2013.03.027.

Google Earth., 2018. Digital Globe Data.

Gornitz, V. M., Daniels, R. C., & White, T. W., (1994). The Development of a Coastal Risk Assessment Database: Vulnerability to Sea-Level Rise in the U.S Southern. Journal of Coastal Research, pp. 327–338.

Kumar, M., 2015. Remote sensing and GIS based sea level rise inundation assessment of Bhitarkanika forest and adjacent eco-fragile area, Odisha, 5(4), pp.674–686.

Malik, A. & Abdalla, R., 2016. Geospatial modeling of the impact of sea level rise on coastal communities: application of Richmond, British Columbia, Canada. Modeling Earth Systems and Environment, 2(3). Available at: http://dx.doi.org/10.1007/s40808-016-0199-2.

McFeeters, S., 2013. Using the Normalized Difference Water Index (NDWI) within a Geographic Information System to Detect Swimming Pools for Mosquito Abatement: A Practical Approach. Remote Sensing, 5(7), pp.3544–3561. Available at: http://dx.doi.org/10.3390/rs5073544.

McGranahan, G., Balk, D. & Anderson, B., 2007. The rising tide: assessing the risks of climate change and human settlements in low elevation coastal zones. Environment and Urbanization, 19(1), pp.17–37. Available at: http://dx.doi.org/10.1177/0956247807076960.

Meyer, B.K. et al., 2015. Shoreline dynamics and environmental change under the modern marine transgression: St. Catherines Island, Georgia, USA. Environmental

Earth Sciences, 75(1). Available at: http://dx.doi.org/10.1007/s12665-015-4780-1.

Moore, R., 2019. IPCC Report: Sea Level Rise is a Present and Future Danger. Available at: https://www.nrdc.org/experts/rob-moore/new-ipcc-report-sea-level-rise-challenges-are-growing, accessed on: 5 October 5, 2020.

Neelamani, S., & Al-Shatti, F., 2014. The expected sea-level rise scenarios and its impacts on the Kuwaiti coast and estuarine wetlands. International Journal of Ecology & Development, 29, pp. 33–43.

New Kuwait, 2018. Development Plan. Available at: http://www.newkuwait.gov.kw/, accessd on: 20 July, 2018.

Nicholls, R. & Mimura, N., 1998. Regional issues raised by sea-level rise and their policy implications. Climate Research, 11, pp.5–18. Available at: http://dx.doi.org/10.3354/cr011005.

Palmer, B. J. et al., 2011. Preliminary coastal vulnerability assessment for KwaZulu-Natal, South Africa. Journal of Coastal Research, 64, pp. 1390–1395.

Rahmstorf, S., 2010. A new view on sea level rise. Nature Climate Change, 1(1004), pp.44–45. Available at: http://dx.doi.org/10.1038/climate.2010.29.

Reyes, S.R.C. & Blanco, A.C., 2012. Assessment of Coastal Vulnerability to Sea Level Rise of Bolinao, Pangasinan Using Remote Sensing and Geographic Information System ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XXXIX-B6, pp.167–172. Available at: http://dx.doi.org/10.5194/isprsarchives-xxxix-b6-167-2012.

Rokni, K. et al., 2014. Water Feature Extraction and Change Detection Using Multitemporal Landsat Imagery. Remote Sensing, 6(5), pp.4173–4189. Available at: http://dx.doi.org/10.3390/rs6054173.

Ryu, J. H., Won, J. S., & Min, K. D., 2002. Waterline extraction from Landsat TM data in a tidal flatA case study in Gomso Bay, Korea. Remote Sensing of Environment, 83(3), pp.442–456. Available at: http://dx.doi.org/10.1016/s0034-4257(02)00059-7.

Shaw, J. et al., 1998. Sensitivity of the coasts of Canada to sea-level rise. Available at: http://dx.doi.org/10.4095/210075.

Stevenson, J. C., Kearney, M. S., & Koch, E. W., 2002. Impacts of Sea Level Rise on Tidal Wetlands and Shallow Water Habitats: A Case Study from Chesapeake Bay. American Fisheries Society Symposium, 32, pp.23–36.

Sweet, W. V. et al., 2018. Global and Regional Sea Level Rise Scenarios.

Titus, J.G., 1990. Greenhouse effect, sea level rise and land use. Land Use Policy, 7(2), pp.138–153. Available at: http://dx.doi.org/10.1016/0264-8377(90)90005-j.

United Nations, 2017. Factsheet: People and Oceans. The Ocean Conference. New York. Available at: https://www.un.org/sustainabledevelopment/wp-content/uploads/2017/05/Ocean-fact-sheet-package.pdf.

USGS, 2018. Earth explorer. Available at: https://earthexplorer.usgs.gov, accessed on: 27 February 2018.

Systematic Review of Literature on Dry Port - Concept Evolution

Nabil Lamii, Fatimazahra Bentaleb, Mouhsene Fri, Kaoutar Douaioui, Charif Mabrouki, El Alami Semma

Dry port plays an important role in supply chain management and mitigates seaport problems. The aim of this paper is to review the dry port concept over the different phases. Today there are different types of dry ports, different interpretations on the dry port life cycle, and different relations with seaport. We will provide a clear vision on the concept development and the advantages that can be added to the seaport and transportation flow. Then, the study will show the evolution of the research community interest on the concept. In the first step, we will briefly present all the challenges faced by seaports today. Next, we will undertake a systematic literature review in order to provide a global vision able to answer questions concerning dry port concept, types, research evolution. Finally, we will present some research topics that open for us at the dry port seaport system.

KEY WORDS
~ Dry port
~ Seaport
~ Multimodal transport
~ Logistic
~ Systematic literature review
~ Inland port

University of Hassan 1st, Faculty of Sscience and Technology, Morocco
e-mail: nabil.lamii.01@gmail.com

doi: 10.7225/toms.v09.n02.009

1. INTRODUCTION

Since the 1970s, the world has experienced an acceleration of interconnections between the different geographical zones of the world. Today it can be defined with the concept of globalisation. It summarizes all flows, capitals, information, technology and goods beyond the national level to form an interconnected global network (Hirst et al., 2009). The global economy today has broken several geographical, technological and political barriers, and gives the global supply chain the capability to be developed in a remarkable way, and to open a new dimension such as the internationalisation of industrial production. As the world has changed since 1970, the international market is becoming increasingly global because of many factors such as the positive evolution of the world economy and the internationalisation of industrial production (UNCTAD, 2018). This is subsequently reflected in the growing demand for the maritime transport services, which has also experienced an unprecedented evolution, as shown in Figure 1 (UNCTAD, 2018), by pushing the maritime transport structure to cope with the global economy (Haralambides and Gujar, 2011).

For this reason, the structure of maritime transport has gone through several transitional phases. One of the most significant phases is containerisation concept emergence, which has clearly contributed to the evolution of maritime transport (Berg and Langen, 2015).

Following the growth of the world economy, the volume of merchandise transported by sea is increasing every year (Figure 1). This can amplify the seaport challenges like the increasing difficulty of container management, lack of space, congestion at seaports access points, and negative environmental impacts.

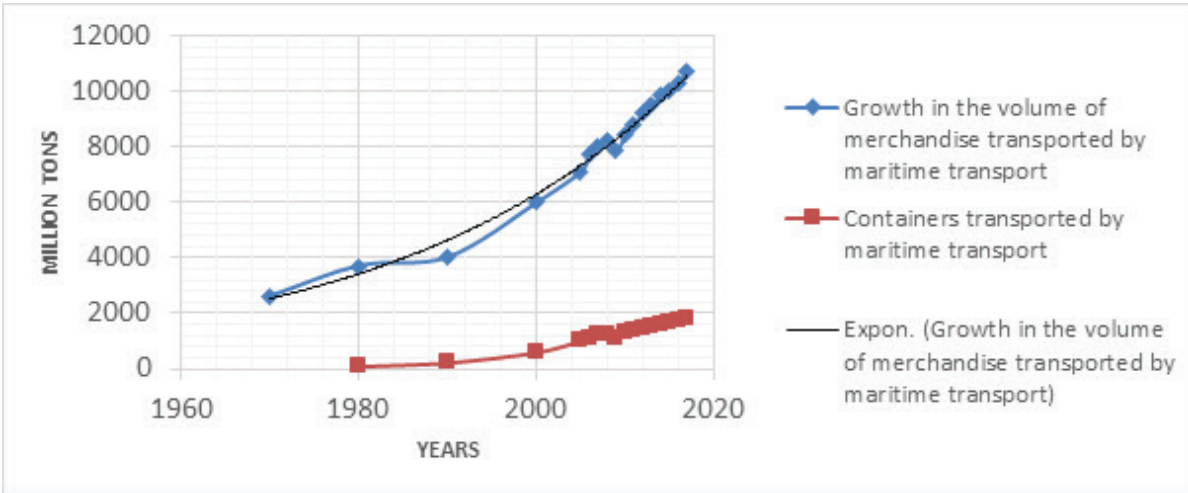


Figure 1.
Maritime transport services evolution (UNCTAD, 2018).

In the remainder of this paper, Section 2 presents an overview of seaport challenges. Dry port concept is defined in Section 3. In Section 4, we propose a systematic literature review in order to give a global vision about the concept development. The results of the research development are presented in Section 5. The concluding remarks and discussion are provided in Section 6.

2. AN OVERVIEW OF SEAPORT CHALLENGES

The seaport is the most important node in the international transportation chain. In general, with the growth of the world economy, the demand for the maritime transport services is increasing considerably (Figure 1), which raises challenges for the seaport.

As a result, it is normal to bring more importance on seaport evolution which becomes more and more critical (Mabrouki et al., 2014). Dry port existence has become a solution for seaport problems. Thus, dry port performance is linked to the seaport performance and with a large vision is linked to the dry port-seaport system (Bentaleb et al., 2015a).

In other words, the understanding of the seaport challenges leads us to recognise the dry port necessity and functioning. In Table 1, the most important seaport challenges are listed.

The critical role that seaport plays in the global supply chain requires an adequate solution to optimize the performance of its services in order to overcome these challenges (Table 1). Dry port can improve significantly the performance of the seaport. Therefore, the performance of the dry port seaport system raises (Bentaleb et al., 2015a). Consequently, in order to increase seaport performance, we need to develop more the dry port concept. It represents an intermodal terminal directly connected to the seaport, with high-capacity means of transport, where customers can leave/pick up their goods as if heading directly to a seaport (Roso et al., 2009; Wiegmans et al., 2015). This gives us a relevant solution for optimising seaport services and transforming it to a more efficient system such as the seaport dry port system.

The main purpose of this systematic literature review is to have a global vision of the dry port concept, and its advantages that can increase the efficiency of the seaport services and the whole transportation chain. We propose to achieve this objective by answering the following questions:

- What are the existing definitions of dry port concept?
- How has the dry port concept evolved over time?
- What are the functions and actors of dry port?
- What are the advantages provided by the seaport dry port system?
- How has the research on the concept of dry port developed?
- What are the methods that research focuses on when it deals with the dry port concept?
- Which countries are interested in the dry port concept and how?
- What are the journals and authors interested in the concept of the dry port?

Answering these questions will allow a deep understanding of e.g. dry port concept, role, functions, importance, interactions, and stakeholders.

Table 1.
The most significant seaport challenges.

Seaport challenges	Causes
The difficulties of managing goods today	- The growth of the world economy (Hirst et al., 2009). - The evolution of maritime traffic (UNCTAD, 2018).
Lack of space	- The steady increase in the volume of merchandise trade (UNCTAD, 2018). - The increase in containerisation and its negative effects such as the increase of the containers' number in distress (Berg and Langen, 2015; UNCTAD, 2018). - Urban growth at the entourage of seaports, which prevents seaport expansion. (Hanaoka and Regmi, 2011) -The different types of goods handled add their effect on the layout: The separation of different types of goods for safety purposes (dangerous goods and zones without dangerous goods), reefer containers, etc. (Santarremigia et al., 2018) -The higher these types of goods in a terminal, the lower are the space for other goods: containers with dangerous goods cannot be stacked as high as non-dangerous containers, and the same happens with empty containers. (Hervás-Peralta et al., 2019)
Congestion at seaport access at trucks' entrance	- The large number of containers accommodated and shipped at the same time. (Bentaleb et al., 2015b) - Loading and unloading time. - The insufficient number of access routes to the terminal service of certain seaports.
The increase of transport costs	Non-optimal management of transport flows between seaports and shippers (Lättilä et al., 2013).
Negative environmental impact	The high number of trucks that have a negative environmental impact. (Lättilä et al., 2013; Li et al., 2019; Roso, 2007).

3. DRY PORT CONCEPT

3.1. Definitions

Since the appearance of the dry port concept, researchers have mentioned several definitions with small differences that developed over time. It is e.g. the type of connection between dry port and seaport. Woxenius et al. (2004) in their definition claim the rail as the only type of connection between seaport and dry port. However, Jaržemskis and Vasiliauskas (2007) added the road as a connection in their definition. Then, Witte et al. (2019) used the waterway as a possible type of connection. Table 2 summarises the most cited definitions.

The past period of research on the dry port topic definitions have shown that the concept is visibly much more fertile than we expect.

Table 2.
The most cited definitions of dry port concept.

Source	Year	Definitions	Determinants
(UNCTAD, 1991)	1991	Dry port is located near inland from seaports. It is linked directly to seaport or, in the case of international land movement, is in contact with the sources of imports and destination of exports. Dry ports may be used either in a country that has seaports or in landlocked country, but only surface transport modes are involved in giving access to dry port.	Connected to seaport by surface transport modes.
(Woxenius et al., 2004)	2004	The dry port concept is based on a seaport directly connected with inland intermodal terminals by rail where goods in intermodal loading units can be turned in as if directly to the seaport.	Connected to seaport principally by rail.

(Jaržemskis and Vasiliauskas, 2007)	2007	A dry port is a port situated in the hinterland servicing an industrial/commercial region connected with one or several seaports by rail and/or road transport and is offering specialized services between the dry port and the transmarine destinations. Normally the dry port is containers and multimodal oriented and has all logistics facilities, which is needed for shipping and forwarding agents in a port.	Connected to seaport by rail and/or road transport and is offering specialized services.
(Roso et al., 2009)	2009	The dry port concept is based on a seaport directly connected by rail to inland intermodal terminals, where shippers can leave and/or collect their standardized units as if directly at the seaport.	Connected to seaport by rail and is offering same services as seaport.
(Ng and Girish, 2009)	2009	Dry port can be understood as an inland setting with cargo-handling facilities to allow several functions to carry out, for example, cargo consolidation and distribution, temporary storage of containers, custom clearance, connection between different transport modes, allowing agglomeration of institutions (both private and public) which facilitates the interactions between different stakeholders along the supply chain, etc.	Connected to seaport by different transport modes, allowing agglomeration of institutions both private and public.
(Witte et al., 2019)	2019	Inland ports or dry ports is an inland facility with or without an intermodal terminal and logistics companies, which is directly connected to the seaport(s) with high capacity transport mean (s) either via rail, road or inland waterways, where customers can leave/pick up their standardized units as if directly to a seaport	Connected to seaport by rail, road or inland waterways, same services as seaport.

Table 3.
Dry port advantages.

	Advantages of dry port
Seaport	Reduce congestion at access points; Facilitate inventory management; Positive influence on the cost of storage; Increase the storage capacity of goods; Facilitate and increase the speed of services.
City	Reduction of traffic congestion.
Environment	Reduction of influence of CO2 caused by emissions from trucks.
Shippers	Reduce transportation cost; Reduce storage cost; Facilitate access to seaports.
Country (society)	Develop commercial transport flows; More benefits for landlocked countries; More jobs in areas near the dry port.
Rail way companies	Diversification of the commercial offer.

3.2. Dry Port Roles

The establishment of the dry port brings a number of advantages to the seaport performance and touches upon other aspects. Table 3 sheds light on the advantages of the dry port.

As an option to decrease congestion, seaport challenges, and reduction in transportation cost, dry ports have a key role to play in advancing seaport connectivity.

3.3. Dry Port Functions

In general, the dry port functions are similar to the seaport except for the connection with the sea. They are replaced with other functions related to other transport means, essentially railway, but sometimes waterway or road are also considered. Figure 2 presents the major dry port functions.

According to Crainic et al. (2015), dry port can assume three main types within the transport chain: satellite terminal, load centre, and transhipment facility. In order for the seaport to function successfully, it is required to develop not only the seaport infrastructure, but also dry port functions.

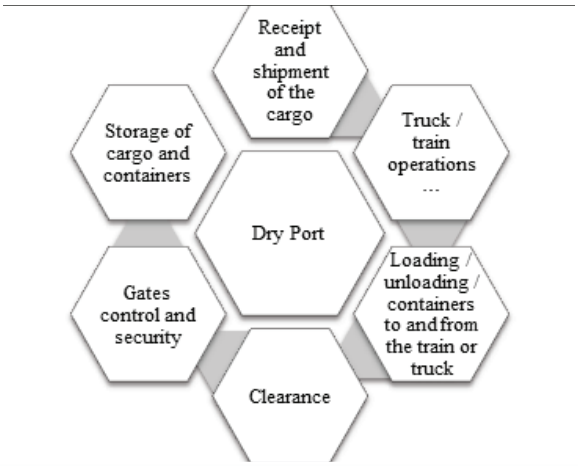


Figure 2.
Dry port functions (Hayut, 1980; Notteboom and Rodrigue, 2009; UNCTAD, 1991).

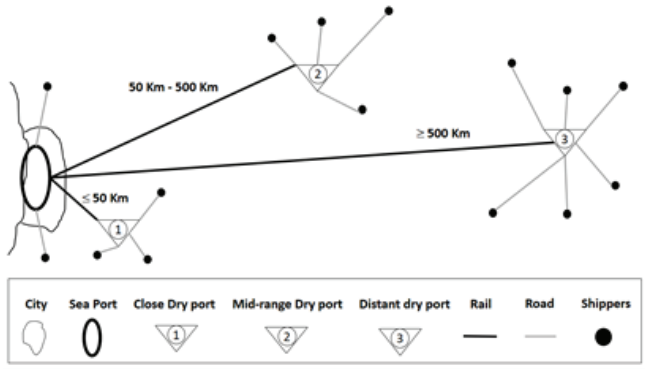


Figure 3.
Dry port types (Bask et al., 2014; Roso et al., 2009).

3.4. Dry Port Types

The research community distinguishes between three types of dry ports based on the distance between seaport and dry port. Thus, they are named close dry port, mid-range dry port, and distant dry port (Figure 3).

Each type has its own characteristics. Table 4 explains the particularities and the advantages (Crainic et al., 2015; Tsao and Thanh, 2019; Woxenius et al., 2004).

There are different dry port types that correspond to different seaport configurations. Hence, different types of dry port have been developed in different regions (Rodrigue and Notteboom, 2012; Santarremigia et al., 2018). The types of dry ports play an essential role in the development process. As shown in Table 4, there are a number of competitive advantages that dry ports can supply to maintain seaport development.

Table 4.
Dry port type particularities.

Type	Distance to seaport	Advantages
Distant dry port	More than 500 kilometres	Transhipment -Transport over long distance; -Reduce traffic congestion (Roso et al., 2009); -The distance factor plays a remarkable role on reducing the transportation costs and the negative impact on the environment. (Bask et al., 2014; Crainic et al., 2015; Roso et al., 2009; Tsao and Thanh, 2019; Woxenius et al., 2004)
Mid-range dry port	Between 50 and 500 kilometres	Load centre -Reduce transportation costs (Roso et al., 2009), -Reduce traffic congestion; -Have positive environmental impact. -Represent effective point for consolidation (Tsao and Thanh, 2019; Woxenius et al., 2004)
Close dry port	Less than 50 kilometres	Satellite terminal - Offer large storage space for seaports;(Bask et al., 2014; Crainic et al., 2015; Tsao and Thanh, 2019) - Offer greater possibilities for buffering containers around seaport to reduce local traffic (Bask et al., 2014; Tsao and Thanh, 2019) -Offer consolidation of transport flow to and from seaport. (Crainic et al., 2015)

3.5. Dry Port Life Cycle Development

In the earliest research on the dry port seaport system, the first mention of a graphic modelling of the system was in 2011, when Wilmsmeier et al. (2011) presented a model that clarifies the spatial evolution of the relation structure between the dry port and the seaport (Figure 4). This model presents two types of connections. The inside-out development begins from the dry port, and the outside-in development starts from the seaport.

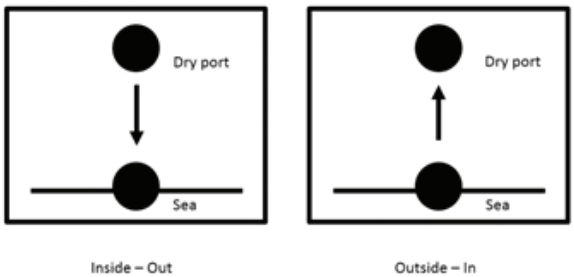


Figure 4.
Wilmsmeier et al. (2011) model.

In addition, Bask et al. (2014) linked the model of Wilmsmeier et al. (2011) with the time factor in order to give a model of three phases: 1) Pre-phase, 2) Start-up phase, and 3) Growth phase, as shown in Figure 5.

Pre-phase is the phase of the dry port creation, where several basic questions arise, e.g. Is the existence of the dry port important? Is there a robust infrastructure and strategy that supports the creation of the dry port?

Start-up phase is the opening. It is the first step in the implementation of the dry port plans. At this stage, the actors involved discuss the execution process and the investment on the direction development.

Growth phases is the development of the dry port in an operational direction, e.g. the introduction of a diversity added-value activities and the increase of relations between the actors involved.

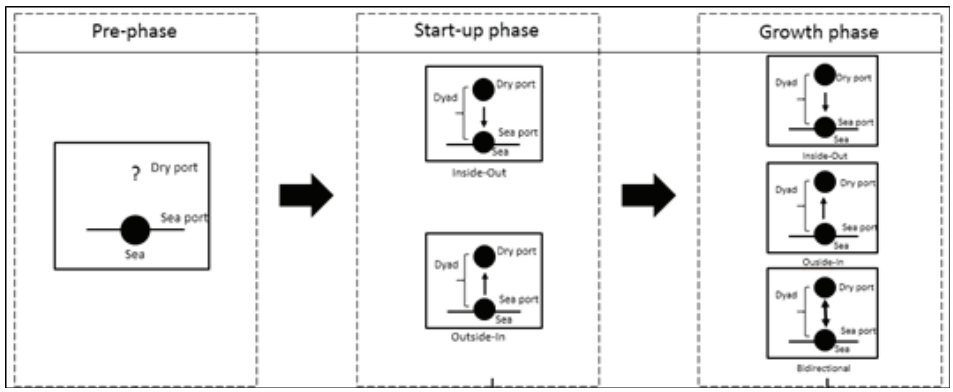


Figure 5.
Bask et al. (2014) model.

In 2016, Bentaleb et al. (2016) apply the Vernon (1966) theory of product life cycle to the dry port-seaport system, which involves a description of its phases as follows:

Development phase: The recognition of dry port in the transportation structure is prepared. The first questions asked at this stage are about the necessity of the dry port. The managers of the dry port put together an implementation plan. The plan should define the targets and goals of the dry port over the short, intermediate, and long term.

Introduction phase: The introduction of a dry port position in the transport system with some services is finished. Activities are elementary. The geographic reach is limited to the adjacent city.

Growth phase: The dry port's services increase. Standardisation and process innovation are addressed and implemented. The dedicated regions of the dry ports increase. Dry port develops in the operational direction.

Maturity phase: The dry port activity increases at a slower rate. Competition in the market augments as the number of dry ports augments. The external competition increases simultaneously and in proportion with increased maturity. This phase includes three sub-phases, i.e.:

Sub-phase (4.1): inside-out or outside-in (the case of one seaport with many dry ports). In this sub-phase, we witness the start of limited connections between the seaport and other dry ports, which represents a spatial development of one seaport with several dry ports.

Sub-phase (4.2): bidirectional development (the case of one seaport with many dry ports). This sub-phase represents the operational development direction of one seaport with many

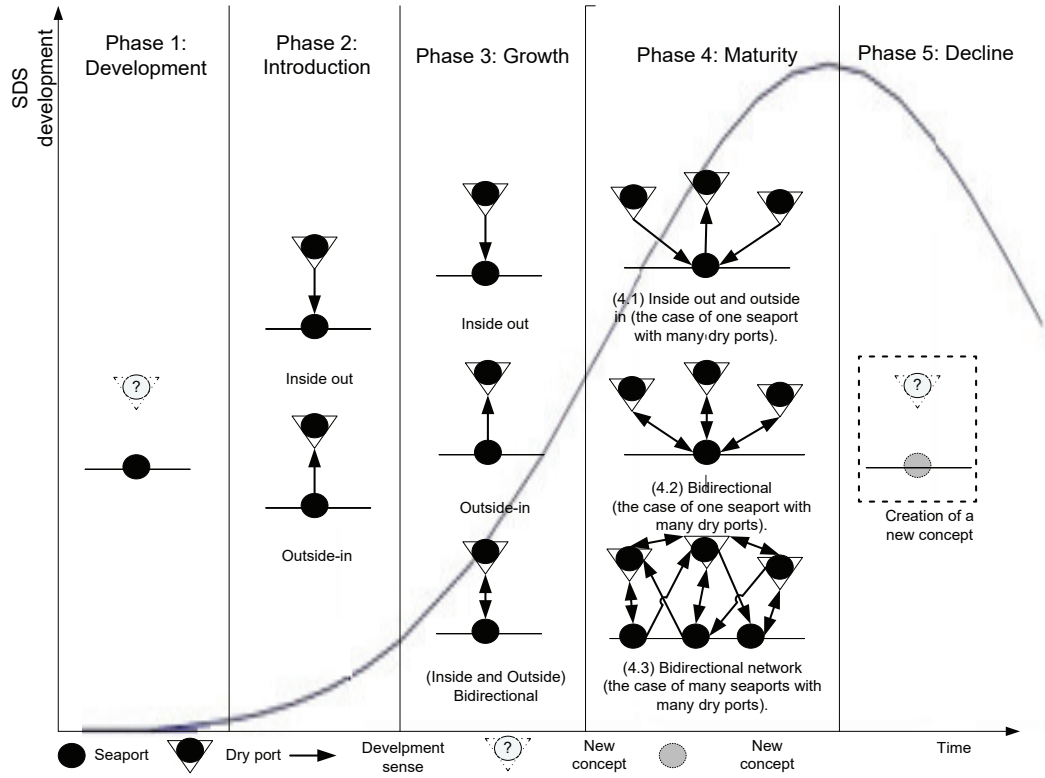


Figure 6.
Bentaleb et al. (2016) model.

dry ports, such as the development of a variety of added-value services, which makes the connection between seaport and the other dry ports more efficient.

Sub-phase (4.3): bidirectional network (i.e. the case of many seaports with many dry ports). This sub-phase represents the operational development direction of many seaports with many dry ports.

Decline phase: This happens eventually when we arrive to the point of the limitations in feasible rationalization or when the improvement process in general is achieved.

In this phase, we can announce the decline of this system, and maybe a new concept will be created, which could be a direction of future research.

The life cycle of the dry port concept will help to make the research more comprehensive. However, as shown above, our literature research is still based on individual case studies. It is essential to conceptualise the progress of the dry port in a more systematic approach. Therefore, this review paper shows a systematic review of journal papers on the dry port progress between 1980 and 2020. We try to organise the concept of the dry port on different investigative levels.

4. SYSTEMATIC LITERATURE REVIEW

Dry port development has had additional consideration by researchers and academics all over the world. A systematic review by Bentaleb et al. (2015a) of the dry port development between 1986 and 2015 revealed that there is a lack of studies relating literature review of the dry port concept. We followed a process of seven steps (Figure 7). This facilitates the analysis of the review and provides possible answers to the questions.

- **Step 1: Establishment of the time period**

In this step, we chose a time interval that starts from 1980 to 2020. The reason behind this choice is to have a more global vision on the concept of dry port, and because of the fact that before 1980 we did not find articles clearly related to the dry port concept.

- **Step 2: Definition of the keywords**

Here we chose three keywords, i.e. Dry Port, Inland Port, and Inland Intermodal Terminal, which define the same concept. Since each author uses one of these keywords to describe the concept of the dry port, we chose these three words to globalize research and increase the number of articles collected.

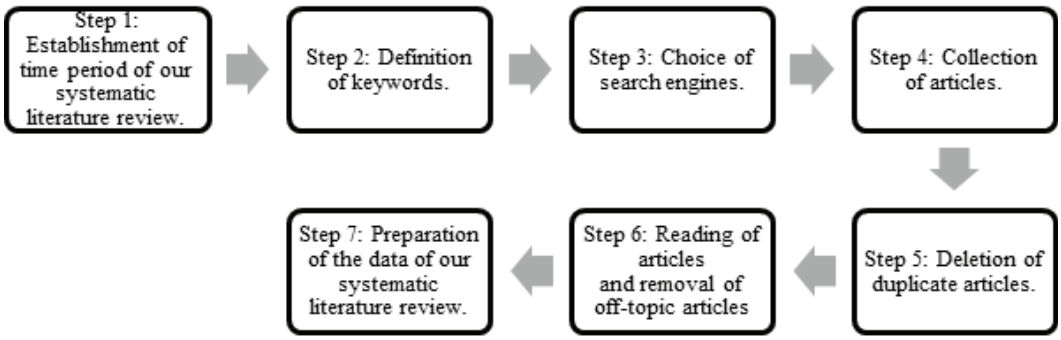


Figure 7.
Systematic literature review process.

- **Step 3: Choice of search engines**

The choice of search engines in the literature review remains as a very important step. In our case, we chose seven engines, i.e. Web of Science, Science direct, Google Scholar, IEEE Explore, Taylor & Francis, Jstor and Springer link, to expand the research scope of the literature review.

- **Step 4: Collection of articles (674 articles)**

In this step, we started the collection of articles with two conditions. The first condition was that the document was a qualified journal article or a chapter (we did not include conference paper), and the second condition was that the title and the abstract of the document collected should be linked with one of the three chosen keywords.

When we typed a keyword in the search engines, each search engine displayed a certain number of results found in a limited number of pages. Table 5 presents the number of articles collected in each search engine whose titles and their abstracts directly related to the concept of the dry port, to arrive at a total of 674 documents collected.

- **Step 5: Deletion of duplicate articles (297 remained articles)**

The keywords used (Dry Port, Inland Port, Inland Intermodal Terminal) are very similar, which justifies the high number of duplicate articles of the total number of documents collected. Therefore, in this step we deleted the duplicate articles.

- **Step 6: Article reading and removal of the off-topic articles (125 removed articles)**

This step required accurate reading of each document to eliminate off-topic articles.

- **Step 7: Preparation of data on systematic literature review (172 retained articles)**

This step represents the final phase of the data structuring process. It facilitates the analysis of the data, and provides the most important information about it. Due to this step, we can have a global idea about the dry port concept and answer the above mentioned questions easily.

Table 5.
Number of articles collected in each search engine.

Key Words	Search engines	Articles collected
Dry Port	Science direct	**52 articles**
	Google scholar	**97 articles**
	IEEE	**1 articles**
	Taylor and Francis	**20 articles**
	Springer	**10 articles**
	Jstor	**4 articles**
	Web of Science	**98 articles**
Inland intermodal terminal	Science direct	**31 articles**
	Google scholar	**73 articles**
	IEEE	**4 articles**
	Taylor and Francis	**10 articles**
	Springer	**12 articles**
	Jstor	**2 articles**
	Web of Science	**18 article**
Inland port	Science direct	**35 articles**
	Google scholar	**134 articles**
	IEEE	**1 articles**
	Taylor and Francis	**13 articles**
	Springer	**6 articles**
	Jstor	**3 articles**
	Web of Science	**51 articles**
Total:		**674**

5. REVIEW ANALYSIS

5.1. Research Evolution

The goal of this section is to understand the evolution and to study tendency research about the dry port concept within the researchers' community. Consequently, based on the publication evolution of the selected papers, we can distinguish three major phases (Figure 8). Due to the limited number of published articles, we determine the first phase between 1980 and 2003. In this first phase, the treatment of the dry port concept is modest; we can explain this reticence by a lack of necessity of the dry port role. The second phase is between 2004 and 2010. It represents a remarkable point of evolution. The number of articles starts to increase clearly due to the increase in interest for the dry port role. Finally, the third phase is from 2011 until 2019. In this stage, the production of the articles related to the dry port concept significantly increases.

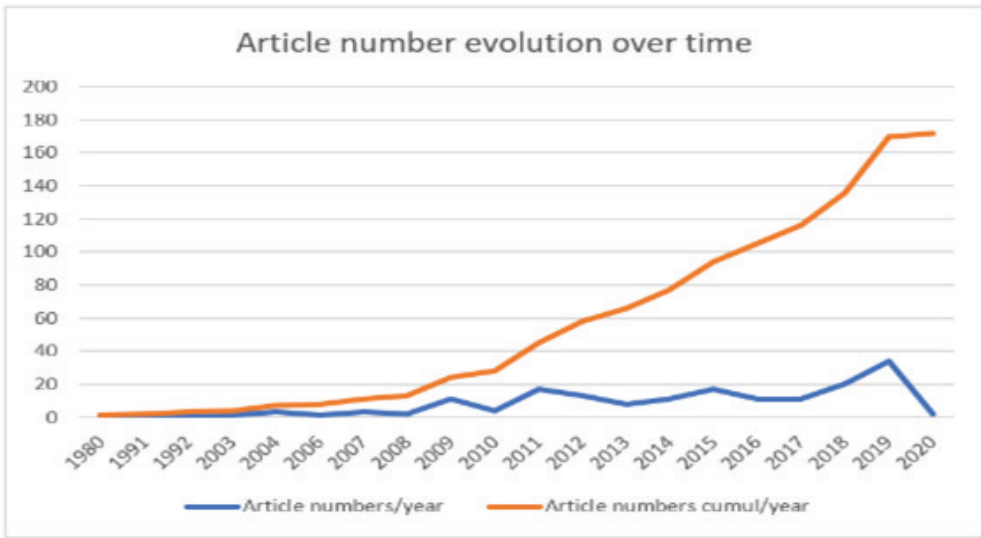


Figure 8.
Evolution of articles' number over time.

We can interpret this result by saying that the concept of the dry port becomes more important each year (Do et al., 2011; Witte et al., 2019). It shows that each year the researchers gain knowledge of the importance of the dry port concept and how it represents a perfect solution of seaport problems.

5.2. Dry Port Research Themes Evolution

We made a classification of the selected articles according to eight topics (see Table 6). These topics came as results of brainstorming done by our research team in order to establish

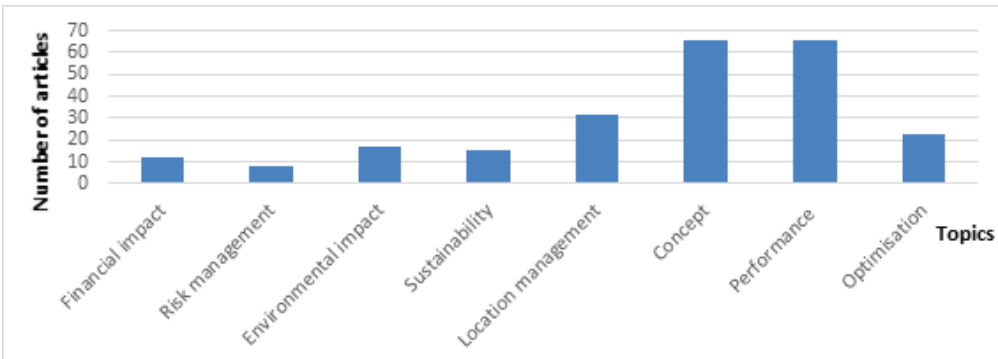


Figure 9.
Number of articles' classification according to different research topics.

the most important topics that we could find in our systematic literature review to reinforce our future research on seaport dry port system.

The point from this classification is to have a vision on the most important topics or themes assessed in the dry port papers. We found that optimization, performance, concept, location management, sustainability, environmental impact, risk management, and financial impact are the most important topics in the systematic literature review.

Moreover, we can note that sometimes we found many themes in the same article.

However, as Figure 9 shows, the majority of the articles cover two topics, concept and performance of the dry port. That is due to the concept novelty, which explains some differences in the definitions of the dry port concept. In addition, researchers try to understand better the dry port performance and its impact.

In the articles that assess location management, we found that most of the criteria used are economic criteria, which focus primarily on the reduction of the cost of transport. Environmental criteria mainly deal with the positive impact of installing a dry port. Geographical or spatial criteria focus on the geographical accessibility and limitation. Social criteria assess the availability and skill level of the workforce, the policy that focuses on the policy of the country related to the chosen place and other criteria that change according to the context assessed in the article (Awad-Núñez et al., 2016; Bentaleb et al., 2016; Komchornrit, 2017; Nguyen and Notteboom, 2016; Roso et al., 2015, 2015). Because of the multiple criteria of the location management problem, we noticed that most articles treated the location management of the dry port using hybrid approaches based on MCDM (multi-criteria decision making) methods like AHP, ELECTRE, Fuzzy ANP or MACBETH (Abdoulkarim et al., 2019; Bentaleb et al., 2016; Ka, 2011; Komchornrit, 2017; Roso et al., 2015; Wei et al., 2010).

Subsequently, we realized the time projection of the themes, which gave us a vision on the temporal progress of each theme in the systematic literature review. Figure 10 shows the evolution of articles about the dry port concept over time and their domain of studies. However, after the year 2010, the number of articles that touch the performance aspect increased in a remarkable way. It could be explained by changing the research angle of vision. In the beginning, research treated the concept in a general way; then, we noticed a development of the topics treating other aspects of the dry port concept over time, e.g. dry port performance.

The main reason behind this development is that at first the concept was ambiguous and unknown. However, over time the importance of the dry port has become more interesting for the researchers, who revealed other themes of research, e.g. performance, in Bentaleb et al. (2015a), Li and Jiang (2014); location management, in Bentaleb et al. (2016), Ka (2011), Nguyen and Notteboom (2016); life cycle, in Bask et al. (2014), Wang (2014); risk management, in Bentaleb et al.(2015b), Gong and Liu (2020).

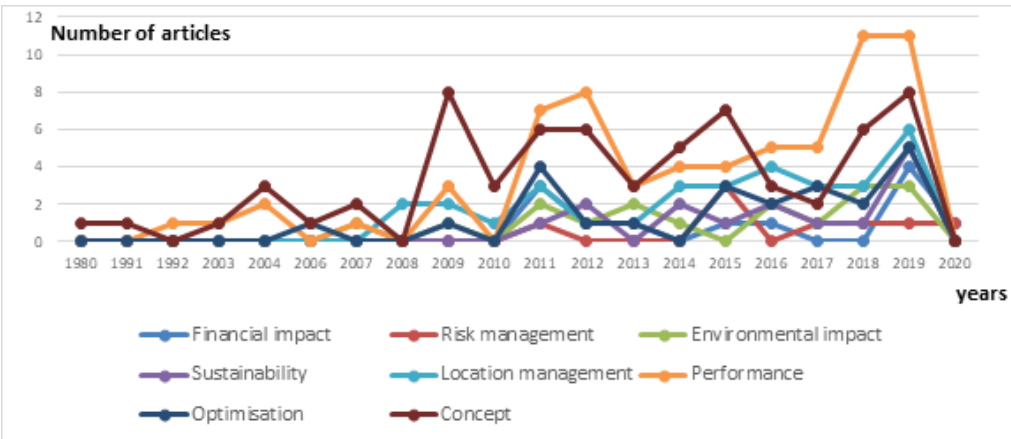


Figure 10.
Evolution of papers' number on dry port theme over time.

5.3. Dry Port Research Methods' Evolution

In this section, a classification is made according to eight sets of methods (Table 6). Each set represents a category of methods used. The goal is to clarify the methods used by the authors of the selected articles.

The eight sets of methods are:

Table 6.
Eight sets of methods used in dry port articles.

Sets	Set description	Methods or types	Papers number
A	Articles dedicated entirely to literature review (4 Articles) Articles contain sections of literature review or about reviews (69 Articles).	Literature reviews and previews.	73
B	Case studies, where the treatment focused on a certain dry port, region or a precise country.	Case studies.	143
C	Articles using graphic modelling methods.	Graphic modelling.	10
D	Studies based on interviews or/and survey.	Interviews and survey	58
E	Articles that use mathematical modelling or optimization methods.	Mathematical models.	71
F	Studies based on the database, reports or archives.	Database, reports or archives analysis.	66
G	Articles based on computer software, numerical analysis or computer languages. For example, Cortés et al. (2007) present a simulation using Arena software in order to simulate the inland port of Seville; Henttu et al. (2011) used an optimisation software CPLEX in their research on the optimal impact of dry port on environment, etc.	Computer languages and computer software	11
H	Articles that contained other analytical methods.	Other analytical methods	14

In this section, we made a time projection (Figure 11) of the method sets (Table 6). The point is to have a clear idea about the used methods' evolution. Moreover, as we can notice in Figure 11, most researchers relate their articles to some region, country or a precise dry port (set B) in order to give their research certain legitimacy which makes the set B the most dominant set over all the period of the systematic literature review.

In 2009, the sets of reviews and previews (A) using interviews/questionnaires (D) and databases, archives or reports (F) rank as the most used methods after the set of case studies (B). Then, the other sets of mathematical methods (E), computer software or computer languages (G), Graphic modelling (C), and the set of methods like SWOT/ benchmarking… (H) started to increase over time.

We can explain this order by the nature of development of the topics in Figure 10. In order to provide a clarification of the concept of the dry port, we return to literature review and archives. If we want to deal with the performance of the dry port or any other theme, interviews, mathematical methods, and other methods like SWOT, graphic modelling, etc. are used.

One of the most important findings that we noticed through our systematic literature review is the existence of four articles entirely dedicated to the dry port literature review (Roso and Lumsden, 2010; Bentaleb et al., 2015c; Rožić et al., 2016; Witte et al., 2019). Each article gives us a different angle of view on the dry port concept (Table 7) starting in 2010 with Roso and Lumsden (2010). They present a literature review that gives us a clear vision of the concept of the dry port and the world's existing dry ports, which represents a good opportunity for any new practitioner or researcher who wants to start discovering the dry port concept. Then, in 2015, Bentaleb et al. (2015c) give us a systematic literature review based on five steps: 1) problem definition; 2) selection of journals based on the time period between 1986 and 2015, taking in consideration four research engines (Jstor, Sciencedirect, Scopus and Google Scholar); 3) selection of studies; 4) critical evaluation, and 5) synthesis that treats the concept of dry port. The most important points of this systematic literature review are the detailed description of the development of the decision level and an illustration of all the countries where researchers were interested in the dry port concept. Furthermore, in 2016, Rožić et al. (2016) focuse on four pillars in their literature review: 1) the development of the dry port concept; 2) classification and function type of the dry port and the functions that can add value to seaports; 3) technological processes that represent the activities at the terminal, which are conducted with the aim of better quality of cargo handling, and which require appropriate technological elements and real-time work; 4) location determination of inland terminals presenting some methods and criteria used to determine the location of inland terminals. Finally, Witte et al. (2019) present a systematic literature review based on four steps: 1) They define the criteria for inclusion or exclusion of papers; 2) They made a systematic search of the scientific literature based on criteria determined; 3) They analysed the papers and retrieved the relevant information for the review; 4) They performed data analysis and synthesis. The most important points mentioned are: papers published across journals over time; a good view made on the papers published over time; papers by geographical focus over time, where they

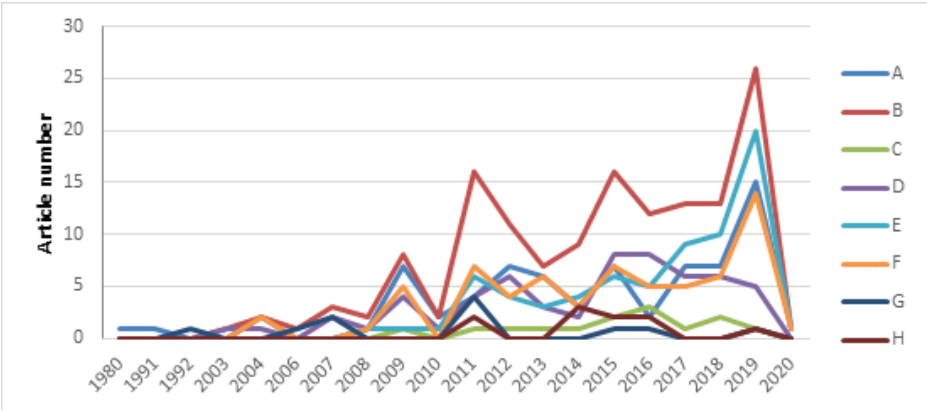


Figure 11.
Methods used evolution over time.

give us an idea about geographical focus; papers by type of methodology over time, dividing the methodology types into six categories: case study, conceptual study, quantitative (modelling), quantitative (empirical), literature reviews and editorials; papers by type of definitions over time; 5) key authors and network collaborations, where they mention most authors contributing in the dry port research; 6) key themes and conceptual approaches over time, where they present tree major periods crossed with four main conceptual approaches globalization/supply chain, port regionalisation, directional development, and institutional governance.

Table 7.
Dry port literature reviews.

Literature reviews	Date	Period time	Systematic (yes or no)	Research methodology	Research engines	Number of articles studied
Roso and Lumsden (2010)	2010	Not specified	no	1) List of dry ports obtained from journals, internet base documents, containerisation International and World Cargo News. 2) After identifying the list of dry ports, interview starts on the dry ports, based on telephone survey and questionnaires sent to emails. 3) Synthesis.	Not specified	Not mentioned.
Bentaleb et al. (2015c)	2015	1986-2015	yes	1) problem definition; 2) selection of journals; 3) selection of studies; 4) critical evaluation; 5) synthesis.	Jstor, Sciencedirect, Scopus, Gooogle Scholar	109
Rožić et al. (2016)	2016	1980-2015	no	Not mentioned.	Not specified	more than 60
Witte et al. (2019)	2019	1992-2017	yes	1) Defining different selection criteria for inclusion or exclusion of papers. 2) A systematic search of the scientific literature based on the criteria. 3) Analysis of the papers and retrieval of the relevant information for the review. 4) Data analysis and synthesis performed.	www.scopus.com	80

However, if we take all the literature reviews found until now on the dry port concept including this paper, we will notice that there are some common points, e.g. the development of the concept of the dry port or the published papers over time.

On the other hand, all these literature reviews complement each other. Each paper gives a different view on the dry port concept: Roso and Lumsden (2010) give a good overview on the existing dry ports; Bentaleb et al. (2015c) give the decision level of the articles between 1986 and 2015, and a detailed geographical description on the dry port concept research. Rožić et al. (2016) add a detailed description of the methods and criteria used to locate the dry port. Witte et al. (2019) illustrate the key themes and conceptual approaches over time. In our paper, we try to give another vision of the themes used in the dry port research.

We add an overview of the life cycle of the dry port development and we try to optimise our systematic methodology of research. We choose our time interval between 1980 and 2019; then, we determine six research engines in order to have more articles evaluating the dry port concept. Therefore, we recommend for all future researchers or practitioners to start with these literature reviews in order to have a clear and complete vision on this interesting concept.

A literature review on the dry port concept contributes to defining the most important flows in the dry port research. Recent studies have shown that the concept is visibly more diversified and much more fertile. Still, as much of the literature is principally based on individual case studies, the research of dry ports has proven to particularly need more focus on operational aspect search, e.g. risk management, performance management, etc.

5.4. Relation Between Topics and Methods

In addition, a cross between the sets of methods and the topics/themes has been realised to get a clear vision of the methods used in each topic (Figure 11). This gave us a great combination in each topic/theme, e.g. in the topic of "concept" we found that the first set of methods used is B (case studies) in order to give legitimacy and realistic aspect to research in this theme. After that, the sets A (literature reviews) and F (return to archives) follow the set B to make a connection between the past and the present in the treatment of the dry port concept. The same reasoning goes for the other themes to make a clear vision on the most used methods in each theme.

Regarding the content of the articles about the relation between topics and methods, Figure 12 shows that cases studies (Set B) are the most treated topics that evoke performance, concept and localization aspects. Furthermore, we observe an important use of methods in relation with performance, concept and localization aspects. With regard to the topic graphic modelling (set C), computer software or computer languages (set G) and other analytical methods (set H) have not been a priority for the research community up to now.

Therefore, most documents are case studies focusing on dry port performance, followed by studies on concepts and localisation.

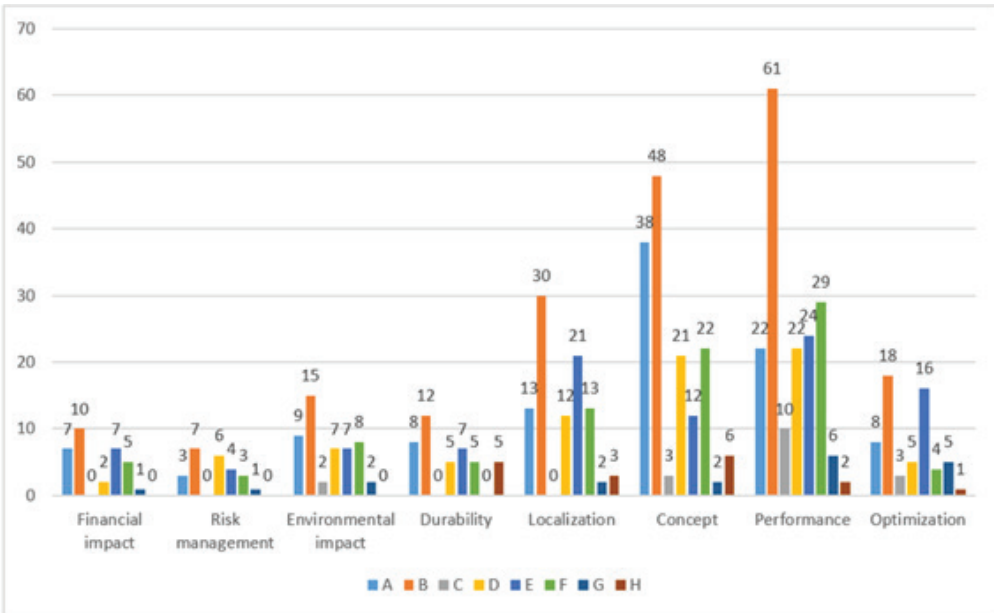


Figure 12.
Methods used in each topic.

5.5. Dry Port Journals and Countries' Trending

In this section, the goal is to identify the most productive journals (Table 8) and countries (Table 9) in relation with the dry port concept. We made a classification of journals and countries according to the number of articles in the systematic literature review. Table 8 shows the most relevant journals found.

This part contains the dry port documents in different countries. Different dry port types were developed in different regions and countries. We accumulate papers from a geographic angle. Table 9 shows the top 20 countries in terms of contribution in the selected documents in the systematic literature review.

Within this trend, interest for the dry port is expanding mutually across the variety of journals covered as well as geographical level. As the recognised research gaps demonstrate, more attention could be covered in terms of further practical studies on the dry port topic.

Table 8.
Journals' trending in dry port topic.

Journals	**Number of articles**
Journal of Transport Geography	**15**
Maritime Policy and Management	**12**
Maritime Economics and Logistics	**9**
Research in Transportation Economics	**9**
Transportation Research Part E	**7**
Research in Transportation Business and Management	**6**
Procedia - Social and Behavioral Sciences	**5**
Sustainability	**5**
the Asian journal of shipping and logistics	**5**
Transportation Research Part A	**4**

Table 9.
Top 20 countries in terms of contribution in the selected documents in the systematic literature review.

Countries	Articles with all the authors from the same country	Articles with authors from different countries	Total number of articles
China	31	16	47
Sweden	9	8	17
The United States of America	7	9	16
The Netherlands	8	7	15
United Kingdom	4	10	14
Spain	10	2	12
Italy	8	1	9
Australia	4	4	8
Belgium	2	6	8
Morocco	5		5
Canada	2	3	5
Croatia	2	3	5
Finland	3	2	5
Malaysia	4	1	5
Chile		4	4
French	2	2	4
Germany	2	2	4
Singapore	2	2	4
Czech Republic	3		3
India	3		3
Russia	3		3

6. CONCLUSION AND DISCUSSION

Over time, the dry port concept has changed from a simple infrastructure exchange point to a real solution for the maritime transport. Dry port studies have also evolved in similar ways. In the end, we found out that the dry port seaport system has become a very interesting subject due to its important contribution in the intermodal transport and its advantages that it can add to the global supply chain management. As this paper reveals, each year the dry port is becoming increasingly attractive for researchers. This is reflected in the development of the dry port concept and the appearance of the dry port types. This evolution has generated a number of implications with regard to the dry port role and functions. The past period of research on the dry port topic definitions have shown that the concept is visibly much more fertile than we expect.

One rising and significant topic emphasised by this study concerns the investigation about dry port case studies and their relationship with the dry port performance. Therefore, this review paper shows a systematic review of journal papers on the dry port progress between 1980 and 2020 (172 considered articles). We have tried to organise the concept on different investigative levels. Based on the evolution and study tendency research as well as the publication evolution of the selected papers, we can distinguish three major phases. First, the research treats the concept in a general way; then, we note a development of topics related to other aspects of the dry port concept over time, like dry port performance. The main reason behind this development is that at first the concept was ambiguous and unknown. Still, over time the importance of the dry port has become more interesting. Within this trend, interest for the dry port as well as the geographical level is increasing mutually in a variety of journals covered. As the recognized research gaps demonstrate, more attention could be expected in terms of further practical studies on the dry port topic. However, as we notice in this paper, despite the development of research, some topics have not been considered adequately, e.g. risk management, environmental impact or the financial influence of the dry port. We notice that there are some gaps in the research about the dry port. Additionally, this article recommends researchers, academics, and professionals to focus more research on the dry port, opening some opportunities for future research on the dry port concept. Finally, it is also essential to present some limitations of this systematic review. A major aspect is the concentration of studies in journals without inclusion of conference papers.

REFERENCES

Abdoulkarim, H.T., Fatouma, S.H. & Kalgora, B., 2019. The Selection of Dry Port Location by Analytic Network Process Model: A Case Study of Dosso-Niger. Journal of Transportation Technologies, 09(02), pp.146–155. Available at: http://dx.doi.org/10.4236/jtts.2019.92009.

Awad-Núñez, S. et al., 2016. A Methodology for Measuring Sustainability of Dry Ports Location Based on Bayesian Networks and Multi-criteria Decision Analysis. Transportation Research Procedia, 13, pp.124–133. Available at: http://dx.doi.org/10.1016/j.trpro.2016.05.013.

Bask, A. et al., 2014. Development of seaport–dry port dyads: two cases from Northern Europe. Journal of Transport Geography, 39, pp.85–95. Available at: http://dx.doi.org/10.1016/j.jtrangeo.2014.06.014.

Bentaleb, F. et al., 2016a. Dry port-seaport system development: Application of the product life cycle theory. Journal of Transportation and Logistics, 1(2), pp.115–128. Available at: http://dx.doi.org/10.22532/jtl.267840.

Bentaleb, F., Mabrouki, C. & Semma, A., 2016b. Dry Port Location Problem: A Hybrid Multi-Criteria Approach. Journal of ETA Maritime Science, 4(1), pp.73–90. Available at: http://dx.doi.org/10.5505/jems.2016.81300.

Bentaleb, F., Mabrouki, C. & Semma, A., 2015a. Key Performance Indicators Evaluation and Performance Measurement in Dry Port-Seaport System: A Multi Criteria Approach. Journal of ETA Maritime Science, 3(2), pp.97–116. Available at: http://dx.doi.org/10.5505/jems.2015.88597.

Bentaleb, F., Mabrouki, C. & Semma, A., 2015b. A Multi-Criteria Approach for Risk Assessment of Dry Port-Seaport System. Supply Chain Forum: An International Journal, 16(4), pp.32–49. Available at: http://dx.doi.org/10.1080/16258312.2015.11728692.

Bentaleb, F., Mabrouki, C. & Semma, A., 2015c. Dry Port Development: A Systematic Review. Journal of ETA Maritime Science, 3(2), pp.75–96. Available at: http://dx.doi.org/10.5505/jems.2015.98608.

Van den Berg, R. & De Langen, P.W., 2014. Towards an "inland terminal centred" value proposition. Maritime Policy & Management, 42(5), pp.499–515. Available at: http://dx.doi.org/10.1080/03088839.2014.928955.

Cortés, P. et al., 2007. Simulation of freight traffic in the Seville inland port. Simulation Modelling Practice and Theory, 15(3), pp.256–271. Available at: http://dx.doi.org/10.1016/j.simpat.2006.11.004.

Crainic, T.G. et al., 2015. Modeling dry-port-based freight distribution planning. Transportation Research Part C: Emerging Technologies, 55, pp.518–534. Available at: http://dx.doi.org/10.1016/j.trc.2015.03.026.

Do, N.-H., Nam, K.-C. & Le, Q.-L.N., 2011. A consideration for developing a dry port system in Indochina area. Maritime Policy & Management, 38(1), pp.1–9. Available at: http://dx.doi.org/10.1080/03088839.2010.533712.

Gong, Z. & Liu, N., 2019. Mitigative and adaptive investments for natural disasters and labor strikes in a seaport–dry port inland logistics network. Maritime Policy & Management, 47(1), pp.92–108. Available at: http://dx.doi.org/10.1080/03088839.2019.1675195.

Hanaoka, S. & Regmi, M.B., 2011. Promoting intermodal freight transport through the development of dry ports in Asia: An environmental perspective. IATSS Research, 35(1), pp.16–23. Available at: http://dx.doi.org/10.1016/j.iatssr.2011.06.001.

Haralambides, H. & Gujar, G., 2011. The Indian dry ports sector, pricing policies and opportunities for public-private partnerships. Research in Transportation Economics, 33(1), pp.51–58. Available at: http://dx.doi.org/10.1016/j.retrec.2011.08.006.

Hayut, Y., 1980. Inland container terminal—function and rationale. Maritime Policy & Management, 7(4), pp.283–289. Available at: http://dx.doi.org/10.1080/03088838000000042.

Henttu, V., Lättilä, L., Hilmola, O.-P., 2011. Optimization of Relative Transport Costs of a Hypothetical Dry Port Structure.

Hervás-Peralta, M. et al., 2019. Improving the Performance of Dry and Maritime Ports by Increasing Knowledge about the Most Relevant Functionalities of the Terminal Operating System (TOS). Sustainability, 11(6), p.1648. Available at: http://dx.doi.org/10.3390/su11061648.

Hirst, P., Thompson, G., Bromley, S., 2009. Globalization in Question (3rd edition). Polity, Cambridge, UK / Malden, MA, USA.

Jaržemskis, A. & Vasiliauskas, A.V., 2007. Research on Dry Port Concept as Intermodal Node. Transport, 22(3), pp.207–213. Available at: http://dx.doi.org/10.3846/16484142.2007.9638126.

Ka, B., 2011. Application of Fuzzy AHP and ELECTRE to China Dry Port Location Selection. The Asian Journal of Shipping and Logistics, 27(2), pp.331–353. Available at: http://dx.doi.org/10.1016/s2092-5212(11)80015-5.

Komchornrit, K., 2017. The Selection of Dry Port Location by a Hybrid CFA-MACBETH-PROMETHEE Method: A Case Study of Southern Thailand. The Asian Journal of Shipping and Logistics, 33(3), pp.141–153. Available at: http://dx.doi.org/10.1016/j.ajsl.2017.09.004.

Lättilä, L., Henttu, V. & Hilmola, O.-P., 2013. Hinterland operations of sea ports do matter: Dry port usage effects on transportation costs and CO2 emissions. Transportation Research Part E: Logistics and Transportation Review, 55, pp.23–42. Available at: http://dx.doi.org/10.1016/j.tre.2013.03.007.

Li, J., Jiang, B., 2014. Cooperation Performance Evaluation between Seaport and Dry Port; Case of Qingdao Port and Xi'an Port. International Journal of e-Navigation and Maritime Economy 1, 99–109. Available at: https://doi.org/10.1016/j.enavi.2014.12.009.

Li, W., Hilmola, O.-P. & Panova, Y., 2019. Container Sea Ports and Dry Ports: Future CO2 Emission Reduction Potential in China. Sustainability, 11(6), p.1515. Available at: http://dx.doi.org/10.3390/su11061515.

Mabrouki, C., Bentaleb, F. & Mousrij, A., 2014. A decision support methodology for risk management within a port terminal. Safety Science, 63, pp.124–132. Available at: http://dx.doi.org/10.1016/j.ssci.2013.09.015.

Ng, A.K.Y., Girish, G., 2009. The spatial characteristics of dry ports in India, in: Transport and Communications Bulletin for Asia and the Pacific. pp. 102–111.

Nguyen, L.C. & Notteboom, T., 2016. A Multi-Criteria Approach to Dry Port Location in Developing Economies with Application to Vietnam. The Asian Journal of Shipping and Logistics, 32(1), pp.23–32. Available at: http://dx.doi.org/10.1016/j.ajsl.2016.03.003.

Notteboom, T., Rodrigue, J.-P., 2009. Inland terminals within North American and European supply chains, in: Transport and Communications Bulletin for Asia and the Pacific. pp. 1–39.

Rodrigue, J.-P. & Notteboom, T., 2012. Dry ports in European and North American intermodal rail systems: Two of a kind? Research in Transportation Business & Management, 5, pp.4–15. Available at: http://dx.doi.org/10.1016/j.rtbm.2012.10.003.

Roso, V., 2007. Evaluation of the dry port concept from an environmental perspective: A note. Transportation Research Part D: Transport and Environment, 12(7), pp.523–527. Available at: http://dx.doi.org/10.1016/j.trd.2007.07.001.

Roso, Brnjac & Abramovic, 2015. Inland Intermodal Terminals Location Criteria Evaluation: The Case of Croatia. Transportation Journal, 54(4), p.496. Available at: http://dx.doi.org/10.5325/transportationj.54.4.0496.

Roso, V. & Lumsden, K., 2010. A review of dry ports. Maritime Economics & Logistics, 12(2), pp.196–213. Available at: http://dx.doi.org/10.1057/mel.2010.5.

Roso, V., Woxenius, J. & Lumsden, K., 2009. The dry port concept: connecting container seaports with the hinterland. Journal of Transport Geography, 17(5), pp.338–345. Available at: http://dx.doi.org/10.1016/j.jtrangeo.2008.10.008.

Rožić, T., Rogić, K. & Bajor, I., 2016. Research Trends of Inland Terminals: A Literature Review. PROMET - Traffic&Transportation, 28(5), pp.539–548. Available at: http://dx.doi.org/10.7307/ptt.v28i5.2090.

Santarremigia, F.E. et al., 2018. Railway safety by designing the layout of inland terminals with dangerous goods connected with the rail transport system. Safety Science, 110, pp.206–216. Available at: http://dx.doi.org/10.1016/j.ssci.2018.03.001.

Tsao, Y.-C. & Thanh, V.-V., 2019. A multi-objective mixed robust possibilistic flexible programming approach for sustainable seaport-dry port network design under an uncertain environment. Transportation Research Part E: Logistics and Transportation Review, 124, pp.13–39. Available at: http://dx.doi.org/10.1016/j.tre.2019.02.006.

UNCTAD, 2018. Review of Maritime Transport 2018.

UNCTAD, 1991. Handbook on the Management and Operation of Dry Ports.

Wang, Y., 2014. Reaserch on Sustainable Development of Inland Port - Hinterland System Based on Life-Cycle Theory. Advanced Materials Research, 962-965, pp.2485–2488. Available at: http://dx.doi.org/10.4028/www.scientific.net/amr.962-965.2485.

Wei, J., Sun, A. & Zhuang, J., 2010. The Selection of Dry Port Location with the Method of Fuzzy-ANP. Advances in Wireless Networks and Information Systems, pp.265–273. Available at: http://dx.doi.org/10.1007/978-3-642-14350-2_33.

Wiegmans, B., Witte, P. & Spit, T., 2015. Characteristics of European inland ports: A statistical analysis of inland waterway port development in Dutch municipalities. Transportation Research Part A: Policy and Practice, 78, pp.566–577. Available at: http://dx.doi.org/10.1016/j.tra.2015.07.004.

Wilmsmeier, G., Monios, J. & Lambert, B., 2011. The directional development of intermodal freight corridors in relation to inland terminals. Journal of Transport Geography, 19(6), pp.1379–1386. Available at: http://dx.doi.org/10.1016/j.jtrangeo.2011.07.010.

Witte, P., Wiegmans, B. & Ng, A.K.Y., 2019. A critical review on the evolution and development of inland port research. Journal of Transport Geography, 74, pp.53–61. Available at: http://dx.doi.org/10.1016/j.jtrangeo.2018.11.001.

Woxenius, J., Roso, V., Lumsden, K., 2004. The dry port concept–connecting seaports with their hinterland by rail.

Vernon, R., 1966. International Investment and International Trade in the Product Cycle. The Quarterly Journal of Economics, 80(2), p.190. Available at: http://dx.doi.org/10.2307/1880689.

SUPPLEMENT

Theme	Number of articles	Articles
Financial impact	12	(Haralambides and Gujar, 2011), (Henttu and Hilmola, 2011), (Henttu et al., 2011), (Lättilä et al., 2013),(Panova and Hilmola, 2015), (Smid et al., 2016), (Facchini et al., 2020), (Qiu and Lee, 2019), (Whitman et al., 2019), (Qiu and Xu, 2019), (Iannone, 2012), (Chang et al., 2019a).
Risk management	8	(Schindlbacher et al., 2011), (Panova and Hilmola, 2015), (Bentaleb et al., 2015c), (Molero et al., 2017), (Santarremigia et al., 2018), (Ng et al., 2015), (Gong and Liu, 2020), (Yosef et al., 2019).
Environmental impact	17	(Roso, 2007), (Roso, 2009), (Hanaoka and Regmi, 2011), (Henttu and Hilmola, 2011), (Haralambides and Gujar, 2012), (Dooms et al., 2013), (Lättilä et al., 2013), (Wu et al., 2014), (Muravev and Rakhmangulov, 2016), (Seguí et al., 2016), (Vejvar et al., 2018), (Tsao and Linh, 2018), (Pham and Lee, 2019), (Chang et al., 2019a), (Li et al., 2019), (Wei and Sheng, 2017), (Qiu and Lam, 2018).
Durability/Sustainability	15	(Cullinane and Wilmsmeier, 2011), (Beresford et al., 2012), (Rodrigue and Notteboom, 2012), (Wu et al., 2014), (Wang, 2014), (Awad-Núñez et al., 2015), (Awad-Núñez et al., 2016a), (Awad-Núñez et al., 2016b), (Vejvar et al., 2018), (Muravev et al., 2019), (Ližbetin, 2019), (Tsao and Thanh, 2019), (Wei and Sheng, 2017), (Hui et al., 2019), (Wiercx et al., 2019), .
Location management	32	(Roso, 2008), (Rahimi et al., 2008), (Rosa and Roscelli, 2009), (Ng and Girish, 2009),(Wei et al., 2010), (Chang et al., 2011), (Flämig and Hesse, 2011), (Bentaleb et al., 2016a), (Ka, 2011), (Feng et al., 2013), (Rožić et al., 2014), (Ambrosino and Sciomachen, 2014), (Awad-Núñez et al., 2014), (Chang et al., 2015), (Awad-Núñez et al., 2015), (Roso et al., 2015a), (Awad-Núñez et al., 2016a), (Awad-Núñez et al., 2016b), (Muravev and Rakhmangulov, 2016), (Nguyen and Notteboom, 2016), (Wang et al., 2018), (Komchornrit, 2017), (Monios and Wilmsmeier, 2012a), (Santos and Guedes Soares, 2017), (Raimbault, 2019), (Ližbetin, 2019), (Van Nguyen et al., 2019), (Chang et al., 2019a), (Gonzalez-Aregall and Bergqvist, 2019), (Owusu Kwateng et al., 2017), (Black et al., 2018), (Sun and Wang, 2018), (Abdoulkarim et al., 2019b).
Concept	66	(Hayut, 1980), (UNCTAD, 1991), (WALTER and POIST, 2003), (Wood, 2004), (Woxenius et al., 2004), (Walter and Poist, 2004), (Jaržemskis and Vasiliauskas, 2007), (Roso, 2007), (Roso et al., 2009), (Ng and Girish, 2009), (K. Y. A. Ng and Gujar, 2009), (Roso and Lumsden, 2009), (Notteboom and Rodrigue, 2009), (Cronje et al., 2009), (AdolfK. Y. Ng and Gujar, 2009), (Caballini and Gattorna, 2009), (Rodrigue et al., 2010), (Bentaleb et al., 2015a), (Roso and Lumsden, 2010), (Ng and Tongzon, 2010), (Hanaoka and Regmi, 2011), (Monios, 2011), (Dadvar et al., 2011), (Cullinane and Wilmsmeier, 2011), (Do et al., 2011), (Korovyakovsky and Panova, 2011), (Cullinane et al., 2012), (Beresford et al., 2012), (Monios and Wilmsmeier, 2012b), (Veenstra et al., 2012), (Chen and Wang, 2012), (Ng and Cetin, 2012), (Ng et al., 2013), (Lättilä et al., 2013), (Zeng et al., 2013), (Rožić et al., 2014), (Bask et al., 2014), (Witte et al., 2014), (Wang, 2014), (Crainic et al., 2015), (Li et al., 2015), (Panova and Hilmola, 2015), (Wiegmans et al., 2015a), (Jeevan et al., 2015), (Berg and Langen, 2015), (Rožić et al., 2016), (Nguyen and Notteboom, 2016), (Witte et al., 2016), (Wang et al., 2018), (Witte et al., 2017), (Wei et al., 2018), (Nguyen and Notteboom, 2019), (Tsao and Linh, 2018), (González-Sánchez et al., 2015), (Witte et al., 2019), (Caris et al., 2014), (Santos and Guedes Soares, 2017), (Pham and Lee, 2019),(Roso et al., 2019),(Tsao and Thanh, 2019)(Montwiłł, 2019), (Khaslavskaya and Roso, 2019), (Bentaleb et al., 2016b), (Protic et al., 2019), (Zhang et al., 2006), (Wiegmans et al., 2019), (Black et al., 2018), (Qiu and Lam, 2018).

Performance	66	(Kondratowicz, 1992), (WALTER and POIST, 2003), (Wood, 2004), (Walter and Poist, 2004), (Cortés et al., 2007), (Cronje et al., 2009), (Garnwa et al., 2009), (AdolfK. Y. Ng and Gujar, 2009), (Hanaoka and Regmi, 2011), (Monios, 2011), (Schindlbacher et al., 2011), (Arango et al., 2011), (Garnwa et al., 2009), (Carrese and Tatarelli, 2011), (Van den Berg and De Langen, 2011), (Liedtke and Carrillo Murillo, 2012), (Padilha and Ng, 2012), (Monios and Wilmsmeier, 2012b), (Rodrigue and Notteboom, 2012), (Chen and Wang, 2012), (Ng and Cetin, 2012), (Mundutéguy, 2012), (Dooms et al., 2013), (Monios and Wang, 2013), (Wen and Chen, 2013), (Wang et al., 2014), (Li and Jiang, 2014), (Witte et al., 2014), (Martínez-Pardo and Garcia-Alonso, 2014), (Wilmsmeier et al., 2015), (Qiu et al., 2015), (Clausen and Kaffka, 2016), (Roso et al., 2015b), (Bentaleb et al., 2015b), (Wiegmans et al., 2015b), (Andersson and Roso, 2016), (Li et al., 2017), (Seguí et al., 2016), (Witte et al., 2016), (Witte et al., 2017), (Wei and Sheng, 2018), (Jeevan et al., 2017), (Jeevan et al., 2018), (Lizbetin and Bartuska, 2019), (Wei et al., 2018), (Carboni and Deflorio, 2018), (Kramberger et al., 2018), (Chang et al., 2019b), (Fazi and Roodbergen, 2018), (Tan et al., 2018), (Oláh et al., 2018), (Wan et al., 2018), (Smid et al., 2016), (Tadić et al., 2019), (Lizbetin and Bartuska, 2019), (Jeevan et al., 2019), (Hossain et al., 2019), (Whitman et al., 2019), (Iannone, 2012), (Khaslavskaya and Roso, 2019), (Gonzalez-Aregall and Bergqvist, 2019), (Protic et al., 2019), (Abdoulkarim et al., 2019a), (Chen et al., 2017), (Hui et al., 2019), (Chen et al., 2018), (Musso and Sciomachen, 2019).
Optimization	23	(K. Y. A. Ng and Gujar, 2009), (Arango et al., 2011), (Carrese and Tatarelli, 2011), (Henttu et al., 2011), (Chang et al., 2011), (Mundutéguy, 2012), (Lam and Gu, 2013), (Crainic et al., 2015), (Qiu et al., 2015), (Rathnayake et al., 2015), (Andersson and Roso, 2016), (Debrie and Raimbault, 2016), (Jeevan et al., 2017), (Nguyen and Notteboom, 2017), (Fazi and Roodbergen, 2018), (Tsao and Linh, 2018), (Wei and Dong, 2019), (Van Nguyen et al., 2019), (Qiu and Xu, 2019), (Chang et al., 2019a), (Zhang et al., 2006), (Wei and Sheng, 2017), (Ji et al., 2019).

REFERENCES

Abdoulkarim, H.T., Fatouma, S.H., Hassane, H.T., 2019a. Assessment of Dry Port Efficiency in Africa Using Data Envelopment Analysis. Journal of Transportation Technologies 09, 193. https://doi.org/10.4236/jtts.2019.92012

Abdoulkarim, H.T., Fatouma, S.H., Kalgora, B., 2019b. The Selection of Dry Port Location by Analytic Network Process Model: A Case Study of Dosso-Niger. Journal of Transportation Technologies 09, 146. https://doi.org/10.4236/jtts.2019.92009

Ambrosino, D., Sciomachen, A., 2014. Location of Mid-range Dry Ports in Multimodal Logistic Networks. Procedia - Social and Behavioral Sciences 108, 118–128. https://doi.org/10.1016/j.sbspro.2013.12.825

Andersson, D., Roso, V., 2016. Developing Dry Ports Through the Use of Value-Added Services, in: Clausen, U., Friedrich, H., Thaller, C., Geiger, C. (Eds.), Commercial Transport, Lecture Notes in Logistics. Springer International Publishing, Cham, pp. 191–203. https://doi.org/10.1007/978-3-319-21266-1_12

Arango, C., Cortés, P., Muñuzuri, J., Onieva, L., 2011. Berth allocation planning in Seville inland port by simulation and optimisation. Advanced Engineering Informatics, Special Section: Engineering informatics in port operations and logistics 25, 452–461. https://doi.org/10.1016/j.aei.2011.05.001

Awad-Núñez, S., González-Cancelas, N., Camarero-Orive, A., 2014. Application of a Model based on the Use of DELPHI Methodology and Multicriteria Analysis for the Assessment of the Quality of the Spanish Dry Ports Location. Procedia - Social and Behavioral Sciences, XVIII Congreso Panamericano de Ingeniería de Tránsito, Transporte y Logística (PANAM 2014) 162, 42–50. https://doi.org/10.1016/j.sbspro.2014.12.184

Awad-Núñez, S., González-Cancelas, N., Soler-Flores, F., Camarero-Orive, A., 2016a. A Methodology for Measuring Sustainability of Dry Ports Location Based on Bayesian Networks and Multi-criteria Decision Analysis. Transportation Research Procedia, Towards future innovative transport: visions, trends and methods 43rd European Transport Conference Selected Proceedings 13, 124–133. https://doi.org/10.1016/j.trpro.2016.05.013

Awad-Núñez, S., González-Cancelas, N., Soler-Flores, F., Camarero-Orive, A., 2015. How should the sustainability of the location of dry ports be measured? A proposed methodology using Bayesian networks and multi-criteria decision analysis. Transport 30, 312–319. https://doi.org/10.3846/16484142.2015.1081618

Awad-Núñez, S., Soler-Flores, F., González-Cancelas, N., Camarero-Orive, A., 2016b. How should the Sustainability of the Location of Dry Ports be Measured? Transportation Research Procedia, Transport Research Arena TRA2016 14, 936–944. https://doi.org/10.1016/j.trpro.2016.05.073

Bask, A., Roso, V., Andersson, D., Hämäläinen, E., 2014. Development of seaport–dry port dyads: two cases from Northern Europe. Journal of Transport Geography 39, 85–95. https://doi.org/10.1016/j.jtrangeo.2014.06.014

Bentaleb, F., Mabrouki, C., Semma, A., 2015c. A Multi-Criteria Approach for Risk Assessment of Dry Port-Seaport System. Supply Chain Forum: An International Journal 16, 32–49. https://doi.org/10.1080/16258312.2015.11728692

Bentaleb, F. Mabrouki, C. Semma A., 2015a. Dry Port Development: A Systematic Review, Journal of ETA Maritime Science, Volume 3, Issue 1, Pages 75 – 96.

Bentaleb, F. Mabrouki, C. Semma A., 2015b. Key Performance Indicators Evaluation and Performance Measurement in Dry Port-Seaport System: A Multi Criteria

Approach, Journal of ETA Maritime Science, Volume 3, Issue 1, Pages 97 -116.

Bentaleb, F. Mabrouki, C. Semma A., 2016a. Dry Port Location Problem: A Hybrid Multi-Criteria Approach, Journal of ETA Maritime Science, Volume 4, Issue 1, Pages 73 – 90.

Beresford, A., Pettit, S., Xu, Q., Williams, S., 2012. A study of dry port development in China. Marit Econ Logist 14, 73–98. https://doi.org/10.1057/mel.2011.17

Berg, R.V. den, Langen, P.W.D., 2015. Towards an 'inland terminal centred' value proposition. Maritime Policy & Management 42, 499–515. https://doi.org/10.1080/03088839.2014.928955

Black, J., Roso, V., Marušić, E., Brnjac, N., 2018. Issues in Dry Port Location and Implementation in Metropolitan Areas: The Case of Sydney, Australia. Transactions on Maritime Science 07, 41–50. https://doi.org/10.7225/toms.v07.n01.004

Caballini, C., Gattorna, E., 2009. THE EXPANSION OF THE PORT OF GENOA: THE RIVALTA SCRIVIA DRY PORT 14.

Carboni, A., Deflorio, F., 2018. Performance indicators and automatic identification systems in inland freight terminals for intermodal transport. IET Intelligent Transport Systems 12, 309–318. https://doi.org/10.1049/iet-its.2017.0349

Caris, A., Limbourg, S., Macharis, C., van Lier, T., Cools, M., 2014. Integration of inland waterway transport in the intermodal supply chain: a taxonomy of research challenges. Journal of Transport Geography 41, 126–136. https://doi.org/10.1016/j.jtrangeo.2014.08.022

Carrese, S., Tatarelli, L., 2011. Optimizing the stacking of the Intermodal Transport Units in an inland terminal: an heuristic procedure. Procedia - Social and Behavioral Sciences, The State of the Art in the European Quantitative Oriented Transportation and Logistics Research – 14th Euro Working Group on Transportation & 26th Mini Euro Conference & 1st European Scientific Conference on Air Transport 20, 994–1003. https://doi.org/10.1016/j.sbspro.2011.08.108

Chang, Z., Lu, J., Qi, Z., 2011. Location Analysis for Dry Ports Based on FCM [WWW Document]. Applied Mechanics and Materials. https://doi.org/10.4028/www.scientific.net/AMM.97-98.1022

Chang, Z., Notteboom, T., Lu, J., 2015. A two-phase model for dry port location with an application to the port of Dalian in China. Transportation Planning and Technology 38, 442–464. https://doi.org/10.1080/03081060.2015.1026103

Chang, Z., Weng, J., Qi, Z., Yang, D., 2019a. Assess economic and environmental trade-off for inland port location. International Journal of Shipping and Transport Logistics 11, 243–261. https://doi.org/10.1504/IJSTL.2019.099277

Chang, Z., Yang, D., Wan, Y., Han, T., 2019b. Analysis on the features of Chinese dry ports: Ownership, customs service, rail service and regional competition. Transport Policy 82, 107–116. https://doi.org/10.1016/j.tranpol.2018.06.008

Chen, H., Cullinane, K., Liu, N., 2017. Developing a model for measuring the resilience of a port-hinterland container transportation network. Transportation Research Part E: Logistics and Transportation Review 97, 282–301. https://doi.org/10.1016/j.tre.2016.10.008

Chen, J., Fei, Y., Zhang, F., Jing, C., 2018. Evaluating Correlations between a Seaport and Its Dry Ports: Case Study of Xiamen Port in China [WWW Document]. Discrete Dynamics in Nature and Society. https://doi.org/10.1155/2018/6831302

Chen, J.H., Wang, Y., 2012. SWOT-PEST Analysis of China's Dry Port [WWW Document]. Advanced Materials Research. https://doi.org/10.4028/www.scientific.net/AMR.479-481.1004

Clausen, U., Kaffka, J., 2016. Development of priority rules for handlings in inland port container terminals with simulation. Journal of Simulation 10, 95–102. https://doi.org/10.1057/jos.2015.11

Cortés, P., Muñuzuri, J., Nicolás Ibáñez, J., Guadix, J., 2007. Simulation of freight traffic in the Seville inland port. Simulation Modelling Practice and Theory 15, 256–271. https://doi.org/10.1016/j.simpat.2006.11.004

Crainic, T.G., Dell'Olmo, P., Ricciardi, N., Sgalambro, A., 2015. Modeling dry-port-based freight distribution planning. Transportation Research Part C: Emerging Technologies, Engineering and Applied Sciences Optimization (OPT-i) - Professor Matthew G. Karlaftis Memorial Issue 55, 518–534. https://doi.org/10.1016/j.trc.2015.03.026

Cronje, E., Matthee, M., Krugell, W., 2009. THE ROLE OF DRY PORTS IN SOUTH AFRICA 9.

Cullinane, K., Bergqvist, R., Wilmsmeier, G., 2012. The dry port concept – Theory and practice. Marit Econ Logist 14, 1–13. https://doi.org/10.1057/mel.2011.14

Cullinane, K., Wilmsmeier, G., 2011. The Contribution of the Dry Port Concept to the Extension of Port Life Cycles, in: Böse, J.W. (Ed.), Handbook of Terminal Planning, Operations Research/Computer Science Interfaces Series. Springer, New York, NY, pp. 359–379. https://doi.org/10.1007/978-1-4419-8408-1_18

Dadvar, E., Ganji, S.R.S., Tanzifi, M., 2011. Feasibility of establishment of "Dry Ports" in the developing countries—the case of Iran. J Transp Secur 4, 19–33. https://doi.org/10.1007/s12198-010-0056-x

Debrie, J., Raimbault, N., 2016. The port–city relationships in two European inland ports: A geographical perspective on urban governance. Cities 50, 180–187. https://doi.org/10.1016/j.cities.2015.10.004

Do, N.-H., Nam, K.-C., Le, Q.-L.N., 2011. A consideration for developing a dry port system in Indochina area. Maritime Policy & Management 38, 1–9. https://doi.org/10.1080/03088839.2010.533712

Dooms, M., Haezendonck, E., Valaert, T., 2013. Dynamic green portfolio analysis for inland ports: An empirical analysis on Western Europe. Research in Transportation Business & Management, Port Performance and Strategy 8, 171–185. https://doi.org/10.1016/j.rtbm.2013.07.006

Facchini, F., Digiesi, S., Mossa, G., 2020. Optimal dry port configuration for container terminals: A non-linear model for sustainable decision making. International Journal of Production Economics 219, 164–178. https://doi.org/10.1016/j.ijpe.2019.06.004

Fazi, S., Roodbergen, K.J., 2018. Effects of demurrage and detention regimes on dry-port-based inland container transport. Transportation Research Part C: Emerging Technologies 89, 1–18. https://doi.org/10.1016/j.trc.2018.01.012

Feng, X., Zhang, Y., Li, Y., Wang, W., 2013. A Location-Allocation Model for Seaport-Dry Port System Optimization [WWW Document]. Discrete Dynamics in Nature and Society. https://doi.org/10.1155/2013/309585

Flämig, H., Hesse, M., 2011. Placing dryports. Port regionalization as a planning challenge – The case of Hamburg, Germany, and the Süderelbe. Research in Transportation Economics, Intermodal Strategies for Integrating Ports and Hinterlands 33, 42–50. https://doi.org/10.1016/j.retrec.2011.08.005

Garnwa, P., Beresford, A.K.C., Pettit, S., 2009. DRY PORTS: A COMPARATIVE STUDY OF THE UNITED KINGDOM AND NIGERIA, in: Transport and Communications Bulletin for Asia and the Pacific.

Gong, Z., Liu, N., 2020. Mitigative and adaptive investments for natural disasters and labor strikes in a seaport–dry port inland logistics network. Maritime Policy & Management 47, 92–108. https://doi.org/10.1080/03088839.2019.1675195

Gonzalez-Aregall, M., Bergqvist, R., 2019. The role of dry ports in solving seaport disruptions: A Swedish case study. Journal of Transport Geography 80, 102499. https://doi.org/10.1016/j.jtrangeo.2019.102499

González-Sánchez, G., Olmo-Sánchez, M.I., Maeso-González, E., 2015. Effects of the Implementation of Antequera Dry Port in Export and Import Flows, in: Cortés, P., Maeso-González, E., Escudero-Santana, A. (Eds.), Enhancing Synergies in a Collaborative Environment, Lecture Notes in Management and Industrial Engineering. Springer International Publishing, Cham, pp. 147–154. https://doi.org/10.1007/978-3-319-14078-0_17

Hanaoka, S., Regmi, M.B., 2011. Promoting intermodal freight transport through the development of dry ports in Asia: An environmental perspective. IATSS Research 35, 16–23. https://doi.org/10.1016/j.iatssr.2011.06.001

Haralambides, H., Gujar, G., 2012. On balancing supply chain efficiency and environmental impacts: An eco-DEA model applied to the dry port sector of India. Marit Econ Logist 14, 122–137. https://doi.org/10.1057/mel.2011.19

Haralambides, H., Gujar, G., 2011. The Indian dry ports sector, pricing policies and opportunities for public-private partnerships. Research in Transportation Economics, Intermodal Strategies for Integrating Ports and Hinterlands 33, 51–58. https://doi.org/10.1016/j.retrec.2011.08.006

Hayut, Y., 1980. Inland container terminal—function and rationale. Maritime Policy & Management 7, 283–289. https://doi.org/10.1080/03088838000000042

Henttu, V., Hilmola, O.-P., 2011. Financial and environmental impacts of hypothetical Finnish dry port structure. Research in Transportation Economics, Intermodal Strategies for Integrating Ports and Hinterlands 33, 35–41. https://doi.org/10.1016/j.retrec.2011.08.004

Henttu, V., Lättilä, L., Hilmola, O.-P., 2011. OPTIMIZATION OF RELATIVE TRANSPORT COSTS OF A HYPOTHETICAL DRY PORT STRUCTURE.

Hossain, N.U.I., Nur, F., Jaradat, R., Hosseini, S., Marufuzzaman, M., Puryear, S.M., Buchanan, R.K., 2019. Metrics for Assessing Overall Performance of Inland Waterway Ports: A Bayesian Network Based Approach [WWW Document]. Complexity. https://doi.org/10.1155/2019/3518705

Hui, F.K.P., Aye, L., Duffield, C.F., 2019. Engaging Employees with Good Sustainability: Key Performance Indicators for Dry Ports. Sustainability 11, 2967. https://doi.org/10.3390/su11102967

Iannone, F., 2012. The private and social cost efficiency of port hinterland container distribution through a regional logistics system. Transportation Research Part A: Policy and Practice 46, 1424–1448. https://doi.org/10.1016/j.tra.2012.05.019

Jaržemskis, A., Vasiliauskas, A.V., 2007. Research on dry port concept as intermodal node. Transport 22, 207–213. https://doi.org/10.1080/16484142.2007.9638126

Jeevan, J., Bandara, Y.M., Mohd Salleh, N.H., Ngah, A.H., Hanafiah, R., 2019. A Procedure of Implementing Exploratry Mixed Method Research in Dry Ports Management. Transactions on Maritime Science 08, 157–170. https://doi.org/10.7225/toms.v08.n02.001

Jeevan, J., Chen, S., Lee, E., 2015. The Challenges of Malaysian Dry Ports Development. The Asian Journal of Shipping and Logistics 31, 109–134. https://doi.org/10.1016/j.ajsl.2015.03.005

Jeevan, J., Chen, S.-L., Cahoon, S., 2018. Determining the influential factors of dry port operations: worldwide experiences and empirical evidence from Malaysia. Marit Econ Logist 20, 476–494. https://doi.org/10.1057/s41278-017-0063-y

Jeevan, J., Salleh, NHM., Loke, K.B., Saharuddin, A.H., 2017. Preparation of dry ports for a competitive environment in the container seaport system: A process benchmarking approach. International Journal of e-Navigation and Maritime Economy 7, 19–33. https://doi.org/10.1016/j.enavi.2017.06.003

Ji, B., Yuan, X., Yuan, Y., Lei, X., Fernando, T., Iu, H.H.C., 2019. Exact and heuristic methods for optimizing lock-quay system in inland waterway. European Journal of Operational Research 277, 740–755. https://doi.org/10.1016/j.ejor.2019.03.010

Ka, B., 2011. Application of Fuzzy AHP and ELECTRE to China Dry Port Location Selection. The Asian Journal of Shipping and Logistics 27, 331–353. https://doi.org/10.1016/S2092-5212(11)80015-5

Khaslavskaya, A., Roso, V., 2019. Outcome-Driven Supply Chain Perspective on Dry Ports. Sustainability 11, 1492. https://doi.org/10.3390/su11051492

Komchornrit, K., 2017. The Selection of Dry Port Location by a Hybrid CFA-MACBETH-PROMETHEE Method: A Case Study of Southern Thailand. The Asian Journal of Shipping and Logistics 33, 141–153. https://doi.org/10.1016/j.ajsl.2017.09.004

Kondratowicz, L.J., 1992. Methodological solutions for increased efficiency of modelling and simulation of seaports and inland freight terminals. Maritime Policy & Management 19, 157–164. https://doi.org/10.1080/03088839200000022

Korovyakovsky, E., Panova, Y., 2011. Dynamics of Russian dry ports. Research in Transportation Economics, Intermodal Strategies for Integrating Ports and Hinterlands 33, 25–34. https://doi.org/10.1016/j.retrec.2011.08.008

Kramberger, T., Monios, J., Strubelj, G., Rupnik, B., 2018. Using dry ports for port co-opetition: the case of Adriatic ports. IJSTL 10, 18. https://doi.org/10.1504/IJSTL.2018.088319

Lam, J.S.L., Gu, Y., 2013. Port hinterland intermodal container flow optimisation with green concerns : a literature review and research agenda. http://dx.doi.org/10.1504/IJSTL.2013.054190

Lättilä, L., Henttu, V., Hilmola, O.-P., 2013. Hinterland operations of sea ports do matter: Dry port usage effects on transportation costs and CO2 emissions. Transportation Research Part E: Logistics and Transportation Review, Green Shipping Management 55, 23–42. https://doi.org/10.1016/j.tre.2013.03.007

Li, J., Jiang, B., 2014. Cooperation Performance Evaluation between Seaport and Dry Port; Case of Qingdao Port and Xi'an Port. International Journal of e-Navigation and Maritime Economy 1, 99–109. https://doi.org/10.1016/j.enavi.2014.12.009

Li, J.Y., Notteboom, T.E., Wang, J.J., 2017. An institutional analysis of the evolution of inland waterway transport and inland ports on the Pearl River. GeoJournal 82, 867–886. https://doi.org/10.1007/s10708-016-9696-0

Li, W., Hilmola, O.-P., Panova, Y., 2019. Container Sea Ports and Dry Ports: Future CO2 Emission Reduction Potential in China. Sustainability 11, 1515. https://doi.org/10.3390/su11061515

Li, Y., Dong, Q., Sun, S., 2015. Dry Port Development in China: Current Status and Future Strategic Directions. coas 73, 641–646. https://doi.org/10.2112/SI73-111.1

Liedtke, G., Carrillo Murillo, D.G., 2012. Assessment of policy strategies to develop intermodal services: The case of inland terminals in Germany. Transport Policy 24, 168–178. https://doi.org/10.1016/j.tranpol.2012.06.002

Ližbetin, J., 2019. Methodology for Determining the Location of Intermodal Transport Terminals for the Development of Sustainable Transport Systems: A Case Study from Slovakia. Sustainability 11, 1230. https://doi.org/10.3390/su11051230

Lizbetin, J., Bartuska, L., 2019. Significance of Proper Selection of Handling Equipment in Inland Intermodal Transport Terminals. Periodica Polytechnica Transportation Engineering 47, 136–139. https://doi.org/10.3311/PPtr.11169

Martínez-Pardo, A., Garcia-Alonso, L., 2014. Analysis of the Inland Port Regionalization Process in Spain. Procedia - Social and Behavioral Sciences, XVIII Congreso Panamericano de Ingeniería de Tránsito, Transporte y Logística (PANAM 2014) 162, 228–236. https://doi.org/10.1016/j.sbspro.2014.12.203

Molero, G.D., Santarremigia, F.E., Aragonés-Beltrán, P., Pastor-Ferrando, J.-P., 2017. Total safety by design: Increased safety and operability of supply chain of

inland terminals for containers with dangerous goods. Safety Science, SAFETY: Methods and applications for Total Safety Management 100, 168–182. https://doi.org/10.1016/j.ssci.2016.10.007

Monios, J., 2011. The role of inland terminal development in the hinterland access strategies of Spanish ports. Research in Transportation Economics, Intermodal Strategies for Integrating Ports and Hinterlands 33, 59–66. https://doi.org/10.1016/j.retrec.2011.08.007

Monios, J., Wang, Y., 2013. Spatial and institutional characteristics of inland port development in China. GeoJournal 78, 897–913. https://doi.org/10.1007/s10708-013-9473-2

Monios, J., Wilmsmeier, G., 2012a. Giving a direction to port regionalisation. Transportation Research Part A: Policy and Practice 46, 1551–1561. https://doi.org/10.1016/j.tra.2012.07.008

Monios, J., Wilmsmeier, G., 2012b. Port-centric logistics, dry ports and offshore logistics hubs: strategies to overcome double peripherality? Maritime Policy & Management 39, 207–226. https://doi.org/10.1080/03088839.2011.650720

Montwiłł, A., 2019. Inland ports in the urban logistics system. Case studies. Transportation Research Procedia 333–340.

Mundutéguy, C., 2012. Exploring the Nature and Consequences of a Fragmented Activity: The Example of Foremen Managing Operations in an Inland Port. Work 41, 6039–6046. https://doi.org/10.3233/WOR-2012-1057-6039

Muravev, D., Rakhmangulov, A., 2016. Environmental Factors' Consideration at Industrial Transportation Organization in the «Seaport – Dry port» System. Open Engineering 6. https://doi.org/10.1515/eng-2016-0070

Muravev, D., Rakhmangulov, A., Hu, H., Zhou, H., 2019. The Introduction to System Dynamics Approach to Operational Efficiency and Sustainability of Dry Port's Main Parameters. Sustainability 11, 2413. https://doi.org/10.3390/su11082413

Musso, E., Sciomachen, A., 2019. Impact of megaships on the performance of port container terminals. Marit Econ Logist. https://doi.org/10.1057/s41278-019-00120-y

Ng, AdolfK.Y., Gujar, G.C., 2009. Government policies, efficiency and competitiveness: The case of dry ports in India. Transport Policy, SI: TBGS 16, 232–239. https://doi.org/10.1016/j.tranpol.2009.08.001

Ng, A.K.Y., Cetin, I.B., 2012. Locational Characteristics of Dry Ports in Developing Economies: Some Lessons from Northern India. Regional Studies 46, 757–773. https://doi.org/10.1080/00343404.2010.532117

Ng, A.K.Y., Girish, G., 2009. The spatial characteristics of dry ports in India, in: Transport and Communications Bulletin for Asia and the Pacific. pp. 102–111.

Ng, A.K.Y., Padilha, F., Pallis, A.A., 2013. Institutions, bureaucratic and logistical roles of dry ports: the Brazilian experiences. Journal of Transport Geography, Institutions and the Transformation of Transport Nodes 27, 46–55. https://doi.org/10.1016/j.jtrangeo.2012.05.003

Ng, A.K.Y., Tongzon, J.L., 2010. The Transportation Sector of India's Economy: Dry Ports as Catalysts for Regional Development. Eurasian Geography and Economics 51, 669–682. https://doi.org/10.2747/1539-7216.51.5.669

Ng, A.K.Y., Velasco-Acosta, A.E., Wang, T., 2015. Institutions and the governance of transport infrastructure projects: Some insight from the planning and construction of the CentrePort Canada Way. Research in Transportation Business & Management, Operational constraints on effective governance of intermodal transport 14, 25–33. https://doi.org/10.1016/j.rtbm.2014.10.012

Ng, K.Y.A., Gujar, G.C., 2009. The spatial characteristics of inland transport hubs: evidences from Southern India. Journal of Transport Geography 17, 346–356. https://doi.org/10.1016/j.jtrangeo.2008.07.010

Nguyen, L.C., Notteboom, T., 2019. The relations between dry port characteristics and regional port-hinterland settings: findings for a global sample of dry ports. Maritime Policy & Management 46, 24–42. https://doi.org/10.1080/03088839.2018.1448478

Nguyen, L.C., Notteboom, T., 2017. Public-private partnership model selection for dry port development: an application to Vietnam 22.

Nguyen, L.C., Notteboom, T., 2016. A Multi-Criteria Approach to Dry Port Location in Developing Economies with Application to Vietnam. The Asian Journal of Shipping and Logistics 32, 23–32. https://doi.org/10.1016/j.ajsl.2016.03.003

Notteboom, T., Rodrigue, J.-P., 2009. Inland terminals within North American and European supply chains, in: Transport and Communications Bulletin for Asia and the Pacific. pp. 1–39.

Oláh, J., Nestler, S., Nobel, T., Popp, J., 2018. Ranking of Dry Ports in Europe - Benchmarking. Periodica Polytechnica Transportation Engineering 46, 95–100. https://doi.org/10.3311/PPtr.11414

Owusu Kwateng, K., Donkoh, A., Muntaka, A.S., 2017. Evaluation of dry port implementation in Ghana. Maritime Business Review 2, 261–278. https://doi.org/10.1108/MABR-01-2017-0005

Padilha, F., Ng, A.K.Y., 2012. The spatial evolution of dry ports in developing economies: The Brazilian experience. Marit Econ Logist 14, 99–121. https://doi.org/10.1057/mel.2011.18

Panova, Y., Hilmola, O.-P., 2015. Justification and evaluation of dry port investments in Russia. Research in Transportation Economics, Austerity and Sustainable Transportation 51, 61–70. https://doi.org/10.1016/j.retrec.2015.07.008

Pham, H.T., Lee, H., 2019. Developing a Green Route Model for Dry Port Selection in Vietnam. The Asian Journal of Shipping and Logistics 35, 96–107. https://doi.org/10.1016/j.ajsl.2019.06.002

Protic, S.M., Fikar, C., Voegl, J., Gronalt, M., 2019. Analysing the impact of value added services at intermodal inland terminals. International Journal of Logistics Research and Applications 0, 1–19. https://doi.org/10.1080/13675567.2019.1657386

Qiu, X., Lam, J.S.L., 2018. The Value of Sharing Inland Transportation Services in a Dry Port System. Transportation Science 52, 835–849. https://doi.org/10.1287/trsc.2017.0755

Qiu, X., Lam, J.S.L., Huang, G.Q., 2015. A bilevel storage pricing model for outbound containers in a dry port system. Transportation Research Part E: Logistics and Transportation Review 73, 65–83. https://doi.org/10.1016/j.tre.2014.10.009

Qiu, X., Lee, C.-Y., 2019. Quantity discount pricing for rail transport in a dry port system. Transportation Research Part E: Logistics and Transportation Review 122, 563–580. https://doi.org/10.1016/j.tre.2019.01.004

Qiu, X., Xu, G., 2019. Optimizing Rail Transport Service in a Dry Port System. IEEE Transactions on Engineering Management 1–15. https://doi.org/10.1109/TEM.2019.2951915

Rahimi, M., Asef-Vaziri, A., Harrison, R., 2008. An Inland Port Location-Allocation Model for a Regional Intermodal Goods Movement System. Marit Econ Logist 10, 362–379. https://doi.org/10.1057/mel.2008.17

Raimbault, N., 2019. From regional planning to port regionalization and urban logistics. The inland port and the governance of logistics development in the Paris region. Journal of Transport Geography 78, 205–213. https://doi.org/10.1016/j.jtrangeo.2019.06.005

Rathnayake, J., Jing, L., Erandi, D., 2015. Truck turnaround time problem at the port of Colombo and a solution through inland ports. International Journal of Logistics Systems and Management 21, 413–441. https://doi.org/10.1504/IJLSM.2015.070208

Rodrigue, J.-P., Debrie, J., Fremont, A., Gouvernal, E., 2010. Functions and actors of inland ports: European and North American dynamics. Journal of Transport Geography, Special Issue on Comparative North American and European gateway logistics 18, 519–529. https://doi.org/10.1016/j.jtrangeo.2010.03.008

Rodrigue, J.-P., Notteboom, T., 2012. Dry ports in European and North American intermodal rail systems: Two of a kind? Research in Transportation Business & Management, Intermodal Freight Transport and Logistics 5, 4–15. https://doi.org/10.1016/j.rtbm.2012.10.003

Rosa, A., Roscelli, R., 2009. Innovative ideas and design of an integrated dry port and seaport system, in: Transport and Communications Bulletin for Asia and the Pacific.

Roso, V., 2009. The emergence and significance of dry ports: the case of the Port of Goteborg. World Review of Intermodal Transportation Research 2, 296–310. https://doi.org/10.1504/WRITR.2009.026209

Roso, V., 2008. Factors influencing implementation of a dry port. International Journal of Physical Distribution & Logistics Management 38, 782–798. https://doi.org/10.1108/09600030810926493

Roso, V., 2007. Evaluation of the dry port concept from an environmental perspective: A note. Transportation Research Part D: Transport and Environment 12, 523–527. https://doi.org/10.1016/j.trd.2007.07.001

Roso, V., Brnjac, N., Abramovic, B., 2015a. Inland Intermodal Terminals Location Criteria Evaluation: The Case of Croatia. Transportation Journal 54, 496–515. https://doi.org/10.5325/transportationj.54.4.0496

Roso, V., Lumsden, K., 2010. A review of dry ports. Marit Econ Logist 12, 196–213. https://doi.org/10.1057/mel.2010.5

Roso, V., Lumsden, K., 2009. THE DRY PORT CONCEPT: MOVING SEAPORT ACTIVITIES INLAND? 15.

Roso, V., Russell, D., Rhoades, D., 2019. Diffusion of Innovation Assessment of Adoption of the Dry Port Concept. Transactions on Maritime Science 08, 26–36. https://doi.org/10.7225/toms.v08.n01.003

Roso, V., Russell, D., Ruamsook, K., Stefansson, G., 2015b. Seaport-inland port dyad dynamics: an investigation of service provisions and intermodal transportation linkages. World Review of Intermodal Transportation Research 5, 263–280. https://doi.org/10.1504/WRITR.2015.069242

Roso, V., Woxenius, J., Lumsden, K., 2009. The dry port concept: connecting container seaports with the hinterland. Journal of Transport Geography 17, 338–345. https://doi.org/10.1016/j.jtrangeo.2008.10.008

Rožić, T., Petrović, M., Ogrizović, D., 2014. CONTAINER TRANSPORT FLOWS AS A PREREQUISITE FOR DETERMINATION OF INLAND TERMINAL LOCATION. Pomorstvo 28, 3–9.

Rožić, T., Rogić, K., Bajor, I., 2016. Research Trends of Inland Terminals: A Literature Review. Promet - Traffic&Transportation 28, 539–548. https://doi.org/10.7307/ptt.v28i5.2090

Santarremigia, F.E., Molero, G.D., Poveda-Reyes, S., Aguilar-Herrando, J., 2018. Railway safety by designing the layout of inland terminals with dangerous goods connected with the rail transport system. Safety Science, Railway safety 110, 206–216. https://doi.org/10.1016/j.ssci.2018.03.001

Santos, T.A., Guedes Soares, C., 2017. Development dynamics of the Portuguese range as a multi-port gateway system. Journal of Transport Geography 60, 178–188. https://doi.org/10.1016/j.jtrangeo.2017.03.003

Schindlbacher, E., Gronalt, M., Hauslmayer, H., 2011. Multi–agent simulation for analysing the robustness of inland container terminal networks. International Journal of Simulation and Process Modelling 6, 317–328. https://doi.org/10.1504/IJSPM.2011.048012

Seguí, X., Puig, M., Quintieri, E., Wooldridge, C., Darbra, R.M., 2016. New environmental performance baseline for inland ports: A benchmark for the European inland port sector. Environmental Science & Policy 58, 29–40. https://doi.org/10.1016/j.envsci.2015.12.014

Smid, M., Dekker, S., Wiegmans, B., 2016. Modeling the cost sensitivity of intermodal inland waterway terminals: A scenario based approach. Transportation Research Part A: Policy and Practice 85, 112–122. https://doi.org/10.1016/j.tra.2016.01.006

Sun, J., Wang, H., 2018. The Location Analysis on Dry Port of the Inland in Jinan City. E3S Web Conf. 38, 01035. https://doi.org/10.1051/e3sconf/20183801035

Tadić, S., Krstić, M., Brnjac, N., 2019. Selection of efficient types of inland intermodal terminals. Journal of Transport Geography 78, 170–180. https://doi.org/10.1016/j.jtrangeo.2019.06.004

Tan, Z., Meng, Q., Wang, F., Kuang, H., 2018. Strategic integration of the inland port and shipping service for the ocean carrier. Transportation Research Part E: Logistics and Transportation Review 110, 90–109. https://doi.org/10.1016/j.tre.2017.12.010

Tsao, Y.-C., Linh, V.T., 2018. Seaport- dry port network design considering multimodal transport and carbon emissions. Journal of Cleaner Production 199, 481–492. https://doi.org/10.1016/j.jclepro.2018.07.137

Tsao, Y.-C., Thanh, V.-V., 2019. A multi-objective mixed robust possibilistic flexible programming approach for sustainable seaport-dry port network design under an uncertain environment. Transportation Research Part E: Logistics and Transportation Review 124, 13–39. https://doi.org/10.1016/j.tre.2019.02.006

UNCTAD, 1991. Handbook on the Management and Operation of Dry Ports.

Van den Berg, R., De Langen, P.W., 2011. Hinterland strategies of port authorities: A case study of the port of Barcelona. Research in Transportation Economics, Intermodal Strategies for Integrating Ports and Hinterlands 33, 6–14. https://doi.org/10.1016/j.retrec.2011.08.002

Van Nguyen, T., Zhang, J., Zhou, L., Meng, M., He, Y., 2019. A data-driven optimization of large-scale dry port location using the hybrid approach of data mining and complex network theory. Transportation Research Part E: Logistics and Transportation Review 101816. https://doi.org/10.1016/j.tre.2019.11.010

Veenstra, A., Zuidwijk, R., van Asperen, E., 2012. The extended gate concept for container terminals: Expanding the notion of dry ports. Marit Econ Logist 14, 14–32. https://doi.org/10.1057/mel.2011.15

Vejvar, M., Lai, K., Lo, C.K.Y., Fürst, E.W.M., 2018. Strategic responses to institutional forces pressuring sustainability practice adoption: Case-based evidence from inland port operations. Transportation Research Part D: Transport and Environment 61, 274–288. https://doi.org/10.1016/j.trd.2017.08.014

Walter, C.K., Poist, R.F., 2004. North American inland port development: international vs domestic shipper preferences. International Journal of Physical Distribution & Logistics Management 34, 579–597. https://doi.org/10.1108/09600030410552267

WALTER, C.K., POIST, R.F., 2003. Desired Attributes of an Inland Port: Shipper vs. Carrier Perspectives. Transportation Journal 42, 42–55.

Wan, C., Zhang, D., Fang, H., 2018. Incorporating AHP and Evidential Reasoning for Quantitative Evaluation of Inland Port Performance, in: Lee, P.T.-W., Yang, Z. (Eds.), Multi-Criteria Decision Making in Maritime Studies and Logistics: Applications and Cases, International Series in Operations Research & Management Science. Springer International Publishing, Cham, pp. 151–173. https://doi.org/10.1007/978-3-319-62338-2_7

Wang, A., Lai, S., Mohmand, Y.T., 2014. Evolution of inland container distribution among the cluster of ports in the Greater Pearl River Delta. Transportation Letters 6, 206–218. https://doi.org/10.1179/1942787514Y.0000000029

Wang, C., Chen, Q., Huang, R., 2018. Locating dry ports on a network: a case study on Tianjin Port. Maritime Policy & Management 45, 71–88. https://doi.org/10.1080/03088839.2017.1330558

Wang, Y., 2014. Reaserch on Sustainable Development of Inland Port - Hinterland System Based on Life-Cycle Theory. Advanced Materials Research 2485–2488. https://doi.org/10.4028/www.scientific.net/AMR.962-965.2485

Wei, H., Dong, M., 2019. Import-export freight organization and optimization in the dry-port-based cross-border logistics network under the Belt and Road Initiative. Computers & Industrial Engineering 130, 472–484. https://doi.org/10.1016/j.cie.2019.03.007

Wei, H., Sheng, Z., 2018. Logistics connectivity considering import and export for Chinese inland regions in the 21st-Century Maritime Silk Road by dry ports. Maritime Policy & Management 45, 53–70. https://doi.org/10.1080/03088839.2017.1403052

Wei, H., Sheng, Z., 2017. Dry Ports-Seaports Sustainable Logistics Network Optimization: Considering the Environment Constraints and the Concession Cooperation Relationships. Polish Maritime Research 24, 143–151. https://doi.org/10.1515/pomr-2017-0117

Wei, H., Sheng, Z., Lee, P.T.-W., 2018. The role of dry port in hub-and-spoke network under Belt and Road Initiative. Maritime Policy & Management 45, 370–387. https://doi.org/10.1080/03088839.2017.1396505

Wei, J., Sun, A., Zhuang, J., 2010. The Selection of Dry Port Location with the Method of Fuzzy-ANP, in: Luo, Q. (Ed.), Advances in Wireless Networks and Information Systems, Lecture Notes in Electrical Engineering. Springer, Berlin, Heidelberg, pp. 265–273. https://doi.org/10.1007/978-3-642-14350-2_33

Wen, X., Chen, N., 2013. Studies on Evaluation of Modernization of the Inland Port and Shipping Management based on DPSIR Model and Gray Correlation Evaluation Model. Procedia - Social and Behavioral Sciences, Intelligent and Integrated Sustainable Multimodal Transportation Systems Proceedings from the 13th COTA International Conference of Transportation Professionals (CICTP2013) 96, 1792–1800. https://doi.org/10.1016/j.sbspro.2013.08.204

Whitman, M., Baroud, H., Barker, K., 2019. Multicriteria risk analysis of commodity-specific dock investments at an inland waterway port. The Engineering Economist 64, 346–367. https://doi.org/10.1080/0013791X.2019.1580808

Wiegmans, B., Witte, P., Roso, V., 2019. Directional inland port development: Powerful strategies for inland ports beyond the inside-out/outside-in dichotomy. Research in Transportation Business & Management 100415. https://doi.org/10.1016/j.rtbm.2019.100415

Wiegmans, B., Witte, P., Spit, T., 2015a. Characteristics of European inland ports: A statistical analysis of inland waterway port development in Dutch municipalities. Transportation Research Part A: Policy and Practice 78, 566–577. https://doi.org/10.1016/j.tra.2015.07.004

Wiegmans, B., Witte, P., Spit, T., 2015b. Inland Port Performance: A Statistical Analysis of Dutch Inland Ports. Transportation Research Procedia, Current practices in transport: appraisal methods, policies and models – 42nd European Transport Conference Selected Proceedings 8, 145–154. https://doi.org/10.1016/j.trpro.2015.06.050

Wiercx, M., van Kalmthout, M., Wiegmans, B., 2019. Inland waterway terminal yard configuration contributing to sustainability: Modeling yard operations. Research in Transportation Economics, Modal shift, emission reductions and behavioral change: Transport policies and innovations to tackle climate change 73, 4–16. https://doi.org/10.1016/j.retrec.2019.02.001

Wilmsmeier, G., Monios, J., Rodrigue, J.-P., 2015. Drivers for Outside-In port hinterland integration in Latin America: The case of Veracruz, Mexico. Research in Transportation Business & Management, Operational constraints on effective governance of intermodal transport 14, 34–43. https://doi.org/10.1016/j.rtbm.2014.10.013

Witte, P., Wiegmans, B., Braun, C., Spit, T., 2016. Weakest link or strongest node? Comparing governance strategies for inland ports in transnational European corridors. Research in Transportation Business & Management, Port Competitiveness: Issues and Challenges 19, 97–105. https://doi.org/10.1016/j.rtbm.2016.03.003

Witte, P., Wiegmans, B., Ng, A.K.Y., 2019. A critical review on the evolution and development of inland port research. Journal of Transport Geography 74, 53–61. https://doi.org/10.1016/j.jtrangeo.2018.11.001

Witte, P., Wiegmans, B., Rodrigue, J.-P., 2017. Competition or complementarity in Dutch inland port development: A case of overproximity? Journal of Transport Geography 60, 80–88. https://doi.org/10.1016/j.jtrangeo.2017.02.008

Witte, P., Wiegmans, B., van Oort, F., Spit, T., 2014. Governing inland ports: a multi-dimensional approach to addressing inland port–city challenges in European transport corridors. Journal of Transport Geography 36, 42–52. https://doi.org/10.1016/j.jtrangeo.2014.02.011

Wood, G., 2004. Tanzanian coastal and inland ports and shipping: crises and policy options. Maritime Policy & Management 31, 157–171. https://doi.org/10.1080/0308830042000205052

Woxenius, J., Roso, V., Lumsden, K., 2004. The dry port concept–connecting seaports with their hinterland by rail.

Wu, X., Xiao, F., Liu, C.L., 2014. Key Points of Strategic Environmental Assessment on Inland Ports – A Case Study Based on Shaoguan Port Master Planning SEA [WWW Document]. Advanced Materials Research. https://doi.org/10.4028/www.scientific.net/AMR.955-959.1289

Yosef, T., Belachew, A., Tefera, Y., 2019. Magnitude and Contributing Factors of Low Back Pain among Long Distance Truck Drivers at Modjo Dry Port, Ethiopia: A Cross-Sectional Study [WWW Document]. Journal of Environmental and Public Health. https://doi.org/10.1155/2019/6793090

Zeng, Q., Maloni, M.J., Paul, J.A., Yang, Z., 2013. Dry port development in China: motivations, challenges, and opportunities. Transportation Journal 52, 234–263. https://doi.org/10.5325/transportationj.52.2.0234

Zhang, J., Ioannou, P.A., Chassiakos, A., 2006. Automated container transport system between inland port and terminals. ACM Trans. Model. Comput. Simul. 16, 95–118. https://doi.org/10.1145/1138464.1138465

Economic Impact of Container-Loading Problem

Alen Jugović

Thousands of containers with different types of cargo are loaded every day in multiple manufacturing and logistics centres in the world. The main problem arising from these handlings is how to make the maximum use of all the available container capacities, while keeping the overall costs of transport per cargo unit as low as possible. The previous research mostly focuses on studying different algorithms for optimising container loading with cargo that has already been assigned based on its dimensions and weight. However, this paper will emphasise the importance of using algorithms in the planning and preparation of the cargo itself during the manufacturing processes before it is dispatched for loading into containers. Besides the length, width, height, and weight of the cargo itself, a fifth component influencing the overall transport costs will be considered, i.e. the manner of loading a container. The research will be carried out on an example of a container shipment of wooden sawn timber materials.

KEY WORDS
~ Container-loading problem
~ Cargo packing
~ Cost optimisation
~ Efficiency of container capacity

University of Rijeka, Faculty of Maritime Studies, Croatia
e-mail: ajugovic@pfri.hr

doi: 10.7225/toms.v09.n02.010

1. INTRODUCTION

Planning and loading cargo into modes of transport or containers represent the most important link in the flow of transporting processes. The efficiency of a particular transport is directly dependent on the optimal cargo loading plan and therefore dependent on the entire transport system.

With respect to loading cargo into containers, the problem is the optimal placement of as many small cargo units as possible into one large storage unit, i.e. container. Therefore, the main goal is to achieve the maximum efficiency of the available capacity of a particular container (Moura and Oliveira, 2005).

A container as a transport unit is defined by three-dimensionality, i.e. defined by its length, width, height, and permissible load-bearing capacity. During the loading process certain cargo first fills the container's available volume, while heavier cargo first fills the container's permissible load-bearing capacity. It follows that planning the loading of a container has limitations deriving from the volume and the load-bearing capacity; however, many other factors also influence the cargo stowage plan such as the possibility of cargo rotation, required level of cargo stability, exposure of cargo to possible damages, time required for loading a container, etc.

In this paper, the research on the topic of cargo loading problems is focused on setting up an algorithm which prioritises the importance of the initial cargo preparation in the manufacturing plants given that the limiting parameters of the storage unit, i.e. the container, are predefined. Moreover, manufacturing assortments are also mostly predefined, thus finding the optimal cargo unit and container loading plan which will economically be the most satisfying for all the participants in the international trade to be the greatest challenge.

The rest of this paper is divided in several, mutually connected chapters. A cross-section of the available literature

on the topic of cargo loading issues is presented in the second chapter. The problem with conducting research is defined in the third chapter. The fourth chapter elaborates on the topic of the algorithm that has been set up, while in the fifth chapter the accuracy of the algorithm is tested on an example of a container dispatch of wooden sawn timber materials. The final, sixth chapter lays down the conclusion of the research carried out and confirms the hypothesis put forward, which states that timely planning of cargo packing and a sophisticated preparation of the cargo stowage plan may significantly lower the costs of transport per cargo unit and improve transport processes.

2. PREVIOUS STUDIES

The basic ideas of the researchers mentioned will be analysed through a review of relevant literature related to the topic. Framework guidelines will be indicated as the foundation of this paper.

The correct layout of the goods, the objects or the cargo in the available container space presents a very difficult task. The available capacities end up unused, and the cargo in the containers is frequently damaged because of inadequate layout and the implementation of inadequate stowage models. In order to make the maximum use of the container capacities and lower the rate of cargo damage in the containers, Patil and Patil (2016) propose creating optimising algorithms for planning the loading. They propose using a simple algorithm, a LAFF (Largest Area First-Fit) algorithm, and a LAFF algorithm with an additional weight variable as new algorithms. These algorithms use heuristic method, which first places the biggest cargo at the bottom of the container and gradually decreases the height available for stowing the cargo. They introduce a new weight variable that specifies that the heavier cargo is to be stowed at the bottom of the container to avoid possible cargo damage. A comparative analysis of the results obtained shows that the LAFF algorithm achieves greater efficiency and that it is more efficient than the other two above-mentioned algorithms.

According to Bortfeld and Wascher (2012), container loading represents the focal point of an efficient flow of the supply chain. For this reason, they thoroughly analyse the available literature on this topic, identify all the factors influencing the issue of loading cargo into containers, and analyse their prevalence in the models that offer solutions to certain problems. They also indicate all the tasks that must be considered while choosing a particular method of loading cargo into containers, and they analyse the achievements and the flaws of previously conducted studies and of the algorithms used.

The literature analysed very often adopts the application of algorithms that use a three-dimensional approach to the loading problem. Every package is placed in its optimal position and so the container is filled to its maximum capacity. The lost container space is minimised, and the number of containers used for shipping larger quantities of cargo is lowered. Layeb et al. (2017) studied the problem of loading a container with square boxes considering multiple realistic limitations of the algorithm regarding weight distribution, positioning of the boxes, and limitations of stowage. Zhao et al. (2016) focused on the evaluation of designing and implementing a methodology with an experimental comparison with different algorithm performances with reference to data sets. They concluded that the studies conducted were mostly based on one loading and much less based on multiple container loadings. They did not consider all the real limitations arising during the process of container loading.

The second group of studies is characterised by the application of a genetic algorithm (GA) which is used for finding precise or approximately precise solutions for optimisation problems. Pino et al. (2013) applied the genetic algorithm to solve the cargo distribution problems of multiple clients and reduce problems to a minimal number of containers while meeting a few basic constraints regarding stowage and balance. The procedure used included basic stowing of the largest and heaviest packages, while the smaller packages were used for filling the gaps. This way the requirements to decrease the time spent planning and to achieve the average occupancy of 85% of the available capacities have been fulfilled.

Other than the application of the genetic algorithm itself, many authors use hybrid approaches by combining various methodologies. Nepomuceno et al. (2007) apply Integer Linear Programming (ILP) and Genetic Algorithms (GAs) to offer competitive solutions for optimising the container loading process. In the study conducted, they integrated two different conceptual components. The first component consists of a generator of reduced original instances, which defines the problems arising during container loading, while the second component is a decoder of reduced instances that interprets and solves any of the generated problems coming out of the generator.

However, the majority of scientists deal with container loading optimisation problems with cargo that has its dimensions and weight already defined, while this paper will emphasise the importance of setting up an algorithm that will be focused on an initial preparation of cargo units in manufacturing plants. Besides the four basic parameters comprising length, width, height, and weight of the cargo, the manner of loading the container will also be considered.

3. DEFINING THE PROBLEM

The problem of loading a container presents a complex problem in logistics processes that aims to lower the unused free space within a container and make maximum use of the available

capacities. The existing limitations are defined as follows (Gehring and Bortfeld, 1997):

- orientation limitation - each cargo cannot be rotated in all directions and, accordingly, cannot be loaded in all the positions;
- limitation to placing cargo in the upper rows - not all types of cargo can withstand the weight of the cargo placed above them, therefore there is a limit to maximum cargo stowage upwards, i.e. heavier cargo is stowed in the lower rows, and lighter cargo in the upper rows;
- volume limitation - a container is limited by its maximum volume;
- weight limitation - a container is limited by its maximum load-bearing capacity;
- stability limitation - refers to the ratio of surface on which the loaded cargo leans on one another by comparison with the total surface, which directly demonstrates the stability of the loaded cargo;
- balance limitation - refers to an even distribution of the load on the surface of the container in accordance with the position of the loaded cargo.

Moreover, the very container loading problem is directly affected by the basic characteristics of the cargo set for shipping, namely its length, height, width, weight, shape, etc. Previous studies of this problem consisted of solving scenarios for cargo that was already prepared for shipping; however, the results of cargo-stowage optimisation plan in this paper will be applied to the preparation of the cargo units in the manufacturing plants for that cargo to which this option can be applied. It follows from the above mentioned that the basic problem of the planned research is finding an optimal cargo unit which will make maximum use of the existing container capacities while maintaining a minimal number of cargo handlings.

4. SETTING UP THE ALGORITHM

In this chapter, the input parameters that determine the set-up of the basic algorithm will be defined. As the process of handling the loading of the container consists of three reciprocally connected elements, i.e. the type of container in which the cargo is meant to be loaded, the type and quantity of cargo meant for shipping, and the planned manner of loading the cargo into the container, the basic algorithm includes all three parameters determined with these three elements of the loading process. The specification of the input parameters is shown in Figure 1.

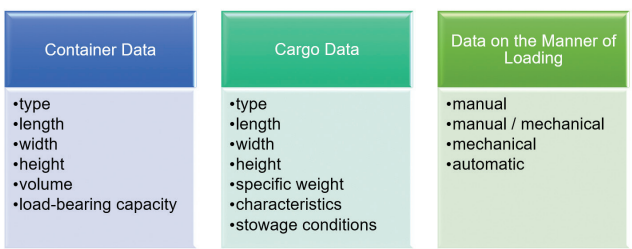


Figure 1.
Input parameters for developing the basic algorithm.

The basic algorithm arising from the above input parameters aims to find the optimal cargo unit with which maximum use of the container capacity will be achieved (Figure 2).

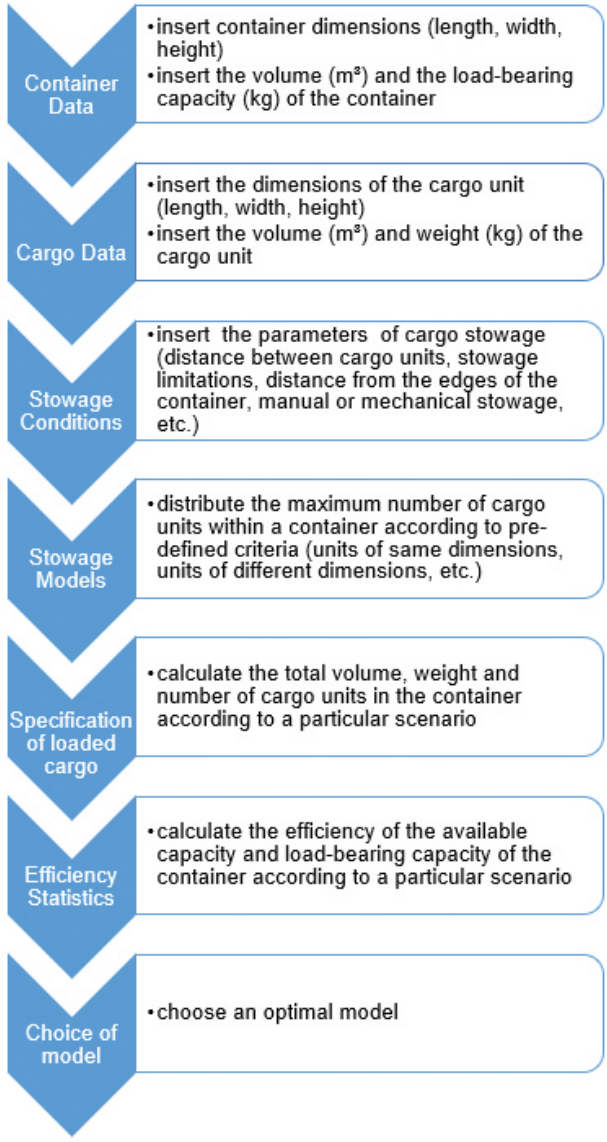


Figure 2.
Scheme of the algorithm developed.

According to the scheme in Figure 2 above, it is possible to achieve different scenarios for loading cargo into containers by inserting different values of particular parameters. A model optimal for the type of cargo tested is chosen depending on the initially set-up requirements.

5. TESTING OF THE ALGORITHM

The testing of the algorithm set up will be performed on an example of a preparatory plan for loading a container of wooden sawn timber materials. As the wooden sawn timber materials are standardized according to the HRN D. C1 022 standard, i.e. based on their thickness, width, length and class, the basic dimensions and the classes determining the criteria for preparing the basic cargo units are the following:

- thickness: 18, 25, 32, 38, (45), 50, 60, 70, 80, 90, and 100 mm;
- width: 8 - 12 cm, and more 12 cm;
- length: very short (50, 55, 60, 65, 70, 75, 80, 85, 90, and 95 cm), short (100, 110, 120, 130, 140, 150, 160, and 170 cm), and long (180, 190, 200, 210, 220, 230, 240, onwards for more than 10 cm);
- class: I, II, (I/II), M, and III.

According to the algorithm set up, a research has been conducted on the optimal dimension of a cargo unit with which maximal use of the volume and load-bearing capacity of a container can be achieved. A simulation was performed on an example of 20' containers and a model for filling the total volume of the container with cargo units of the same dimensions in a variant of mechanical and automatic loading. A unit of wooden sawn timber materials of 50 mm in thickness, ultra-short dimensions in length, varying width and height, and of a specific density of 700 kg/m3 was used as a representative sample. The data was analysed with a programme for optimising cargo stowage in a container, packVol version 3.6.2. Standard, and the results of the analysis are shown in Table 1. packVol uses an algorithm developed in many years of license ownership research, and is based on the implementation of a set of different rules that allow the application of a large number of different conditions when planning the stacking of cargo in a container. The programme is applied to different types and dimensions of cargo, and allows you to set different stacking conditions such as maximum height and width of cargo, maximum allowed weight, loading packages according to the list of priorities or sizes of packages, allowed orientation and position of each package, spatial separation of packages, and many other conditions and restrictions of stacking. In addition to the automatic stacking plan, the program also allows the user to manually create their own cargo-stacking plan in the container. The applied program was used in a free version that provides full functionality over a period of 30 days. After the expiration of the free trial period, the packVol programme is charged in an amount that depends on individual types of packages and the possibilities it provides. The program is applied to all forms of loading when smaller units of cargo are loaded into one larger unit such as containers, trucks and alike.

The applied conditions for stacking sawn timber in a 20' container for the purposes of proven simulation were length, width, and height of the container, permissible load capacity of the container, certain distances between individual packages and between the package and the container side, machine loading package, automatic package-stacking plan in the container, and packages of the same dimensions and weights with the same priority level.

According to Table 1, the unit with 550 mm in length, 1,900 mm in width and 1,100 mm in height, with a volume efficiency coefficient of 83.08% and load-bearing efficiency coefficient of 68.36% (Figure 3) has the highest efficiency while stowing cargo units of wooden sawn timber materials in a 20' container. The other data in the table shows the optimal dimensions of the cargo unit in all the lengths of the ultra-short class (500, 550, 600, 650, 700, 750, 800, 850, 900, and 950 mm) based on which the cargo units can be prepared if one wants to use the maximum efficiency of the capacity of a 20' container.

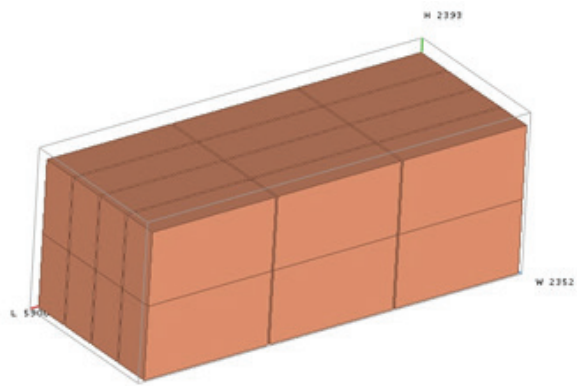


Figure 1.
Configuration of a 20' container with cargo units sized 550 x 1,900 x 1,100 mm.

Given that the majority of the optimal cargo units in Table 1 differ in width, and because of the setting up of a unified model for the preparation and stowage of cargo units, Table 2 shows the results of the analysis of the dimensions of cargo units with a maximum average efficiency of the container's capacity.

Table 1.
Dimensions of an optimal cargo unit for stowing wooden sawn timber materials into a 20′ container.

No.	LENGTH (mm)	WIDTH (mm)	HEIGHT (mm)	NUMBER OF UNITS (PCS)	VOLUME EFFICIENCY (%)	WEIGHT EFFICIENCY (%)
1	550	1,900	1,100	24	83.08	68.36
2	800	2,200	2,200	7	81.62	67.16
3	800	1,400	2,200	11	81.62	67.16
4	800	2,200	1,100	14	81.62	67.16
5	800	1,100	2,200	14	81.62	67.16
6	700	2,200	1,100	16	81.62	67.16
7	800	1,400	1,100	22	81.62	67.16
8	800	1,100	1,100	28	81.62	67.16
9	700	1,100	1,100	32	81.62	67.16
10	700	800	1,100	44	81.62	67.16
11	500	2,200	1,100	22	80.16	65.96
12	500	1,100	1,100	44	80.16	65.96
13	750	700	1,100	46	80.00	65.82
14	600	1,000	1,100	40	79.50	65.42
15	600	800	1,100	50	79.50	65.42
16	850	1,400	1,100	20	78.84	64.87
17	850	500	1,100	56	78.84	64.87
18	900	2,200	1,100	12	78.71	64.76
19	900	1,100	1,100	24	78.71	64.76
20	650	900	1,100	40	77.51	63.78
21	650	500	1,100	72	77.51	63.78
22	950	1,200	1,100	20	75.53	62.15
23	950	400	1,100	60	75.53	62.15

Table 2.
The average volume efficiency of a 20' container during the loading of a full container with cargo units of the same width and height, but different length.

		LENGTH										
WIDTH	**HEIGHT**	**500**	**550**	**600**	**650**	**700**	**750**	**800**	**850**	**900**	**950**	**AVERAGE (%)**
300	**1,100**	76.52	76.52	75.13	76.22	77.91	76.02	77.91	74.33	75.13	73.64	**75.93**
400	**1,100**	75.53	77.25	77.91	75.79	77.91	69.56	74.20	72.08	76.32	75.53	**75.21**
500	**1,100**	72.88	78.34	79.50	77.51	81.16	72.05	74.20	78.84	71.55	69.23	**75.53**
600	**1,100**	79.50	78.71	64.40	69.76	75.13	74.53	73,14	74.33	75.13	75.53	**74.02**
700	**1,100**	76.52	81.62	75.13	72.35	77.91	80.00	77,91	70.95	75.13	74.90	**76.24**
800	**1,100**	76.85	81.62	79.50	75.79	81.62	55.65	59,36	63.07	66.78	70.49	**71.07**
900	**1,100**	71.55	78.71	75.13	77.51	75.13	62.61	66,78	60.82	64.40	67.97	**70.06**
1,000	**1,100**	72.88	76.52	79.50	73.21	74.20	69.56	74,20	67.58	71.55	62.94	**72.21**
1,100	**1,100**	80.16	80.16	78.71	75.79	81.62	76.52	81,62	74.33	78.71	69.23	**77.69**
1,200	**1,100**	75.53	74.33	62.01	67.18	72.35	65.59	69,96	74.33	71.55	75.53	**70.84**
1,300	**1,100**	68.90	75.79	67.18	67.18	72.35	71.05	75,79	73.21	77.51	73.64	**72.26**
1,400	**1,100**	74.20	81.62	72.35	72.35	77.91	76.52	81,62	78.84	66.78	70.49	**75.27**
1,500	**1,100**	69.56	76.52	71.55	71.05	76.52	74.53	55,65	59.13	62.61	66.09	**68.32**
1,600	**1,100**	74.20	75.79	76.32	75.79	74.20	55.65	59,36	63.07	66.78	60.42	**68.16**
1,700	**1,100**	78.84	80.53	67.58	65.89	70.95	59.13	63,07	57.44	60.82	64.20	**66.85**
1,800	**1,100**	65.59	78.71	64.40	69.76	75.13	62.61	66,78	60.82	64.40	67.97	**67.62**
1,900	**1,100**	69.23	83.08	67.97	73.64	79.30	66.09	70,49	64.20	67.97	71.75	**71.37**
2,000	**1,100**	72.88	80.16	71.55	68.90	74.20	69.56	74,20	67.58	71.55	62.94	**71.35**
2,100	**1,100**	76.52	76.52	75.13	72.35	77.91	73.04	77,91	70.95	75.13	66.09	**74.16**
2,200	**1,100**	80.16	80.16	78.71	75.79	81.62	76.52	81,62	74.33	78.71	69.23	**77.69**

According to Table 2, the cargo units with the highest container volume-efficiency coefficient regardless of length are 1,100 mm in width and 1,100 mm in height, and 2,200 mm in width and 1,100 mm in height. Their average container volume efficiency is 77.69 %. While choosing one of the two optimal models, the complexity of stowing cargo units and their stability must be considered. Given the above-mentioned criteria, the most acceptable size of a cargo unit is 1,100 mm in width and 1,100 mm in height.

6. CONCLUSION

The maximum efficiency of the available container capacity in the international trade presents a continuous challenge for logistics planning of transport processes. The problem of loading a greater number of smaller cargo units into a single storage unit, i.e. container, always presents a complex problem for which there is no unique solution.

Therefore, many authors analyse the topic of solving container-loading problems with the help of different methods and algorithms. In these studies, the cargo units are known in advance, and the optimal models of loading plans are analysed based on the limitations and the conditions set up. However, the emphasis in this paper is placed on the application of a new algorithm that, besides the basic data on the container and the cargo, also introduces a new parameter referring to the planned manner of loading the cargo units into the container. The basic goal of the algorithm set up is to find the optimal cargo unit and its preparation in the manufacturing plants before the dispatch of the whole shipment for handling during container loading.

Through seven steps, the algorithm arrives to an optimal cargo unit that achieves the maximum efficiency of the available container capacity. The algorithm contains basic data on the container and the cargo as well as the conditions and the models of loading and stowage. The results obtained are compared with the different loading specifications obtained, and the optimal model of a cargo unit is chosen based on the statistical data on maximum efficiency.

The suggested algorithm model was tested on the example of loading wooden sawn timber materials into containers and, with the help of the programme packVol version 3.6.2. Standard, the optimal size of the cargo unit was analysed. The result of the conducted analysis for the ultra-short class of wooden sawn timber materials showed that the optimal package for stowage into a 20' container is 1,100 mm in width and 1,100 mm in height. In this case, the average efficiency of the container volume is 77.69%.

The conclusion of the conducted research shows that the container-loading problem is solved in a high-quality way if sophisticated methods and advanced algorithms are used in the initial stages when the cargo units are prepared in the manufacturing plants.

REFERENCES

Bortfeldt, A. & Wäscher, G., 2013. Constraints in container loading – A state-of-the-art review. European Journal of Operational Research, 229(1), pp.1–20. Available at: http://dx.doi.org/10.1016/j.ejor.2012.12.006.

Feng, X., Moon, I. & Shin, J., 2013. Hybrid genetic algorithms for the three-dimensional multiple container packing problem. Flexible Services and Manufacturing Journal, 27(2-3), pp.451–477. Available at: http://dx.doi.org/10.1007/s10696-013-9181-8.

Gehring, H. & Bortfeldt, A., 1997. A Genetic Algorithm for Solving the Container Loading Problem. International Transactions in Operational Research, 4(5-6), pp.401–418. Available at: http://dx.doi.org/10.1111/j.1475-3995.1997.tb00095.x.

Gürbüz, M. Z., Akyokuş, S., Emiroğlu, I., Güran, A., 2009. An Efficient Algorithm for 3D Rectangular Box Packing, Proceedings of Selected AAS 2009 Papers, Ohrid 26-29. September, Society for ETAI of Republic of Macedonia, Skopje. Available at: https://www.parkbeachsystems.com/images/usps/An_Efficient_Algorithm_for_3D_Rectangular_Box_Packing.pdf.

ISO 668, 2013. Series 1 freight containers – Classification, dimensions and ratings. Available at: https://www.sis.se/api/document/preview/916460, accessed on: 5 September 2018.

Patil, J.T. & Patil, M.E., 2016. Cargo space optimization for container. 2016 International Conference on Global Trends in Signal Processing, Information Computing and Communication (ICGTSPICC). Available at: http://dx.doi.org/10.1109/icgtspicc.2016.7955271.

Kanniga, E., 2014. Optimization Solution of Equal Dimension Boxes in Container Loading Problem using a Permutation Block Algorithm. Indian Journal of Science and Technology, 7(is5), pp.22–26. Available at: http://dx.doi.org/10.17485/ijst/2014/v7sp5.5.

Kothawade, A.R., Patil, M.E., 2017. Review on Cargo Space Optimization Methodologies. International Journal of Computer Applications, 162(3), pp.31–34. Available at: http://dx.doi.org/10.5120/ijca2017913323.

Layeb, S. B., Jabloun, O., Jaoua, A., 2017. New Heuristic for the Single Container Loading Problem, International Journal of Economics & Strategic Management of Business Process (ESMB), 8 (1), pp. 1-7. Available at: https://www.researchgate.net/publication/309731780_New_Heuristic_for_the_Single_Container_Loading_Problem.

Liang, S. C., Lee, C. Y. and Huang, S. W., 2007. A Hybrid Meta-heuristic for the Container Loading Problem, Communications of the IIMA, 7(4), pp. 73-84. Available at: https://scholarworks.lib.csusb.edu/ciima/vol7/iss4/9.

Moura, A. & Oliveira, J.F., 2005. A GRASP Approach to the Container-Loading Problem. IEEE Intelligent Systems, 20(4), pp.50–57. Available at: http://dx.doi.org/10.1109/mis.2005.57.

Nepomuceno, N., Pinheiro, P. & Coelho, A.L.V., 2007. Tackling the Container Loading Problem: A Hybrid Approach Based on Integer Linear Programming and Genetic Algorithms. Lecture Notes in Computer Science, pp.154–165. Available at: http://dx.doi.org/10.1007/978-3-540-71615-0_14.

Parreño, F. et al., 2008. A Maximal-Space Algorithm for the Container Loading Problem. INFORMS Journal on Computing, 20(3), pp.412–422. Available at: http://dx.doi.org/10.1287/ijoc.1070.0254.

Patil, J.T., Patil, M.E., 2016. Review on Cargo Space Optimization, International Conference on Global Trends in Engineering, Technology and Management, 4.-6. January, Jalgaon, India, pp. 188-191. Available at: http://www.ijettjournal.org/Special%20issue/ICGTETM-2016/ICGTETM_2016_paper_57.pdf.

Patil, J.T. & Patil, M.E., 2016. Cargo space optimization for container. 2016 International Conference on Global Trends in Signal Processing, Information Computing and Communication (ICGTSPICC). Available at: http://dx.doi.org/10.1109/icgtspicc.2016.7955271.

Pino, R. et al., 2013. Application of Genetic Algorithms to Container Loading Optimization. International Journal of Trade, Economics and Finance, pp.304–309. Available at: http://dx.doi.org/10.7763/ijtef.2013.v4.306.

Raidl, G.R., 1999. The multiple container packing problem. ACM SIGAPP Applied Computing Review, 7(2), pp.22–31. Available at: http://dx.doi.org/10.1145/335527.335530.

Ramos, A.G., Oliveira, J.F. & Lopes, M.P., 2014. A physical packing sequence algorithm for the container loading problem with static mechanical equilibrium conditions. International Transactions in Operational Research, 23(1-2), pp.215–238. Available at: http://dx.doi.org/10.1111/itor.12124.

Thapatsuwan, P., Chainate, W. and Pongcharoen, P., 2007. Improving Packing Efficiency for Shipping Container, Special Issue of the International Journal of the Computer, the Internet and Management, 15(4), pp. 26.1-26.6. Available at: https://pdfs.semanticscholar.org/1aa5/c05be2ed03f2fddbb79ec16d8fd05ed6686d.pdf?_ga=2.123865417.2103835026.1599322871-1634521767.1599322871.

Zhao, X. et al., 2014. A comparative review of 3D container loading algorithms. International Transactions in Operational Research, 23(1-2), pp.287–320. Available at: http://dx.doi.org/10.1111/itor.12094.

Emergence of Emergency Logistics Centre (ELC): Humanitarian Logistics Operations at the Straits of Malacca

Jagan Jeevan, Nurul Haqimin Mohd Salleh, Rudiah Md Hanafiah, Abdul Hafaz Ngah

Despite the apprehension of certain parties, the demand for maritime emergency logistics has emerged following the occurrence of maritime accidents around the world while trading activities are performed. The requirement of Emergency Logistics Centre (ELC) is crucial as part of the maritime disaster preparedness at the Straits of Malacca (SOM). The ELC prevents massive losses, should any disaster occur in the rough ocean. Based on unforeseen situations at sea, this paper explores the contributing factors of the ELC in proposing and improving strategies for Kuala Linggi seaport as an ELC. The Exploratory Factor Analysis (EFA) has been employed to achieve the objectives of this paper. The outcome of this paper indicates that resource availability, risk management, and geographical factors are the three key attributes that are substantially required to transform Kuala Linggi seaport into an ELC. Furthermore, disaster preparedness, ELC supply-chain management system, and safety procedures are the crucial components to enhance the operational efficacy at this seaport as an ELC. The findings of this research may contribute to the safety of the maritime route and disaster preparedness at the SOM.

KEY WORDS
~ Emergency Logistics Centre
~ Straits of Malacca
~ Malaysia

University of Malaysia Terengganu, Faculty of Maritime Studies, Malaysia
e-mail: jagan@umt.edu.my

doi: 10.7225/toms.v09.n02.011

1. INTRODUCTION

Maritime disasters have occurred throughout the ages and have caused significant damages to the environment, society, and trade activity. For example, the shipwreck of the Oriental Star in 2015, the Exxon Valdez oil spill in 1989, and the notorious sinking of the Titanic in the North Atlantic Ocean in 1912 indicate a substantial need for this ELC. Over the past few years, numerous incidents have occurred, and these catastrophes have been classified as either natural disaster or man-made disaster. Disaster is defined as a situation or event causing widespread damage which is difficult or beyond human ability to control (Timoleon, 2012). Disasters occur frequently in various parts of the world and normally bring enormous consequences such as human death and injury, property loss, pollution, and others. Maritime disaster is a man-made disaster, as classified by the International Civil Defence Organisation. It has received considerable attention due to the enormous property damage, casualties and serious environmental impact that it potentially brings (Yan et al., 2017). Although there is low probability of its occurrence, maritime disaster is a serious disaster with grave consequences such as loss of human life, damage to the economy, and the environment (Yan et al., 2009). Therefore, maritime disasters have motivated decision-makers and researchers to initiate the ELC in order to serve the victims. The ELC plays an important role in providing effective and efficient rescue procedures to save human life, assets, and the environment (Cozzolino, 2012).

In general, maritime disasters usually occur in a confined area such as a strait or channel where the density of vessel traffic is high (Akten, 2006). Operating an ELC will be pointless if the

execution process is not timely. Therefore, the emergency relief must be delivered to the affected area as swiftly as possible with minimum time access to constitute effective rescue operation after the occurrence of a disaster (Ji and Zhu, 2012). Since the Straits of Malacca (SOM) is one of the vital shipping routes in the world with a high potential of ship accident, quick emergency operation response in the event of maritime disaster is very important to reduce the disaster impact at the location.

Every year, the number of vessels navigating along this strait keeps increasing. According to a report from the Marine Department of Malaysia (2017), deep-draft vessels, tanker vessel, LNG carrier, cargo vessel, container vessel, bulk carrier, Ro-Ro, passenger vessel, livestock carrier, tugboats, government vessel, and fishing vessel are all major types of fleets that actively navigate along the SOM. In addition, the volume of the vessels also indicates a progressive pattern from 2009 until 2016. For example, in 2009, the number of vessels recorded to be navigating along this strait was 71,359, and in 2010 the number went up to 74,133. In 2011, the number further increased to 73,528 vessels. Between 2012 and 2019, a smooth rise has been witnessed whereby the number of vessels climbed up from 75, 477 to 83,740 within the seven-year period.

The SOM experiences high-density vessel traffic; therefore, it is a busy area with a high potential for collisions (Zaman et al., 2015). More than 80,000 vessels pass through the SOM annually. Managing the narrow SOM that caters for a large number of international maritime vessels is one of the significant issues in this region. Maritime accidents such as collision and explosion at the straits can cause traffic obstruction, environmental degradation, loss of revenue, and damage to the economy (Rusli, 2012). A maritime accident will affect the economy, environment as well as the performance of trade activities. Consequently, the existence of the ELC is required to provide efficient and effective emergency response procedures especially at the SOM.

There are five types of maritime disasters recorded at the SOM. These are collision, sinking of a ship, fire on board, grounding of a ship, and others. . Other types of disasters are flooding, capsizing, hijacking, man overboard, crew injuries, as well as engine failure. Among these, collisions, ship sinking, vessel on fire, and vessel grounded are the main maritime catastrophes that have occurred at the SOM. From 2006 to 2016, there were 35 cases of collision, 28 cases of ship sinking, 23 cases of vessel on fire, 13 cases of vessel grounded, and 19 cases under the category of 'others' that were recorded at the SOM.

The SOM is about 180 nautical miles long from One Fathom Bank (Choke point 1) off the coast of Port Klang to Tanjung Piai (Choke point 3) in the south and west entrance to the Strait of Singapore (see Figure 1). Choke point 1 is about 3,582 meters

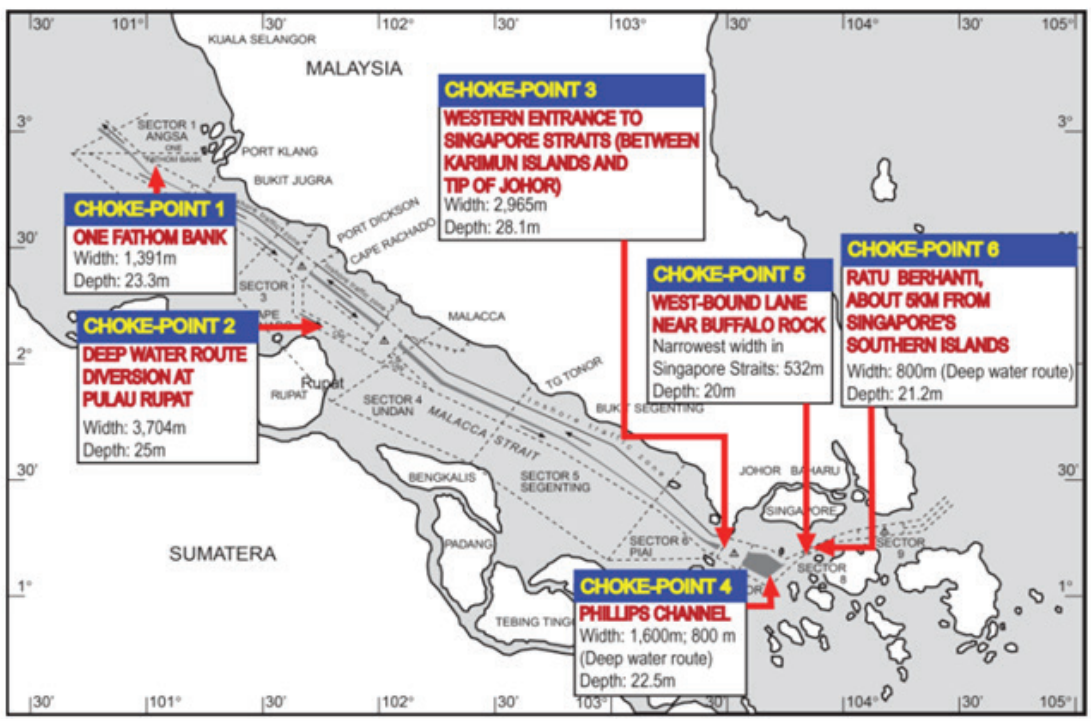


Figure 1.
Major choke points along the SOM.
Source: Adapted from IRGC (2011).

wide and Choke point 3 is about 2,965 meters wide (Awaludin and Abu, 2017). Limited space for vessel navigation and accessibility has labelled Choke point 1 and Choke point 2 as two major chokepoints with limited depth for safe navigation and vulnerable navigation points along the SOM. The traffic flow will be severely affected and could cause a 'shut down' if any casualties occur at the SOM, especially at the two major chokepoints. Unfortunately, according to Awaludin and Abu (2017), with the current emergency capability along this strait, it will take several months for the strait to be re-opened for navigation. This will affect the sustainability of the SOM in the respective regions especially in Indonesia, Singapore, Thailand, and Brunei.

Due to the limitations of the humanitarian services provided by the Marine Department and the Malaysian Maritime Enforcement (MME), it was seen as suitable for Kuala Linggi seaport to be proposed as the ELC to maintain the efficiency of the SOM and enhance the productivity of Malaysian seaports. Conversely, limited availability of research on the ELC at the SOM is the main motivation for this paper. Very few studies have been carried out on the topic of the ELC compared to business logistics, which has a reasonable amount of literature involved (Caunhye et al., 2012). Most of the research on the ELC discusses disasters at inland via 'humanitarian logistics' rather than disasters at foreland, especially in terms of maritime disasters. Therefore, this paper will examine two main questions, i.e. the factors contributing to the development of Kuala Linggi Port as an ELC on the west coast of Peninsular Malaysia, and the improvement strategies for the performance development of the ELCs on the west coast of Peninsular Malaysia. The outcome of this paper may reduce the gap in the academic research that occurred between maritime disasters and business logistics.

Owing to the limited academic research into the functions of the ELC at the SOM, this paper seeks to provide a clear depiction of the development and operation of the ELC at this particular location through an online survey with important stakeholders. The paper starts by addressing the motivation and basic requirements for the ELC operations. Development factors explored and strategies suggested by respondents to cope with the challenges of operational efficiency at the SOM are discussed in Section 2. The methodological approach applied will be explained in Section 3. Section 4 reveals the key outcome of this paper, while Section 5 discusses the application of inland terminals in the ELC operations. The conclusions reached will be presented in Section 6 of the paper.

2. EMERGENCE OF THE ELC IN THE SOM: REVIEW OF THE LITERATURE

This section elaborates two main components of this research, which include the reason for ELC development and strategies to improve the performance of ELC. The outcome of this section will be utilised for questionnaire development to ease the data collection procedure and analysis.

2.1. Reasons for the ELC Development

This section explains the motivation of ELC developed at SOM which includes ship accident, hazardous substance spills, tsunami, unpredictable weather conditions, and the demand for seaport of refuge on this coast.

2.1.1. Ship accident

The increasing number of ships navigating through the SOM has caused a concern for domestic and international users. The growing of ships' traffic and the narrow path of the SOM led to the increasing of navigational hazards (Khalid, 2013). The responsibility carried out by the SOM accommodating one-third of the world trade needs to be secured by an effective support system such as the ELC. Shipping accident is the term used in an accident that resulted in the loss of either life or property, or both. Shipping activity is one of the risky activities, which can lead to maritime accidents (International Maritime Organisation, 2005). Between the years of 2000 and 2010, maritime collision represents the largest fraction of casualty in the Strait of Malacca (Rusli, 2012).

2.1.2. Hazardous substance spills

Ship traffic at the SOM is contributing to the potential hazard disastrous to the environment (Ibrahim and Khalid, 2007). As oil transportation worldwide continues to increase, many communities are at risk of oil spill disasters and must anticipate and prepare for it (Chang et al., 2014). One of the factors that cause marine oil spill is the accidents of marine oil tankers or freighters (Mei and Yin, 2009). For example, the wreck of the MV Rena off the northeast coast of New Zealand is one of the worst maritime disasters resulting in the pollutant combination of oil and dangerous goods debris in a dynamic oceanic environment (Schiel et al., 2016). Hence, the ELC is urgently needed to execute the maritime emergency operation effectively to save human life and the environment.

2.1.3. Tsunami

Emergency logistics planning during the 2004 Indian Ocean tsunami was conducted manually without logistics experts, which caused a significant inefficiency during the procedure (Fritz Institute, 2005). A systematic emergency logistics procedure is crucial for disaster response to provide an effective reaction. The tsunami case proves that the effectiveness of the emergency aid response hinges on logistics speed and efficiency (Pettit et al., 2011).

2.1.4. Unpredictable weather condition

Regions around the SOM including Malaysia, Singapore, and Indonesia experience high humidity with a considerable amount of rainfall, and the wind velocity is reported to be light along the length of the waterways (Ibrahim et al., 2008). The movement of the sea current at the southern part of the SOM is unstable compared to the northern part of the strait (Rusli, 2012). The currents in this part of the Strait form large sand waves, sandbanks and shallow shoals along the waterway, which is vulnerable for commercial vessels (George, 2008).

2.1.5. Demand for the port of refuge

The port of refuge has become a relief node for the vessels in distress because of the several notorious maritime disasters such as the Erika (1999), the Castor (2000), the Prestige (2002), the Napoli (2007), and the Flaminia (2012) (EMSA, 2017). When a ship gets into difficulties, one of the main options of the owner or master is to seek a relief space where the difficulties can be remedied or minimised before proceeding on the voyage (Morrison, 2011). In this critical situation, a ship can use a port of refuge to unload its cargo of fuel oil or to carry out repairs so that the situation does not become worse and prevents pollution to the environment (Yang, 2006).

2.2. Strategies for ELC Performance Improvement

This section discusses how the performance of the ELC can be improved to perform as relief node to victims at the SOM. Hence, several components will be considered such as infrastructure supports, unified command and network coordination, contingency plan, procurement management, warehousing, collaboration among the parties involved, disaster preparedness, application of information system in the ELC, technological advancement and implementation as well as a comprehensive logistics training programme.

2.2.1. The infrastructure support

The infrastructure support includes transportation network, storage structure and information exchange etc. (Ji and Zhu, 2012). Insufficient infrastructure will affect the accessibility of the emergency logistics to the affected area and may raise the uncertainties, complexity and difficulty of the emergency logistics operation (Sheu, 2007). In order to respond during a maritime disaster, the difficulties and challenges to respond to the affected area depend on the state of the sea and the disaster/s. A well-designed transportation network and storage infrastructure could make the distribution operation to the affected areas faster (Ji and Zhu, 2012).

2.2.2. Unified command and network coordination

The unified command and network coordination refer to integrated network and the coordination of capacities, devise the relief distribution plan and organise the dispatch commands. In a massive disaster, unified command is important to ensure response and recovery in an immediate and orderly manner (Ji and Zhu, 2012). Furthermore, unified command and coordination are crucial while dealing with the victims from different nationalities or backgrounds.

2.2.3. Contingency plan

Contingency planning aims to prepare an organisation to respond well to an emergency and its potential humanitarian impact. A contingency plan comprises the hardware such as relief service models, relief reserve funds, infrastructures and goods as well as the software including expert teams, volunteers, exchange of information and contingency measures (Ji and Zhu, 2012). The management of logistics for the emergency operation is part of contingency planning that needs a special attention and focus (Amna, 2013).

2.2.4. Procurement management

Procurement management considers the need for supplies, competitive price for supplies and eventuality arrangements if the shortages occur (Bozorgi et al., 2012). The purpose of the procurement management is to ensure the supplies of the emergency operation resources are provided timely in the right amount, good quality and at a reasonable price (Sunyoto and Wismadi, 2008). The supplies for emergency operation come from different sources, either from disaster relief organisation, donation from the national or international community or loans (Timoleon, 2012). The delay of the procurement is one of the most important factors that can result in the slow delivery of the emergency operation supplies after the disaster occurs (Holguín et al., 2007).

2.2.5. Warehousing

Warehousing is a key component for disaster relief where the emergency aid resources that will be pre-positioned properly to minimise the response time and allow for better procurement planning while improving distribution cost (Bozorgi et al., 2012). Every resource needs to be placed in an appropriate storage, and the significance of the warehousing is to ensure the quality and quantity of the resources is in a good condition during the process of the emergency response (Sunyoto and Wismadi, 2008). The purpose of the logistics warehouse is to facilitate the management of the efficient emergency logistics operation to the affected area (Ariyanti, 2013).

2.2.6. Collaboration plan

The collaboration includes government institutions, both at the central and regional levels, donor institutions and countries, volunteer groups, military, non-government organisations, the private sector and academics (Sunyoto and Wismadi, 2008). The collaboration between all the parties involved shall be mobilised with proper communication, cooperation and coordination, and shall be united in the same objective, examples like providing help and aids to reduce the victims' sufferings. According to the Yan et al. (2017), the emergency responses for the maritime accident are very complex, and all the experts from a different organisation should be involved in this process.

2.2.7. Disaster preparedness

Disaster preparedness is the process of building up and prepare the emergency response capacities before a disaster situation prevails in order to reduce impacts (Sena and Michael, 2006). Improved disaster preparedness may save life, reduce the suffering of survivors, and enable communities to restart normal life more quickly (Wisetjindawat et al., 2014). Wassenhove (2006) pointed out that disaster preparedness consists of five key elements, which are human resources, knowledge management, operations and process management, financial resources and community.

2.2.8. Application of information system in ELC

Emergency aid information system provides a better flow of emergency operation information and increases the efficiency of the emergency logistics supply chain (Koseoglu and Yildirimli, 2015). Furthermore, with the information system, the information flows, which integrated logistics unit and the non-logistics unit, will be more efficient to overcome unpredictable disasters (Howden, 2009).

2.2.9. Technological advancement and implementation

It is easy to manage disasters, either natural or man-made disasters, in the era of technology. The role of technology in disaster emergency operation is to connect, inform, and ultimately save the lives of the victims (Holdeman, 2014). Sufficient technology can contribute to a better and appropriate connectivity during the disaster operation. For example, space technology plays an important role in minimising the disaster impact by providing the information about the disaster to telecommunications, global navigational satellite systems, geographic information system and web technology which can be used for disaster prevention, relief, recovery, warning and monitoring the various phase of disaster management (Subbarao et al., 2014). With the enhancement in information technology, the capability to carry logistical operations timely and deliver the required inventory to the victims has been efficient (Amna, 2013).

2.2.10. A comprehensive logistics training program

According to the Holguín et al. (2007), based on the Katrina disaster case, most of the emergency logistics staff does not have an adequate training to respond to the extreme circumstances. This is because the effectiveness of the emergency response and recovery operations are based on the knowledge and skills possessed by the staffs working at the disaster sites (Schaafstal et al., 2001) and their ability to practice them when the disaster occurs (Sinclair, 2012). Hence, the emergency logistics operation training is very important towards providing effective and efficient emergency response with a good skill level to handle critical supply chain (Holguín et al., 2007).

3. METHODOLOGICAL PROCEDURE

An exploratory factor analysis (EFA) has been carried out in this research to investigate the influential factors and improvement strategies of ELC development in this region especially at the SOM. A list-based stratified sampling technique has been employed to enhance the sample's statistical efficiency rather than just a simple random sampling and is appropriate for the survey when the respondents' organisations are dispersed (Cooper and Schindler 2014). A list-based stratified sampling strategy is used to gather sufficient data to analyse the multiple subpopulations. It is effective for studying certain population's characters, their points of view or their standing on certain issues (Creswell and Amanda, 2008). The target respondents are key stakeholders of seaports in Malaysia.

The population of this research are experts from Kuala Linggi Port Operator (10 participants), Malaysian Marine Department (25 participants), Ministry of Transport (25 participants), and Malaysian Maritime Enforcement (10 participants). Top and middle-level managers from the above mentioned subpopulations who are directly involved in the ELC, managing intermodal terminals, seaports, humanitarian aid, policy makers and related logistics operations have been invited to participate due to their experience and knowledge in the ELC and humanitarian logistics operations. They are expected to contribute with their viewpoints or opinions on the major contributing factors to the development of the ELC at the SOM and strategies to improve the ELC performance at the SOM.

The survey in the form of a questionnaire was distributed online. The instrument was structured using five-point Likert scale ranging from "strongly agree", "agree", "neutral", "disagree" to "strongly disagree". The questionnaires were distributed to the key experts in each organisation to ensure the validity and appropriateness of the outcome. There are three sections in the questionnaire, namely Section A (the demographic profile of the participant), Section B (contributing factors to the development

of Kuala Linggi Port as an ELC), and Section C (improvement strategies for Kuala Linggi Port as an ELC). This questionnaire was designed based on the outcome in the literature review. The literature review in this paper has focused on the aim of the research. Therefore, the outcome has been critically reviewed and shortlisted based on the influencing factors and improvement strategies of the ELC.

Participants were then instructed to respond according to their degree of agreement with the statements contained in the instrument. An EFA has been used for decision-making process to assess the contribution factor of the ELC development at the SOM and to validate the appropriate strategy to improve the performance of the ELC at the location. The aim of the EFA is to reveal any latent variables and to reduce data to a smaller set of summary variables. Besides, it is also intended to explore the underlining theoretical structure of the phenomena and to identify the relationship structure between the variable and the respondent. The broad purpose of the EFA is to summarise the existing data so that relationships and patterns can be easily interpreted (Yong and Pearce, 2013). Moreover, they argue that the main role of the EFA is to assist researchers to reduce a large dataset that consists of several variables by observing 'groups' of variables. In this paper, the factors that influence the ELC development and appropriate strategies to enhance the ELC performance will be classified accordingly, based on the views of Malaysian seaports.

Interpretation is an important aspect of the EFA, which requires pragmatic, theoretical, and subjective procedures to develop meaningful latent factors to answer the proposed research questions. A labelling procedure should reflect the conceptual and theoretical intent (Tabachnick and Fiddell, 2000). Inputs to develop all items for the questions in the questionnaire were derived from a reliable data collection instrument developed from an extensive literature review. These procedures were utilised to generate significant insights for latent interpretation and labelling. In this paper, the above-mentioned interpretation and labelling procedures have been employed to generate three themes on the influencing factors for the ELC development in Malaysia, and other three themes for the strategies to improve the ELC performance in this region. The ELC (1) has been proposed in Malacca seaport due to its close proximity with Choke points 1, 2, and 3. This will be the most critical location with risk of maritime disasters. However, the ELC (2) has been proposed in the northern region of Peninsular Malaysia in order to provide comprehensive benefits to the users of the SOM.

4. FINDINGS

A total of 40 people responded out of 70 potential participants, which brings the response rate to 57.14 per cent. Among the respondents, 67.5 per cent of them have working experience of more than six years. In terms of academic qualifications, 50 per cent of the respondents are bachelor degree holders. About 15 per cent of the responses were received from seaport operators, 35 per cent from the Marine Department, and 50 per cent from the Ministry of Transport and the MME (see Table 1).

While reviewing the literature, very limited researches on the ELC were found. It is evident from very few variables identified as influencing factors of the ELC development at the SOM (9 variables) and improvement strategies of the ELC at the SOM (11 variables). Hence, to avoid over extraction and under extraction, all variables were used to answer both research questions. There is no standard rule to determine the optimum loading values in the EFA. However, Comrey and Lee (1992) offered a guideline for interpreting the loading values as follows: 0.71 = excellent, 0.63 = very good, 0.55 = good, 0.45 = fair, and 0.32 = poor. They indicated that variables with loading value of more than 0.5 assist the researcher in drawing a definite conclusion about the component. Hence, in this paper, factor loading of more than 0.55 has been implemented to gain significant outcome to meet the research objectives of the paper. The outcome of this analysis has been re-labelled to fit the newly developed variables in the research frame.

4.1. Influencing Factors of ELC Development at SOM

Kaiser-Meyer-Olkin (KMO) measures sampling adequacy (MSA) and Bartlett's Test of Sphericity are part of the main method to test the appropriateness of factor analysis. The KMO value should always be above 0.50 before proceeding with factor analysis while the Bartlett's Test is significant when lower than 0.05 (Hair et al., 2010 and Bertsch, 2012). The sampling adequacy and appropriateness of the result in this paper are aligned with the requirements as proposed. The KMO result of the contributing factors to the development of the ELC at the west coast of Peninsular Malaysia is 0.581, which is barely acceptable for the sampling adequacy (see Table 2). The results of the EFA indicate that there are three major factors influencing the ELC development at the SOM including resources availability, risk, and geographical factor with a 66.5 per cent total variance.

The first component is resources availability, which has five variables, i.e. adequate port facilities and infrastructure (0.887), sufficient human resources (0.834), adequate transportation and distribution infrastructure (0.799), role of the port as a port of refuge (0.673), and strategic location (0.548). The Cronbach alpha value for this component is 0.791 (see Table 3). The Port of Linggi in Malacca has been proposed to be a regional centre for the ELC because this particular seaport is well equipped to execute a safe and efficient operation. Additional resources are strategically located at this seaport to ensure optimum operation readiness and fast response besides fulfilling commercial

Table 1.
Demographic characteristics of the respondents.

Items	Frequency	Per cent (%)
Years of experience		
Below 1 year	5	12.5
2-5 years	8	20.0
6-9 years	16	40.0
Above 10 years	11	27.5
Total	40	100
Education background		
Diploma	5	12.5
Certificate	5	12.5
Bachelor Degree	20	50.0
Others	10	25.0
Total	40	100
Organisation of the respondent		
Malaysia Marine Department	14	35
Malaysian Maritime Enforcement Agency	10	25
Seaport operator	6	15
Ministry of Transport	10	25
Total	40	100

Table 2.
The KMO and Bartlett's Test.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		**.581**
Bartlett's Test of Sphericity	Approx. Chi-Square	114.601
	Df	36
	Sig.	.000

needs. For example, this seaport possesses ship-to-ship transfer facilities (STS) and oil-spill response equipment. This equipment is crucial for salvaging human life, cargo as well as protecting the environment.

Resources availability refers to sufficient human resources to execute emergency logistics procedures effectively. Professional human resources play a vital role in disaster preparedness in implementing an organisation's emergency disaster plan. According to Thompson (2015), having well trained personnel is crucial to ensure that all the pieces are in place to mount an efficient and effective response.

Currently, search-and-rescue procedures would be handled by the MME. However, the procedure to execute ship-to-ship transfer requires special skills and experience. Cooperation between the MME and Kuala Linggi seaport will be an appropriate combination to provide humanitarian services via the ELC in this region. Besides the MME, Kuala Linggi seaport may collaborate with the relevant disaster management organisations including Malaysian Red Crescent Society (MRCS), National Disaster Relief Fund, Malaysian Meteorological Service, Special Malaysia Disaster Assistance and Rescue Team, and Malaysia Social Welfare Department in providing comprehensive humanitarian

services to victims. These disaster management organisations are designed to provide accurate information, supplies, relief funds, search and rescue services, space for evacuations, registration of disaster victims for purposes of rehabilitation, as well as post-trauma counselling (MDMRH, 2016). This indicates that the infusion of inland facilities and comprehensive cooperation from various dimensions are required to provide effective services to the victims at the SOM instead of solely depending on seaports to provide all the facilities, services, and additional aid. Examples of additional aid include rehabilitation, counselling services, search and rescue services, space for evacuations, in-situ and ex-situ oil debris cleaning services, cargo salvaging, finding a connecting vessel to carry the remaining cargo and continuing the navigation to the seaport of destination.

Table 3.
Contributing factors to the development of the ELC at the SOM.

Components	**Resource availability *0.791**	**Risk management *0.598**	**Geographical factor * *0.886**
Adequate port facilities and infrastructure	**.887**	-.100	.019
Sufficient human resources for the ELC operations	**.834**	.238	-.197
Adequate transportation and distribution infrastructure	**.799**	.002	-.152
The role of Kuala Linggi Port as a port of refuge	**.673**	.071	.378
The port strategically located at the SOM	**.548**	-.397	.393
Ship accident threat at the SOM	.041	**.813**	-.016
The increasing volume of ship traffic at the SOM	.217	**.744**	.118
Disaster caused by dangerous goods or noxious and hazardous substance spills from the ship at the SOM	-.141	**.649**	.008
Unpredictable weather and geographical conditions	-.108	.103	**.886**
Note: Extraction Method: Principal Component Analysis *Rotation Method: Varimax with Kaiser Normalisation* ***Estimated/*Cronbach alpha value*			

Without a proper transportation system, not all resources for emergency aid can reach the affected location. Adequate transportation and distribution infrastructure constitute the third component in resources and availability, which contributes to the development of the ELC. Places of refuge play a vital role in the provision of rapid and effective assistance to distressed ships (Yang, 2006). The ELC is very important as a hub to facilitate the emergency resources so that it may play a role in emergency relief aid such as collecting, transporting, storing, and assigning the materials needed (Wang and Zhu, 2015).

The second component that affects the ELC development is risk, which involves three variables, i.e. threat of a ship accident (0.831), numbers of ship traffic at the SOM (0.744), and disasters due to dangerous goods or noxious and hazardous substance spills (0.649). The Cronbach alpha value for this component is 0.598.

The growing volume of ship traffic and the narrow path have led to increasing navigational hazards causing risks of accidents and pollution in the sea lane. This can affect the performance of seaports and shipping along the SOM as well as the interests of domestic and international users. Shipping is one of the high-risk activities that is highly exposed to maritime accidents or casualties which commonly happen in constricted waters such as the SOM (International Maritime Organisation, 2005).

There is another conservative trade going on at the SOM besides commercial trade activities. Barter trade is actively taking place especially between Malaysia and Indonesia (Jeevan et al., 2018a). This trade activity involves a barter trade system between two nations with the involvement of a small amount of financial transactions. From 2004 to 2010, barter trade recorded 84,000 vessels in the SOM, which contributed approximately 18–24 per cent of the total trade to Malaysia (Dollah and Mohammad, 2010). In addition to Port Klang, Penang Port, and the Port of Tanjung Pelepas (PTP), Malacca port is also involved in barter trade between Thailand, the Philippines, and Indonesia (Rusli, 2012). This indicates that barter trade activity has been developed, and the number of vessels for this activity is almost equivalent to commercial vessels. Hence, it can be said that the SOM is overexposed to commercial and traditional shipping activities; therefore, a significant ELC needs to be set up to ensure the navigational safety at this location.

The third component affecting the ELC development is the geographical factor, namely the unpredictable weather and geographical conditions at the SOM (0.886). In the meantime, the estimated Cronbach alpha value for this component is 0.886. Vessel traffic will be severely affected due to the collisions in Choke points 1 and 3. This condition will have a significant impact on the seaports located along the Straits, including Port Klang, PTP, and Penang. If this condition is prolonged, the shipping lines will prefer to detour their navigation route through Indonesia via the Sunda Strait or the North Pole. The availability of these alternative routes will affect the competitiveness of Malaysian seaports and affect the performance of the Malaysian trade system in the long run. To avoid this situation from occurring, an immediate ELC development with sufficient resources availability, prolific risk management, and advantages in terms of geographical factor need to be utilised to execute the ELC at the SOM.

4.2. Improvement Strategies of the ELC at the SOM

The KMO result of the improvement strategies for the development of the ELC at the west coast of Peninsular Malaysia is 0.602, which is acceptable for the sampling adequacy (see Table 4).

Table 4.
The KMO and Bartlett's Test.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.602
Bartlett's Test of Sphericity	Approx. Chi-Square	157.721
	Df	55
	Sig.	.000

Three components have been validated as significant improvement strategies to enhance the performance of the ELC at the SOM. These three components make up a total of 61.467 per cent of the variance. The first group is labelled as disaster preparedness, which involves technology improvement and implementation (0.908), comprehensive emergency logistics training programme (0.805), application of information system (0.653), disaster preparedness (0.585), and collaboration among parties involved (0.582). The reliability value of this component is 0.791(see Table 5). In this paper, the proposed improvement strategies are substantial to enhance the performance of this ELC particularly in Malaysia. Further, the ELC operation can be utilised as a benchmark for neighbouring regions including Indonesia, Thailand, Brunei, Philippines, to preserve the trade efficiency in the SOM and South China Sea. In addition, this improvement strategy emphasises the infusion of inland components in the ELC operation to produce a comprehensive emergency logistics services to the victims in both waters.

Technology plays an important role nowadays and it is able to ease the management of disasters. The role of technology in disaster emergency operation is to connect, inform, and ultimately save the lives of victims (Holdeman, 2014). In this case, the integration of air, sea, and land transportation is required to provide comprehensive recovery procedure to the victims. Advancement in drone technology can be utilised to capture real time situations and deliver urgent supplies such as medicine and communication devices to the victims. Moreover, Geographic Information System (GIS) needs to be updated to the Visual Information System (VIS) to preserve, manage, and disseminate visual information to the response unit.

Although the effectiveness of the emergency response and recovery operations are based on technological advancement, the involvement of human factor is needed to improve the performance of the ELC. Therefore, a wide range of emergency-logistics training programmes is required to train the respective work force in Kuala Linggi seaport. Besides mastering the task of shipping and seaport operation, a sense of responsibility as humanitarian providers needs to be established among the workers at this seaport. For example, training needs to be provided for the workers on the application of the Fixed-Line Disaster Alert System (FLDAS) to promote awareness and disseminate early warnings to the public (shipping lines at the SOM), Government Integrated Radio Network (GIRN) providing radio communications between responders during emergencies or disasters, and the Malaysia Emergency Response System (MERS) as an efficient disaster reporting hotline. Apart from technological application training, the personnel in this seaport also needs to be equipped with disaster management skills and should be well versed with the concept of aero-mobility emergency services on foreland and overland. To ensure the effectiveness of the ELC, training is required for the participants from the neighbouring regions including Thailand, Indonesia and Singapore, and other shipping lines to ensure the flow of the procedure is well disseminated, especially in Southeast Asia. Therefore, collaboration among parties is substantial to ensure the fluidity of the traffic at the SOM as well as the safety of its users.

The second component is the ELC management system, which involves unified command and network coordination (0.900), infrastructure support system (0.834), and procurement management (0.526). The Cronbach alpha value for this second component is 0.652. In a massive disaster, unified command is important to ensure response and recovery in an immediate and orderly manner. According to the MDMRH (2016), the role of a unified command system is unlike the regimented order, but has been improved to cater for the need for humanitarian aid. This unified command is responsible to define clear roles and responsibilities within the organisation, provide information, and unite humanitarian and development groups within the organisation by introducing a common language. Hence, the collaboration between the players (neighbouring regions and shipping lines) is crucial to ensure that the orders are well provided and received during an emergency.

In Malaysia, the infrastructure support system to cater for the requirements for the ELC is almost adequate. The road network connects all the states in this region; however, the development of rail network is still in progress. Initially, the rail network only connects major cities in Peninsular Malaysia (not all cities). From an intra-region perspective, the rail connectivity is not comprehensive, as most of the small towns have no rail connection at all (Jeevan et al., 2018a). This indicates that the existing rail network will not be adequate to support the ELC in Kuala Linggi seaport. According to Sheu (2007), insufficient infrastructure will affect the transportability of the emergency logistics to the affected area and may raise uncertainties and difficulties during the execution of the emergency logistics operation. There are three major seaports located along the SOM: Penang Port, Port Klang, and PTP. In addition, there are four inland terminals: Padang Besar Cargo Terminal (PBCT), Ipoh Cargo Terminal (ICT), Nilai Inland Port (NIP), and Segamat Inland Port (SIP). These inland terminals are vertically located across Peninsular Malaysia from north to south (Jeevan et al., 2015; 2020). The incorporation of these facilities will provide an effective ELC to the victims both at sea and on land. The efficiency of ELC can be optimised after the connectivity between these nodes has been established. It is crucial to ensure fast response from the ELC to the disaster zone and vice versa.

Table 5.
Strategies to improve the ELC performance at the SOM.

Components	**Disaster preparedness *0.791**	**ELC Management system *0.652**	**Safety procedure *0.639**
Technology improvement and implementation	**.908**	.074	-.109
Comprehensive emergency logistics training program	**.805**	.128	.008
Application of information system in the ELC.	**.653**	.230	.334
Disaster preparedness	**.585**	.030	.365
Collaboration among parties involved	**.582**	.257	.177
Unified command and network coordination	.141	**.900**	.005
Infrastructure support system	.201	**.834**	-.178
Procurement management	.080	**.526**	.357
Contingency plan	.083	.015	**.801**
Emergency transportation channel	.082	-.049	**.776**
Legal guarantee	.313	.456	**.527**
Extraction Method: Principal Component Analysis Rotation Method: Varimax with Kaiser Normalization *Cronbach alpha value			

Procurement management is another dimension in the ELC that needs to be considered for performance enhancement. The aim of procurement management is to ensure that the supply of resources for emergency operation is provided in a timely manner, in the right amount, in good quality, and at reasonable prices (Sunyoto and Wismadi, 2008). In this regard, the transport facilities in this region need to be updated. Furthermore, the dry ports in this region need to be roped in for humanitarian purposes besides providing space, customs services, and transportation for freight. Currently, the United Nations Humanitarian Response Depot (UNHRD) is located in Subang, Malaysia. In this case, the integration of dry ports needs to be utilised by Kuala Linggi seaport in order to receive additional food, medical supplies, and other ancillary support throughout the region in an immediate and timely manner.

The third component is safety procedure, which involves contingency plan (0.801), development of emergency transportation channel (0.776), and legal guarantee (0.527). The Cronbach alpha value for this third component is 0.639. Contingency plan comprises several components such as infrastructures, goods, expert teams, and volunteers. Again, effective transportation system and unified command system become the main determinants of the performance of the ELC. Effective transportation system and a unified command system will ensure that the transformation of a contingency plan is well transferred from the point of origin to the point of destination. In order to execute a systematic contingency plan, collaboration between Kuala Linggi seaport, dry ports, Malaysian UNHRD, and transportation network needs to be synchronised. Other seaports aside from Kuala Linggi seaport need to be utilised by providing emergency transport channel to and from foreland. This situation could prevent an over-dependency on single nodes as the ELC at the SOM. Finally, the implementation of legal guarantees may assist towards recognising the rights and obligations of the victims, public and government, in order to maintain social stability in the affected zone.

5. DISCUSSION: A CASE STUDY ON THE COOPERATION OF THE ELC AND INLAND TERMINALS

With the ELC operating independently at Kuala Linggi seaport, other major seaports on the west coast such as Penang Port, Port Klang, and PTP can serve as back-up in case the initial ELC entity is unable to operate due to unavoidable reasons including issues on connectivity, limited options of multimodalism or incapability to handle modal shifting. This component is known as centre for disaster mitigation and preparedness. It involves human capacity, knowledge management, process management, resources, and community to mitigate and prepare for any disaster at the SOM.

The centre for disaster response and recovery will be based at the inland terminals. This centre will provide additional support system especially from inland to the seaports in order to respond and execute recovery procedure at the SOM through the ELC. The players at the centre will be all the Malaysian dry ports including the PBCT, ICT, NIP, and SIP. These dry ports are connected to the seaports via rail and road network. This will enable the response and recovery procedure to be carried out not only at sea, but also inland. This centre is connected to the UNHRD to provide sufficient information, supply, and other required goods to dry ports, ELC and, finally, to the affected zone at the SOM. The UNHRD is classified as a centre for disaster prevention because it delivers training to humanitarian personnel, provides a warehouse to store supplies, and collaborates with inter-regional humanitarian organisations.

The incorporation between the ELC and dry ports is important due to the specific roles of these inland terminals, which include an extended seaport, regional intermodal nodes as well as interface terminal between seaport and hinterland. As an extended seaport, dry port manages to perform various services including storage function and simplifies seaport activities in the humanitarian supply chain. Meanwhile, as regional intermodal nodes, these dry ports may perform as regional centric entities to transform supplies, information, and other required facilities faster from seaport to inland and vice versa. This situation reduces the over-reliance on the ELC and improves the participation of regional area to assist the victim at Malacca straits via the ELC. Furthermore, as an interface terminal, this inland terminal is a link between rail and road transportation. The assimilation of unimodal and multimodal transportation via synchromodal transportation is also available between the NIP and other dry ports and seaport (See Figure 2). Moreover, the ELC 2 has been proposed as a plan to enhance humanitarian efficiency along the SOM (see Figure 2)

Although dry ports are designed to ease freight transportation and improve the competitiveness of seaports, it can be utilised to transform the operation procedure towards humanitarian logistics by serving the ELC. According to Jeevan et al. (2018b), the involvement of dry ports in seaports affects seaport performance, increases service variations for seaports, improves seaport-hinterland proximity, increases seaport trade volume, and enhances seaport capacity. Owing to these operational strengths, the incorporation of dry ports in the ELC is important to ensure the fluidity and protection of cargo vessels, crews, assets, and environment at this congested strait. Integration of all the components in maritime logistics is essential to improve the performance of the ELC at the SOM. Furthermore, the incorporation of the ELC with inland components ensures that immediate action will be taken towards maritime disaster victims, including cargo and crew members.

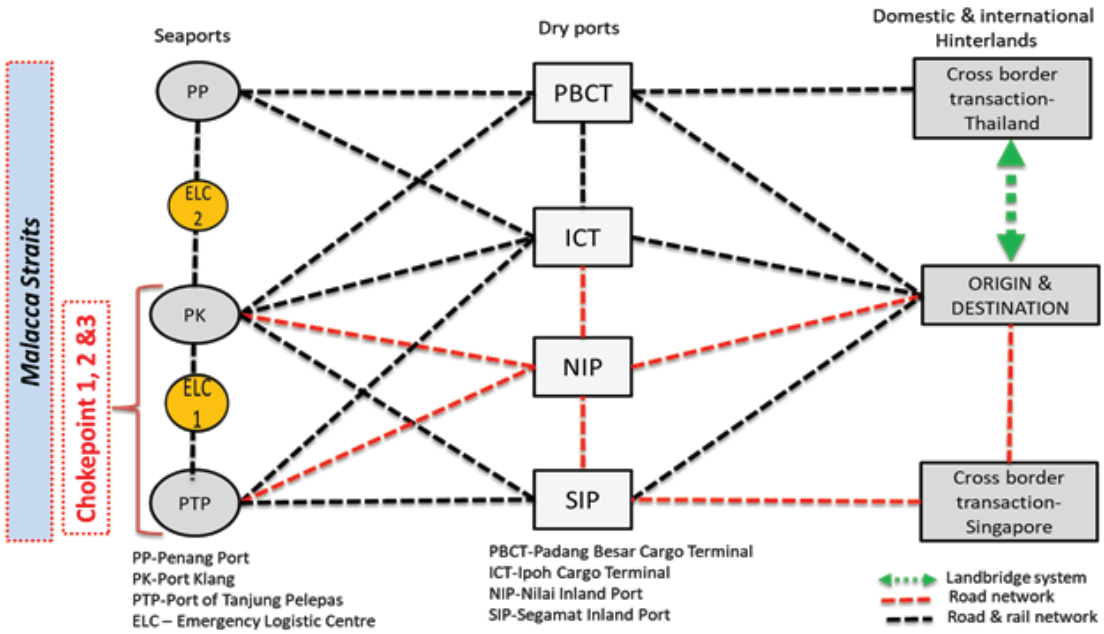


Figure 2.
Incorporation of logistics nodes in the ELC operations.
Source: Authors.

6. CONCLUSION AND FUTURE RESEARCH

Concisely, the outcome of this research shows that there are three main factors contributing to the development of the ELC at the SOM. The first factor is resources availability, which comprise adequate port facilities and infrastructure, sufficient human resources for the ELC operations, adequate transportation and distribution infrastructure, and the role of Kuala Linggi Port as a port of refuge strategically located at the SOM. The second factor that contributes to the ELC development at the SOM is risk management, which includes threat of ship accidents, increasing volume of ship traffic, and disaster caused by dangerous goods or noxious and hazardous substance spills from ships. Thirdly, the geographical factor (i.e. unpredictable weather and geographical conditions at the SOM) motivates the emergence of the ELC in this region. In this case, policy makers, shipping lines, and seaport authorities need to execute the development of the ELC at the SOM to ensure that the performance of seaports and shipping lines at this waterway are not affected for any reasons. Moreover, the development of the ELC is urgently required to ensure that the relationship between Malaysia and other neighbouring regions in Southeast Asia are not affected due to a disaster occurring in the SOM.

This research finds that all the components of the ELC including seaports, dry ports, and hinterland need to improve their disaster preparedness. This can be done through technology enhancement and implementation, comprehensive emergency logistics training program, application of information system in the ELC, disaster preparedness, and collaboration among parties involved. In addition, the performance of the ELC can be improved by placing emphasis on the ELC management system, especially on unified command and network, coordination, infrastructure support system, and procurement management. Finally, the third strategy to enhance the performance of the ELC in this region are safety procedures focusing on contingency plan, emergency transportation channel, and legal guarantee. The performance of the ELC needs to be periodically upgraded due to rapid changes in maritime business and technology. Furthermore, the application of artificial intelligence is urgently required to handle potentially dangerous rescue situations at the Straits. In such a scenario, the application of e-navigation via unmanned vessels, especially for the purpose of search and rescue, will be highly encouraged for safety reasons.

As a maritime nation located adjacent to the world's busiest straits, the development of the ELC in Malaysia is vital to protect the trade system in this region as well as the efficiency of the global trade. Carriage of one third of the world's traded cargo through this waterway requires a smooth flow with sufficient and effective support system. Therefore, awareness of the importance of the ELC needs to be instilled among shipping lines, seaport operators, neighbouring regions, Sungai Linggi seaport ELC, and logistics nodes from inland. This will help them to understand the

role, objectives, and operating procedure of the ELC. In addition, the main limitation of this research is the respondent involved, not fully aware on the role of foreland, seaports, hinterland in the ELC operations. Therefore, an awareness needs to be developed among all the players in seaport system to indicate they have equal responsibility to be executed in the ELC operations. Besides establishing an ELC in Malaysia, ELC branches also need to be developed in all the neighbouring regions in order to bring comprehensive and collective benefits to the entire region, and this area is worthy of being explored in future.

REFERENCES

Akten, N., 2006. Shipping accidents: a serious threat for marine environment. Journal of the Black Sea Mediterranean Environment, 12(3), pp. 269-304.

Amna, S., 2013. Logistics support and its management during disaster relief operations. International Journal of Scientific Footprints, 1(1), pp. 1–12.

Ariyanti, S.D., 2013, Site selection and transportation routes of tsunami emergency logistics warehouse assessment using (GIS) in Cilacap Regency, Central Java Province, Indonesia, Doctoral dissertation, Universitas Gadjah Mada.

Awaludin, N. A. & Abu. M.I., 2017. Malaysia's emergency straits of Malacca response in strait of Malacca. Centre for Maritime Security & Diplomacy, Maritime Institute of Malaysia.

Bertsch, A.M., 2012. Validating GLOBE's societal values scales: a test in the USA. International Journal of Business and Social Science, 3(8).

Bozorgi-Amiri, A. et al., 2011. A modified particle swarm optimization for disaster relief logistics under uncertain environment. The International Journal of Advanced Manufacturing Technology, 60(1-4), pp.357–371. Available at: http://dx.doi.org/10.1007/s00170-011-3596-8.

Caunhye, A.M., Nie, X. & Pokharel, S., 2012. Optimization models in emergency logistics: A literature review. Socio-Economic Planning Sciences, 46(1), pp.4–13. Available at: http://dx.doi.org/10.1016/j.seps.2011.04.004.

Chang, S.E. et al., 2014. Consequences of oil spills: a review and framework for informing planning. Ecology and Society, 19(2). Available at: http://dx.doi.org/10.5751/es-06406-190226.

Cooper, D. R., & Schindler, P.S., 2014. Business Research Methods. McGraw Hill, New York, International Edition, pp. 421–445.

Cozzolino, A., 2012. Humanitarian Logistics and Supply Chain Management. SpringerBriefs in Business, pp.5–16. Available at: http://dx.doi.org/10.1007/978-3-642-30186-5_2.

Creswell, J.W. & Garrett, A.L., 2008. The "movement" of mixed methods research and the role of educators. South African Journal of Education, 28(3), pp.321–333. Available at: http://dx.doi.org/10.15700/saje.v28n3a176.

Dollah, R., M and Mohammad, A. M., 2010. Malaysia–Indonesia Barter Trade: Opportunities and challenges, Journal of Southeast Asian Studies, 12(1), pp.411-419.

EMSA, 2017. European Maritime Safety Agency, Places of Refuge. Available at: http://www.emsa.europa.eu/implementation-tasks/places-of-refuge.html, accessed on: 12 September 2018.

Fritz Institute, 2005. Logistics and the effective delivery of humanitarian relief. Available at: http://www.fritzinstitute.org/, accessed on 10 September 2018.

George, M., 2008. Legal regime of the Straits of Malacca and Singapore: Lexis Nexis Malaysia Sdn. Bhd.

Hair, J. F., Black, W.C., Babin, B. and Anderson, R.E., (2010), Multivariate Data Analysis: A Global Perspective, 7th ed., Pearson, London.

Holdeman E., 2014. Technology plays an increasing role in emergency management, Emergency Management. Available at: http://www.govtech.com/em/training/Technology-Increasing-Role-Emergency-Management.html, accessed on: 22 September 2017.

Holguín-Veras, J. et al., 2007. Emergency Logistics Issues Affecting the Response to Katrina. Transportation Research Record: Journal of the Transportation Research Board, 2022(1), pp.76–82. Available at: http://dx.doi.org/10.3141/2022-09.

Howden, M., 2009. How humanitarian logistics information systems can improve humanitarian supply chains: A view from the field. Proceedings of the 6th ISCRAM.

Ibrahim, H. & Khalid, N., 2007. Growing shipping traffic in the Strait of Malacca: Some reflections on the environmental impact, in Maritime Institute of Malaysia, pp. 17–18.

Ibrahim, H. M., Husin, H. A., & Sivaguru, D., 2008. Physical, Ecological and Demographic Characteristics. Profile of the Straits of Malacca: Malaysia's perspective. Maritime Institute of Malaysia, Kuala Lumpur.

IRGC, 2011. International Risk Governance Council Report, Chemin de Balexert Châtelaine, Geneva.

Jeevan, J. et al., 2020. Implication of e-navigation on maritime transportation efficiency. WMU Journal of Maritime Affairs, 19(1), pp.73–94. Available at: http://dx.doi.org/10.1007/s13437-020-00194-z.

Jeevan, J., Chen, S. & Lee, E., 2015. The Challenges of Malaysian Dry Ports Development. The Asian Journal of Shipping and Logistics, 31(1), pp.109–134. Available at: http://dx.doi.org/10.1016/j.ajsl.2015.03.005.

Jeevan, J., Chen, S.-L. & Cahoon, S., 2018a. Determining the influential factors of dry port operations: worldwide experiences and empirical evidence from Malaysia. Maritime Economics & Logistics, 20(3), pp. 476–494. Available at: http://dx.doi.org/10.1057/s41278-017-0063-y.

Jeevan, J., Chen, S.-L. & Cahoon, S., 2018b. The impact of dry port operations on container seaports competitiveness. Maritime Policy & Management, 46(1), pp.4–23. Available at: http://dx.doi.org/10.1080/03088839.2018.1505054.

Ji, G. & Zhu, C., 2012. A Study on Emergency Supply Chain and Risk Based on Urgent Relief Service in Disasters. Systems Engineering Procedia, 5, pp.313–325. Available at: http://dx.doi.org/10.1016/j.sepro.2012.04.049.

Jiaxin Wang & Xiaoxia Zhu, 2015. Research on emergency logistics center location decision approach based on synthetic information entropy. 2015 International Conference on Logistics, Informatics and Service Sciences (LISS). Available at: http://dx.doi.org/10.1109/liss.2015.7369790.

Khalid, N., 2013. Keep calm and carry on shipping, Maritime Risk International, 27(7), pp. 14–15.

Koseoglu, A. M. & Yildirimli, H., 2015. The role of logistics in disaster management, Journal of Teaching Education, 4(3), pp. 377–388.

Malaysian Marine Department, 2017. Vessel traffic at Malacca Straits. Available at: http://www.marine.gov.my/jlm/Contentdetail.asp?article_id=515&category_id=4&subcategory_id=45#.W6BO3egzaUk, accessed on: 18 September 2018.

MDMRH, 2016. Malaysia Disaster Management Reference Handbook, Center for Excellence in Disaster Management and Humanitarian Assistance, USA.

Mei, H. & Yin, Y., 2009. Studies on marine oil spills and their ecological damage. Journal of Ocean University of China, 8(3), pp.312–316. Available at: http://dx.doi.org/10.1007/s11802-009-0312-5.

Mohd Rusli, M.H., 2020. Navigational Hazards in International Maritime Chokepoints: A Study of the Straits of Malacca and Singapore. Journal of International Studies. Available at: http://dx.doi.org/10.32890/jis.8.2012.7926.

Morrison, A., 2011. Shelter from the Storm – the problem of places of refuge for ships in distress and proposals to remedy the problem, pp. 1–442. Available at: http://ro.uow.edu.au/theses/3218/, accessed on: 15 December 2017.

Pettit, S., Beresford, A., Whiting, M., and Banomyong R., 2011. The 2004 Thailand tsunami reviewed: Lesson learned. Humanitarian logistics. Meeting the challenge of preparing for and responding to disasters, pp. 103–119.

Schaafstal, A.M., Johnston, J.H. & Oser, R.L., 2001. Training teams for emergency management. Computers in Human Behavior, 17(5-6), pp.615–626. Available at: http://dx.doi.org/10.1016/s0747-5632(01)00026-7.

Schiel, D., Ross, P. & Battershill, C., 2016. Environmental effects of the MV Rena shipwreck: cross-disciplinary investigations of oil and debris impacts on a coastal ecosystem. New Zealand Journal of Marine and Freshwater Research, 50(1), pp.1–9. Available at: http://dx.doi.org/10.1080/00288330.2015.1133665.

Sena, L. and Michael, K. W., 2006. Disaster prevention and preparedness. Ethiopia Public Heal Train Initiate, 1, pp.1-180.

Sheu, J.-B., 2007. Challenges of emergency logistics management. Transportation Research Part E: Logistics and Transportation Review, 43(6), pp.655–659. Available at: http://dx.doi.org/10.1016/j.tre.2007.01.001.

Subbarao, A., Priya, R. & Joshi, K. J., 2014. Space technology in disaster management. Science Horizon, pp. 18.

Sunyoto and Wismadi, A., 2008. Developing Humanitarian Logistics Strategy: An Intersectionist View. Asia Pacific Whitepaper Series, Volume 12.

Tabachnick, B. G. & Fidell, L. S., 2000. Using multivariate statistics, 4th Ed., Harper Collins, New York.

Thompson, D.D.P., 2015. Disaster logistics in small island developing states: Caribbean perspective. Disaster Prevention and Management: An International Journal, 24(2), pp.166–184. Available at: http://dx.doi.org/10.1108/dpm-09-2014-0187.

Timoleon, C., 2012. The logistics chain of emergency supplies in disasters. International medicine health crisis management, School of Medicine, Athens University.

Van Wassenhove, L.N., 2006. Humanitarian aid logistics: supply chain management in high gear. Journal of the Operational Research Society, 57(5), pp.475–489. Available at: http://dx.doi.org/10.1057/palgrave.jors.2602125.

Wisetjindawat, W. et al., 2014. Planning Disaster Relief Operations. Procedia - Social and Behavioral Sciences, 125, pp.412–421. Available at: http://dx.doi.org/10.1016/j.sbspro.2014.01.1484.

Yan, L. et al., 2009. A heuristic project scheduling approach for quick response to maritime disaster rescue. International Journal of Project Management, 27(6), pp.620–628. Available at: http://dx.doi.org/10.1016/j.ijproman.2008.10.001.

Yan, X.P. et al., 2017. Emergency Management of Maritime Accidents in the Yangtze River: Problems, Practice and Prospects. TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation, 11(1), pp.111–118. Available at: http://dx.doi.org/10.12716/1001.11.01.13.

Yang, W., 2006. A study on the legal problems related to places of refuge. The Maritime Commons: Digital Repository of the World.

Yong, A.G. & Pearce, S., 2013. A Beginner's Guide to Factor Analysis: Focusing on Exploratory Factor Analysis. Tutorials in Quantitative Methods for Psychology, 9(2), pp.79–94. Available at: http://dx.doi.org/10.20982/tqmp.09.2.p079.

Zaman, M.B. et al., 2015. Risk of Navigation for Marine Traffic in the Malacca Strait Using AIS. Procedia Earth and Planetary Science, 14, pp.33–40. Available at: http://dx.doi.org/10.1016/j.proeps.2015.07.082.

The Influence of Dry Port Establishment on Regional Development Through Regional Development Index

Ivica Lovrić[a], Dajana Bartulović[b], Sanja Steiner[c]

The goal of the Regional Development Policy of the Republic of Croatia is to contribute to the identification of priority activities that would strengthen the development potential of all Croatian regions, reduce regional disparities, strengthen and build the development potential of less developed parts of the country. The aim of this paper is to illustrate the effect of establishment of a new dry port on regional development through increased development index. Details of regional development index calculation are presented in the paper, and an example of the calculation containing the actual data for the regions/counties of the Republic of Croatia is given. A simulation of regional development index calculation in case of establishment of a new dry port was run and presented. The simulation of development index increase as a result of dry port establishment in the town of Vinkovci in the Vukovar-Srijem County was conducted. Vinkovci was chosen primarily owing to its favourable geographic position in the TEN-T network connecting Croatia with various destinations through the Orient East-Med Corridor or Rhine-Danube Corridor, existing infrastructure that can be used for new dry port terminal, and the fact that Vukovar-Srijem is one of the most undeveloped regions (counties) in Croatia. The results have shown that the regional development index would increase in the region/ county of dry port establishment. The contribution of this research is that the paper proves the influence of dry port establishment on regional development, with emphasis on the number of newly employed persons and the effect thereof on regional development index indicators.

KEY WORDS

~ Dry port establishment,
~ Regional development
~ Increase
~ Regional development index

a. City of Zagreb, Croatia

e-mail: ivica.lovric@zagreb.hr

b. Institute of Traffic and Communications, Croatia

e-mail: dbartulovic@gmail.com

c. Croatian Academy of Sciences and Arts, Institute of Traffic and Communications, Zagreb, Croatia

e-mail: ssteiener@hazu.hr

doi: 10.7225/toms.v09.n02.012

1. INTRODUCTION

Dry ports are inland freight terminals directly connected to one or more seaports where activities such as freight consolidation, custom services, logistic activities, warehousing, and other value-added services are provided. Dry ports can move goods from the road to more energy efficient and environmentally friendly modes of transportation (such as rail), reduce congestion in cities, make handling of goods in seaports more efficient and make it easier for carriers to improve logistics solutions in seaport hinterland. The goal of the Regional Development Policy of the Republic of Croatia is to contribute to the identification of priority activities that would strengthen the development potential of all Croatian regions, reduce regional disparities, strengthen and build the development potential of less developed parts of the country. In addition to many advantages brought by dry ports, this paper intends to demonstrate the effect of dry port establishment on regional development.

The aim of this paper is to prove that dry port establishment would increase the regional development index, i.e. to illustrate the effect of dry port establishment on regional development. Details of regional development index calculation are presented in the paper, and an example of the calculation is given containing the actual data for the regions/ counties of the Republic of Croatia.

A parallel was drawn between dry port establishment and the factors influenced thereby, i.e. the defined national indicators in the Republic of Croatia used to calculate the regional development index of an individual county/ region. The emphasis is primarily on the number of newly employed persons in case of dry port establishment.

The method of calculation selected was defined by the national authorities of the Republic of Croatia, and is explained and used to simulate the actual conditions in case of dry port establishment (specifically in Vinkovci, i.e. in the Vukovar-Srijem County). This method was chosen primarily because it is the best way to simulate the actual situation in case of dry port establishment.

The results have shown that dry port establishment with emphasis on the number of newly employed persons, would increase the regional development index of the observed county/ region.

The simulation of regional development index calculation with a newly established dry port was run and presented. An increase of the development index by dry port establishment was simulated by running the scenario of dry port establishment in the Vukovar-Srijem County in the Republic of Croatia. The results of the simulation show the regional development index increased owing to dry port establishment.

2. LITERATURE OVERVIEW: CONCEPT AND ADVANTAGES OF DRY PORT ESTABLISHMENT

Literature overview is divided into two sections. The first section covers previous research on the concept and advantages of dry ports. The second section covers literature on the influence of dry port establishment on regional development.

2.1. Concept and Advantages of Dry Ports: a Chronological Overview of Literature

The most common factors influencing dry port implementation are infrastructure, land use, environment, and regulations. Hence, the same factors reduce the efficiency of freight movement on land access routes to and from seaports (Roso, 2008).

The dry port concept can help identify ways to shift freight volumes from roads to more energy efficient modes of transportation less harmful to the environment, relieve seaport cities from some congestion and facilitate improved logistics solutions for shippers in the port's hinterland (Roso et al., 2009).

For various reasons, global supply chains are getting stretched further into the hinterland from gateway seaports. This single fact enhances the importance of dry ports (Chandrakant, 2011).

According to FDT, a dry port is an intermodal terminal situated in the hinterland servicing a region connected with one or several ports by rail and/or road transport, offering specialised services between the dry port and overseas destinations. Dry port is usually container-oriented and provides all logistics facilities required by shipping and forwarding agents in a port. An important aspect worth mentioning in the context of the dry port concept are value-added services providing dry port users extra values such as saved time, convenience, reduced operational costs, etc. (FDT, 2011).

Hanaoka and Regmi pointed out that the volume of international trade and freight transport in Asia has seen fast growth in the recent decades. The resulting environmental impact of freight transport operations has become a major cause of concern. Intermodal transport recently gained prominence due to its potential to offer door-to-door service through the integration of various modes of transportation in the logistics chain, improved coordination and services, and the development of intermodal interfaces. The development of intermodal transport requires transport links, nodes, and services. The development of dry ports, an important component of intermodal transport, could play a major role in promoting intermodal transport (Hanaoka and Regmi, 2011).

The basic idea behind the dry port concept is more efficient seaport access, movement of the seaport's interface inland with the shift of flows from road to rail. The application of the concept results in the reduction of road transport to/from the seaport together with the associated broad social and environmental benefits (Black et al., 2018).

As container transport volumes continue to grow, sea flow generates almost proportionate inland flow; connections with the hinterland will become critical factors for seaport functionality. Intermodal transport with dry ports could be a potential solution for seaport terminal congestion, as well as for better seaport inland access (Roso, 2013).

Rožić and others stated that technical-technological advancements and globalization influence the development of logistics and distribution methods from the point of manufacture to the point of consumption. To make this process as successful as possible, logistics-distribution centers where goods are collected, stored, upgraded, and prepared for further distribution to customers need to be built. One of the possible functions of logistics distribution centers is their transformation to so called "inland port terminals" (dry ports) (Rožić et al., 2013).

An increase in sea freight flows generates an almost proportionate increase in inland freight flows, and what takes place inland will influence the ability of intermodal transport systems to further accommodate the growth of international trade. This could be facilitated by dry ports developed to support both seaport operations and the overall operations of intermodal transport systems (Bask et al., 2014).

Current trends in maritime logistics often consider the presence of inland freight terminals where consolidation of goods, customs services, information processing activities, short-term storage and value-added manufacturing services for containerized goods take place before shipment to further destinations. Dry ports are defined as inland freight terminals directly connected to one or more seaports with high-capacity means of transportation, where customers can drop and pick up their standardized units as if directly at a seaport. The benefits of introduction of one or more dry ports into freight distribution was confirmed by several experiences in terms of logistics integration and port regionalization (Crainic et al., 2015; Olah et al., 2018; Bask et al., 2014; Roso et al., 2009).

With respect to the assessment of the development of dry ports in Germany and Europe, extensive data are regularly collected. The collected data give an in-depth insight into the status quo of the dry ports (national or international) studied and facilitate ranking to identify, e.g. best practices (Olah et al., 2018).

2.2. Dry Port Impact on Regional Development: a Chronological Overview of Literature

According to Notteboom and Rodrigue, logistics integration and network orientation in the port and maritime industry have redefined the functional role of ports in value chains and generated new patterns of freight distribution and new approaches to port hierarchy. The existing models of spatial and functional evolution of ports and port systems only partially fit into the new freight distribution paradigm. Their research aims to introduce a port regionalization stage in port and port system development (Notteboom and Rodrigue, 2005).

Ng and Gujar (2009) studied dry ports in India with emphasis on regional development around dry ports that could attract users. Value added services offered at dry ports can make a region more attractive to actors in its immediate vicinity, as well as attract potential new users from more remote locations (Ng and Gujar, 2009).

Ng and Tongzon stated that since a dry port acts as a seaport's inland interface, shifting port services to an inland region, it provides a stimulus for development and generates new employment. Furthermore, regional development might positively influence competitiveness by maximizing the use of existing infrastructure and generating trade volumes. They went so far as to declare that dry ports were catalysts for regional development, at least in India (Ng and Tongzon, 2010).

In 2010, Rodrigue and Notteboom focused on a particular dimension of the regionalization paradigm, i.e. the evolving role of intermediate hubs. It is argued that, in addition to hinterland-based regionalization, there is also a foreland-based regionalization where intermediate hubs capture the maritime hinterland. This intensity and viability of processes of foreland-based regionalization depend on multiple geographical, technical, and market-related factors, and the paper identifies and analyses these underlying parameters (Rodrigue and Notteboom, 2010).

Contemporary economic development has underlined the importance of establishing distribution centers at appropriate locations in developing economies. In 2011, Ng and Cetin examined the locational characteristics of distribution centers in developing economies (Ng and Cetin, 2011).

Wilmsmeier and others examined the spatial development of freight infrastructure, and developed a conceptual model that draws attention to the directional development of intermodal corridors in relation to inland terminals. They presented different approaches to the development of inland terminal facilities, elaborated government strategies and policies in terms of dry port regulation, and developed a conceptual model of directional development: inside-out and outside-in (Wilmsmeier et al., 2011).

Flämig and Hesse (2011) put an emphasis on dry ports in the context of port regionalization. Their paper specifically deals with dry ports as a challenge for planning, policy, and metropolitan governance in the vicinity of seaports. Flämig and Hesse also adopted a long-term perspective and investigated the positioning of dry ports. The authors considered the potential consequences of the development of dry ports as elements of port regionalization strategies, i.e. the changes in transportation flow management, land use, governance, and planning (Flamig and Hesse, 2011).

According to Li and Jiang, reaching the vast economic hinterland and suppling it with goods have become strategic problems for port operators. In addition, the establishment of a low-cost and highly efficient transportation and customs clearance route has become an inevitable requirement for the regional development of the hinterland (Li and Jiang, 2014).

Shi and Li, studying the impact of the global supply chain and regional economic development, proposed different perspectives for analysing the development of port hinterland and applied these perspectives to Shenzhen Port in China. Due to the changing nature of a port's function, hinterland development was viewed from physical, logistics, and macroeconomic perspectives, and the influencing factors were analysed from the shippers' viewpoint in terms of three driving forces: space, value, and organization (Shi and Li, 2016).

The recent development of dry ports in the hinterland, feeder service networks, and heavy foreign trade traffic make the ports in Bohai Bay a unique case in the analysis of inter-port connectivity and competitiveness. Using an integrated port connectivity index to define the above features, the advantages and challenges of individual ports can be assessed in a dynamic interconnected environment. The model presented by Wang and others can be used to obtain unbiased port development strategies for each port, to ensure long-term sustainability (Wang et al, 2016).

Agallos stated that ports are important gateways for domestic and global trade since approximately 80% of the world trade depends on maritime transport. In the globalized world where distances are being continually compressed, the role of ports in local communities is becoming increasingly important. However, the relationship between regional development and port activity, as indicated by various studies, is a complex issue and an important field of conflict. The aim was to develop a complex indicator assessment of port sustainability on a comparable basis (Agallos, 2016).

In the case of Iran, establishing a dry port in the province of Yazd could potentially increase freight transit in that country and foster development (Dorostkar et al., 2016).

In 2017, Dragović and others stated that the simulation modelling of shore-side and sea-side port operations constitutes a fundamental prerequisite for effective project planning in port development, as the influence of numerous often interactive parameters has to be addressed at an early stage to account for the optimum supply of port facilities and services to meet current and future demand (Dragović et al., 2017).

The application of mixed methods was proposed in dry port research to provide a multidimensional insight into seaport research issues. Jeevan and others provided guidance on the application of mixed methods in dry port research and demonstrated that mixed method research is capable of providing comprehensive results through integration of qualitative and quantitative results in a single research (Jeevan et al., 2019).

Nguyen and Notteboom defined the generic characteristics of dry ports by carrying out an analysis on a large sample of dry ports worldwide. The data collected include the terminologies used, actors driving the development, terminal throughput, total area, services provided and connection with corresponding seaports. Using statistical analysis, the paper examines how dry port parameters are influenced by different terminal set ups, like sea-driven and land-driven development, developed and developing systems, dry port functions, specifications of seaports with which the dry port is connected, i.e. seaport traffic, connectivity, utilization, etc. and the transport leg linking dry ports and seaports. The findings could be applied to the planning and development of inland nodes from the perspectives of different stakeholders (Nguyen and Notteboom, 2019).

Khaslavskaya and Roso stated that dry ports faced a variety of challenges in implementation and development stages in the form of existing social, political, environmental, and financial regulations or the lack thereof, as well as technical and technological development, land and infrastructure use, location and optimization issues, development and availability of infrastructure, stakeholder interests, investments and competitive business environment. At the same time, their research shows that dry ports could bring significant benefits to the stakeholders involved in hinterland transport operations by improving distribution systems, reducing direct and indirect logistics costs, stimulating regional development, and lowering the level of transportation emissions (Khaslavskaya and Roso, 2020).

Based on existing literature dry ports can be concluded to have a significant impact on regional development. Studying the factors influenced by dry port establishment and the method of calculation of the regional development index of a county/ region (specifically in the Republic of Croatia), a correlation was found between dry port establishment and regional development index calculation, i.e. the number of newly employed persons, as well as other relevant parameters: income per capita, budget revenues per capita, and education rate. The aim of this paper is to fill a hole in existing literature by providing an example of regional development index increase due to dry port establishment, by simulating the impact thereof using a defined mathematical method and defined parameters to calculate the regional development index in the Republic of Croatia in case of establishment of a dry port in Vinkovci, i.e. in the Vukovar-Srijem County.

3. DEFINITION AND RELEVANCE OF THE REGIONAL DEVELOPMENT FACTOR

The Ministry of Regional Development and EU Funds (Ministry of Regional Development and EU Funds, 2018) adopts the policy of balanced regional development aiming to further develop less developed areas of the Republic of Croatia and thus reduce regional development inequalities in the Republic of Croatia. Regional development is one of the most important guidelines of the European Union, which allocates as much as a third of its budget to the development of less developed regions in the EU, through the so-called EU cohesion policy. The policy of balanced regional development in the Republic of Croatia implies planning, implementation and coordination of regional development policy activities and the establishment of a comprehensive system of regional development programming, management, and financing.

The enactment of the Regional Development Act followed by the adoption of the Regional Development Strategy of the Republic of Croatia laid the foundations for regional development policy management, aimed at building the overall development potential of the Republic of Croatia.

In an effort to reduce imbalances in the development of certain areas and help create the preconditions for sustainable economic and social development, programs and measures for the construction and modernization of municipal and social infrastructure based on partnership and solidarity are being implemented.

In accordance with the Regional Development Act of the Republic of Croatia and its amendment (Regional Development Act of the Republic of Croatia, 2014), the Ministry of Regional Development and EU Funds (Ministry of Regional Development and EU Funds, 2018) is conducting an assessment and development index-based classification of all units of local and regional self-government units (LRUs) in the Republic of Croatia.

Amendments to the Act that entered into force on 13 December 2017 (Amendment of Regional Development Act of the Republic of Croatia, 2017) improved the legal framework regulating the procedure of LRU assessment and classification depending on the level of development and the method of identifying less developed areas.

The new model of development index calculation is based on an expert study titled "Evaluation of the Existing and Proposal of a New Model of Index Calculation and Calculation of the New Development Index of Local and Regional Self-Government Units in the Republic of Croatia" prepared by the Centre for Local Economic Development (CLER, 2017) for the Ministry.

Following the adoption of amendments to the Act and the development of a new model of development index calculation, a new Regulation on the Development Index was adopted (Regulation on the Development Index, 2017). The Regulation identifies the basic indicators for development index calculation, their calculation and data sources, and the method of development index calculation.

The development index facilitates the measurement of the level of development of LRUs in the Republic of Croatia. The classification or categorization of all territorial units according to development is based on the modern understanding of regional policy which, although focused on the least developed areas, encourages the development of entire territory of a country. The categorization of all territorial units facilitates better regulation of the key issue of the amount of regional development incentives. The establishment of a direct correlation between the amount of regional development incentives and the level of development allowed the creation of a quality framework encouraging the development of all local and county units depending on their individual level of development. Likewise, this approach allows the inclusion and exclusion of individual units from the system of assisted areas (less developed areas) depending on changes in their development level.

Regional self-government units are classified into four groups (Regulation on the Development Index, 2017):

I. group are regional self-government units which, according to the value of the index, are in the second half of the below-average ranked regional self-government units;
II. group are regional self-government units which, according to the value of the index, are in the first half of the below-average ranked regional self-government units;
III. group are regional self-government units which, according to the value of the index, are in the second half of the above-average ranked regional self-government units;
IV. group are regional self-government units which, according to the value of the index, are in the first half of the above-average ranked regional self-government units.

Local self-government units are divided into eight groups (Regulation on the Development Index, 2017):

I. group are local self-government units which, according to the value of the index, are in the last quarter of below-average ranked local self-government units;
II. group are local self-government units which, according to the value of the index, are in the third quarter of below-average ranked local self-government units;
III. group are local self-government units which, according to the value of the index, are in the second quarter of below-average ranked local self-government units;
IV. group are local self-government units which, according to the value of the index, are in the first quarter of below-average ranked local self-government units;
V. group are local self-government units which, according to the value of the index, are in the last quarter of above-average ranked local self-government units;
VI. group are local self-government units which, according to the value of the index, are in the third quarter of above-average ranked local self-government units;
VII. group are local self-government units which, according to the value of the index, are in the second quarter of above-average ranked local self-government units;
VIII. group are local self-government units which, according to the value of the index, are in the first quarter of above-average ranked local self-government units.

4. REGIONAL DEVELOPMENT INDEX

According to the Regulation on the Development Index (Regulation on the Development Index, 2017), the development index of a regional or local self-government unit in the Republic of Croatia is calculated on the basis of the following basic indicators:

5. unemployment rate,
6. income per capita,

7. budget revenues per capita,
8. general population movement,
9. education rate,
10. ageing index.

4.1. Unemployment Rate

Unemployment rate is calculated as the ratio of the number of unemployed and the sum of all employed and unemployed persons on the territory of a local or regional self-government unit. Unemployment rate is calculated using the following equation (Regulation on the Development Index, 2017):

$$x_1 = \frac{N_{(0)}}{RS_{(0)}} \quad (1)$$

where variables are:

$N_{(0)}$ – the number of the unemployed on the territory of a particular local or regional self-government unit,

$RS_{(0)}$ – the sum of all employed and unemployed persons on the territory of a particular local or regional self-government unit.

This indicator was calculated using the data of the Croatian Employment Service on the number of registered unemployed persons and the data of the Croatian Tax Administration on the number of employed persons at the level of local or regional self-government units over a one-year period.

4.2. Income Per Capita

İncome per capita is determined in keeping with the act governing income tax, and includes income earned from non-self-employment and income earned from self-employment. The total amount of income also includes profit from independent activity realized in a given tax period (calendar year) on the territory of a local or regional self-government unit for which the calculation is made. Income Tax Act defines income from self-employment as income less deductions and retained loss. Profit is defined as profit after prescribed reductions and increases in profit, in accordance with the Income Tax Act.

İncome per capita is calculated as the ratio of the total amount of income earned in a given tax period (calendar year) by taxpayers with permanent residence on the territory of a local or regional self-government unit for which the calculation is made, and the number of residents living on the territory of that unit. İncome per capita is calculated using the following equation (Regulation on the Development Index, 2017):

$$x_2 = \frac{D_i}{P_i} \quad (2)$$

where variables are:

D_i – the sum of incomes earned by residents in the i-th local or regional self-government unit during one calendar year,

P_i – estimated number of residents in the i-th local or regional self-government unit at the end of the year.

This indicator was calculated using the data of the Croatian Tax Administration on paid incomes and the data of the Croatian Bureau of Statistics on the number of residents of local or regional self-government units.

4.3. Budget Revenues Per Capita

Budget revenues of local or regional self-government units per capita are calculated as the ratio of realized revenues of local or regional self-government unit less income:

- from domestic and foreign aids and donations or means of fiscal equalization,
- from special contracts: co-financing of local self-government by citizens,
- realized based on additional shares in income tax and equalization aid for financing decentralized functions,
- from the sale of non-financial assets,
- from surtax on income tax, and
- the number of residents on the territory of a local or regional self-government unit.

Budget revenue per capita is calculated using the following equation (Regulation on the Development Index, 2017):

$$x_3 = \frac{IPP_i}{P_i} \quad (3)$$

where variables are:

IPP_i – the amount of budget revenues generated in the area of the i-th local or regional self-government unit during one calendar year, i.e. the amount of budget revenues generated on the territory of the i-th regional self-government unit and all of its local self-government units,

P_i – the estimate of the number of residents in the i-th local or regional self-government unit at the end of the year.

This indicator was calculated using the data of the Ministry of Finance on budget revenues of local or regional self-government units and the Croatian Bureau of Statistics on the number of residents of local or regional self-government units.

4.4. General Population Movement

The general movement of the population is calculated as the ratio of a comparable number of residents of a local or regional self-government unit in the last available ten-year period. The general movement of the population is calculated using the following equation (Regulation on the Development Index, 2017):

$$x_4 = \frac{P_n}{P_{n-10}} \tag{4}$$

where variables are:

P_n – the estimated number of residents in the i-th local or regional self-government unit in the observed year,

P_{n-10} – the estimated number of residents of the i-th local or regional self-government unit in the last available ten-year period.

This indicator was calculated using the data of the Croatian Bureau of Statistics on the number of residents of local and regional self-government units.

4.5. Education Rate

Education rate is the share of population with completed higher education in the total population aged 20-65 in the area of a local or regional self-government unit. The education rate is calculated using the following equation (Regulation on the Development Index, 2017):

$$x_5 = \frac{P_{(he+)}}{P_{(20+)}} \tag{5}$$

where variables are:

$P_{(he+)}$ – the number of residents in the i-th local or regional self-government unit with completed higher education,

$P_{(20+)}$ – the number of residents in the i-th local or regional self-government unit aged 20-65.

This indicator was calculated using the data of the Croatian Bureau of Statistics on the educational structure of the population of the Republic of Croatia and the number of population aged 20-65 at the level of local or regional self-government units.

4.6. Ageing Index

The ageing index is calculated as the percentage of the population aged 60 and above in relation to the population aged 0-19. The ageing index is calculated using the following equation (Regulation on the Development Index, 2017):

$$x_6 = \frac{P_{(60+)}}{P_{(0-19)}} \tag{6}$$

where variables are:

$P_{(60+)}$ – the number of residents in the i-th local or regional self-government unit aged 60 and above,

$P_{(0-19)}$ – the number of residents in the i-th local or regional self-government unit aged 0-19.

This indicator was calculated using the data of the Croatian Bureau of Statistics on age contingents of the population at the level of local or regional self-government units.

5. REGIONAL DEVELOPMENT INDEX CALCULATION METHODOLOGY

The value of the development index is calculated as an adjusted average of the standardized values of the six previously mentioned basic indicators over a given period of time. The value of the development index is calculated to three decimal places.

Calculation is based on the so-called z-score methodology (CLER, 2017; Bogdan et al., 2019). The z-score method is a nonlinear method for creating composite indices that transforms the values of individual indicators into standardized values and summarizes them into a composite index using the arithmetic mean and a penalty coefficient. This method was developed by the authors Mazziotta and Pareto, and is known in the scientific and professional literature as the Mazziotta-Pareto index (De Muro et al., 2011; Mazziotta and Pareto, 2016). The Mazziotta-Pareto index is designed to solve the problem of objective measurement, evaluation, comparison and ranking of units at higher or lower territorial-administrative levels depending on their development in a given period of time when individual unit(s) have uncoordinated sets of indicators, i.e. when according to some indicators they achieve above-average results, and according to others below-average results.

The development index is interpreted so that local or regional self-government units with an index value greater than 100 are classified as units with above-average development level, while local or regional self-government units with an index value under 100 are classified as units with below-average development level.

The process of indicator standardization for the income per capita, budget revenues per capita, general population movements and education rate indicators, whose high values are positive in the context of development, is carried out using the following equation (Regulation on the Development Index, 2017):

$$Z_{ij} = 100 + \frac{x_{ij} - M_{xj}}{S_{xj}} * 10 \quad (7)$$

while the process of indicator standardization for the unemployment rate and ageing index indicators, whose high values are negative in the context of development, is carried out using the following equation (Regulation on the Development Index, 2017):

$$Z_{ij} = 100 - \frac{x_{ij} - M_{xj}}{S_{xj}} * 10 \quad (8)$$

where variables are:

Z_{ij} – standardized value (*z-score*) of basic indicator *x* for an observed local or regional self-government unit,

x_{ij} – the value of the basic indicator *x* for an observed local or regional self-government unit,

M_{xj} – the arithmetic mean of the basic indicator *x* for all units of local or regional self-government,

S_{xj} – standard deviation of the set of values of the basic indicator *x* for all units of local or regional self-government.

The steps of aggregating the standardized values of the basic indicators obtained by the previous equations into the development index are carried out using the arithmetic mean method and the penalty coefficient as shown in the following equation (Regulation on the Development Index, 2017):

$$I_i = M_{zi} - (S_{zi} * cv_i) \quad (9)$$

where variables are:

I_i – development index of a local or regional self-government unit,

M_{zi} – arithmetic mean of standardized values of all indicators for an observed unit of local or regional self-government,

$(S_{zi} * cv_i)$ – penalty coefficient for an observed unit of local or regional self-government,

S_{zi} – standard deviation of the set of standardized values of all indicators for an observed unit of local or regional self-government,

cv_i – coefficient of variation of a set of standardized values of all indicators for an observed unit of local or regional self-government.

6. EXAMPLE OF REGIONAL DEVELOPMENT INDEX CALCULATION

The calculation of the basic development index indicators requires the data requisite to calculate each basic indicator. All variables are data taken from statistical reports of the Croatian Employment Service, the Croatian Tax Administration, the Ministry of Finance and the Croatian Bureau of Statistics (Regulation on the Development Index, 2017), i.e. they represent constants in the mathematical sense.

If development index calculation indicators are defined as follows:

x_1 – unemployment rate

$$x_1 = \frac{N_{(0)}}{RS_{(0)}} \quad (10)$$

x_2 – income per capita

$$x_2 = \frac{D_i}{P_i} \quad (11)$$

x_3 – budget revenues per capita

$$x_3 = \frac{IPP_i}{P_i} \quad (12)$$

x_4 – general population movement

$$x_4 = \frac{P_n}{P_{n-10}} \quad (13)$$

x_5 – education rate

$$x_5 = \frac{P_{(he+)}}{P_{(20+)}} \tag{14}$$

x_6 – ageing index

$$x_6 = \frac{P_{(60+)}}{P_{(0\text{-}19)}} \tag{15}$$

the standardized values of the indicators are as follows:
Z_{x1j} – standardized value of the unemployment rate indicator

$$Z_{x1j} = 100 - \frac{x_{1j} - M_{x1j}}{S_{x1j}} * 10 \tag{16}$$

Z_{x2j} – standardized value of the income per capita indicator

$$Z_{x2j} = 100 + \frac{x_{2j} - M_{x2j}}{S_{x2j}} * 10 \tag{17}$$

Z_{x3j} – standardized value of the budget revenues per capita indicator

$$Z_{x3j} = 100 + \frac{x_{3j} - M_{x3j}}{S_{x3j}} * 10 \tag{18}$$

Z_{x4j} – standardized value of general population movement indicator

$$Z_{x4j} = 100 + \frac{x_{4j} - M_{x4j}}{S_{x4j}} * 10 \tag{19}$$

Z_{x5j} – standardized value of the education rate indicator

$$Z_{x5j} = 100 + \frac{x_{5j} - M_{x5j}}{S_{x5j}} * 10 \tag{20}$$

Z_{x6j} – standardized value of the ageing index indicator

$$Z_{x6j} = 100 - \frac{x_{6j} - M_{x6j}}{S_{x6j}} * 10 \tag{21}$$

where the arithmetic mean and standard deviation are expressed with equations:

$$M_{xj} = \frac{\sum_{j=1}^{m} x_j}{m}, m=1...3 \tag{22}$$

$$S_{xj} = \sqrt{\frac{1}{m}\sum_{j=1}^{m}(x_j - M_{xj})^2}, m=1...3 \tag{23}$$

and the development index is calculated as follows:

$$I_i = M_{zi} - (S_{zi} * cv_i) \tag{24}$$

that is, using the following steps:
1) Arithmetic mean of standardized values of all indicators for a single local or regional self-government unit:

$$M_{Zi} = \frac{\sum_{i=1}^{n} Z_i}{n}, n=1...6 \tag{25}$$

or:

$$M_{Zi} = \frac{Z_{x1j} + Z_{x2j} + Z_{x3j} + Z_{x4j} + Z_{x5j} + Z_{x6j}}{6} \tag{26}$$

2) Standard deviation of standardized values of all indicators for a single local or regional self-government unit:

$$S_{Zi} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(Z_i - M_{Zi})^2}, n=1...6 \quad (27)$$

3) Coefficient of variation of the set of standardized values of all indicators for a single local or regional self-government unit:

$$cv_i = \frac{S_{Zi}}{M_{Zi}} \quad (28)$$

Table 1.
Example of the values of basic indicators required for regional development index calculation.
Source: Authors according to (Ministry of Regional Development and EU Funds, 2018)

County	**Values of basic indicators for the county (regional unit)**					
	x1	**x2**	**x3**	**x4**	**x5**	**x6**
	Unemployment rate	Income per capita	Budget revenues per capita	General population movement	Education rate	Ageing index
City of Zagreb	0.1007	44,733.21	6,232.49	103.10	0.3935	118.9
Istria	0.0654	35,191.17	5,535.63	101.17	0.2250	136.8
Dubrovnik-Neretva	0.1323	30,904.76	4,848.62	101.07	0.2618	109.4
Zagreb	0.1079	32,579.23	3,222.84	100.54	0.1678	100.1
Primorje-Gorski Kotar	0.1141	35,367.41	5,229.00	96.91	0.2747	155.3
Zadar	0.1200	26,630.15	3,908.88	102.30	0.2085	117.4
Split-Dalmatia	0.1923	28,190.12	3,476.57	99.75	0.2472	102.3
Varaždin	0.0974	28,714.71	2,387.25	95.45	0.1628	107.3
Međimurje	0.1164	24,835.25	2,077.08	97.99	0.1367	91.8
Krapina-Zagorje	0.1135	28,783.48	2,092.17	93.73	0.1266	112.6
Koprivnica-Križevci	0.1370	24,587.95	2,703.28	93.24	0.1483	110.5
Šibenik-Knin	0.1622	27,315.29	3,283.90	91.58	0.1944	146.1
Osijek-Baranja	0.2369	26,216.25	2,271.75	91.90	0.1749	106.3
Karlovac	0.1728	29,715.33	2,547.26	88.93	0.1836	149.0
Požega-Slavonia	0.1814	22,925.23	1,550.25	87.42	0.1429	99.2
Brod-Posavina	0.2143	22,105.97	1,550.91	90.09	0.1342	96.5
Bjelovar-Bilogora	0.2246	23,529.44	1,912.61	89.02	0.1310	114.9
Lika-Senj	0.1696	27,401.26	3,392.29	86.29	0.1596	166.0
Vukovar-Srijem	0.2431	22,256.51	1,627.30	88.41	0.1320	98.3
Sisak-Moslavina	0.2461	27,197.16	2,502.17	85.20	0.1481	131.1
Virovitica-Podravina	0.2613	21,297.29	1,872.32	88.54	0.1145	103.3

Table 1 gives an example of the values (data) of basic indicators for development index calculation. The values of variables required for the calculation of basic indicators were taken from Croatian Employment Service, the Croatian Tax Administration, the Ministry of Finance and the Croatian Bureau of Statistics official data for year 2016 (Croatian Employment Service, 2016; Croatian Bureau of Statistics, 2016; Croatian Bureau of Statistics, 2011; Ministry of Regional Development and EU Funds, 2018) for 21 regional self-government units i.e. counties of the Republic of Croatia.

In the next step, the arithmetic mean and standard deviation of all values of one basic indicator for all regional units (counties) are calculated:

$$M_{xj} = \frac{\sum_{j=1}^{m} x_j}{m}, m=1...21 \tag{29}$$

$$S_{xj} = \sqrt{\frac{1}{m}\sum_{j=1}^{m}(x_j - M_{xj})^2}, m=1...21$$

that is, the arithmetic mean and standard deviation of all values of each indicator in all regional governments are as follows:

$$M_{x1j} = \frac{\sum_{j=1}^{m} x_{1j}}{21} = 0.16 \tag{30}$$

$$S_{x1j} = \sqrt{\frac{1}{21}\sum_{j=1}^{m}(x_{1j} - M_{x1j})^2} = 0.06$$

$$M_{x2j} = \frac{\sum_{j=1}^{m} x_{2j}}{21} = 28.117.96$$

$$S_{x2j} = \sqrt{\frac{1}{21}\sum_{j=1}^{m}(x_{2j} - M_{x2j})^2} = 5,370.96$$

$$M_{x3j} = \frac{\sum_{j=1}^{m} x_{3j}}{21} = 3,058.31$$

$$S_{x3j} = \sqrt{\frac{1}{21}\sum_{j=1}^{m}(x_{3j} - M_{x3j})^2} = 1,348.59$$

$$M_{x4j} = \frac{\sum_{j=1}^{m} x_{4j}}{21} = 93.93$$

$$S_{x4j} = \sqrt{\frac{1}{21}\sum_{j=1}^{m}(x_{4j} - M_{x4j})^2} = 5.66$$

$$M_{x5j} = \frac{\sum_{j=1}^{m} x_{5j}}{21} = 0.18$$

$$S_{x5j} = \sqrt{\frac{1}{21}\sum_{j=1}^{m}(x_{5j} - M_{x5j})^2} = 0.06$$

$$M_{x6j} = \frac{\sum_{j=1}^{m} x_{6j}}{21} = 117.77$$

$$S_{x6j} = \sqrt{\frac{1}{21}\sum_{j=1}^{m}(x_{6j} - M_{x6j})^2} = 20.78$$

The next step is to calculate the standardized values of the indicators, i.e.:

Z_{x1j} – standardized value of the unemployment rate indicator

$$Z_{x1j} = 100 - \frac{x_{1j} - M_{x1j}}{S_{x1j}} * 10 \tag{31}$$

$$Z_{x11} = 100 - \frac{x_{11} - M_{x1j}}{S_{x1j}} * 10 = 100 - \frac{0,1007-0,16}{0,06} * 10 = 110.88$$

All remaining 20 values are calculated in the same way: Z_{x12}, Z_{x13}, Z_{x14}, Z_{x15}, Z_{x16}, Z_{x17}, Z_{x18}, Z_{x19}, Z_{x110}, Z_{x111}, Z_{x112}, Z_{x113}, Z_{x114}, Z_{x115}, Z_{x116}, Z_{x117}, Z_{x118}, Z_{x119}, Z_{x120}, Z_{x121}.

Z_{x2j} is standardized value of the income per capita indicator:

$$Z_{x2j} = 100 + \frac{x_{2j} - M_{x2j}}{S_{x2j}} * 10 \quad (32)$$

$$Z_{x21} = 100 - \frac{x_{21} - M_{x2j}}{S_{x2j}} * 10 = 100 - \frac{44.733{,}21 - 28.117{,}96}{5.370{,}96} * 10 = 130.94$$

All remaining 20 values are calculated in the same way.

Z_{x3j} – standardized value of the budget revenues per capita indicator

$$Z_{x3j} = 100 + \frac{x_{3j} - M_{x3j}}{S_{x3j}} * 10 \quad (33)$$

$$Z_{x31} = 100 - \frac{x_{31} - M_{x3j}}{S_{x3j}} * 10 = 100 - \frac{6.232{,}49 - 3.058{,}31}{1.348{,}59} * 10 = 123.54$$

All remaining 20 values are calculated in the same way.

Z_{x4j} – standardized value of general population movement indicator

$$Z_{x4j} = 100 + \frac{x_{4j} - M_{x4j}}{S_{x4j}} * 10 \quad (34)$$

$$Z_{x41} = 100 - \frac{x_{41} - M_{x4j}}{S_{x4j}} * 10 = 100 - \frac{103{,}10 - 93{,}93}{5{,}66} * 10 = 116.19$$

All remaining 20 values are calculated in the same way.

Z_{x5j} – standardized value of the education rate indicator

$$Z_{x5j} = 100 + \frac{x_{5j} - M_{x5j}}{S_{x5j}} * 10 \quad (35)$$

$$Z_{x51} = 100 - \frac{x_{51} - M_{x5j}}{S_{x5j}} * 10 = 100 - \frac{0{,}3935 - 0{,}18}{0{,}06} * 10 = 132.24$$

All remaining 20 values are calculated in the same way.

Z_{x6j} – standardized value of the ageing index indicator

$$Z_{x6j} = 100 - \frac{x_{6j} - M_{x6j}}{S_{x6j}} * 10 \quad (36)$$

$$Z_{x61} = 100 - \frac{x_{61} - M_{x6j}}{S_{x6j}} * 10 = 100 - \frac{118{,}9 - 117{,}77}{20{,}78} * 10 = 99.46$$

All remaining 20 values are calculated in the same way.

In the next step, the arithmetic mean of the standardized values of all indicators for one unit of local or regional self-government is calculated:

$$M_{Zi} = \frac{\sum_{i=1}^{n} Z_j}{n} \quad (37)$$

$$M_{Zi} = \frac{Z_{x1j} + Z_{x2j} + Z_{x3j} + Z_{x4j} + Z_{x5j} + Z_{x6j}}{6}$$

$$M_{Zi} = \frac{Z_{x11} + Z_{x21} + Z_{x31} + Z_{x41} + Z_{x51} + Z_{x61}}{6}$$

$$M_{Zi} = \frac{110{,}88 + 130{,}94 + 123{,}54 + 116{,}19 + 132{,}24 + 99{,}46}{6} = 118.875$$

All remaining 20 values are calculated in the same way: M_{Z2}, M_{Z3}, M_{Z4}, M_{Z5}, M_{Z6}, M_{Z7}, M_{Z8}, M_{Z9}, M_{Z10}, M_{Z11}, M_{Z12}, M_{Z13}, M_{Z14}, M_{Z15}, M_{Z16}, M_{Z17}, M_{Z18}, M_{Z19}, M_{Z20}, M_{Z21}.

The standard deviation of the standardized values of all indicators for a single local or regional self-government unit is calculated by the following equation:

$$S_{Zi} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(Z_i - M_{Zi})^2} \tag{38}$$

$$S_{Zi} = \sqrt{\frac{1}{6}\sum_{i=1}^{n}(Z_i - M_{Zi})^2} = 11.504$$

All remaining 20 values are calculated in the same way: S_{Z2}, S_{Z3}, S_{Z4}, S_{Z5}, S_{Z6}, S_{Z7}, S_{Z8}, S_{Z9}, S_{Z10}, S_{Z11}, S_{Z12}, S_{Z13}, S_{Z14}, S_{Z15}, S_{Z16}, S_{Z17}, S_{Z18}, S_{Z19}, S_{Z20}, S_{Z21}.

The coefficient of variation of the set of standardized values of all indicators for a single local or regional self-government unit is calculated by the following equation:

$$cv_i = \frac{S_{Zi}}{M_{Zi}} \tag{39}$$

$$cv_i = \frac{S_{Zi}}{M_{Zi}} = \frac{11,504}{118,875} = 0.097$$

In the last step, the development index is calculated using the equation:

$$I_i = M_{zi} - (S_{zi} * cv_i) \tag{40}$$

$$I_1 = M_{z1} - (S_{z1} * cv_1) = 118,875 - (11,504 * 0,097) = 117.762$$

Thus, according to the example of development index calculation by counties (Table 2), I1 represents the development index of the City of Zagreb.

$I_1 = I_{\text{CITY OF ZAGREB}} = 117.762$.

The development index of all remaining 20 counties is calculated in the same way:

$I_2 = I_{\text{ISTRIA}} = 108.972$
$I_3 = I_{\text{DUBROVAČKO-NERETVANSKA}} = 108.588$
$I_4 = I_{\text{ZAGREB}} = 105.894$
$I_5 = I_{\text{PRIMORJE-GORASKI KOTAR}} = 105.284$
$I_6 = I_{\text{ZADAR}} = 104.655$
$I_7 = I_{\text{SPLIT-DALMATIA}} = 103.939$
$I_8 = I_{\text{VARAŽDIN}} = 101.720$
$I_9 = I_{\text{MEĐIMURJE}} = 100.508$
$I_{10} = I_{\text{KRAPINA-ZAGORJE}} = 98.979$
$I_{11} = I_{\text{KOPRIVNICA-KRIŽEVCI}} = 98.498$
$I_{12} = I_{\text{ŠIBENIK-KNIN}} = 97.049$
$I_{13} = I_{\text{OSIJEK-BARANJA}} = 96.012$
$I_{14} = I_{\text{KARLOVAC}} = 95.198$
$I_{15} = I_{\text{POŽEGA-SLAVONIA}} = 93.954$
$I_{16} = I_{\text{BROD-POSAVINA}} = 93.454$
$I_{17} = I_{\text{BJELOVAR-BILOGORA}} = 92.582$
$I_{18} = I_{\text{LIKA-SENJ}} = 92.392$
$I_{19} = I_{\text{VUKOVAR-SRIJEM}} = 91.995$
$I_{20} = I_{\text{SISAK-MOSLAVINA}} = 91.704$
$I_{21} = I_{\text{VIROVITICA-PODRAVINA}} = 90.670$

The example of development index calculation by counties (regional self-government units) in the Republic of Croatia (Table 2) shows the calculation of the development index for each county of the Republic of Croatia based on current data and in the current scenario without established dry port.

All counties and their development indexes are presented in Figure 1, in keeping with the development index results by counties of the Republic of Croatia (Table 2). The threshold is 100, and counties below 100 are counties with below-average development level (undeveloped) or assisted counties.

Table 2.
Calculation of development index by counties in the Republic of Croatia.

County	Values of basic indicators for the region/ county						Values of standardized indicators for					
	x1	x2	x3	x4	x5	x6	x1					x2
	Unemployment Rate	Income Per Capita	Budget Revenues per Capita	General Population Movement	Education Rate	Ageing Index	Mxj	Sxj	Unemployment Rate (-)	Mxj	Sxj	Income Per Capita
City of Zagreb	0.1007	44,733.21	6,232.49	103.1	0.3935	118.9	0.16	0.06	110.88	28,117.96	5,370.96	130.94
Bjelovar-Bilogora	0.2246	23,529.44	1,912.61	89.02	0.131	114.9	0.16	0.06	89.02	28,117.96	5,370.96	91.46
Brod-Posavina	0.2143	22,105.97	1,550.91	90.09	0.1342	96.5	0.16	0.06	90.84	28,117.96	5,370.96	88.81
Dubrovnik-Neretva	0.1323	30,904.76	4,848.62	101.07	0.2618	109.4	0.16	0.06	105.31	28,117.96	5,370.96	105.19
Istria	0.0654	35,191.17	5,535.63	101.17	0.225	136.8	0.16	0.06	117.11	28,117.96	5,370.96	113.17
Karlovac	0.1728	29,715.33	2,547.26	88.93	0.1836	149	0.16	0.06	98.16	28,117.96	5,370.96	102.98
Koprivnica-Križevci	0.137	24,587.95	2,703.28	93.24	0.1483	110.5	0.16	0.06	104.48	28,117.96	5,370.96	93.43
Krapina-Zagorje	0.1135	28,783.48	2,092.17	93.73	0.1266	112.6	0.16	0.06	108.63	28,117.96	5,370.96	101.24
Lika-Senj	0.1696	27,401.26	3,392.29	86.29	0.1596	166	0.16	0.06	98.73	28,117.96	5,370.96	98.67
Međimurje	0.1164	24,835.25	2,077.08	97.99	0.1367	91.8	0.16	0.06	108.11	28,117.96	5,370.96	93.89
Osijek-Baranja	0.2369	26,216.25	2,271.75	91.9	0.1749	106.3	0.16	0.06	86.85	28,117.96	5,370.96	96.46
Požega-Slavonia	0.1814	22,925.23	1,550.25	87.42	0.1429	99.2	0.16	0.06	96.64	28,117.96	5,370.96	90.34
Primorje-Gorski Kotar	0.1141	35,367.41	5,229.00	96.91	0.2747	155.3	0.16	0.06	108.52	28,117.96	5,370.96	113.5
Sisak-Moslavina	0.2461	27,197.16	2,502.17	85.2	0.1481	131.1	0.16	0.06	85.22	28,117.96	5,370.96	98.29
Split-Dalmatia	0.1923	28,190.12	3,476.57	99.75	0.2472	102.3	0.16	0.06	94.72	28,117.96	5,370.96	100.14
Šibenik-Knin	0.1622	27,315.29	3,283.90	91.58	0.1944	146.1	0.16	0.06	100.03	28,117.96	5,370.96	98.51
Varaždin	0.0974	28,714.71	2,387.25	95.45	0.1628	107.3	0.16	0.06	111.47	28,117.96	5,370.96	101.12
Virovitica-Podravina	0.2613	21,297.29	1,872.32	88.54	0.1145	103.3	0.16	0.06	82.54	28,117.96	5,370.96	87.31
Vukovar-Srijem	0.2431	22,256.51	1,627.30	88.41	0.132	98.3	0.16	0.06	85.75	28,117.96	5,370.96	89.09
Zadar	0.12	26,630.15	3,908.88	102.3	0.2085	117.4	0.16	0.06	107.48	28,117.96	5,370.96	97.23
Zagreb	0.1079	32,579.23	3,222.84	100.54	0.1678	100.1	0.16	0.06	109.61	28,117.96	5,370.96	108.31

the regional unit/ county												Regional (County) Development Index			
		x3			x4			x5			x6				
Mxj	Sxj	Budget Revenues per Capita	Mxj	Sxj	General Population Movement	Mxj	Sxj	Education Rate	Mxj	Sxj	Ageing Index (-)	Mzi	Szi	cvi	Ii
3,058.31	1,348.59	123.54	93.93	5.66	116.19	0.18	0.06	132.24	117.77	20.78	99.46	118.875	11.504	0.097	117.762
3,058.31	1,348.59	91.51	93.93	5.66	91.33	0.18	0.06	91.81	117.77	20.78	101.38	92.752	3.968	0.043	92.582
3,058.31	1,348.59	88.83	93.93	5.66	93.21	0.18	0.06	92.31	117.77	20.78	110.24	94.04	7.426	0.079	93.454
3,058.31	1,348.59	113.28	93.93	5.66	112.61	0.18	0.06	111.96	117.77	20.78	104.03	108.73	3.927	0.036	108.588
3,058.31	1,348.59	118.37	93.93	5.66	112.78	0.18	0.06	106.29	117.77	20.78	90.84	109.76	9.3	0.085	108.972
3,058.31	1,348.59	96.22	93.93	5.66	91.17	0.18	0.06	99.91	117.77	20.78	84.97	95.568	5.953	0.062	95.198
3,058.31	1,348.59	97.37	93.93	5.66	98.78	0.18	0.06	94.48	117.77	20.78	103.5	98.673	4.159	0.042	98.498
3,058.31	1,348.59	92.84	93.93	5.66	99.64	0.18	0.06	91.14	117.77	20.78	102.49	99.33	5.908	0.059	98.979
3,058.31	1,348.59	102.48	93.93	5.66	86.5	0.18	0.06	96.22	117.77	20.78	76.79	93.232	8.85	0.095	92.392
3,058.31	1,348.59	92.73	93.93	5.66	107.17	0.18	0.06	92.69	117.77	20.78	112.5	101.182	8.253	0.082	100.508
3,058.31	1,348.59	94.17	93.93	5.66	96.41	0.18	0.06	98.57	117.77	20.78	105.52	96.33	5.538	0.057	96.012
3,058.31	1,348.59	88.82	93.93	5.66	88.5	0.18	0.06	93.65	117.77	20.78	108.94	94.482	7.064	0.075	93.954
3,058.31	1,348.59	116.1	93.93	5.66	105.26	0.18	0.06	113.94	117.77	20.78	81.94	106.543	11.585	0.109	105.284
3,058.31	1,348.59	95.88	93.93	5.66	84.58	0.18	0.06	94.45	117.77	20.78	93.59	92.002	5.231	0.057	91.704
3,058.31	1,348.59	103.11	93.93	5.66	110.28	0.18	0.06	109.71	117.77	20.78	107.45	104.235	5.559	0.053	103.939
3,058.31	1,348.59	101.68	93.93	5.66	95.85	0.18	0.06	101.58	117.77	20.78	86.37	97.337	5.291	0.054	97.049
3,058.31	1,348.59	95.03	93.93	5.66	102.68	0.18	0.06	96.71	117.77	20.78	105.04	102.008	5.427	0.053	101.72
3,058.31	1,348.59	91.21	93.93	5.66	90.48	0.18	0.06	89.27	117.77	20.78	106.97	91.297	7.561	0.083	90.67
3,058.31	1,348.59	89.39	93.93	5.66	90.25	0.18	0.06	91.97	117.77	20.78	109.37	92.637	7.71	0.083	91.995
3,058.31	1,348.59	106.31	93.93	5.66	114.78	0.18	0.06	103.75	117.77	20.78	100.18	104.955	5.608	0.053	104.655
3,058.31	1,348.59	101.22	93.93	5.66	111.67	0.18	0.06	97.48	117.77	20.78	108.51	106.133	5.036	0.047	105.894

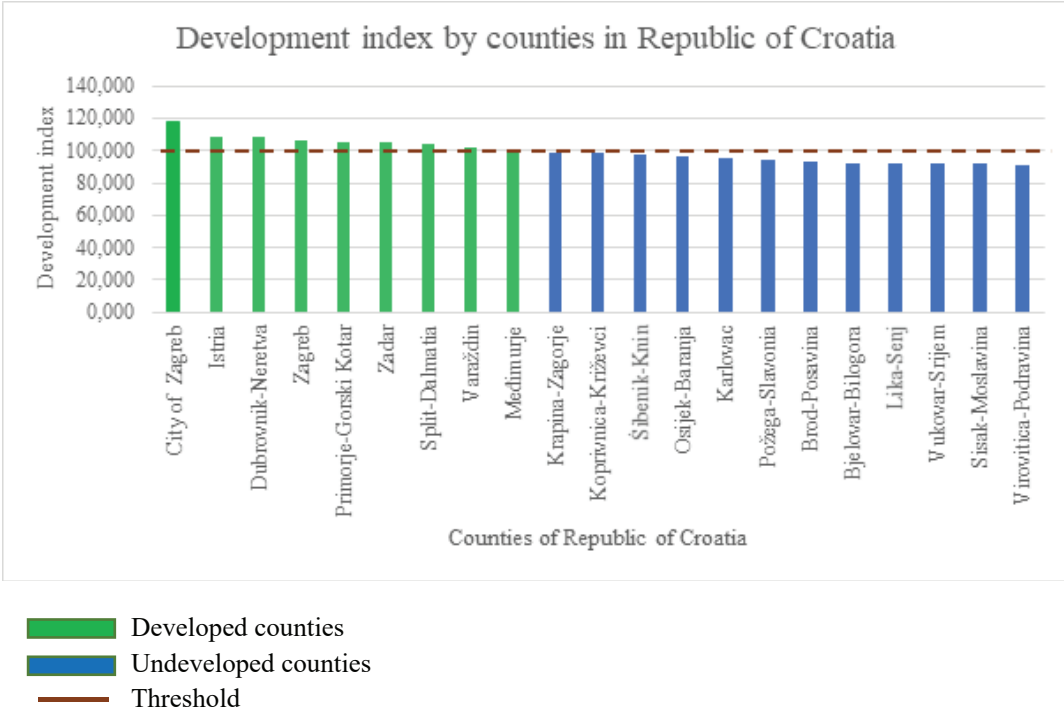


Figure 1.
Regional development index by counties of the Republic of Croatia in 2016.t

7. THE INFLUENCE OF DRY PORT ESTABLISHMENT ON REGIONAL DEVELOPMENT AND INCREASE OF REGIONAL DEVELOPMENT INDEX – ANALYSIS AND RESULTS

7.1. Determining the Decrease/Increase Coefficients of Basic Indicators of the Regional Development Index

As previously mentioned, the values of 6 basic indicators have an effect on development index increase:

1. unemployment rate,
2. income per capita,
3. budget revenues per capita,
4. general population movement,
5. education rate,
6. ageing index.

The basic indicators are obtained using ratios of variables, i.e. data taken from the Croatian Employment Service, the Croatian Tax Administration, the Ministry of Finance and the Croatian Bureau of Statistics.

Dry port establishment can affect a maximum of 4 basic indicators. General population movement and the ageing index are not expected to be affected by the establishment of a dry port.

Establishment of a dry port affects the following basic indicators: unemployment rate, income per capita, budget revenues per capita and education rate. The following text explains (in mathematical equations) the impact of dry port establishment on the basic development index indicators.

Unemployment rate is calculated using the following equation:

$$x_1 = \frac{N_{(0)}}{RS_{(0)}} = \frac{N_{(0)}}{Z_{(0)} + N_{(0)}} \tag{41}$$

where variables are:

$N_{(0)}$ – the number of the unemployed in the area of a given local or regional self-government unit,

$RS_{(0)}$ – the sum of all employed and unemployed persons on the territory of a given local or regional self-government unit.

Therefore, if the number of the unemployed on the territory of a given local or regional self-government unit decreases due to the establishment of a new dry port terminal, i.e. due to new job vacancies at the dry port terminal, the equation for the new unemployment rate will be as follows:

$$x_1' = \frac{N_{(0)} - p_1}{RS_{(0)}} = \frac{N_{(0)} - p_1}{Z_{(0)} + p_1 + N_{(0)} - p_1} = \frac{N_{(0)} - p_1}{RS_{(0)}} \quad (42)$$

where variables are:

x_1' – new value of the basic indicator,

p_1 – number of newly employed persons.

Note. Although the value of variable p_1 is determined arbitrarily, it is the value closest to the possible actual value in the scenario of dry port establishment.

The *unemployment rate decrease coefficient* can then be illustrated as follows:

$$k_1 = \frac{x_1'}{x_1} = \frac{\frac{N_{(0)} - p_1}{RS_{(0)}}}{\frac{N_{(0)}}{RS_{(0)}}} = \frac{N_{(0)} - p_1}{N_{(0)}} = 1 - \frac{p_1}{N_{(0)}} \quad (43)$$

where:

k_1 – the unemployment rate decrease coefficient.

İncome per capita is calculated using the following equation:

$$x_2 = \frac{D_i}{P_i} \quad (44)$$

where variables are:

D_i – the sum of incomes earned by residents in the i-th local or regional self-government unit during one calendar year,

P_i – the estimated number of residents in the i-th local or regional self-government unit at the end of the year.

Therefore, if the number of the unemployed in a given local or regional self-government unit decreases owing to the establishment of a new dry port terminal through the creation of new jobs and new employees earning income, the equation will then be as follows:

$$x_2' = \frac{D_i + p_2}{P_1} \quad (45)$$

where variables are:

x_2' – new value of the basic indicator,

p_2 – the amount of new income per capita depending on the number of newly employed persons.

Note. Value of variable p2 is determined by multiplying the average yearly income per capita with arbitrarily determined number of newly employed persons (p1). Average yearly income per capita is calculated by multiplying the average monthly income per capita (in Republic of Croatia) with twelve months.

The *income per capita increase coefficient* can then be shown as follows:

$$k_2 = \frac{x_2'}{x_2} = \frac{\frac{D_i + p_2}{P_i}}{\frac{D_i}{P_i}} = \frac{D_i + p_2}{D_i} = 1 + \frac{p_2}{D_i} \quad (46)$$

where:

k_2 – is the income per capita increase coefficient.

Budget revenue per capita is calculated using the following equation:

$$x_3 = \frac{IPP_i}{P_i} \quad (47)$$

where variables are:

IPP_i – the amount of budget revenues generated on the territory of the i-th local or regional self-government unit during one calendar year,

P_i – the estimate of the number of residents in the i-th local or regional self-government unit at the end of the year.

Therefore, if the number of the unemployed in a given local or regional self-government unit decreases owing to the establishment of a new dry port terminal through the creation of new jobs and new employees earning income, resulting in the employer paying taxes for them, budget revenues will increase, and the equation will then be as follows:

$$x_3' = \frac{IPP_i + P_i}{P_i} \quad (48)$$

where variables are:

x_3' – new value of the basic indicator,

p_3 – the amount of new budget revenue per capita depending on the number of newly employed persons.

Note. Value of variable p3 is determined by multiplying the average yearly budget revenues per capita with arbitrarily determined number of newly employed persons (p1). Average yearly budget revenue per capita is calculated by multiplying average monthly budget revenue per capita (in Republic of Croatia) with twelve months.

The *budget revenues per capita increase coefficient* can then be shown as follows:

$$k_3 = \frac{x_3'}{x_3} = \frac{\frac{IPP_i + p_3}{P_i}}{\frac{IPP_i}{P_i}} = \frac{IPP_i + p_3}{IPP_i} = 1 + \frac{p_3}{IPP_i} \quad (49)$$

where:

k_3 – budget revenues per capita increase coefficient.

The education rate is calculated using the following equation:

$$x_5 = \frac{P_{(he+)}}{P_{(20+)}} \quad (50)$$

where variables are:

$P_{(he+)}$ – the number of residents in the i-th local or regional self-government unit with completed higher education,

$P_{(20+)}$ – the number of residents in the i-th local or regional self-government unit aged 20-65.

Therefore, if the establishment of a new dry port terminal creates new jobs, the need for highly educated staff will also increase, in turn encouraging more people to acquire higher education at higher education institutions, and the equation will then be as follows:

$$x_5' = \frac{P_{(he+)} + p_5}{P_{(20+)}} \quad (51)$$

where variables are:

x_5' – new value of the basic indicator,

p_5 – number of new highly educated persons.

Note. Although the value of variable p5 is determined arbitrarily, it is the value closest to the possible actual value in the scenario of dry port establishment.

The *education rate increase coefficient* can then be shown as follows:

$$k_5 = \frac{x_5'}{x_5} = \frac{\frac{P_{(he+)} + p_5}{P_{(20+)}}}{\frac{P_{(he+)}}{P_{(20+)}}} = \frac{P_{(he+)} + p_5}{P_{(he+)}} = 1 + \frac{p_5}{P_{(he+)}} \quad (52)$$

where:

k_5 – the education rate increase coefficient.

7.2. Simulation and Results of Regional Development Index Increase by Dry Port Establishment

The value of p1 was arbitrarily chosen based on the previous section 7.1, where variables p1, p2, p3, and p5 were defined, while p2, p3, and p5 were calculated as explained in 7.1. Variables p1, p2, p3, and p5 are the values that would change (add or subtract) in the basic indicators values in case of dry port establishment, i.e. following the application of their values, the new values of basic indicators would be obtained for the Vukovar-Srijem county/ region, as well as the new values of mean average and standard deviation for all counties of the Republic of Croatia in the observed case.

A simulation of development index increase by dry port establishment was run (Table 3) by simulating the scenario of dry port establishment in the town of Vinkovci in the Vukovar-Srijem County. The increase is primarily attributable to the increased number of newly employed persons due to dry port establishment. Vinkovci was chosen primarily owing to its favourable geographic position in the TEN-T network connecting Croatia with various destinations through the Orient East-Med Corridor or Rhine-Danube Corridor, existing infrastructure that can be used for new dry port terminal, and the fact that Vukovar-Srijem is one of the most undeveloped regions (counties) in Croatia. The simulation calculated the development index for each county of the Republic of Croatia, using statistical data taken from the Croatian Employment Service, the Croatian Tax Administration, the Ministry of Finance and the Croatian Bureau of Statistics for year 2016, and the calculated number of persons employed in the new dry port (as if the dry port was established), their incomes, budget revenues, and estimated education rate. The results, i.e. new values of the development index were obtained. The development index of the Vukovar-Srijem county was 92,175 (Table 3), whereas the development index in case of non-establishment of a dry port was 91,995 (Table 2), which proves the influence of dry port establishment on regional development.

Table 3.

Simulation of development index increase by dry port establishment – new calculation of the development index.

County	Parameters for calculating the value of basic indicators for the county (including established dry port in Vinkovci)											
	x1				x2				x3			
	N(0) (2016)	N(0)'	RS(0)	p1	Di	Di'	Pi (2016)	p2	IPPi	IPPi'	Pi (2016)	p3
Bjelovar-Bilogora	9,789	0	43,584	0	2,632,167,864	0	111,867	0	213,957,943	0	111,867	0
Brod-Posavina	12,471	0	58,194	0	3,279,929,087	0	148,373	0	230,113,169	0	148,373	0
Dubrovnik-Neretva	9,714	0	73,424	0	3,769,453,577	0	121,970	0	591,386,181	0	121,970	0
City of Zagreb	36,636	0	363,813	0	35,891,154,245	0	802,338	0	5,000,563,562	0	802,338	0
Istria	12,142	0	185,657	0	7,323,458,433	0	208,105	0	1,151,992,281	0	208,105	0
Karlovac	7,122	0	41,215	0	3,575,378,221	0	120,321	0	306,488,870	0	120,321	0
Koprivnica-Križevci	7,244	0	52,876	0	2,728,672,339	0	110,976	0	299,999,201	0	110,976	0
Krapina-Zagorje	6,533	0	57,559	0	3,677,032,003	0	127,748	0	267,270,533	0	127,748	0
Lika-Senj	3,413	0	20,124	0	1,284,790,279	0	46,888	0	159,057,694	0	46,888	0
Međimurje	6,415	0	55,112	0	2,783,758,337	0	112,089	0	232,817,820	0	112,089	0
Osijek-Baranja	25,525	0	107,746	0	7,613,513,595	0	290,412	0	659,743,461	0	290,412	0
Požega-Slavonia	5,803	0	31,990	0	1,648,782,542	0	71,920	0	111,493,980	0	71,920	0
Primorje-Gorski Kotar	16,919	0	148,282	0	10,238,122,479	0	289,479	0	1,513,685,691	0	289,479	0
Sisak-Moslavina	12,968	0	52,694	0	4,275,502,341	0	157,204	0	393,351,133	0	157,204	0
Split-Dalmatia	37,089	0	192,871	0	12,742,920,894	0	452,035	0	1,571,531,320	0	452,035	0
Šibenik-Knin	9,054	0	55,820	0	2,814,048,491	0	103,021	0	338,310,662	0	103,021	0
Varaždin	8,955	0	91,940	0	4,897,667,082	0	170,563	0	407,176,522	0	170,563	0
Virovitica-Podravina	7,513	0	28,752	0	1,684,849,909	0	79,111	0	148,121,108	0	79,111	0
Vukovar-Srijem	15,819	15,569	65,072	250	3,690,107,101	3,708,837,474	165,799	18,730,372	269,804,713	271,174,197	165,799	1,369,484
Zadar	11,327	0	94,392	0	4,515,967,467	0	169,581	0	662,871,779	0	169,581	0
Zagreb	15,045	0	139,435	0	10,247,764,217	0	314,549	0	1,013,741,099	0	314,549	0
	CES		Tax adm,		Tax adm,		CBS		Min, of Fin,		CBS	

				Values of new standardized indicators for the county						Values of new standardized indicators for the county					
x5				**x1'**	**x2'**	**x3'**	**x4**	**x5'**	**x6**	**x1**			**x2**		
Phe+ (2011)	Phe+'	P20+	p5							Mxj	Sxj	x1	Mxj	Sxj	x2
9.426	0	71,954	0	0.2246	23,529.44	1,912.61	89.02	0.131	114.9	0.1622	0.0564	88.94	28,123.34	5,365.14	91.44
12.455	0	92,809	0	0.2143	22,105.97	1,550.91	90.09	0.1342	96.5	0.1622	0.0564	90.76	28,123.34	5,365.14	88.79
19.221	0	73,419	0	0.1323	30,904.76	4,848.62	101.07	0.2618	109.4	0.1622	0.0564	105.3	28,123.34	5,365.14	105.19
195.326	0	496,381	0	0.1007	44,733.21	6,232.49	103.1	0.3935	118.9	0.1622	0.0564	110.9	28,123.34	5,365.14	130.96
29.874	0	132,773	0	0.0654	35,191.17	5,535.63	101.17	0.225	136.8	0.1622	0.0564	117.16	28,123.34	5,365.14	113.18
14.332	0	78,061	0	0.1728	29,715.33	2,547.26	88.93	0.1836	149	0.1622	0.0564	98.12	28,123.34	5,365.14	102.97
10.404	0	70,155	0	0.137	24,587.95	2,703.28	93.24	0.1483	110.5	0.1622	0.0564	104.47	28,123.34	5,365.14	93.42
10.352	0	81,769	0	0.1135	28,783.48	2,092.17	93.73	0.1266	112.6	0.1622	0.0564	108.63	28,123.34	5,365.14	101.24
4.605	0	28,853	0	0.1696	27,401.26	3,392.29	86.29	0.1596	166	0.1622	0.0564	98.69	28,123.34	5,365.14	98.66
9.547	0	69,839	0	0.1164	24,835.25	2,077.08	97.99	0.1367	91.8	0.1622	0.0564	108.12	28,123.34	5,365.14	93.88
32.878	0	187,982	0	0.2369	26,216.25	2,271.75	91.9	0.1749	106.3	0.1622	0.0564	86.76	28,123.34	5,365.14	96.45
6.498	0	45,472	0	0.1814	22,925.23	1,550.25	87.42	0.1429	99.2	0.1622	0.0564	96.6	28,123.34	5,365.14	90.32
52.036	0	189,428	0	0.1141	35,367.41	5.,229.00	96.91	0.2747	155.3	0.1622	0.0564	108.53	28,123.34	5,365.14	113.51
15.446	0	104,294	0	0.2461	27,197.16	2,502.17	85.2	0.1481	131.1	0.1622	0.0564	85.13	28,123.34	5,365.14	98.28
68.450	0	276,901	0	0.1923	28,190.12	3,476.57	99.75	0.2472	102.3	0.1622	0.0564	94.66	28,123.34	5,365.14	100.13
12.405	0	63,812	0	0.1622	27,315.29	3,283.90	91.58	0.1944	146.1	0.1622	0.0564	100	28,123.34	5,365.14	98.5
17.742	0	108,980	0	0.0974	28,714.71	2,387.25	95.45	0.1628	107.3	0.1622	0.0564	111.49	28,123.34	5,365.14	101.11
5.882	0	51,371	0	0.2613	21,297.29	1,872.32	88.54	0.1145	103.3	0.1622	0.0564	82.43	28,123.34	5,365.14	87.28
14.089	14.189	106,735	100	0.2393	22,369.48	1,635.56	88.41	0.1329	98.3	0.1622	0.0564	86.34	28,123.34	5,365.14	89.28
21.179	0	101,578	0	0.12	26,630.15	3,908.88	102.3	0.2085	117.4	0.1622	0.0564	107.48	28,123.34	5,365.14	97.22
33.086	0	197,175	0	0.1079	32,579.23	3,222.84	100.54	0.1678	100.1	0.1622	0.0564	109.62	28,123.34	5,365.14	108.31
CBS		CBS													

Values of new standardized indicators for the county												Regional (County) Development Index			
x3			x4			x5			x6			Mzi	Szi	cvi	Ii'
Mxj	Sxj	x3	Mxj	Sxj	x4	Mxj	Sxj	x5	Mxj	Sxj	x6				
3,058.71	1,348.18	91.5	93.9348	5.6622	91.33	0.1842	0.0649	91.8	117.7667	20.7761	101.38	92.732	3.983	0.043	92.561
3,058.71	1,348.18	88.82	93.9348	5.6622	93.21	0.1842	0.0649	92.29	117.7667	20.7761	110.24	94.018	7.436	0.079	93.43
3,058.71	1,348.18	113.28	93.9348	5.6622	112.61	0.1842	0.0649	111.96	117.7667	20.7761	104.03	108.728	3.928	0.036	108.586
3,058.71	1,348.18	123.55	93.9348	5.6622	116.19	0.1842	0.0649	132.25	117.7667	20.7761	99.46	118.885	11.508	0.097	117.771
3,058.71	1,348.18	118.38	93.9348	5.6622	112.78	0.1842	0.0649	106.29	117.7667	20.7761	90.84	109.772	9.308	0.085	108.982
3,058.71	1,348.18	96.21	93.9348	5.6622	91.17	0.1842	0.0649	99.91	117.7667	20.7761	84.97	95.558	5.947	0.062	95.188
3,058.71	1,348.18	97.37	93.9348	5.6622	98.78	0.1842	0.0649	94.47	117.7667	20.7761	103.5	98.668	4.161	0.042	98.493
3,058.71	1,348.18	92.84	93.9348	5.6622	99.64	0.1842	0.0649	91.12	117.7667	20.7761	102.49	99.327	5.912	0.06	98.975
3,058.71	1,348.18	102.48	93.9348	5.6622	86.5	0.1842	0.0649	96.21	117.7667	20.7761	76.79	93.222	8.844	0.095	92.383
3,058.71	1,348.18	92.72	93.9348	5.6622	107.17	0.1842	0.0649	92.68	117.7667	20.7761	112.5	101.178	8.259	0.082	100.504
3,058.71	1,348.18	94.17	93.9348	5.6622	96.41	0.1842	0.0649	98.57	117.7667	20.7761	105.52	96.313	5.564	0.058	95.992
3,058.71	1,348.18	88.82	93.9348	5.6622	88.5	0.1842	0.0649	93.64	117.7667	20.7761	108.94	94.47	7.064	0.075	93.942
3,058.71	1,348.18	116.1	93.9348	5.6622	105.26	0.1842	0.0649	113.94	117.7667	20.7761	81.94	106.547	11.587	0.109	105.287
3,058.71	1,348.18	95.88	93.9348	5.6622	84.58	0.1842	0.0649	94.44	117.7667	20.7761	93.59	91.983	5.248	0.057	91.684
3,058.71	1,348.18	103.1	93.9348	5.6622	110.28	0.1842	0.0649	109.71	117.7667	20.7761	107.45	104.222	5.578	0.054	103.923
3,058.71	1,348.18	101.68	93.9348	5.6622	95.85	0.1842	0.0649	101.57	117.7667	20.7761	86.37	97.328	5.287	0.054	97.041
3,058.71	1,348.18	95.02	93.9348	5.6622	102.68	0.1842	0.0649	96.7	117.7667	20.7761	105.04	102.007	5.437	0.053	101.717
3,058.71	1,348.18	91.21	93.9348	5.6622	90.48	0.1842	0.0649	89.26	117.7667	20.7761	106.97	91.272	7.585	0.083	90.641
3,058.71	1,348.18	89.45	93.9348	5.6622	90.25	0.1842	0.0649	92.1	117.7667	20.7761	109.37	92.798	7.604	0.082	92.175
3,058.71	1,348.18	106.31	93.9348	5.6622	114.78	0.1842	0.0649	103.74	117.7667	20.7761	100.18	104.952	5.61	0.053	104.652
3,058.71	1,348.18	101.22	93.9348	5.6622	111.67	0.1842	0.0649	97.47	117.7667	20.7761	108.51	106.133	5.04	0.047	105.894

8. DISCUSSION

Based on existing literature on regional development, the dry port concept and the influence of dry ports on regional development, the authors found a correlation between regional development factors and dry port establishment.

The regional development index calculation method is based on six basic indicators. The parameters required to calculate the six basic indicators are explained earlier in this paper. The hypothesis was that dry port establishment would affect the unemployment rate, as one of the basic indicators for the calculation of the regional development index. Consequently, the number of newly employed persons affects other three basic indicators for the calculation of the regional development index: income per capita, budget revenues per capita and education rate.

The influence of dry port establishment was illustrated by introducing new variables related to newly employed persons and running simulations for both the current scenario, without a dry port, and scenario in case of dry port establishment.

The results show a conclusive increase in regional development index due to dry port establishment.

The result is significant as it conclusively proves that a dry port would increase the regional development index, by observing solely its influence on the unemployment rate (and consequently parameters such as income per capita, budget revenue per capita and education rate). If the number of employed persons was higher, or other factors were included and analyzed, the increase in the regional development index would be greater, which is the area for further research.

9. CONCLUSIONS

After defining the concept of dry port and its importance for regional development, the method of calculation of the development index of a region was defined and explained. Using statistical data, an example of the calculation of the development index by regions/ counties in the Republic of Croatia in the current scenario without an established dry port, was provided. After that, a simulation of development index calculation was made that included data in case of dry port establishment in the Vukovar-Srijem County, in the town of Vinkovci. Simulation results have shown that the development index of the Vukovar-Srijem County would increase compared to the current situation without a dry port, proving the effect of dry port establishment on the development of the region/ county. Only factors influenced by the establishment of the dry port were included in the simulation. Although the results suggest that the development index would increase by approximately 1% in comparison with the current scenario, that percentage would actually be higher as dry port establishment would attract new operators/ companies into the region, who would cooperate with the dry port and open further new jobs and thus directly influence the development index, which shall be the subject of future research.

Source of research support: Institute of Traffic and Communications

REFERENCES

Agallos, I-C.D., 2016. The Contribution of Ports in Regional Development: Comparative Estimates via Indicator of Port Sustainability, Master of Science Thesis, Athens University of Economics and Business. Available at: https://doi.org/10.13140/RG.2.2.20796.44167.

Amendment of Regional Development Act of the Republic of Croatia, 2017. Official Gazette 2017(123).

Bask, A. et al., 2014. Development of seaport–dry port dyads: two cases from Northern Europe. Journal of Transport Geography, 39, pp.85–95. Available at: http://dx.doi.org/10.1016/j.jtrangeo.2014.06.014.

Black, J. et al., 2018. Issues in Dry Port Location and Implementation in Metropolitan Areas: The Case of Sydney, Australia. Transactions on Maritime Science, 7(1), pp.41–50. Available at: http://dx.doi.org/10.7225/toms.v07.n01.004.

Bogdan, S., Bareša, S. & Hađina, V., 2019. Testiranje primjenjivosti Altmanovog Z-score modela za predviđanje stečaja u Republici Hrvatskoj. Notitia, 5(1), pp.31–46. Available at: http://dx.doi.org/10.32676/n.5.1.4.

Centar za lokalni ekonomski razvoj Ekonomskog fakulteta Sveučilišta u Rijeci, 2017. Evaluacija postojećeg i prijedlog novog modela za izračun indeksa te izračun novog indeksa razvijenosti jedinica lokalne i područne samouprave u Republici Hrvatskoj, available at: https://razvoj.gov.hr/UserDocsImages//O%20ministarstvu/Regionalni%20razvoj/indeks%20razvijenosti//Studija_novi%20model%20indeksa%20razvijenosti_CLER.pdf, accessed on: 12 August 2020.

Chandrakant, G. G., 2011. Essays on Dry Ports, Erasmus Universiteit Rotterdam, Mumbai, India. Available at: http://repub.eur.nl/res/pub/26877/, accessed on: 12 August 2020.

Crainic, T.G. et al., 2015. Modeling dry-port-based freight distribution planning. Transportation Research Part C: Emerging Technologies, 55, pp.518–534. Available at: http://dx.doi.org/10.1016/j.trc.2015.03.026.

Croatian Bureau of Statistics, 2011. Census of Population, Households and Dwellings 2011, Population According to Education Features. Available at: https://www.dzs.hr/Hrv_Eng/publication/2016/SI-1582.pdf, accessed on: 12 August 2020.

Croatian Bureau of Statistics, 2016. Population Estimate of Republic of Croatia. Available at: https://www.dzs.hr/Hrv_Eng/publication/2017/07-01-03_01_2017.htm, accessed on: 12 August 2020.

Croatian Employment Service, 2016. Statistics On-line. Available at: https://statistika.hzz.hr/Statistika.aspx?tiplzvjestaja=1, accessed on: 12 August 2020.

De Muro, P., Mazziotta, M. & Pareto, A., 2010. Composite Indices of Development and Poverty: An Application to MDGs. Social Indicators Research, 104(1), pp.1–18. Available at: http://dx.doi.org/10.1007/s11205-010-9727-z.

Dorostkar, E., Shahbazi, S. and Naeini, S.A., 2016. The effect of forming dry port in spatial and regional planning system in Yazd Province, Journal of Engineering and Applied Sciences, 11(1), pp. 145-152. Available at: https://medwelljournals.com/abstract/?doi=jeasci.2016.145.152.

Dragović, B., Tzannatos, E. & Park, N.K., 2016. Simulation modelling in ports and container terminals: literature overview and analysis by research field, application area and tool. Flexible Services and Manufacturing Journal, 29(1), pp.4–34. Available at: http://dx.doi.org/10.1007/s10696-016-9239-5.

FDT – Association of Danish Transport and Logistics Centers, 2011. The Dry Port – Concept and Perspectives. Available at: http://archive.northsearegion.eu/files/repository/20130301142236_WPC-TheDryPortConcept.pdf, accessed on: 14 August 2020.

Flämig, H. & Hesse, M., 2011. Placing dryports. Port regionalization as a planning challenge – The case of Hamburg, Germany, and the Süderelbe. Research in Transportation Economics, 33(1), pp.42–50. Available at: http://dx.doi.org/10.1016/j.retrec.2011.08.005.

Hanaoka, S. & Regmi, M.B., 2011. Promoting intermodal freight transport through the development of dry ports in Asia: An environmental perspective. IATSS Research, 35(1), pp.16–23. Available at: http://dx.doi.org/10.1016/j.iatssr.2011.06.001.

Jeevan, J. et al., 2019. A Procedure for Implementing Exploratory Mixed Methods Research into Dry Port Management. Transactions on Maritime Science, 8(2), pp.157–170. Available at: http://dx.doi.org/10.7225/toms.v08.n02.001.

Khaslavskaya, A. & Roso, V., 2020. Dry ports: research outcomes, trends, and future implications. Maritime Economics & Logistics, 22(2), pp.265–292. Available at: http://dx.doi.org/10.1057/s41278-020-00152-9.

Li, J. and Jiang, B., 2014. Cooperation performance evaluation between seaport and dry port; case of Qingdao Port and Xi'an Port, International Journal of e-Navigation and Maritime Economy, 1, pp. 99–109. Available at: https://doi.org/10.1016/j.enavi.2014.12.009.

Mazziotta, M. & Pareto, A., 2015. On a Generalized Non-compensatory Composite Index for Measuring Socio-economic Phenomena. Social Indicators Research, 127(3), pp.983–1003. Available at: http://dx.doi.org/10.1007/s11205-015-0998-2.

Ministry of Regional Development and EU Funds, 2018. Development Index. Available at: https://razvoj.gov.hr/o-ministarstvu/djelokrug-1939/regionalni-razvoj/indeks-razvijenosti/112, accessed on:12 August 2020.

Ng, A.K. and Tongzon, J.L., 2010. The transportation sector of India's economy: Dry ports as catalysts for regional development, Eurasian Geography and Economics, 51(5), pp. 669-682. Available at: https://doi.org/10.2747/1539-7216.51.5.669.

Ng, A.K.Y. & Cetin, I.B., 2012. Locational Characteristics of Dry Ports in Developing Economies: Some Lessons from Northern India. Regional Studies, 46(6), pp.757–773. Available at: http://dx.doi.org/10.1080/00343404.2010.532117.

Ng, A.Y. & Gujar, G.C., 2009. Government policies, efficiency and competitiveness: The case of dry ports in India. Transport Policy, 16(5), pp.232–239. Available at: http://dx.doi.org/10.1016/j.tranpol.2009.08.001.

Nguyen, L.C. & Notteboom, T., 2018. The relations between dry port characteristics and regional port-hinterland settings: findings for a global sample of dry ports. Maritime Policy & Management, 46(1), pp.24–42. Available at: http://dx.doi.org/10.1080/03088839.2018.1448478.

Notteboom, T.E. & Rodrigue, J.-P., 2005. Port regionalization: towards a new phase in port development. Maritime Policy & Management, 32(3), pp.297–313. Available at: http://dx.doi.org/10.1080/03088830500139885.

Oláh, J. et al., 2018. Development of dry ports in Europe. International Journal of Applied Management Science, 10(4), p.269. Available at: http://dx.doi.org/10.1504/ijams.2018.095330.

Regional Development Act of the Republic of Croatia, 2014. Official Gazette 2014(147).

Regulation on the Development Index, 2017. Official Gazette 2017(131).

Rodrigue, J.-P. & Notteboom, T., 2010. Foreland-based regionalization: Integrating intermediate hubs with port hinterlands. Research in Transportation Economics, 27(1), pp.19–29. Available at: http://dx.doi.org/10.1016/j.retrec.2009.12.004.

Rogić, K., Rožić, T. & Kolarić, G., 2013. Functionality of logistics distribution centers as a inland port terminal (dry port terminals) – case study city of Zagreb, Conference of Planning and development of sustainable transport system, Zagreb, Croatia, April 16, pp. 83-95. Available at: https://www.researchgate.net/publication/271836273_FUNKCIONALNOST_LOGISTICKO-DISTRIBUCIJSKIH_CENTARA_KAO_LUCKIH_POZADINSKIH_TERMINALA_DRY_PORT_TERMINALA_-CASE_STUDY_CITY_OF_ZAGREB_FUNCTIONALITY_OF_LOGISTICS_DISTRIBUTION_CENTERS_AS_A_INLAND_PORT_TERMIN, accessed on: 15 August 2020.

Roso, V., 2008. Factors influencing implementation of a dry port G. Kovacs, ed. International Journal of Physical Distribution & Logistics Management, 38(10), pp.782–798. Available at: http://dx.doi.org/10.1108/09600030810926493.

Roso, V., 2013. Sustainable intermodal transport via dry ports - importance of directional development. World Review of Intermodal Transportation Research, 4(2/3), p.140. Available at: http://dx.doi.org/10.1504/writr.2013.058976.

Roso, V., Woxenius, J. & Lumsden, K., 2009. The dry port concept: connecting container seaports with the hinterland. Journal of Transport Geography, 17(5), pp.338–345. Available at: http://dx.doi.org/10.1016/j.jtrangeo.2008.10.008.

Shi, X. & Li, H., 2016. Developing the port hinterland: Different perspectives and their application to Shenzhen Port, China. Research in Transportation Business & Management, 19, pp.42–50. Available at: http://dx.doi.org/10.1016/j.rtbm.2016.05.004.

Wang, G.W.Y. et al., 2016. Port connectivity in a logistic network: The case of Bohai Bay, China. Transportation Research Part E: Logistics and Transportation Review, 95, pp.341–354. Available at: http://dx.doi.org/10.1016/j.tre.2016.04.009.

Wilmsmeier, G., Monios, J. & Lambert, B., 2011. The directional development of intermodal freight corridors in relation to inland terminals. Journal of Transport Geography, 19(6), pp.1379–1386. Available at: http://dx.doi.org/10.1016/j.jtrangeo.2011.07.010.

Analytical Research on the Methodological Suitability of Multi-Criteria Analysis for the Scientific Evaluation of the Coastal Area

Mirjana Kovačić, Ante Mrvica, Marija Šimić Hlača

Coastal areas have always been more attractive than the inlands as they offer more opportunities and advantages. Nowadays a growing number of mutually (in)compatible economic and social activities have a significant impact on coastal development. Some countries are particularly aware of the lack of valuation and unplanned access to coastal area organization. As of 1995, owing to the numerous pressures on coastal areas, Croatia was forced to recognize that it needed an appropriate decision-making system.

The authors' focus is on the sustainable management of the coastal area. The purpose of the research is to propose coastal area evaluation criteria. The paper particularly aims to select a suitable method for the resolution of this problem.

Prior experience with the evaluation of an area's value justified the validity of the use of multi-criteria analysis. The method facilitates an overview and evaluation of the various aspects of the problem across different criteria. Several methods and techniques can be used to solve the problem, such as linear programming, AHP, ELECTREE, PROMETHEE, GAIA, scenario methods, and others in which the authors' experience in the area differs. Following research, the authors suggest using the PROMETHEE and GAIA methods.

KEY WORDS

~ Coastal area
~ Sustainability
~ Evaluation criteria
~ MCA

University of Rijeka, Faculty of Maritime Studies, Croatia

e-mail: mirjana051@gmail.com

doi: 10.7225/toms.v09.n02.013

1. INTRODUCTION

In recent years, Croatia has been facing deindustrialization, intensive development of tourism and massive apartment building along the coast. These processes and issues do not contribute to balanced development but rather diminish the value of the coastal area in the long term. Public administration has a distinctive management role and is responsible for making the relevant decisions. The decision-making process is never simple as it requires knowledge and experience, especially in the complex field of the management of the coastal area and its environment.

The paper defines the criteria and proposes a valuation model based on a holistic approach to coastal zone management, to reduce/prevent further devastation of the coastal area. The paper aims to justify the importance of coastal area evaluation and explore the suitability of multi-criteria analysis methods for defining the general model.

2. RECENT RESEARCH

For a very long time, coastal area has been in the focus of researchers worldwide, who have been exploring the legislative framework, the historical-geographical aspect, the socio-economic advantages of the area or the need to establish an integrated monitoring and protection system. There are consequently numerous analyses, studies, projects, plans, scientific papers, books, all of which have contributed to the better understanding of complex coastal processes.

The exploitation of coastal resources has been the subject of conflict for centuries and the reason for the adoption of legislation in the field concerned. Historically, governments

have always strived to regulate the exploitation of resources. While in absolute monarchies, the rulers decided who had the right to use the resources of a particular area, in feudal states, that right was most frequently bestowed only on the nobility. In Western Europe, spatial planning developed in recent centuries to regulate the use of space. The fundamental principle is that land resources are common and must be accessible to all on equal terms.

In the United States of America (USA), everyone had the right to use their real-estate as they pleased, but the system was not sustainable in the long-term. The coastal area has become a rare resource due to population growth and pressures. The need for the planned use of the coastal zone has emerged, and the first Coastal Zone Management Act was adopted in 1972 to force the States to take jurisdiction over coastal zone management. The purpose of the Act was to facilitate:

- coastal resource management;
- dealing with the consequences of natural disasters and
- mitigating negative impacts on valuable ecosystems.

After 1972, coastal zone management in the USA focused on institutional arrangements, while in Europe, all the necessary institutions already existed, but lacked an understanding of how different functions and activities interacted with the coastal zone.

Croatia is geographically a very specific country, due to its almost 5,000 km long coastline, 1,246 islands (Duplančić Leder, 2004), well-indented coast and more. Up until 1990, Croatia successfully protected and preserved its coastal area. The protection and preservation can be attributed to cooperation of many stakeholders, and especially to projects and spatial plans that did not allow intensive use of the coastal area. The development slowed down, but the coastal area was protected from the over-building of apartments and other potentially adverse influences over the last twenty years. It should be emphasized that spatial planning is the starting point, the beginning and the end of protection and overuse of the coastal area.

The Long-Term Development Program and Plan for the Spatial Planning of the Adriatic Area from 1967 is the first spatial planning document for the systematic reflection on the state and developmental possibilities of the Croatian coast. This document, conceived as a complex regional plan, should have served as the basis directing the economic development of the Adriatic area. It analyzed the characteristics of extant construction, estimated the spatial possibilities for the development of tourism (depending on the accommodation capacity of the coast), and established the methodology for the development of spatial plans for tourist areas. Essential characteristics of the preexistent construction in the Adriatic area are:

- geologic position and traffic connections of the Adriatic coast to the sources of tourist demand;
- agreeable climate and
- attractiveness of the coastal area.

The plans covered the entire Adriatic coast of the former Yugoslavia and:

- identified the most suitable locations for public ports, nautical tourism ports, and nautical centers;
- introduced a systematic approach to integrated coastal zone planning and management.

The document supersedes the Regional Development Plan for the Adriatic Region of Croatia. It envisioned approximately 60% of the tourist capacity on the mainland and 40% on the Croatian Adriatic islands.

- The Southern Adriatic Regional Spatial Plan (1968) and the Upper Adriatic Coordination Regional Spatial Plan (1972) covered the entire Adriatic coast of the former Yugoslavia. Developed in the framework of the United Nations Development Program (UNDP) it placed special emphasis on the high suitability of the Croatian part of the Adriatic for the development of tourism. Particular comparative advantages include:
  - the geographic position of the Adriatic coast with respect to the sources of tourist demand, especially in terms of accessibility;
  - exceptional natural attractiveness, especially due to the climate, landscape, and the sea as the main motivating factors for tourists to visit the Adriatic,
  - preexistent tourism structure that needs to be refurbished and adapted to the quality and the magnitude of the natural potential.

In 1978, the UNDP launched the Adriatic III project, which placed a particular focus on ecology and was the cornerstone of integrated coastal management.

In 1977, the UN supported the establishment of the PAP / RAC Centre (Priority Action Program / Centre for Regional Activities) in Split, which became operational in 1978.

Despite this, environmental and spatial planning legislation has not been consistent in addressing coastal issues in a sustainable and integrated manner. The Croatian Physical Planning Program tried to solve the problem. The main goal was to create spatial preconditions that would improve the quality of life and help achieve balanced development. The fundamental determinants of development are:

- focusing spatial development priorities by improving the organization of previously constructed spaces and
- creation of preconditions favorable for economic development and halting the process of depopulation on the mainland and the islands.

Although the Decree provides for the protection of the Croatian coast in accordance with the Regulation on the Protection of the Coastal Sea Area (2004), the fact is that the Regulation is frequently violated due to capital interests. The Decree regulates planning and landscaping in the 1,000 m wide land and 300 m wide sea belt area.

It also prohibits the planning of nautical ports, coastal embankments and berth constructions outside the construction area. Berths should be available only at locations published in official maritime publications.

3. ANALYSIS OF DEVELOPMENTAL FEATURES AND PRESSURES ON THE COASTAL ZONE

In the broader sense, the coast is the area where the influences of different natural geographic elements intersect. In contrast, in the narrow sense, the coast consists of the land and the sea from the lowest tide level to the zone under the influence of the waves. The coastal area may include the entire catchment area, large ecosystems, national parks, and even entire inland regions, while from the seaside, it may include a marine domain where an economic zone can be declared.

Where the sea and the mainland meet, a complex community of natural, economic, and social life is established in which the quality of life depends on the mutual tolerance of its members. The awareness of resource constraints has stimulated numerous surveys that seek to identify a long-term solution to the problem of overexploitation of coastal resources. These issues were first systematically addressed in 1972 in a report by the Club of Rome. The results are published in the books The Limits to Growth and Beyond the Limits.

The term sustainable development was defined in 1987 by the World Commission on Environment and Development, which published the so called Brundtland Report - entitled "Our Common Future" (WCED, 1987). The report contains a well-known definition of development. Goodland and Ledec (1986) define sustainable development as "a model for social and structurally economic transformations that optimize today's benefits without jeopardizing the potential for similar benefits in the future." According to scientists Bojö, Mähler and Unemo (1990), economic development in specific areas (region, nation, globally) is sustainable if total inventories (human capital, physically renewable capital, ecological wealth and exhaustive wealth) are not steadily diminishing (Filipić, Šimunović, 1993).

Over the last couple of decades, increased littoralisation and relocation of economic activity from the continental area to the coast have led to pollution of the coastal areas. As littoralisation is often accompanied by a crisis of congestion and pollution of the coast and the sea, reasonable planning is paramount for sustainable development. Economic and capital pressures are growing stronger and more inhumane. Authors (Phillips et al., 2006; Newton et al., 2012; Batista et al., 2014) stress the need to evaluate the coastal area, ensure its reasonable use and stop unplanned construction, especially the development of mass tourism apartments and hotel resorts. Marine Spatial Planning (MSP) is a reasonable option that enables coastal management to better plan and use the coastal area in an appropriate manner (Papageorgiou, 2016).

Due to the value of natural resources, the MSP promotes the concept of sustainable development as being of the utmost importance for the coastal areas. Therefore, the following is required:

- identify a minimum 100 m wide land belt, where construction will be prohibited, taking into account areas exposed to direct and negative impacts of climate change and natural risks;
- ensure that national legal instruments include criteria for the sustainable use of the coastal zone:
  - determine the boundaries of areas where urban development and other activities are restricted or entirely prohibited;
  - limit the expansion of the urban area and create new transport infrastructure;
  - ensure that coastal area care is regulated by law and one of its leading management activities;
  - grant all citizens free access to the coast, and
  - restrict or completely prohibit the movement and parking of motor vehicles, as well as the movement and anchoring of yachts and vessels in particularly sensitive coastal areas and broader waters.

Although Croatia adopted several regulations (Protocol for Integrated Coastal Zone Management, etc.) on coastal zone management, their implementation is questionable.

Integrated coastal zone management (ICZM) can be defined as a dynamic sustainability process, that takes into account the fragility of coastal ecosystems and landscapes, the diversity of activities and uses, the maritime orientation of individual activities and uses, and their impact on the sea and the coast. The principles of integrated coastal zone management indicate that:

- coastal area can solely be considered a unique resource system, requiring specific management and planning to conserve resources for long-term use;
- all levels of government within the state must participate in the regulation of coastal zone planning.

Integrated management implies a holistic approach to sustainable coastal development and a sophisticated resource management process adaptable to and focused on sustainable

coastal development. It requires an understanding of the relationship between coastal resources, their use, and the impact of construction on the coastal environment.

Croatia evidently still lacks effective integrated management capable of and responsible for coastal zone management.

Particular attention should be paid to hydrological, geomorphological, climate, environmental, socio-economic, and cultural systems, which must be taken into account to preserve the adequate reception capacity of the coastal area. This alone could prevent a variety of negative impacts from making themselves manifest. Connecting local and regional self-government units and involving citizens in the decision-making process would contribute to a better understanding of the value of coastal space. The development of land-use strategies, plans, and programs regulating urban development and socio-economic activities must be free from interests and other pressures. Authors (Fabiano et al., 2009, Diedrich et al, 2010, Palazon et al, 2016) stress that the risks associated with different human and economic activities need to be assessed to eliminate/reduce their negative impact.

4. METHODOLOGICAL APPROACH

The methodological approach to problem solving includes the selection of the appropriate method, definition and evaluation of criteria, as well as the establishment of the general coastal zone evaluation model.

4.1. Multi-Criteria Analysis

Several methods can be used to solve the problem of coastal zone valuation, depending on different stakeholder preferences. In addition to economic (market) methods (Jin et al., 2003), non-market and other methods and techniques have also been used. Scenario methods view development as unrestricted, intensive, selective, and sustainable development. However, special attention is paid to linear programming, AHP, ELECTREE, PROMETHEE and GAIA, where the authors' experiences vary (Brans et al., 1986; Zeleny, 1992, Nikolić and Borović, 1996), and GIS (Kitsiou et al., 2002). Linear programming methods allow problem resolution at the operational level (Roubens, 1982), while the PROMETHEE method (Brans and Vincke, 1985) is characterized by (Vincke, 1992):

- coverage of criteria;
- an estimated higher-ranking relationship;
- use of higher-ranking relationship.

The following methods are used in conjunction with PROMETHEE I and II:

- PROMETHEE III - gives the interval order of alternatives;
- PROMETHEE IV – is an extension of the previous method to continuous sets of alternatives;
- PROMETHEE V - allows the elaboration of a complete survey taking into account additional issues such as cost constraints, geographical diversification of problems, and more.

When the PROMETHEE method is applied to MCA problems, there are two potential outcomes - partial, and complete ranking of alternatives. However, given the existence of other options that cannot be linked, additional geometric information on the behavior of options is needed according to specific criteria. The GAIA method is a geometric representation of the results obtained using the PROMETHEE method. The multidimensional problem is reduced to a two-dimensional one, allowing for simple presentation. When the number of dimensions is reduced, there is a specific loss of information. To minimize the loss of data, the plane in which the geometric representation is given is determined with the two most characteristic values of the co-variation matrix.

4.2. Criteria Definition and Evaluation

All factors, both positive and negative, must be taken into account when deciding how to use the coastal zone. Countries that have managed to preserve their coastline are under pressure to subject their coastal region to intense development. That is especially true of underdeveloped, developing, and transitioning countries which are under constant pressure from capital interests. It is therefore essential to recognize environmental risks, prevent devastation, preserve local benefits, and the coastal area now and in the future. The coastal area should be evaluated in order to set developmental goals and establish the criteria for its potential use. Objectives can be grouped into several basic qualitative determinants of development:

- Economic - systematic coastal zone valorization based on the principles of sustainable development to prevent the overuse of coastal space for commercial / tourism purposes;
- Social - raising the standard of living in the coastal area, while observing the principles of spatial organization and the needs of the people who live and work there;
- Environmentally-friendly and sustainable development of the coastal area:
  - the coastal area should be rationally used and protected in all elements and stages of use;
  - negative environmental impact should be minimized;
  - interaction between individual centers and activities in space should be based on cooperation;
  - the coastal area should be organized in keeping with the principle of openness and integration, which should be evident in all organizational elements: economic, service, institutional, transport and other functions;

- the sort of development that fosters long-term harmonization of the scope and dynamics of production and consumption activities with the scope and dynamics of processes taking place in the coastal zone should be encouraged.

• Functional-organizational - implementation of a theoretically based and practically feasible coastal zone evaluation model.

The objectives defined above allow the identification of coastal zone evaluation criteria. In 2017/2018, the authors conducted a comprehensive study of criteria for general models of coastal area evaluation. The research took into account the stated theoretical premises and past analyses of the criteria. The goal of the research was to determine, evaluate, and rank the criteria and sub-criteria identified, rank the proposed groups of criteria and recommend other criteria or sub-criteria. For each of the identified sub-criteria, the extent of the impact on the coastal area was determined by establishing the maximum or minimum impact. E.g. spatial plan is a sub-criterion of particular importance and must have the condition of maximum since the goal is to plan the use of the coastal area with maximum respect for its natural features. Legislation, frequent changes, and inconsistencies, also have the condition of maximum, since, in the long run, they can be detrimental to the development of the area in terms of redevelopment and more. Of course, the environmental criterion has a minimum requirement when it comes to specially protected areas. However, investment in environmental protection must be maximized, since it does not matter if polluters (such as oil and other industries, and cruisers) generate pollution without paying the adequate fines and being obligated to invest in appropriate green technology.

Criteria and sub-criteria are as follows:

• institutional and political (physical plan, marine spatial planning, views and regional developmental policy, acts, and legal framework), 20%

• natural and physical (geomorphologic and oceanographic characteristics, hydrographic, microclimate characteristics), 15%

• environmental (nature parks, susceptibility to human activities, estimated adverse impacts on the environment, monitoring of the coastal area, value of investments into environmental protection), 25%

• technical and technological (development of traffic and other infrastructure, vicinity of city centers, safety conditions), 10%

• economic (developmental possibilities, investments, taxes, concession fees, external costs), 15%

• social and cultural (direct and indirect benefits, level of urbanization, increased/decreased quality of life in the local community, social and cultural aspects of the region), 15%.

4.3. General Model Using the PROMETHEE Method

Criteria have been identified, ranked and their weight calculated based on the global analysis and development of the general model. The equation for criteria weight based on internecine ranking is:

$$w_j = \frac{\sum_{k=1}^{n} R_{jk}}{\sum_{j=1}^{m} \sum_{k=1}^{n} R_{jk}}; \quad (1)$$

$$R_{jk} \in \{m - i : i \in (1,..,m)\}$$

where R_{jk} is the rank of the criterion according to the expert ranking and its value is:

R_{jk}= m-1 for the most important criterion

.

.

.

R_{jk}= 0 for the least important criterion

n – total number of experts,
m – total number of criteria,
w_j – weight calculated for the criterion j^{th}.

The above equation is used for criteria ranking.

The environmental criterion ranks the highest, followed by the institutional and political criterion, owing to the exceptionally high influence of the Act and policies on coastal zone use. The environmental criterion is of utmost importance. Its role is to prevent damage and overuse of natural resources.

Normalized property values were calculated using a more straightforward approximate procedure. Each element of the matrix was divided by the sum of the corresponding column values. Then the weights were calculated as average values of elements in individual lines, i.e. the equation system was not solved directly.

The definition of the general model was followed by the execution of the above described operations and then, as a result, by the calculation of the weight criterion vector. The following expression was used to obtain the weights of criteria whose importance ratio is contained in matrix A:

$$(A - 6 \cdot 1) \cdot W = 0 \quad (2)$$

$$w_i > 0, i = 1,2,...,6 \quad (3)$$

$$\sum_{i=1}^{6} w_i = 1 \quad (4)$$

Where:

$$A = \begin{vmatrix} a_{11} & a_{12} & \dots & a_{16} \\ a_{12} & a_{22} & \dots & a_{26} \\ \dots & \dots & \dots & \dots \\ a_{13} & a_{62} & \dots & a_{66} \end{vmatrix} = \begin{vmatrix} w_1/w_1 & w_1/w_2 & \dots & w_1/w_6 \\ w_2/w_1 & w_2/w_2 & \dots & w_2/w_6 \\ \dots & \dots & \dots & \dots \\ w_6/w_1 & w_6/w_2 & \dots & w_6/w_6 \end{vmatrix}, \quad (5)$$

$$W = \begin{vmatrix} w_1 \\ w_2 \\ \dots \\ w_6 \end{vmatrix}, \quad (6)$$

$$I = \begin{vmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{vmatrix} \quad (7)$$

Where the solutions are sought through the use of additional conditions of non-negativity and the normalization of the values of solution components, where:

I - unit matrix

W - vector of criteria weights.

Since not all criteria have the same weight, based on their mutual rankings, a weighted preference index obtained by the application of the equation used to calculate the weight criterion was introduced.

The function of the $P_j(a,b)$ preference in the general model is of type III, since it allows the decision-maker the progressive preference of "a "over "b "during the progressive growth of the difference between functions of the f(a) and f(b) criteria. The preference intensity is linearly increased until the difference equals parameter "*p* ", that can be determined in specific cases, and after that value, the preference is strict.

The criteria weights W_j are specific for each criterion j =1...6,.., hence, multi-criteria index of preference for $a, b \in A$ is defined as:

$$\Pi(a,b) = \frac{\sum_{j=1}^{6} W_j P_j(a,b)}{\sum_{j=1}^{6} W_j} \quad (8)$$

where A is the set of possible alternatives, i. e. the rank of coastal area evaluation.

The directed graph, with action nodes from *A*, is such that, for every $a, b \in A$, the sinuosity (a,b) has the value of its index of preference $\Pi(a,b)$, and is called an estimated graph of higher rank. Calculations can be facilitated by an appropriate software. The general model of coastal area evaluation using global analysis does not meet the key requirements in the case of individual coastal areas. For example, the most convenient criteria should be identified, taking into account other criteria at appropriate levels, that offer the highest protection of the coastal area. The best developmental scenario for individual coastal areas should be identified, as well as the requisite infrastructure and traffic solutions in terms of costs. Therefore, a specific analysis was carried out to introduce and rank sub-criteria. Based on the experts' evaluation, the following expression for sub-criteria was defined:

$$w_j = \frac{\sum_{k=1}^{n} w_{jk}}{\sum_{j=1}^{m} \sum_{k=1}^{n} w_{jk}} \quad (9)$$

where

$$w_{jk} = \frac{p_{jk}}{\sum_{j=1}^{m} p_{jk}} \quad (10)$$

n – the total number of experts, m – the total number of sub-criteria, ρ_{jk} – the evaluation of k^{th} expert for j^{th} sub-criterion, w_{jk} – the weight derived for j^{th} sub-criterion of k^{th} expert, w_j – weight calculated for j^{th} sub-criterion.

Using the above expression, an equation for obtaining sub-criterion weight was developed based on their mutual ranking:

$$R_{jk} \in \{ m - i : i \in (1,..., m) \} \quad (11)$$

where R_{jk} is the rank of sub-criterion j, according to the ranking of the k^{th} expert, as follows:

$$R_{jk} = m - 1 \text{ for the most important criteria}$$
$$R_{jk} = m - 0 \text{ for the least important criteria} \quad (12)$$

n – total number of experts, m – total number of criteria, weight derived for the j^{th} sub-criterion.

Further development of the model requires the input of real data about a specific coastal area.

5. THE APPLICATION OF THE GENERAL MODEL

The authors presented the general problem defining model. The model development process, data and documentation collection were conducted in parallel, with an emphasis on collaboration with experts and users. The general model does not provide answers as to which requirements are essential for individual areas, e.g. which activity is the most favorable. The process takes into account, in the multi-criteria sense, other appropriate level criteria that offer the best technological solution, reasonable construction costs and concession fees, relevant safety features and relatively lowest total costs of pollution prevention and area protection, have a positive impact on the local community, and acceptable indicators for other characteristics.

The presented model should be improved on the basis of the results obtained through its application, taking into account the potentially new conditions that may occur in the system.

Therefore, this paper analyzed the evaluation of the coastal area using the established criteria and sub-criteria to facilitate operative decision-making.

The model will be tested by applying the PROMETHEEI (I and II) and GAIA methods to a selected coastal area in the Northern Adriatic. That will be the subject of new research.

6. CONCLUSION

Coastal development requires the coexistence of ecosystems and production. Although the number of coastal areas that have adopted the principles of sustainable development as an all-encompassing developmental concept is limited, in this sense, the concept of sustainable development can also be considered a contemporary philosophy of coastal economy.

Tourism is becoming a significant economic activity, which, among other things, puts it in a position to define spatial requirements. This creates new conflicts that can only be overcome by proper valorization and monitoring of the coastal zone.

As the evaluation of the coastal area using various methods (survey, ranking, rating, MCA) was previously not well-researched, the research carried out by the authors strived to contribute to the evaluation of the coastal area by focusing on the issues, complexity, importance, valorization and protection of the coastal area.

The multi-criteria analysis allows the decision-makers to attribute weight values to each criterion, taking into account clearly defined objectives. Weight coefficients differ at different decision-making levels. The contribution of this research is the identification of criteria and sub-criteria for coastal area evaluation. The implementation of the defining criteria and sub-criteria allows the application of the holistic approach, and ensures the achievement of quality and efficiency of business operations in the coastal area. The model presented in this paper may serve as a theoretical basis for modeling individual coastal areas. The general model may be used to plan new activities and techno-technological solutions.

REFERENCES

Barković, D., 2002. Operacijska istraživanja, Sveučilište J. Jurja Srossmayera u Osijeku, Ekonomski fakultet Osijek.

Batista, M.I. et al., 2014. Assessment of cumulative human pressures on a coastal area: Integrating information for MPA planning and management. Ocean & Coastal Management, 102, pp.248–257. Available at: http://dx.doi.org/10.1016/j.ocecoaman.2014.09.020.

Bojö, J., Mäler, K.-G. & Unemo, L., 1990. Economic Analysis of Environmental Consequences. Economy & Environment, pp.57–85. Available at: http://dx.doi.org/10.1007/978-94-009-0623-5_5.

Brans J. P., Mareschal B., A New Family of Outranking Methods in Multi-criteria Analysis, Operational Research, 1984. North Holland.

Brans, J.P. & Vincke, P., 1985. Note—A Preference Ranking Organisation Method. Management Science, 31(6), pp.647–656. Available at: http://dx.doi.org/10.1287/mnsc.31.6.647.

Brans, J.P., Vincke, P. & Mareschal, B., 1986. How to select and how to rank projects: The Promethee method. European Journal of Operational Research, 24(2), pp.228–238. Available at: http://dx.doi.org/10.1016/0377-2217(86)90044-5.

Cicin Sain, B., Knecht, R. W., 1998. Integrated coastal and ocean menagement. Washington DC: Center for the Study of Marine Policy University of Delaware.

Duplančić Leder, T., Ujević, T. & Čala, M., 2017. Duljine obalne crte i površine otoka na hrvatskom dijelu Jadranskog mora određene sa topografskih karata mjerila. Geoadria, 9(1), p.5. Available at: http://dx.doi.org/10.15291/geoadria.127.

Coastal Zone Management Act, 1972. United States of America. Available at: https://coast.noaa.gov/data/czm/media/CZMA_10_11_06.pdf.

Diedrich, A., Tintoré, J. & Navinés, F., 2010. Balancing science and society through establishing indicators for integrated coastal zone management in the Balearic Islands. Marine Policy, 34(4), pp.772–781. Available at: http://dx.doi.org/10.1016/j.marpol.2010.01.017.

Fabiano M., Marin V., Paoli C., Vassallo P., 2009. Methods for the Sustainability Evaluation of Coastal Zone, Journal of Mediterranean Ecology vol. 10, p. 5-11. Available at: http://www.jmecology.com/wp-content/uploads/2014/03/5-12-Fabiano.pdf

Filipić, P., Šimunović, I., 1993. O ekonomiji obalnih područja: planiranje i upravljanje. Split: Ekonomski fakultet.

Jin, J., Wang, Z., 2003. Study on Coastal Resource Evaluation Theories and Methods, International Conference on Estuaries and Coasts, November 9-11, 2003, Hangzhou, China. Available at: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.530.3686&rep=rep1&type=pdf.

Kidd, S. & Shaw, D., 2013. Reconceptualising territoriality and spatial planning: insights from the sea. Planning Theory & Practice, 14(2), pp.180–197. Available at: http://dx.doi.org/10.1080/14649357.2013.784348.

Kitsiou, D., Coccossis, H. & Karydis, M., 2002. Multi-dimensional evaluation and ranking of coastal areas using GIS and multiple criteria choice methods. Science of The Total Environment, 284(1-3), pp.1–17. Available at: http://dx.doi.org/10.1016/s0048-9697(01)00851-8.

Koordinacioni regionalni prostorni plan Gornjeg Jadrana: Koordinacijski regionalni prostorski načrt Gornjega Jadrana, 1972. Urbanistički Institut SR Hrvatske-Zagreb.

Kovačić, M., 2012. Selecting the Location of a Nautical Tourism Port by Applying PROMETHEE And GAIA Methods Case Study – Croatian Northern Adriatic. PROMET - Traffic&Transportation, 22(5), pp. 341–351. Available at: http://dx.doi.org/10.7307/ptt.v22i5.199.

Kovačić M., Komadina P., 2011. Upravljanje obalnim područjem i održivi razvoj. Rijeka: Sveučilište u Rijeci, Pomorski fakultet u Rijeci.

Kovačić, M., Zekić, A. & Rukavina, B., 2016. Maritime spatial planning in Croatia – necessity or opportunity for balanced development. Pomorstvo, 30(1), pp.82–87. Available at: http://dx.doi.org/10.31217/p.30.1.11.

Martić, LJ., 1992. Matematičke metode za ekonomske analize I, IX izdanje, Narodne novine, Zagreb.

Meadows, D. H., Meadows, D. L., Randers, J., Behrens III, William W., 1974. The Limits to Growth: A Report for the Club of Rome's Project on the Predicament of Mankind, Universe Books, New York.

Meadows, D. H., Meadows, D. L., Randers, J., 1974. Beyond the Limits: Confronting Global Collapse, Envisioning a Sustainable Future, Chelsea Green Publishing Company.

Mladineo, N. et al., 1987. Multicriteria ranking of alternative locations for small scale hydro plants. European Journal of Operational Research, 31(2), pp.215–222. Available at: http://dx.doi.org/10.1016/0377-2217(87)90025-7.

Newton, A., Carruthers, T.J.B. & Icely, J., 2012. The coastal syndromes and hotspots on the coast. Estuarine, Coastal and Shelf Science, 96, pp.39–47. Available at: http://dx.doi.org/10.1016/j.ecss.2011.07.012.

Nikolić, I., Borović, S., 1996. Višekriterijumska optimizacija – metode, primena u logistici, softver, Beograd: Vojno - izdavački zavod.

Palazón, A., Aragonés, L. & López, I., 2016. Evaluation of coastal management: Study case in the province of Alicante, Spain. Science of The Total Environment, 572, pp.1184–1194. Available at: http://dx.doi.org/10.1016/j.scitotenv.2016.08.032.

Papageorgiou, M., 2016. Coastal and marine tourism: A challenging factor in Marine Spatial Planning. Ocean & Coastal Management, 129, pp.44–48. Available at: http://dx.doi.org/10.1016/j.ocecoaman.2016.05.006.

Phillips, M.R, Jones, A.L., 2006. Erosion and tourism infrastructure in the coastal zone: Problems, consequences and management, An international Journal of Tourism Management, Volume 27, Issue 3, p 517-524. Available at: https://doi.org/10.1016/j.tourman.2005.10.019.

Program dugoročnog razvoja i plan prostornog uređenja jadranskog područja SR Hrvatske, 1967. Urbanistički institut SR Hrvatske, Zagreb.

Projekt južni Jadran: regionalni prostorni plan južnog Jadrana, 1968. Urbanistički institut SR Hrvatske, Republički zavod za urbanizam SR Crne gore, Urbanistički zavod SR BiH.

Protection of the Human Environment in the Adriatic Region (Adriatic III), 1978. United Nations Development Programme.

Regulation and Protection of the Coastal Sea Area, Official Gazette of the Republic of Croatia, No. 128/2004.

Report of the World Commission on Environment and Development: Our Common Future, 1987. World Commission on Environment and Development (WCED)

Roubens, M., 1982. Preference relations on actions and criteria in multicriteria decision making. European Journal of Operational Research, 10(1), pp.51–55. Available at: http://dx.doi.org/10.1016/0377-2217(82)90131-x.

UNEP/MAP/PAP., 2008. Protocol on Integrated Coastal Zone Management in the Mediterranean. Split, Priority Actions Programme. Available at: https://www.pap-thecoastcentre.org/pdfs/Protocol_publikacija_May09.pdf.

Bouyssou, D., 1994. Multicriteria decision-aid, Vincke, Ph., Chichester: Wiley, 1992. Journal of Multi-Criteria Decision Analysis, 3(2), pp.131–131. Available at: http://dx.doi.org/10.1002/mcda.4020030208.

Zeleny, M., 1992. Multiple Criteria Decision Making. New York: McGraw – Hill. Available at: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.320.9165&rep=rep1&type=pdf.

Model for the Development of a Specialized Dark Tourist Product

Neven Šerić[a], Ante Mihanović[b], Ante Tolj[c]

Dark tourist facilities are a modern tourism phenomenon. Although *dark* tourism is conceptually associated with the legal inconsistency of tourism, it is based on content related to human suffering. Tourist interest in *dark* tourist products is growing, and such contents have become a part of standard tourist packages in the markets where such offer exists. Despite their proven contribution to destination differentiation and competitiveness, potential resources for the development of *dark* tourist facilities are often neglected due to tourist workers lacking the knowledge requisite for the development of specialized tourism products. Unsustainable approach to the development of specialized tourism products results in focus on content, that ignores the broader benefits of an integrated destination product. In the case of *dark* tourism products, socio-cultural and tantalogic consequences are particularly problematic, as *dark* tourist offer is particularly sensitive to the ethical standards of the general public. The result is that visitors and organizers of such tourist packages are frequently given negative publicity. In spite of the growing global interest in the *dark* tourism offer, its development is slow and modest due to the above-mentioned risks and insufficient education in the tourist industry. The existing global supply often ignores some of the potential benefits of implementation of such content into a destination's and national integrated tourism product. In an attempt to clear up doubts, and provide examples of positive and negative experiences from the global tourism practice, the authors carried out several studies based on which they devised a framework model for the development of a *dark* tourism product with recommended variables of significant impact.

KEY WORDS
~ Tourism
~ Specialized
~ Dark
~ Product
~ Destination

a. University of Split, Faculty of Economics, Business and Tourism
e-mail: nevseric@inet.hr
b. Split-Dalmatia County Pharmacies
e-mail: ante.mihanovic@ljekarnasdz.hr
c. University of Split, Faculty of Science
e-mail: atolj@pmfst.hr

doi: 10.7225/toms.v09.n02.014

1. INTRODUCTION

1.1. Subject of the Research and Research Problem

Contribution to the originality of a competitive integrated destination product is significantly increasing (Anholt, 2011; Šerić, Jurišić, 2014; Kesar, 2015; Prorok et al. 2019). The attractiveness of destination offers is increasingly dependent on the number of specialized tourist products (Bornhost et al. 2010; Šerić, 2019). In the 3rd millennium, specialized tourist products are often based on rare and unusual resources (Tarlow, 2005; Hosany et al. 2007; Kladou, Kehagias, 2014; Šerić, Marušić, 2019). Unusual resources are also the platform for the development of *dark* tourist products (Stone, 2006; Šerić, 2017). *Dark* tourism, though conceptually assimilating the legal mismatch of the offer, is actually based on content related to accidents, deaths and other testimonies of human suffering (Sharpley and Stone, 2009). The interest of

tourists in specialized tourist products based on *dark* content is growing (Stone, 2013). *Dark* content is increasingly included in standard tourist packages (Drvenkar et al., 2015).

The potential of *dark* tourism stems from the multidimensionality of motivation (diversity of perceptions of tragic events) of contemporary tourists (Kesar, 2015). However, in real life, the development and management of such content is frequently carried out at an elementary level (Rašetina, 2010). The subject of this research is the contribution of *dark* tourism to the competitiveness of a destination's integrated offer. Research problem is the concept of development and management of *dark* tourist products.

The optimization of any specialized tourist product requires systematic development and management throughout its lifecycle (Šerić et al., 2020). The implementation of *dark* content into an integrated destination product entails commitment to a particular category - *dark* subject matter, *dark* exhibitions, dungeons and penitentiaries, cemeteries, locations of military conflicts, concentration camps, etc. (Stone, 2006). The mission and vision of a destination's tourist development should be defined. Isolated development of *dark* tourist content can result in its hijacking of a destination's image, which is not rational if there are resources to develop a variety of specialized tourist products (Campelo, Aitken, Gnoth, Thyne, 2009, Hanna, Rowley, 2011; Šerić, Batalić, 2018).

Arguments in favor of the development of *dark* tourism offer are its year-round potential and independence from weather conditions (Joly, 2010; Šerić et al. 2020). Based on the analysis of selected global experiences with the *dark* tourism offer, the authors conducted a primary research on the potential for the development of this offer in Dalmatia in the Republic of Croatia in order to extract potential variables and offer a model for the development of *dark* tourist products for wider real life application.

1.2. Research Methods and the Basic Research Question

Based on the findings of the survey study, a desk research was conducted (Šerić and Jurišić, 2014). Research findings have helped define the guidelines for the implementation of primary research based on the opinion of a sample of knowledgeable subjects (opinion of experienced tourism workers on the potential for the development of this offer, and the opinion of loyal visitors of Dalmatia (Croatia) on the attractiveness of *dark* tourist facilities). The sample excluded individuals who failed to demonstrate relevant competences or interest in the problem and subject matter of the research. The fundamental research question was: What are the key variables of the model for the systematic development of the *dark* tourist product?

2. THEORETICAL APPROACH

2.1. Theoretical Groundwork

Natural disasters, sites of battles, military conflicts, mass murders, terrorist attacks and cemeteries where popular politicians, intellectuals or musicians are buried are becoming increasingly attractive to visiting individuals and groups (Lennon and Foley, 2010). Cemeteries, monuments to war victims, historical events related to nation, culture and ideology and their marketing are useful content for tourist products (Ashworth, 2008). Concentration camps from World War II attract millions of tourists (Rašetina, 2010; Filipović, 2017). Since *dark* tourism is developing on the resources of historical tourism, such contents can be concluded to have been recorded since the 19th century (Sharpley, 2005). In that respect, it cannot be considered a new form of specialized tourist offer. Although the first research on this tourism phenomenon was conducted in the 1970s, its subject matter has only come to be systematically analyzed in the 1990s (Stone, 2013).

Dark tourism can be defined as systematic integration of travel-based tourism products in a place associated with death, tragedy and suffering (Tarlow, 2005). Analyzing the modest theoretical opus of the developmental concepts of *dark* tourism, we have identified the variables of the immediate and spontaneous nature of sensational tourist contents, and the difference between intentionally created attractions and the promotion of interpreted experiences (or re-emerging events or acts related to death and suffering). Another relevant component of a *dark* tourist story is the anticipated range of tourist interest in actual suffering (Stone, 2013). Along with these recognized variables, primary research instruments were created for this paper. The starting points were defined as in Stone (2006), as shown in Figure 1.

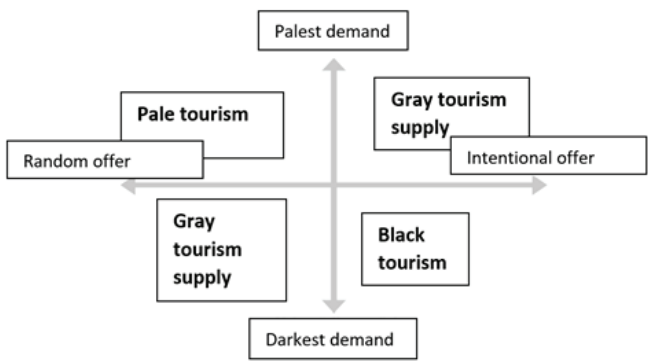


Figure 1.
Dark tourism shades - matrix approach.
(Source: Stone, 2006).

2.2. Current scientific knowledge

Some authors (Bieger, 2000, Bigne, Sancez, Sanchez, 2001, Vargas-Sanchez, Porras-Bueno, Plaza-Mejia Bigne, 2011, Angelevska Najdeska, Rakicevik, 2012, Tsung Hung, 2013 etc.) warn that when creating specialized tourist products in accordance with the standards of sustainable tourism development, particular attention should be paid to access to the commercialization of links between the past and the present. In the case of *dark* tourism, this is manifested in the relationship between the victims (and their present descendants) and visitors.

When conceptualizing the relationship between sites and resources serving as the basis for the development of *dark* tourist facilities, observance of the heterotopic standard (Stone, 2013), stressing the need to identify the critical level of social acceptance of particular content, is advisable. According to Stone (2013), *dark* tourist sites are places of contradiction and division. They can be the sites of real events, but their significance could be artificially intensified, places characterized by deviant behavior of former residents, etc. In some of these places, restrictions with respect to the intensity of tourist visits should also be defined (Tarlow, 2005). Regardless of the historical context and the complexity of human tragedies, the introduction of heterotopic standards will contribute to the appropriateness of content implementation into the contemporary *dark* tourism offer. The need to differentiate individual *dark* tourism sites and related segments of visitors, and take the gradation of the *dark* side of human behavior and indirect crimes into account necessitates the identification of sites for which even additional standards for designing *dark* tourist contents are recommended to ensure an acceptable understanding of a particular tragedy. Ethical and moral standards, media and promotional implications and issues of the political interpretation of content on which the *dark* tourist product is based should likewise be taken into account (Aas et al., 2005; Edgell et al., 2008; Vargas-Sanchez et al., 2011; Armenian et al., 2012; Šerić et al. 2015). Especially in *dark* tourism, such contents are frequently used as tools of political interpretation of history (Joly, 2010; Šerić and Jurišić, 2015).

As the political dimension of the interpretation of historical content imprints on collective consciousness, the issue of the ethics of using this variable as an integral component of *dark* tourist offer should be examined (according to Hankinson, 2007).

Finally, a number of quoted and other authors (Haughland et al., 2011, Ringer, 2013, etc.) also point to the need to regulate the standards of behavior of tourists in such places, to address potential socio-cultural and tantalogic issues. Finally, it is advisable to evaluate the role and potential of *dark* tourism in the wider secularization of society, especially as persons connected with it either individually or collectively are faced with sadness and trauma, and their relationship to death and dying needs to be examined (Stone, 2006).

3. RESEARCH RESULTS

Research findings indicate that many *dark* tourism products are currently not systematically designed, but have been identified as useful resources that are estimated to attract the attention of certain tourist segments (Lennon, Foley, 2010; Šerić et al. 2020). The commercialization of potential *dark* resources often does not have the characteristics of a specialized tourist product (Šerić et al. 2020), especially since the marketing potential of the development and management of their commercialization is neglected. The implementation of marketing in specialized tourist facility supply management increases both the attractiveness of that facility and the competitiveness of the destination as a whole (Dwyer et al., 2004; Crouch, 2007; Šerić, 2012a; Šerić 2012b). Although interest in *dark* tourist facilities is encouraged especially by the media (Filipović, 2017), marketing activities are key to long-term efficient valorization of these tourist facilities. They need to be adapted to the particularities of *dark* resources, respectively – the story on which a specific specialized tourist offer is based (Oppermann, 2000; Pike, 2008; Šerić and Perišić, 2012). Tourists find it difficult to find concrete explanations for the attraction of *dark* content, as confirmed by neuro-marketing research (Šerić, 2016). Given that the sensationalism of media reports on accidents and casualties is subject to public rebuke, tourists who visit these places independently could also be viewed negatively. If *dark* tourist facilities are offered as a component of an integrated destination product, the public condemnation of visitors usually transfers to the organizers (Rašetina, 2010), which simplifies decision-making when it comes to interest in visiting such places, which is an increase in annual turnover. Shaping the content of disaster and human suffering into a *dark* tourist product currently entails creating a connection between a tourist story that provokes a specific emotional response in visitors and the tour program (Stone and Sharpley, 2008).

Current global tourism trends indicate growing interest in all *dark* content shaped into a specific tourist offer (Sheng, 2012). Cemeteries, places of individual and mass murders, sites of historical battles and possessions by deceased persons of global renown, mausoleums etc. are being increasingly commercialized for purposes of development of such tourist products. While Lennon and Foley (2010) emphasize specific emotional consequences for visitors, interest in visiting such places is on the rise. Such tourist facilities can also be used for educational purposes, to improve the perception of added value of an integrated tourist product. Depending on the intensity of impact on a specific location, *dark* tourism products can be shaped

for different tourist segments (Stone, 2006). Not all people are equally sensitive to sites of human suffering.

The following business incidents of *dark* tourism were explored to determine the intensity of *dark* content commercialization: Hiroshima, Nagasaki and Aogikahara (Japan), the World Trade Center (USA), Pompeii and the ridge of the Costa Concordia (Italia), forced labor camps (Russia) and Auschwitz concentration camp (Germany). In the cases analyzed, *dark* tendencies stemmed from the intensity of local heritage, history, political consequences, as well as from playing up the visitors' fears, even though not consciously. The earliest content implies a detailed historical basis, educational meaning and authenticity of the site without significant implementation of the targeted political influence. The same elements are identified as exploitable variables of transformation of potential *dark* resources into the *dark* tourist product.

In addition to the variables mentioned, the potential of technological and socio-cultural factors should be emphasized as these can significantly contribute to the attractiveness of *dark* tourist offer. Technological factors contribute to public awareness of *dark* content, and socio-cultural contributions to the social acceptability of such tourist contents. In the business cases analyzed, the vision and mission of the integrated destination product were not defined in the process of development of the idea of *dark* tourist product commercialization. The vision should be aligned with the direction of tourist development of the destination within which the *dark* content is being commercialized.

Growing secularization and individualization, combined with weakening influence of religion on the public, simplify the delineation of the moral framework for the commercialization of such content. This is an important point, as *dark* tourism assumes a modern moral platform graded depending on the intensity of suffering relating to a particular *dark* content. Promotions also contribute to the media by creating a state of moral panic (Seaton and Lennon, 2004). This condition is the result of moral debates in the context of globally known *dark* contents. Since moral panic is a symptom, rather than a consequence of *dark* tourism, the potential of marketing in the development and management of such tourism products is evident.

3.1. Model Proposition

Primary research was carried out in the Croatian region of Dalmatia. This geographic area has historically been characterized by frequent migrations and military conflicts on land and at sea, as evidenced by a number of historical artefacts, as well as a variety of exploitable stories and legends (Hitrec, 2012). Despite this, the potential of *dark* tourism is only modestly used in the development of specialized tourist products (Filipović, 2017; Šerić et al. 2020). Findings of the conducted primary research have pointed out the limitations and opportunities for the development of the *dark* tourist offer.

Fundamental constraints are the financial resources required for the development of such tourist facilities, the lack of professional staff for the creation and management of *dark* tourist products, the need to modify the promotion of destinations in which *dark* tourist facilities would be commercialized, the complexity of the implementation of the *dark* tourist offer into an integrated destination product (mixed feelings of the local population on the subject of tourist interpretation of the *dark* content), the limited interest of local tourist stakeholders in marketing investments in *dark* tourism, mixed feelings of the local population about historical events and other (author's research, 2017-2019).

Potential benefits include opening of new emissive markets, modification of potential higher level *dark* contents for tourist consumption, contribution of the *dark* content to the preservation of neglected heritage and identity constituents, increased number of tourists, networking of various local entities into an integrated tourist offer, encouraging additional training of local tourist workers (summer or winter tourism), long-term sustainable positioning of the integrated destination offer, etc. (author's research, 2017-2019).

The geographic region of Dalmatia abounds with sites suitable for the development of *dark* tourism. Given that the *dark* tourist facilities contribute to the strengthening of the recognizability and competitiveness of the integrated tourist product, there is no justification for continued neglect of the resources suitable for the development of *dark* tourism in Dalmatia. Research findings have confirmed that most tourist segments find *dark* tourism appealing, since no segment of respondents indicated they would not visit such places in Dalmatia due on ethical or other grounds. All respondents agreed with the statement that the introduction of such tourist facilities would be beneficial for the tourist season in the analyzed geographic area.

Despite the constraints, the investments needed to develop *dark* tourist products are economically justified owing to the high rate of return (findings of this research) and their contribution to the destination's differentiation and competitiveness. Following the research conducted and the findings of primary research, the recommended model for the creation of a *dark* tourist product for wider application illustrated in Figure 2 was formulated.

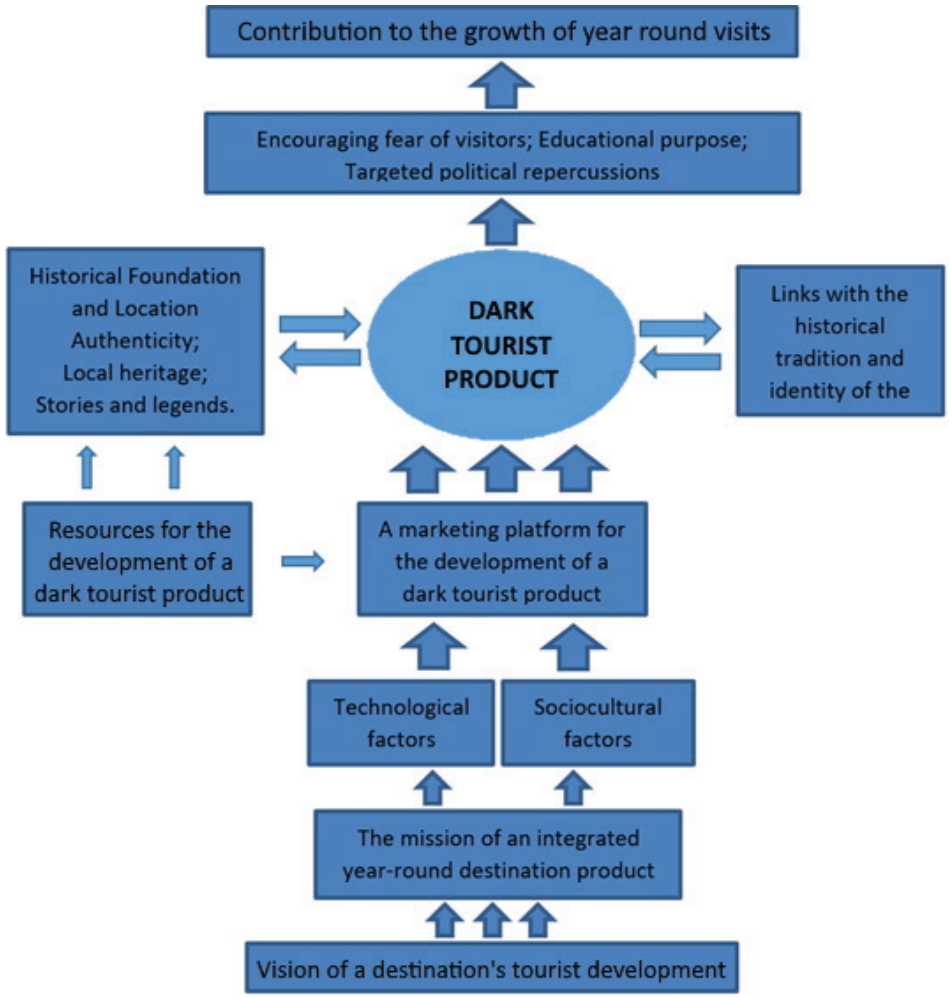


Figure 2.
Recommended model for the creation of a dark tourist product for wider application (Source: Authors, 2019).

4. CONCLUSION

The conducted research confirms the importance of *dark* tourist content for the differentiation, competitiveness and growth of the number of year-round visitors to the destination in which they are offered. However, in the current global tourism practice of *dark* content development and management, their mismatch with other receptive components is overwhelmingly focused on *dark* content. Socio-cultural and tantalogic issues are often neglected, making the *dark* tourist offer vulnerable to the ethical standards of the public. Consequently, both interested tourists and tour operators offering such contents are frequently subjected to condemnation by a part of the public.

Tourist workers who are insufficiently educated to develop and manage specialized tourism products neglect potential sources of *dark* tourism development in many geographic areas. The fact that such sites attract tourists year-round, regardless of the hydro-meteorological conditions in the micro location is frequently disregarded.

The development of a sustainable competitive integrated destination tourism product implies the valorization of all potentially usable resources for the development of specialized tourist facilities. However, sustainable tourism development requires the systematic development of all specialized tourist products, including *dark* tourist products. Each category of a specialized tourist product is based on certain influencing variables. In case of *dark* tourism products, research has shown that these variables are: historical foundations, site authenticity, and local heritage. In regions that have been inhabited for centuries, migrations, continuous warring and the loss of stories and legends are also useful variables. In addition to the aforementioned findings, the research has also demonstrated the

effect of technological and socio-cultural factors on the reduction of the risk of negative publicity of the commercialization of *dark* tourist contents. The variable of a destination's historical traditions and identity also provides a useful feedback for the *dark* tourist product. Finally, it is also important to establish the *dark* tourist contents in the vision and mission of the destination in which they are offered. All these variables are rationally linked through the marketing platform that ultimately aims to create *dark* tourist content that plays on fear, educates visitors and achieves targeted political goals with respect to the interpretation of *dark* tourist content. The *dark* tourist product thus created can ensure the growth of tourist visits year-round. In the end, the extent to which the defined political objectives of the *dark* content used for that purpose left the impression on the general tourist public is doubtful. The fact is that the potential of such unconventional approach to the development of *dark* tourist products for increasing the number of total tourist visits has yet to be realized.

Considering the economic consequences of *dark* tourist products and the possibility of realization of targeted political goals using concrete *dark* content, a systematic approach to the development of this offer at the level of each state and national entity is more than desirable.

With respect to the Croatian region of Dalmatia, owing to the centuries of military conflict, there is a variety of potential resources for the development of *dark* tourist facilities. Findings based on the opinions of a sample of loyal tourists indicate that the number of visits to such amenities in the area would increase, regardless of time of year. Attracting new and keeping old tourists, preserving social resources and historical heritage, networking different tourism stakeholders and creating the image of a multicultural tourist destination are just some of the benefits illustrating the potential and importance of the development of *dark* tourism in Dalmatia and the wider region. However, it is always advisable to bear in mind the ethical rights of those whose death such offer is capitalizing upon. We should strive for positive publicity and affirmative political perception, which can also influence the collective consciousness. Such approach to the development of *dark* tourist products is an expression of political maturity and understanding of historical events.

Creation of a *dark* tourist product should be based on respect for the victims and observance of the current socio-cultural criteria. Ignoring the potential of *dark* tourism or neglecting to develop such tourist content in destinations which have the resources for their development will leave them silent witnesses and hostages of the past. On the other hand, the development of *dark* tourist facilities contributes to the growth of a year-round tourist visits, irrespective of weather conditions. In the end, systematic management of a *dark* tourist product can contribute to the reconciliation of people and the creation of a new image of local and national communities. An image that promotes multiculturalism, understanding and the development of good neighborly relations based on people's association and *dark* tourism.

The growth of global interest in the *dark* tourist facilities is an incentive for new investments and further education of tourist workers and gives tourist an additional motivation to travel and visit destinations offering such content. However, to ensure a systematic approach to the development and management of *dark* tourism products, influencing variables from the presented model need to be taken into account.

REFERENCES

Aas, C., Ladkin, A. & Fletcher, J., 2005. Stakeholder collaboration and heritage management. Annals of Tourism Research, 32(1), pp.28–48. Available at: http://dx.doi.org/10.1016/j.annals.2004.04.005.

Angelevska-Najdeska, K. & Rakicevik, G., 2012. Planning of Sustainable Tourism Development. Procedia - Social and Behavioral Sciences, 44, pp.210–220. Available at: http://dx.doi.org/10.1016/j.sbspro.2012.05.022.

Anholt, S., 2011. Competitive Identity. Destination Brands, pp.21–31. Available at: http://dx.doi.org/10.1016/b978-0-08-096930-5.10002-3.

Armenski, T. et al., 2012. Tourism Destination Competitiveness-between Two Flags. Economic Research-Ekonomska Istraživanja, 25(2), pp.485–502. Available at: http://dx.doi.org/10.1080/1331677x.2012.11517519.

Ashworth, G., 2008. The Memoralization of Violence and Tragedy, Human Trauma as Heritage, Heritage and Identity, Ashgate Publishing.

Bieger, T., 2000. Management von Destinationen und Tourismusorganisationen, Munchen: Oldenbourg.

Bigné, J.E., Sánchez, M.I. & Sánchez, J., 2001. Tourism image, evaluation variables and after purchase behaviour: inter-relationship. Tourism Management, 22(6), pp.607–616. Available at: http://dx.doi.org/10.1016/s0261-5177(01)00035-8.

Bornhost, T. et al., 2010. Determinants of tourism success for DMOs and destinations: An empirical examination of stakeholders' perspectives, Tourism Management, 31(5), pp.572-589. Available at: http://dx.doi.org/10.1016/j.tourman.2009.06.008.

Campelo, A., Aitken, R., Gnoth, J., Thyne, M., 2009. Place branding: Representing sense of place, ANZMAC 2009: Proceedings o f the Australian and New Zealand Marketing Academy Conference 2009, Canning Bridge, W. A, Promaco Conventions Pty Ltd, pp. 1-18.

Crouch, I. G., 2007. Modelling Destination Competitiveness – A Survey and Analysis of the Impact of Competitiveness Attributes, Cooperative Research Centre for Sustainable Tourism Queensland, Australia.

Drvenkar, N., Banožić, M., Živić, D., 2015. Development of memorial tourism as a new concept – possibilities and restrictions, Tourism and hospitality management, 21(1), pp. 63-77.

Dwyer, L., et al., Attributes of Destination Competitiveness: a factor analysis, Tourism Analysis, 9(1), pp.91–101. Available at: http://dx.doi.org/10.3727/1083542041437558.

Edgell, D. L., et al., 2008. Tourism Policy and Planning: Yesterday, Today and Tomorrow, Oxford: Elsevier, Butterworth Heinemann.

Filipović, M., 2017. Resursi za razvoj tamnog turizma na prostoru Dalmacije, Ekonomski fakultet Split.

Hankinson, G., 2007. The management of destination brands: Five guiding principles based on recent developments in corporate branding theory. Journal of Brand Management, 14(3), pp.240–254. Available at: http://dx.doi.org/10.1057/palgrave.bm.2550065.

Hanna, S. & Rowley, J., 2011. Towards a strategic place brand-management model. Journal of Marketing Management, 27(5-6), pp.458–476. Available at: http://dx.doi.org/10.1080/02672571003683797.

Haugland, S.A. et al., 2011. Development of tourism destinations. Annals of Tourism Research, 38(1), pp.268–290. Available at: http://dx.doi.org/10.1016/j.annals.2010.08.008.

Hitrec, H., 2012. Hrvatske legende, Školska knjiga Zagreb.

Hosany, S., Ekinci, Y. & Uysal, M., 2007. Destination image and destination personality. International Journal of Culture, Tourism and Hospitality Research, 1(1), pp.62–81. Available at: http://dx.doi.org/10.1108/17506180710729619.

Joly, D., 2010. The Dark Tourist: Sightseeing in the world's unlikely holiday destinations, London: Simon & Schuster.

Kesar, O., 2015. Razvoj turističke destinacije prema specifičnim oblicima turizma, Available at: http://web.efzg.hr/dok/TUR/okesar/Web_Razvoj%20turisti%C4%8Dke%20destinacije%20prema%20SOT.pdf.

Kladou, S. & Kehagias, J., 2014. Developing a structural brand equity model for cultural destinations. Journal of Place Management and Development, 7(2), pp.112–125. Available at: http://dx.doi.org/10.1108/jpmd-03-2013-0007.

Lennon, J., Foley, M., 2010. Dark Tourism: The attraction of death and disaster, London: Continuum.

Oppermann, M., 2000. Tourism Destination Loyalty. Journal of Travel Research, 39(1), pp.78–84. Available at: http://dx.doi.org/10.1177/004728750003900110.

Pike, S., 2008. Destination marketing: an integrated marketing communication approach, Oxford: Elsevier.

Rašetina, S., 2010. Fenomen tamnog turizma u kontekstu razvoja selektivnih oblika turizma. Ekonomski fakultet Split.

Ringer, G. ed., 2013. Destinations. Available at: http://dx.doi.org/10.4324/9780203441381.

Seaton, A.V. & Lennon, J.J., Thanatourism in the early 21st century: moral panics, ulterior motives and alterior desires. New horizons in tourism: strange experiences and stranger practices, pp.63–82. Available at: http://dx.doi.org/10.1079/9780851998633.0063.

Sharpley, R., 2014. Host perceptions of tourism: A review of the research. Tourism Management, 42, pp.37–49. Available at: http://dx.doi.org/10.1016/j.tourman.2013.10.007.

Sharpley, R., 2005. Travels to the Edge of Darkness: Towards a Typology of "Dark Tourism." Taking Tourism to the Limits, pp.215–226. Available at: http://dx.doi.org/10.1016/b978-0-08-044644-8.50023-0.

Sharpley, R., Stone, P.R., 2009. The Darker Side of Travel: The Theory and Practice of Dark Tourism, Bristol: Channel View Publications.

Sheng, Y., 2012. The impact of destination personality dimensions on destination brand awareness and attractiveness: Australia as a case study, Tourism, 60(4), pp. 397-409.

Stone, P.R., 2006. A dark tourism spectrum: Towards a typology of death and macabre related tourist sites, attractions and exhibitions, Available at: http://hrcak.srce.hr/161464.

Stone, P.R., 2013. Dark Tourism, heterotopias and post-apocaplyctic places – The case of Chernobyl, Dark Tourism and Place Identity, Routledge Melbourne.

Šerić, N., 2012a. Brendiranje otoka istočnog Jadrana u funkciji jačanja identiteta turističke destinacije, Identitet jadranskog prostora Hrvatske: Retrospekt i prospekt, Ekonomski fakultet Split.

Šerić, N., 2012b. Brendiranje turističke destinacije temeljeno na identitetu, Proceedings of Tourism Human resources developement RT-SEE-2012, Univerzitet u Istočnom Sarajevu, BiH, pp.428-436.

Seric, N. & Perisic, M., 2012. Branding Strategy for Specialist Tourism Products. Cruise Tourism and Society, pp.39–46. Available at: http://dx.doi.org/10.1007/978-3-642-32992-0_4.

Šerić, N., Jurišić, M., 2014. Istraživanje tržišta za turističke subjekte, Redak, Split.

Šerić, N., Jurišić, M., Petričević, D., 2015. Neuromarketing potential for tourist destination brand positioning, Proceedings of ToSee 3nd International Scientific Conference Tourism in Southern and Eastern Europe 2015, University of Rijeka, Faculty of Tourism and Hospitality Management, Opatija, pp. 429 – 439.

Šerić, N., Jurišić, M., 2015. Methodological approach and model analysis for identification of tourist trends, Journal of Economics and Business, 10/2015, University of East Sarajevo, BiH pp. 47–54.

Šerić, N., 2016. Upravljanje proizvodom, Redak, Split.

Šerić, N. & Marušić, F., 2019. Tourism Promotion of Destination for Swedish Emissive Market. Advances in Economics and Business, 7(1), pp.1–8. Available at: http://dx.doi.org/10.13189/aeb.2019.070101.

Šerić, N., Batalić, M., 2018. Marketinško upravljanje informacijama u funkciji jačanja privlačnosti turističke destinacije, Podstranska revija XVII/36, Ogranak Matice Hrvatske u Podstrani, pp. 12-15.

Šerić, N., 2017. Lucije Ertorije Kast – iskoristiva platforma kreiranja vrijedne destinacijske ikone Podstrane, Podstranska revija XVI/34, Ogranak Matice Hrvatske u Podstrani, pp. 10-13

Prorok, V., Šerić, N. & Peronja, I., 2019. Analysis of Overall and Pure Technical Efficiency of Tourism in Europe. Transactions on Maritime Science, 8(2), pp.219–229. Available at: http://dx.doi.org/10.7225/toms.v08.n02.007.

Šerić, N., 2019. Inovativan kružni koncept upravljanja dualnom destinacijskom ikonom Podstrane: Od legende Kralja Arthura do povijesne ličnosti Artoriusa Luciusa Kasta, Podstranska revija XVIII/37, Ogranak Matice Hrvatske u Podstrani, pp. 10-12.

Šerić, N., Peronja, I., Marušić, F., 2020. Upravljanje razvojem specijaliziranog turističkog proizvoda, Redak, Split.

Tarlow, P., 2005. Dark tourismThe appealing "dark" side of tourism and more. Niche Tourism, pp.47–58. Available at: http://dx.doi.org/10.1016/b978-0-7506-6133-1.50012-3.

Lee, T.H., 2013. Influence analysis of community resident support for sustainable tourism development. Tourism Management, 34, pp.37–46. Available at: http://dx.doi.org/10.1016/j.tourman.2012.03.007.

Vargas-Sánchez, A., Porras-Bueno, N. & Plaza-Mejía, M. de los Á., 2011. Explaining residents' attitudes to tourism. Annals of Tourism Research, 38(2), pp.460–480. Available at: http://dx.doi.org/10.1016/j.annals.2010.10.004.

Analysis of Port Community System Introduction in Croatian Seaports - Case Study Split

Ivan Torlak[a], Edvard Tijan[b], Saša Aksentijević[c], Renato Oblak[d]

The introduction of a Port Community System (PCS) is identified as one of the key elements facilitating seaport development. In this paper, the analysis of seaport stakeholders and Maritime Single Window systems in Croatia is performed, including NSW (National Single Window), MNSW (Maritime National Single Window: CIMIS - Croatian Integrated Maritime Information System), their interaction and development of the national model for a PCS, ongoing in the form of a pilot project in the Port of Rijeka. This development is selected as a precedent for creation of the nation-wide PCS to be used also in other cargo ports of national interest, including Split. Further building on this newly gained knowledge and taking into consideration the development of the national PCS model, we explain the inherent characteristics of the Port of Split in terms of traffic evaluation in various port basins. We also provide a comprehensive set of operative guidelines for adjustment of the functional PCS module architecture to be deployed in the Port of Split and serving specific business needs of all identified port cluster's stakeholders after the initial development in the Port of Rijeka is completed.

KEY WORDS
~ Croatian searports
~ Split cargo port,
~ Seaport cluster
~ Port Community System

a. Jadroagent Rijeka PLC, Croatia
e-mail: torlak.ivan@gmail.com
b. University of Rijeka, Faculty of Maritime Studies, Croatia
e-mail: etijan@pfri.hr
c. Aksentijevic Forensics and Consulting LTD, Viškovo, Croatia
e-mail: axy@vip.hr
d. Adria Polymers LTD, Omišalj, Croatia
e-mail: renato.oblak@ri.htnet.hr

doi: 10.7225/toms.v09.n02.015

1. INTRODUCTION

Six publicly open ports operate in the Republic of Croatia and have the status of 'port with special international economic interest' for the state. These are the Ports of Rijeka, Ploče, Zadar, Šibenik, Split, and Dubrovnik. Taking into consideration cargo operations using piers of port basins under the Port of Split Authority's management, the Port of Split can be characterised as one of the most complex port areas on the Croatian side of the Adriatic. The port itself offers various types of stevedoring and cargo handling services in its port basins. In order to improve the business processes and increase the level of quality of services offered by the port and port's stakeholders, it is of utmost importance to plan mid-term implementation of information technologies that strive to increase the quality of the provided services and enhance timely data exchange. Due to the use of information from different sources, the common problems are inconsistency and contradictions, which ultimately lead to inefficiencies of information systems in management support (Asproth, 2007).

The literature review shows that the trend towards collaborative innovation in the maritime supply chain implies a good understanding of the actors and their roles, and an efficient exchange of information (Carlan et al., 2016). Information systems

have become indispensable to the competitiveness of ports, facilitating communication and decision making for enhancing the visibility, efficiency, reliability, and security in port operations under various conditions (Heilig and Voß, 2017). Strong facilitators of the digitalisation are investments into technology and cooperation for promoting information sharing and a better coordination and collaboration (Heilig et al., 2017).

Significant efforts have been done to enhance efficiency, effectiveness, and transparency of the port information flow by implementing different kinds of collaborative Port Information Systems, such as the Port Community Systems (PCSs). A PCS is an open electronic platform that enables information exchange among public and private port stakeholders, and its scope may cover a wide number of activities (Zerbino et al., 2019). PCS connects port community actors, enabling commercial services and information exchange between the port to their customers and a variety of stakeholders (Moros-Daza et al., 2020). It is very important to emphasize that a PCS must customize its services based on the type of users (Moros-Daza et al., 2018). PCSs are rapidly being developed in order to enhance the communications among ports and other port-related institutions and gain competitive advantage against the world's leading ports (Aydogdu and Aksoy, 2015). Analysing international solutions and good practice in the application of PCS, Constante (2019) provides valuable guidelines for cost-effective development of PCS.

Tsamboulas et al. (2012) assessed the changes in port performance resulting from the introduction of PCS, which directly affects the efficiency of port management in a competitive environment. Caldeirinha et al. (2020) analysed the various mechanisms that allow ports to adapt and develop PCS characteristics as well as new features that affect port performance.

The PCS helps port authorities to take the lead by providing a logistics solution to private actors, encouraging them to share information that may lead to lower logistics costs, to faster delivery/pickup in the import/export chain, and to higher customer satisfaction. Bringing all users together enhances the efficiency of the physical flow of freight, drives economic growth and, as a secondary result, assists in reducing externalities such as pollution, congestion, and land use impacts (Irannezhad, 2017).

Preliminary research (Tijan et al., 2014) has shown that the achieved level of development of PCS in Croatia is modest in terms of their use in the management of port facilities. The reasons identified for this issue are:

- The general issue of inadequate rate of ICT (information and communication technology) implementation in comparison with the speed of its overall development;
- Inadequate level of knowledge and adjustment ability of the entrepreneurs and the management caused by rapid scientific and technological development;
- Lack of knowledge and understanding of ICT as major economic resources;
- Inadequate level of employee education.

In addition, it has been noted that complex systems like the Croatian seaports are exposed to challenges of modern, de-materialised economy (Tijan et al., 2012).

Therefore, this paper will provide an overview of the development of a PCS in the Republic of Croatia so far (specifically, Ports of Ploče and Rijeka will be analysed, representing the bearers of the development of port information technologies, and the influence on the Port of Split). This paper will also analyse the involvement of the stakeholders of the seaport system and the transport chain. In order to achieve a satisfactory level of system usefulness in the Port of Split, the Split Port Authority should work closely with the Port Authorities of Rijeka and Ploče in order to derive benefits from their accumulated expertise in developing PCS Rijeka and Ploče that can help in the further development and implementation of a PCS in Split. Finally, this work will propose arrangement of macro-level modules for the processing and distribution of data, in a manner that will enable the system as a whole to function properly.

2. PCS SPLIT AS PART OF CROATIAN NATIONAL SINGLE WINDOW

As stated before, a PCS is an electronic platform that interconnects multiple information management systems operated by a variety of organizations and stakeholders that make up a port community cluster. A PCS is a platform that allows exchange between public and private operators in a port, by creating efficient processes, reducing procedure time and the use of paper documents (Vaghi and Lucietti, 2016). A PCS is also a digital solution for the optimization of port's commercial activities, and should represent an intermediary between all the users, CIMIS (Croatian Integrated Maritime Information System) and the Customs system of the Republic of Croatia, if it is given the role of a local Single Window under prescribed conditions and with appropriate authorisation and certificates for such purpose (Ministry of the Sea, Transport and Infrastructure, 2011).

The definition of a PCS determines the role of the system in port activities as support to all the commercial processes and activities within given process regulations. Its utilisation generally increases the use of electronic communication in the port cluster's businesses; the PCS's role is not management or administration by nature; in fact, it provides support to the commercial aspect of all stakeholders involved in seaport business. The final goal of the PCS implementation is an enhanced exchange of information, maintaining set standards of quality, reliability, and timeliness. Port-collaboration physical, information, and financial flows are

interdependent, thus causing many coordination challenges for the parties in the port. As multiple organisations rely on a PCS, even for business-critical processes, effective governance of the collaboration is crucial (Chandra and van Hillegersberg, 2018).

Implementation of a PCS results in significant improvements to the time consumption of ship's arrival to the port that can be expected after process reengineering and especially after introduction of a PCS, which would result in increased efficiency and variable labour cost reduction (Tijan et al., 2014). For example, research has shown that only administrative labour savings related to ship processing can amount to 48.5% if proper reengineering is used and PCS is implemented (Tijan et al., 2014).

The National Single Window (NSW) can be defined as the standalone information system operating at national level, providing connectivity and data (document) exchange with other systems by using standard and well-established ways of communication, accepting information in strictly defined structure and making information available to various different stakeholders within the country in a harmonised manner (Mihai-Cosmin and Minea, 2016). Single Windows may also be supranational or regional. According to the Directive 2010/65/EU of the European Parliament and of the Council (Directive 2010/65EU, 2010), each Member State should implement the Maritime National Single Window (MNSW) in order to optimise and facilitate the process of announcement and registration of ships that arrive to ports and/or depart from ports of the Member States (Tijan et al., 2017).

In order to achieve the cohesion goals during the implementation of the NSW, the European Commission has issued in mid-2019 a National Single Window Data Mapping Report, identifying full set of data to be exchanged using NSW among member states, aligned with the new requirements according to revised PAX legislation (European Commission, 2019).

PCS needs to be connected to the surrounding systems (such as CIMIS) with the underlying goal being avoidance of multiple data entry and facilitation of data exchange between stakeholders. Along with all the other systems enabling electronic communication in maritime traffic, PCS forms an important constituting and participating element of the NSW platform. The "Project of setting up a single national Port Community System" is currently underway, with the Ministry of the Sea, Transport and Infrastructure being the bearer of the project (Ministry of the Sea, Transport and Infrastructure, 2018). Cooperating parties in this project are, among others, the Port of Rijeka Authority and the Port of Ploče Authority. The latter maintains the only functional PCS system in the country used by the stakeholders in the port community, whose initial design started in 2009. (Buis, 2009) Since then, it has been constantly upgraded, so it presents a positive precedent for the development of a national PCS system to be implemented in other Croatian ports. Once the mentioned project is completed in 2021, all the Croatian Port Authorities will have a fully functional PCS system at their disposal, which will be adaptable to all Croatian cargo ports with very little changes and adaptation dependent on the local characteristics of each individual participating port. The Port of Split Authority, managing the second largest port in the Republic of Croatia (traffic of over 3.1 million tons of cargo), is currently not actively involved in the development of this project. This PCS system will follow all supranational guidelines set by the European Commission and UNECE, and especially those outlined by the European Port Community Systems Association. (European Port Community Systems Association, 2020). Furthermore, a set of guidelines presented by IPCSA (International Port Community Systems Association) will also be respected in the creation of a national PCS model. The IPCSA objectives are the following (International Port Community Systems Association, 2020):

- To ensure that the importance of Port Community Systems' Operators is recognised internationally and in the EU and its member States, and that the sector is consulted substantively on any measure likely to affect it;
- To ensure that the Port Community System Operators play their full part in delivering e-services internationally;
- To promote the highest possible standards in the European and International Port Community System Operators;
- To encourage all port communities to be proactive in the Port Community System development.

Stakeholders and users of PCS system can be divided into two groups (Tijan et al., 2017): stakeholders controlling the entered data, and commercial data users and providers.

Supervisory part of the application, i.e. agencies controlling the data entered are:

- Harbour Master's Office,
- Port Authority,
- Border police,
- Phytosanitary and veterinary inspections,
- Sanitary inspection, and
- Customs office.

Commercial users providing the data are:

- Waste disposal concessionaires,
- Mooring, piloting and tug service providers,
- Ships' agents,
- Freight forwarders,
- Cargo terminal concessionaires, and
- Land transport companies.

2.1. PCS in Croatian Ports

The Port of Ploče has made the most significant progress in the development and implementation of the PCS system. It is important to emphasise that the system developed in one port

cannot be translated to another port in its entirety, but certain segments and basic logical settings of the system can.

The idea of the Port of Ploče was to make the port itself a hub where processes of trade and transport would be integrated. This project was designed under the title 'Project of Integration, Trade and Transport' (Port of Ploče Authority, 2018). The idea of this project was to transform the Port of Ploče from a traditional-type port, an intersection of land and sea transport, into a modern logistical hub. This would create conditions to develop the Pan-European Corridor Vc (Poletan Jugović, 2006) whose route is Ploče - Osijek - Sarajevo, originating in the Port of Ploče.

The Port of Ploče PCS is in its mature development stage. It was intended to serve as a "local single window", and some of the basic implemented and supported processes are (Port of Ploče Authority, 2018):

- Integration of Notice of call with CIMIS,
- Integration with Terminal Operating System (TOS),
- Exchange of data based on XML (EXtensible Markup Language) and UN/EDIFACT (The United Nations rules for Electronic Data Interchange for Administration, Commerce and Transport),
- Customs procedures,
- Linking other forms of transport (road, rail),
- Procedures of cargo entry and exit, and
- Entry/exit and movement of cargo through the Port's Free zone.

Currently, the implementation of PCS module for the needs of operators of the liquid cargo terminal is underway in the Port of Ploče. In the Port area, the PCS system is used depending on the needs of the terminal operators and the concessionaires. Considering that the Port of Ploče Authority has built a new entry terminal, their goal is to automate the processes of this particular terminal. The PCS platform plays a key role in the process automation. Data is exchanged between different subsystems via defined business rules using the PCS platform. It is the priority to develop and integrate in the near future the module for the Notice for trucks' arrival. The intention is to connect the modules for permit issuing, Customs module, and module for port security. Finally, all terminal operators will be obligated to use a single system of notice, regardless of which Terminal Operating System (Tijan et al., 2010) they use.

Currently, the PCS is not implemented in the Port of Rijeka even though implementation was initially planned for 2008, and an international request for quotation was announced that received four valid offers and the selected vendor started with initial analysis and implementations. The project was suspended in 2011, partly due to the development of the CIMIS system and a change of focus. The effectuation of PCS continued in mid-2017 with preparations for the involvement of the project Technical Assistance (TA) whose the full implementation is planned by the end of 2021. The project is financed with the support of Connecting Europe Facility, in the amount of 1.6 million EUR. The Government of the Republic of Croatia will provide 15% of that amount (Ministry of the Sea, Transport and Infrastructure, 2018). The project is well underway and executed on time. The contract for Technical Assistance for design and implementation of PCS in Rijeka, whose value is 297,312.50 Croatian kunas, was signed on 19 April 2018. The Technical Assistance team comprised of subject matter experts from Sarda Ltd., Aksentijevic Forensics and Consulting, Ltd., Faculty of Maritime Studies of the University of Rijeka, and Kiss Patterns immediately started with the activities whose goal is to produce the required PCS tender documentation including the involved Port stakeholders' process description, required hardware, system software and information security levels, rules for the transfer of intellectual property and business continuity. The public counselling process was announced on time on 24 December 2018. After the comments of interested public members were incorporated, the public procurement announcement was issued on 31 December 2018. Commercial offers were collected, requests for clarifications were issued, and the offers were technically and financially evaluated within rules set by the public procurement legislation rules according to which the Port of Rijeka Authority has to abide, with the final goal being the selection of an economically most viable offer for the implementation of PCS in Rijeka, which will serve as a basis for the nation-wide implementation of PCS after specific adjustments, including the Port of Split. The vendor was selected according to public procurement rules, and development and integration services contract was stipulated in April 2019. Within the portfolio of Connecting Europe Facility of the European Union instrument (Innovation and networks executive agency, 2016), this project carries the code "CEF-POR2CORE-PCS". (Port of Rijeka Authority, 2017)

The Port of Rijeka is situated on a Pan-European route called Corridor Vb (Croatian encyclopaedia, 2018). Its route is Rijeka - Zagreb - Budapest. Apart from the corridor, the oil pipeline of great significance is connecting Rijeka to refineries in Croatia, Hungary, Serbia and Bosnia and Herzegovina.

Rijeka GATEWAY (Port of Rijeka Authority, 2018) project's goal is to develop and modernise the above-mentioned traffic route, i.e. to develop and modernise the Port of Rijeka as the point of intersection of maritime and land traffic. This project signifies a large breakthrough for Rijeka as a port hub. The following activities are planned as parts of the project: extricating piers from the city centre, modernising all the segments of operative port business, modernisation of the state road D 403, which will remove road traffic from the city centre (City of Rijeka, 2019), and implementing a modern PCS system. The particularity of the Port of Rijeka in comparison with the Port of Ploče is the dispersion of port basins and land terminals, which is limiting the development

of the project since it requires additional human and financial resources to support diverse locations and modalities of cargo transport inside the Port itself. The development project should include all possible future users and stakeholders, and especially companies that operate within the seaport cluster. This applies most of all to the ports that have dislocated basins and different piers concessionaires. The current processes require multiplication of data, i.e. the same information needs to be entered several times delivered to multiple addresses, which increases the possibility of error and reduces the efficiency of the administrative and cargo-related procedures.

2.2. Traffic Evaluation as Basis for Development of PCS in the Port of Split

While the Port of Split is primarily considered as a passenger port, its function as a cargo port that has handled over 2.9 million tons of cargo in 2019 cannot be disregarded. According to the latest available data from year 2019, the Port of Split was the leading passenger port in the Republic of Croatia, with over 5.6 million passengers, and was the 3rd port in the tonnage of handled cargo (Port of Split Authority, 2020). The Port of Split operates in diverse and dislocated basins and several dock areas, as shown in the following Figure 1.

Figure 1.
Dock areas within competence of Port of Split Authority.
Source: Port of Split Authority, 2019.

In 2017, using the cargo handling piers of the Split basin area, 3,136,347 tons of cargo were handled, which is a 14% increase in relation to the weight of goods handled in 2016. Most goods were handled in June, 357,566 tons (a 31% increase in comparison with June 2016), and in July, 334,039 tons (a 55% increase in comparison with July 2016) (Port of Split Authority, 2018).

The majority of cargo was handled at the piers for handling cement and cement products, 31.36% (983,535 tons), at the terminal for handling oil and oil derivatives - 13.88% (435,170 tons), the North Port - 12.12% (380,125 tons), and finally, at the silo-terminal for handling and storing grains - 6.62% (207,477 tons). A large portion of cargo was transported by trucks to the islands or to Italy (967,330 tons) (Port of Split Authority, 2018).

Seven Port basins operate under the management of the Port of Split Authority, four of which are areas where cargo is handled. The Port basins where cargo is handled are Vranjic - Solin basin, Kaštela basin B, Kaštela basin C, and City Port of Split. In the Port basin City Port of Split, truck traffic embarking on RO-RO ships can be considered as cargo traffic. The other Port basins are used for passenger traffic.

2.2.1. Vranjic - Solin Basin

In the area of Vranjic - Solin basin, two Port concessionaires operate: Luka Inc. Split and Ameropa žitni terminal Ltd. Luka Inc. Split manages the area known as the North Port Split. The services it provides as a concessionaire are handling bulk cargo, general cargo, and RO - RO container manipulations. It is open for public traffic and has several outdoor and indoor warehouses, both conventional and refrigerated. In 2017, 380,125 tons of cargo were handled (8% increase in cargo). Most of the cargo handled was in cargo containers, i.e. 115,624 tons (30.4%). The North Port (Port Inc.) handled 12.12% of all the cargo handled on piers under the management of Port of Split Authority (Port of Split Authority, 2018). In 2017, the North Port achieved 158 calls of cargo ships on commercial voyages (Port of Split Authority, 2018).

Ameropa žitni terminal Ltd. manages area known as Vranjic silo, which specialises in handling bulk grain - primarily corn, wheat and barley. In 2017, 207,477 tons of grains were handled, and a decrease of 34% in cargo manipulations was recorded in comparison with 2016. Vranjic silo (Ameropa žitni terminal Ltd.) handled 6.62% of all the cargo handled on piers under the management of the Port of Split Authority (Port of Split Authority, 2018) in 2017 and recorded 56 calls of cargo ships (Port of Split Authority, 2018).

2.2.2. Kaštela Basin B

Kaštela basin B is the area of the pier of Sv. Juraj (Eng. St. George Pier) – CEMEX Hrvatska Llc cement factory, concessionaire of the Port area. The area is used for the needs of the cement factory: cement, clinker, ground granulated blast furnace slag (GGBFS), petrol coke and thermal coal cargo manipulations. In the year 2017, 983,535 tons were handled, 310 calls of cargo ships were recorded, and an increase of 31% was achieved in comparison to 2016 (Port of Split Authority, 2018). The Pier of St. Juraj factory handled 31% of all the cargo handled under the management of the Port of Split Authority (Port of Split Authority, 2018).

2.2.3. Kaštela Basin C

Kaštela basin C incorporates several piers, of which the most important are:

- INA - tanker terminal, and
- St. Kajo - CEMEX Hrvatska Llc, cement factory.

The national integrated oil company INA Inc. of Zagreb is the concessionaire of INA - tanker terminal area. The terminal is used for the coastal shipping of fuel, which is usually loaded in the Port of Bakar and unloaded at this terminal. In 2017, 435,170 tons were handled, and an increase of 23% was achieved in comparison with 2016. INA - tanker terminal handled 13.88% of all the cargo traffic (Port of Split Authority, 2017) and achieved 127 commercial ship calls (Port of Split Authority, 2018).

St. Kajo - CEMEX Hrvatska Llc is a concessionaire of the Port area and uses the piers for manipulation of ground granulated blast furnace slag (GGBFS) and cement. In 2017, 211,260 tons were handled and an increase of 15% was achieved in comparison with 2016 (Port of Split Authority, 2018). St. Kajo - CEMEX Hrvatska Llc recorded 48 commercial ship calls (Port of Split Authority, 2018).

3. PROPOSAL OF FUNCTIONAL PCS MODULE ARCHITECTURE IN THE PORT OF SPLIT

Plans for the development of the Port of Split, unlike the above-mentioned Ports of Ploče and Rijeka, do not contain implementation and execution of a PCS project of such magnitude for the entire Port cluster. However, according to the plans of the Ministry in charge, the future system implemented in the Ports of Ploče and Rijeka will have inherent ability to function also in other Croatian Ports, after installation and adjustment of the system to the needs of each particular Port. The important part of preparation for implementation is adapting the business processes and achieving compliance with the legislative framework. The introduction of ICT business process support (such as PCS) can be counterproductive if the state agencies in charge do not fully endorse implementation of e-commerce principles and standards. The implementation and subsequent utilisation of CIMIS system indicates the possibility of such a problem because certain state bodies still require both electronic and paper documentation, with the paper documentation being mandatory.

As mentioned above, the Port of Split will have the option of PCS implementation after the Ports of Ploče and Rijeka. The systems comprised of modules are either already implemented or are in the process of implementation in those Ports. Each Port's system should have the same basic modules, while additional modules would differ depending on the specific needs of an individual Port. The proposed modules belong to the class of business application software that also includes information router service and certificate server used for user authentication. General composition of PCS modules is shown in Figure 2.

Figure 2.
General composition of PCS module.
Source: Tijan et al., 2009.

The authors propose the following modules for initial implementation in the Port of Split PCS:

- Port administration module,
- Module for notices of arrival,
- Module for ISPS (International Ship and Port Facility Security Code) control of Port areas,
- Modules for bulk, liquid, and general cargo, and
- Interconnection module connecting TOS of the container terminal and PCS.

The implementation of these modules will enable all the three macro-functions of PCS, which are data and documentation storage (recording), information processing, and information management (Naglić et al., 2015).

All the business processes facilitated by the PCS should be fully aligned with the needs of the members of the Port cluster, with the objective of reengineering and digitalization of the business processes currently conducted using traditional methods (paperwork and physical document flow, and management). They should also be in line with the legal and EU regulations and requirements, and the respect of good business practices of the seaport cluster.

3.1. Port Administration Module and Module for Notices of Movement of Ships and Cargoes

Several processes can be grouped under the umbrella of 'notice of arrival of ships', all of which serve the purpose of fulfilling administrative procedural requirements for the preparation of ships and cargo for the execution of Port operations. The processes governing the arrival of ships in the Port of Split are outdated in comparison to the contemporary processes used by modern Ports, and have not been changed for over four decades in the cargo management part, except for the introduction of CIMIS system, related to ship formalities, which will be integrated with the PCS system.

Currently, CIMIS system performs the role of a single national interface for the registration of arrivals and departures of ships, and management of the mandated formalities. Among other functions, its role as the collector of data should be used in the future setup of the Port's PCS. (Puškarić, 2013). Below are listed those processes that are currently executed in dual manner through CIMIS system and by physical delivery of the paper documents. Such processes slow down business execution in the seaport cluster.

The procedure of registering the arrival of ship to the Customs office in charge is carried out dually. Via CIMIS system, the Customs office is provided by the shipping agent with data and information such as:

- IMO (International Maritime Organization) crew list,
- IMO crew effect declaration,
- Cargo manifest and stowage plan,
- IMO ship store declaration,
- IMO narcotic and nil list,
- ISPS list of last ten Ports visited, and
- Declaration of dangerous and polluting goods (only if applicable).

The Customs office still requires paper (i.e. physical) version of the documents listed above in the so-called Cargo statement, and the operators' TOS systems are not used for this purpose. This results in the slowdown of the operative work of those in charge for cargo management and creates avoidable delays.

The arrival of cargo is registered by using the 'Customs e-expediter' application. This application, with CIMIS system, constitutes the national system of registering the movement of ships and cargo. Currently, these two systems have no interconnectivity. The same as CIMIS, 'Customs e-expediter' should have the role of a data collector for the future PCS in the Port of Split. It has a dual role while registering ships:

- Security registration of cargo done by the ship's agent: Customs office uses this process to assign the MRN (Movement Reference Number) numbers. When the agent acquires the requested MRN numbers and the permission to enter the cargo into the Republic of Croatia's territory, the ship's agent is obligated to deliver the above-mentioned data to the Customs office.
- Summary cargo declaration is a document used by the cargo agent to report to the Customs that the cargo is stored in the Customs' warehouse. After the Customs release this document to the agents, they need to present it again to the Customs office before each further action with the cargo.

During its stay in the Port and under the Customs' supervision, every movement of the cargo through the Port needs to be reported by physically handing in a document called 'Cargo disposition'. This document is made using the Port of Split TOS. The authors suggest connecting the TOS application to the future PCS to avoid the multiplication of paperwork.

All the mentioned processes can be simplified by increasing the level of interconnectivity of the already existing information technology solutions used by seaport cluster's stakeholders. The PCS's administrative module, CIMIS, and the Customs e-expediter can help the cluster's stakeholders to simplify their own administrative procedures and facilitate mutual communication.

3.2. Module for ISPS Control of Port Areas

A basic prerequisite for any business, especially for businesses closely related to international traffic, is a high level of security regarding the flow of cargo and persons. International Ship and Port Facility Security (ISPS) Code (IMO, 2019) states the minimal conditions prescribed by the International Maritime Organization (IMO) via SOLAS (IMO, 2019) convention that Ports open for international traffic have to fulfil. In its essence,

it is a system of controls of movement through the Port areas. As defined by the IMO, ISPS code is a comprehensive set of measures used to enhance the security of ships and Port facilities, developed in response to the threat to ships and Port facilities in wake of 9/11 attack in the United States (Steenbergen et al., 2013).

As seaports are places where land and sea traffic meet, control of the entrances and exits to and from the Port area is necessary. Due to its dispersion, there is no uniform system of movement control in the Port of Split. The authors suggest that the Port of Split's PCS establishes a module that will satisfy the conditions of the ISPS system regarding tracking of the movement of persons, goods, and vehicles in Port areas. It is necessary to enable the entry of the notice or arrival via the ISPS module of the PCS. The authorized users that would conduct those entries could easily and efficiently ensure the passage for persons and vehicles into the Port area. This could achieve a multitude of positive effects with the primary one being an increased level of security.

Possible commercial benefits for the Port itself are various. As every private and legal entity doing business in the Port area must pay concession fees, this would eliminate those commercial activities that are not subject to fees. This system would be most beneficial to the area under the management of Luka Inc. (the North Port). Since the highest level of vehicle traffic is found precisely at the entrance to the area of this Port basin, a higher degree of control and charging entry to persons and vehicles could be achieved. The Customs could precisely follow the movement of cargo and vehicles if the system is to be linked to truck scales. This would also simplify the processes of delivering cargo dispositions and controlling cargo movements. Perhaps the most important effect could be achieved in the peak moments of the traffic at the Port's entrance if the entrance itself is to be 'ICT-enabled'. If the entrance is to be able to recognise the vehicles announced via the PCS, unnecessary delays at the Port's gates could be avoided. This would result in shorter waiting times, which in turn usually means financial savings.

In the medium term, an important role of the ISPS module will also be the management of data gathered from the Internet of Things (IoT) and similar platforms used in the logistics processes in the Port. The convergence of various technologies will raise numerous questions, and maritime cargo logistics sector will certainly not be left out of the development. These questions can be divided into several categories that need to be addressed, among them the most important being information security, design, sustainability and environmental impact and privacy, autonomy and control (Aksentijević et al., 2015). Considering the rapid adoption of this technology, its position can be naturally recognized and situated within the ISPS module. From the recent developments, it is evident that traceability of this information will be crucial for security purposes, and it is quite possible that storage will be achieved using blockchain or similar general ledger technology (Tijan et al., 2019).

3.3. Module for Bulk, Liquid and General Cargo

The most important module of the proposed Port of Split's PCS is the 'Module for bulk and general cargo'. Its importance is visible in two functions: the first is the Port's primary function of cargo manipulation and storage. The second function is specific to the Port of Split, whose primary type of cargo is bulk cargo, which is handled by the majority of the Port cluster's stakeholders. The bearers of the development of this module should be the largest concessionaires, Luka Inc., CEMEX Hrvatska Llc cement factory, Ameropa Žitni terminal Ltd., and INA tanker terminal. The Port of Split's advantage over e.g. the Port of Ploče is the fact that the TOS is used only by one concessionaire, i.e. Luka Inc., and is not used for handling bulk cargo, but only for container traffic management.

The processes included in this module should be connected to other processes in the modules pertaining to administrative processes of the movement of ships and cargo. Connecting data in such a way can accomplish the basic purpose of the PCS system, i.e. process optimisation and the reduction of multiple data entry. The data entered through this module would be available to other modules since the underlying logic of the system is to distribute information through the whole system.

The basic purpose of this module is to track entry, internal movement, and exit of all the cargo covered by this module. The documents used in these processes in the Ports in the Republic of Croatia are diverse and sometimes depend on the Port-specific practices of each Customs office. They include various tracking documents and dispositions that follow cargo movement and storage, and all the data on the Customs' records. The PCS facilitates these processes since a large number of these documents currently need to be handed in physically to the Customs offices, a procedure which complicates and slows down the work of cargo agents and shippers.

Since the PCS is a process-based system, it should entail all the procedures in cargo traffic, a fact that is especially reflected in this module where the emphasis is on the cargo management and all the processes necessary for the Port cluster's business.

3.4. Connecting TOS to PCS Module

The Port of Split TOS system was developed solely by the concessionaire Luka Inc., and it is exclusively used as a support for container traffic. The system serves only a small number of the processes necessary for recording actions involving cargo containers. The TOS records the processes through which the Port communicates with its own system, and these are:

- Cargo storing request,
- Order for loading and unloading of cargo into containers,
- Container status reports, and
- Booking of containers.

According to Gekara, et. al., (2020), "Ports, and particularly container terminals, are the central nodes in these complex supply chains, so much so that their individual performance determines the performance of entire global supply chains. They are therefore under increasing innovative pressure to maintain optimum performance in terms of productivity and efficiency. Consequently, the past four decades, beginning in the mid-1980s, have seen a proliferation of ICT products specifically designed for the optimisation of container port administration, management and operations. These systems are generally known as Container Terminal Operating Systems or CTOS in abbreviation."

Cargo and ship agents have access to these processes, but they do not have the ability to enter information into the system, which slows down the business processes. Delivery orders, notices of cargo's arrival into Port and cargo manifest cannot be exchanged with the Port via TOS. Instead, they are sent using e-mail or fax. The Customs office does not use the data available in the system, but instead, requests the Port and the agents to deliver the data as paper documents.

Once the implementation of the PCS into Port of Split is well underway and achieves high level of adoption, it will be necessary to connect TOS and the PCS to achieve the complete exchange of information. In order to avoid synchronisation, if commercial stakeholders decide so, it would be fully feasible for them to stop using TOS for cargo-container handling and use TOS functionalities within the PCS itself. Such a solution will be possible when the PCS attains high level of development. In addition, this scenario needs to be mutually agreed with the managing body of the Port of Split, i.e. the Port of Split Authority.

4. CONCLUSION

The PCS implementation should be viewed as the continuation of digitalisation of seaport cluster operations in the Republic of Croatia. The current level of e-commerce adoption is not satisfactory, and that it is one of the reasons why Croatian seaports are less competitive than other competing Adriatic seaports. The bearer of the PCS development endeavour is the Ministry of the Sea, Transport and Infrastructure, also in charge of all the seaports of the state interest, among which are the Ports of Split, Rijeka, and Ploče. The introduction of CIMIS was supposed to have been the first step towards the development of a single window for maritime business in the Republic of Croatia. Without the legislative changes that would obligate all the stakeholders of the seaport cluster (especially government bodies) to accept new methods of processing data within the Port businesses, the implementation of the PCS will not entirely fulfil the expectations of the involved stakeholders. As the PCS is a service aimed at seaport cluster stakeholders, the architecture of the system, implemented processes, and all other segments necessary for the creation of such a complex system should not be defined before a high-quality analysis of the needs of the cluster's stakeholders is conducted. By using this approach, it is possible to upgrade the logic within the procedures and achieve an adequate level of optimisation that would certainly decrease expenses in the later phases of implementation and increase the level of satisfaction and efficiency of all the stakeholders involved. The PCS alone cannot be a generator of the development of seaports, i.e. a high level of system implementation will not increase the handled tonnage in the Croatian seaports regardless of its quality, but will surely be an important segment in the development of seaports and their preparation for a faster business growth.

Taking into consideration that the tentative instance of PCS in the Port of Split will be the third PCS system in the Croatian Ports, the process of implementation will be simpler in Split than in Rijeka and Ploče. Each Port's system should have the same basic modules; additional modules must cater to specific needs of each individual Port. Each process that is facilitated in the PCS should be fully aligned with the needs of the members of Split seaport cluster and with the objective of increasing the level of business optimisation.

ACKNOWLEDGEMENT

This paper has been financially supported by the University of Rijeka under the Faculty of Maritime Studies' projects.

REFERENCES

Aksentijević, S., Krnjak, D., Tijan, E., 2015. Logistics environment awareness system prototype based on modular Internet of Things platform, Scientific Journal of Maritime Research, 29 (1), pp. 170-179. Available at: https://hrcak.srce.hr/149934.

Asproth, V., 2007. Integrated Information Systems - A Challenge for Long-Term Digital Preservation. Interdisciplinary Journal of Information, Knowledge, and Management, 2, pp.089–098. Available at: http://dx.doi.org/10.28945/102.

Aydogdu, Y.V. & Aksoy, S., 2015. A study on quantitative benefits of port community systems. Maritime Policy & Management, 42(1), pp.1–10. Available at: http://dx.doi.org/10.1080/03088839.2013.825053.

Buis, J., 2009. Port Community System for the Port of Ploče, Amsterdam Port Consultants, September 2009., Internal project documentation presentation.

Caldeirinha, V. et al., 2020. The impact of port community systems (PCS) characteristics on performance. Research in Transportation Economics, 80, p.100818. Available at: http://dx.doi.org/10.1016/j.retrec.2020.100818.

Carlan, V., Sys, C. & Vanelslander, T., 2016. How port community systems can contribute to port competitiveness: Developing a cost–benefit framework. Research in Transportation Business & Management, 19, pp.51–64. Available at: http://dx.doi.org/10.1016/j.rtbm.2016.03.009.

Chandra, D. R., & van Hillegersberg, J., 2018. Governance of inter-organizational systems: a longitudinal case study of Rotterdam's Port Community System, International Journal of Information Systems and Project Management, 6 (2), pp. 47-68. Available at: https://www.sciencesphere.org/ijispm/archive/ijispm-060203.pdf.

City of Rijeka, 2019. Project for the construction of the state road D403 from the Škurinje junction to the port of Rijeka. Available at: https://www.rijeka.hr/pocetkom-iduce-godine-pocetak-radova-na-izgradnji-drzavne-ceste-dc-403/, accessed on 10 May 2019.

Constante, J.M., 2019. International case studies and good practices for implementing Port Community Systems, Inter-American Development Bank. Available at: https://publications.iadb.org/publications/english/document/International_Case_Studies_and_Good_Practices_for_Implementing_Port_Community_Systems.pdf, accessed on 29 September 2020.

Croatian encyclopedia, 2020. List of land transport corridors. Available at: http://www.enciklopedija.hr/natuknica.aspx?ID=46418, accessed on 11 June 2020.

European Commission, 2019. Directive 2010/65/EU on Reporting Formalities, National Single Window Data Mapping Report, Version: 1.9 final, 19 June 2019. Available at: https://ec.europa.eu/transport/sites/transport/files/nsw-data-mapping-report.pdf, accessed on: 11 October 2020.

European Port Community Systems Association, 2020. How to develop a Port Community System. Available at https://www.unece.org/fileadmin/DAM/trade/Trade_Facilitation_Forum/BkgrdDocs/HowToDevelopPortCommunitySystem-EPCSAGuide.pdf, accessed on 10 October 2020.

Gekara, V.O. & Nguyen, X.-V.T., 2020. Challenges of Implementing Container Terminal Operating System: The Case of the Port of Mombasa from the Belt and Road Initiative (BRI) Perspective. Journal of International Logistics and Trade, 18(1), pp.49–60. Available at: http://dx.doi.org/10.24006/jilt.2020.18.1.049.

Heilig, L., Lalla-Ruiz, E. & Voß, S., 2017. Digital transformation in maritime ports: analysis and a game theoretic framework. NETNOMICS: Economic Research and Electronic Networking, 18(2-3), pp.227–254. Available at: http://dx.doi.org/10.1007/s11066-017-9122-x.

Heilig, L. & Voß, S., 2016. Information systems in seaports: a categorization and overview. Information Technology and Management, 18(3), pp.179–201. Available at: http://dx.doi.org/10.1007/s10799-016-0269-1.

Innovation and networks executive agency, 2016. Upgrade of the Rijeka Port infrastructure - Port Community System (POR2CORE-PCS) - 2016-HR-TMC-0082-S. Available at: https://ec.europa.eu/inea/en/connecting-europe-facility/cef-transport/2016-hr-tmc-0082-s, accessed on: 6 October 2020.

International Maritime Organization, 1974. International Convention for the Safety of Life at Sea SOLAS, 1974. Available at: http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/International-Convention-for-the-Safety-of-Life-at-Sea-(SOLAS)-1974.aspx, accessed on 15 May 2020.

International Maritime Organization, 2020. ISPS Code. Available at: http://www.imo.org/en/OurWork/Security/Guide_to_Maritime_Security/Pages/FAQ.aspx, accessed on: 15 May 2020.

International Port Community Systems Association, 2020. Mission & Objectives. Available at: https://ipcsa.international/about/mission, accessed on: 9 October 2020.

Irannezhad, E., Hickman, M. & Prato, C.G., 2017. Modeling the Efficiency of a Port Community System as an Agent-based Process. Procedia Computer Science, 109, pp.917–922. Available at: http://dx.doi.org/10.1016/j.procs.2017.05.422.

Niculescu, M.-C. & Minea, M., 2016. Developing a Single Window Integrated Platform for Multimodal Transport Management and Logistics. Transportation Research Procedia, 14, pp.1453–1462. Available at: http://dx.doi.org/10.1016/j.trpro.2016.05.219.

Ministry of the Sea, Transport and Infrastructure, 2011. Prerequisites for building an integrated IT infrastructure of MMPI system with the goal of achieving functionality NSW, Zagreb. Available at: https://mmpi.gov.hr/UserDocsImages/arhiva/NSW%20Studija%2012_11.pdf, accessed on: 3 May 2020.

Ministry of the Sea, Transport and Infrastructure, 2018a. Conference of Digitalisation in Maritime Traffic, Zagreb. Available at: http://mppi.hr/default.aspx?id=10393, accessed 3 May 2020.

Ministry of the Sea, Transport and Infrastructure, 2018b. Improvement of the infrastructure of the port of Rijeka - information system of the port community. Available at: http://www.mppi.hr/default.aspx?id=34136, accessed on: 12 July 2020.

Moros-Daza, A., Amaya-Mier, R. & Paternina-Arboleda, C., 2020. Port Community Systems: A structured literature review. Transportation Research Part A: Policy and Practice, 133, pp.27–46. Available at: http://dx.doi.org/10.1016/j.tra.2019.12.021.

Moros-Daza, A. et al., 2018. A multivariate analysis for the creation of Port Community System approaches. Transportation Research Procedia, 30, pp.127–136. Available at: http://dx.doi.org/10.1016/j.trpro.2018.09.015.

Naglić, M., Tijan, E., Aksentijević, S., 2015. Container terminal business information systems, ICT Security Conference Proceedings, Slović, S. (ed.), Kladovo, Serbia, 14.-16. May, College of Economics and Administration, pp. 95-114. Available at: https://www.scribd.com/doc/298163707/Zbornik-Radova-IKT-Bezbednost-2015-ICT-Security-Kladovo-Republika-Srbija, accessed 3 May 2020.

Poletan Jugović, T., 2006. The Integration of The Republic of Croatia Into The Paneuropean Transport Corridor Network, Scientific Journal Of Maritime Research, 20(1), pp. 49-65. Available at: https://hrcak.srce.hr/4006.

Port of Ploče Authority, 2020a. Integration, Trade and Transport (ITT) Project. Available at: https://www.ppa.hr/hr/projekt-itt/, accessed on: 23 May 2020.

Port of Ploče Authority, 2020b. PCS information system. Available at: https://www.ppa.hr/hr/lucki-informacijski-sustav/, accessed on: 3 August 2020.

Port of Rijeka Authority, 2017. CEF – POR2CORE – PCS. Available at: https://www.portauthority.hr/en/european-projects/cef-por2core-pcs/, accessed on: 5 October 2020.

Port of Rijeka Authority, 2019. Rijeka Gateway Project. Available at: http://www.portauthority.hr/en/development_projects/rijeka_gateway_project, accessed on 1 May 2019.

Port of Split Authority, 2017a. Annual cargo traffic report for 2017. Available at: https://portsplit.hr/, accessed on: 10 October 2019.

Port of Split Authority, 2017b. Cargo traffic report for 1991 - 2017 period. Available at: https://portsplit.hr/, accessed on: 18 October 2019.

Port of Split Authority, 2019. Dock areas within the competence of Port Authority Split. Available at: https://portsplit.hr/, accessed on 4 March 2019.

Port of Split Authority, Harbor operations center, 2017. Report for 2017, Available at: https://portsplit.hr/, accessed on: 30 October 2019.

Puškarić, J., Martinčić-Ipšić, S. & Tijan, E., 2013. Data Warehouse Development in Maritime Traffic. Journal of Maritime & Transportation Science, 49-50(1), pp.167–179. Available at: http://dx.doi.org/10.18048/2015.49-50.167.

Steenbergen, R.D.J.M. et al. eds., 2013. Safety, Reliability and Risk Analysis. Available at: http://dx.doi.org/10.1201/b15938.

Tijan, E., Agatić, A., & Hlača, B., 2010. ICT evolution in container terminals, Scientific Journal of Maritime Research, 24(1), pp. 27-40. Available at: https://hrcak.srce.hr/54924.

Tijan, E., Aksentijević, S., Čišić, D., 2014. Seaport cluster information systems - a foundation for Port Community Systems' architecture, MIPRO 2014, 37th International Convention Proceedings, Opatija 2014, pp. 1774-1779. Available at: http://dx.doi.org/10.1109/MIPRO.2014.6859813.

Tijan, E., Aksentijević, S., Hlača, B., 2012. Investment Analysis of Information Security Management in Croatian Seaports, MIPRO 2012, 35th International Convention Proceedings, Rijeka 2012, pp. 1783-1788. Available at: https://www.researchgate.net/publication/261424870_Investment_analysis_of_Information_Security_Management_in_Croatian_seaports.

Tijan, E., Aksentijević, S., Hlača, B., 2014a. Seaport cluster labour cost reduction - a modelling approach, Scientific Journal of Maritime Research, 28 (2), pp. 103-110. Available at: https://hrcak.srce.hr/131698.

Tijan, E., Aksentijević, S., Hlača, B., 2014b. Simulation of administrative labour costs in seaport clusters, Scientific Journal of Maritime Research, 28(1), pp. 22-30. Available at: https://hrcak.srce.hr/123239.

Tijan, E. et al., 2019. Blockchain Technology Implementation in Logistics. Sustainability, 11(4), p.1185. Available at: http://dx.doi.org/10.3390/su11041185.

Tijan, E., et al., 2017. Elaborate development of the single interface for formalities in maritime traffic (NSW), University of Rijeka, Faculty of Maritime Studies, Rijeka, Croatia. Available at: https://mmpi.gov.hr/UserDocsImages/arhiva/Elaborat%20razvoja%20jedinstvenog%20pomorskog%20sucelja_PFRI%202017%2022-1_18.pdf, accessed on: 28 July 2019.

Tijan, E. et al., 2018. Integrating Maritime National Single Window with Port Community System – Case Study Croatia. Digital Transformation – Meeting the challenges. Available at: http://dx.doi.org/10.18690/978-961-286-170-4.1.

Tijan, E., Kos, S., Ogrizović, D., 2009. Disaster Recovery and Business Continuity in Port Community Systems, Scientific Journal of Maritime Research, 23(1), pp. 243-260. Available at: https://hrcak.srce.hr/38367.

Tsamboulas, D., Moraiti, P. & Lekka, A.M., 2012. Performance Evaluation for Implementation of Port Community System. Transportation Research Record: Journal of the Transportation Research Board, 2273(1), pp.29–37. Available at: http://dx.doi.org/10.3141/2273-04.

Vaghi, C. & Lucietti, L., 2016. Costs and Benefits of Speeding up Reporting Formalities in Maritime Transport. Transportation Research Procedia, 14, pp.213–222. Available at: http://dx.doi.org/10.1016/j.trpro.2016.05.057.

Zerbino, P. et al., 2019. Towards Analytics-Enabled Efficiency Improvements in Maritime Transportation: A Case Study in a Mediterranean Port. Sustainability, 11(16), p.4473. Available at: http://dx.doi.org/10.3390/su11164473.

Analysis of Female Interest in Maritime Education at Nikola Vaptsarov Naval Academy Varna and at the Faculty of Maritime Studies, University of Split

Blagovest Belev[a], Gorana Jelić Mrčelić[b], Zdeslav Jurić[b], Ivan Karin[c]

The promotion of gender equality and women's empowerment is one of the main goals of the United Nations. The aim of this study is to analyze the gradual change of conservative perceptions about the role of women in shipping. Maritime education and training institutions are fully involved in the process. The Nikola Vaptsarov Naval Academy and the Split University's Faculty of Maritime Studies are a part of this process of general change in human attitude towards the acceptance of women on merchant ships. Data on female admittance and graduation are collected by both academies. In the period examined, i.e. 2012 – 2018, 129 women were enrolled at and 60 graduated from the NVNA. 281 women were enrolled at and 68 graduated from the Faculty of Maritime Studies. The attitudes of female candidates at the academy Nikola Vaptsarov were studied by means of a questionnaire. The growing number of female candidates at Nikola Vaptsarov's *Navigation, Ship Engineering and Electrician* studies proves that a competitive environment was created on a completely new basis, namely the ability of women to work at an equal footing with men in a purely male-dominated profession. This paper opens the door to future research of the recruitment market required to establish the reasons behind skepticism about women on board and the ways to overcome this conservative line of thinking.

KEY WORDS
~ Women
~ Maritime professions
~ Maritime education

a. Nikola Vaptsarov Naval Academy, Varna, Bulgaria
e-mail: bl.belev@naval-acad.bg
b. University of Split, Faculty of Maritime Studies, Split, Croatia
e-mail: gorana.jelic@pfst.hr
c. Plovput d.o.o., Split, Croatia
e-mail: ivan.karin@plovput.hr

doi: 10.7225/toms.v09.n02.016

1. INTRODUCTION

Up until the 19th century, women had very few rights, due to religious, political or national reasons. Guided by the idea of equality between men and women and the elimination of discrimination, the International Labor Organization (ILO) adopted the *Declaration of the Missionary Mission and the Purposes of the ILO* in 1944. The Declaration states that "all human beings, irrespective of race, creed or sex, have the right to pursue their material well-being and their spiritual development in conditions of freedom and dignity, of economic security and equal opportunity" (ILO, 2020, page 1). For ILO, women's rights are an integral part of the values, principles and goals of the promotion of social justice and decent work (ILO, 2007). Globally, men are more likely to be part of the workforce than women. A United Nations (2015) report shows that 77% of men and 50% of women of working age are employed.

In maritime industry, one of the biggest challenges is ensuring diversity in seafarer hiring, including the hiring of women and other under-represented groups (Safety4sea, 2020). All seafarers regardless of race, color, sex, religion,

political opinion, national extraction or social origin, as well as nationality, gender and sexual orientation have the right to equal opportunities and treatment. Today, women account for only 2 percent of the world's 1.2 million seafarers and 94 percent of female seafarers work in the cruise industry (IMO, 2020). Though women often graduate from their maritime education and training institutions with excellent results, their job applications are sometimes systematically turned down. Finding female workers at sea is still rare, but an increasing number of women are confronting prejudice and becoming valuable members of ship crews with the help of the trade unions (ITF, 2019).

Within this historically male-dominated industry, the International Maritime Organization (IMO) is making a concerted effort to help the industry move forward and supports women in the achievement of representation that is in keeping with twenty-first century expectations (IMO, 2019).

In 1988, the IMO adopted a *Strategy on the Integration of Women in the Maritime Sector*, based on the United Nation's (UN) policy on the development of female human resources and to strengthen the role of women (IMO, 1988).

In 1989 (IMO), launched the IMO *Women in Development Program* (WID) that aimed at expanding women's capabilities in the maritime sector. The program focused on equal access to maritime training through both mainstream programs and gender specific projects (Lares, 2017). According to Lares (2017), the World Maritime University (WMU), the postgraduate maritime university founded by IMO, has put in place its own policies to promote the participation of women in the maritime transport sector.

The IMO has facilitated the creation of professional networks to improve gender balance in the shipping industry. Women in Maritime Associations (WIMAs) launched the following associations in the new century through IMO's gender and capacity-building program:

1. Pacific Women in Maritime Association (PacWIMA) set up in Fiji in February 2004 and relaunched in Tonga in April 2016.
2. Network of Professional Women in the Maritime and Port Sectors for West and Central Africa launched in Benin in February 2007, set for a relaunch in 2019.
3. Association for Women in the Maritime Sector in Eastern and Southern Africa (WOMESA) established in Kenya in December 2007.
4. Women in Maritime Association, Asia (WIMA Asia) established in January 2010 and relaunched in the Philippines in 2015.
5. Women in Maritime Association, the Caribbean (WiMAC), set up in Jamaica in April 2015.
6. The Arab Association for Women in the Maritime Sector (AWIMA), established in Egypt in October 2017. The second AWIMA conference will be held in Egypt in the first quarter of 2019.
7. Red de Mujeres de Autoridades Marítimas de Latinoamérica (Red-MAMLa), established in Chile in December 2017. (Figure 1).

Women's International Shipping & Trading Association (WISTA) is an international networking organization whose mission is to attract and support women at the management level, in the maritime, trading and logistics sectors (WISTA, 2020).

Figure 1.
Women in Maritime Associations – World map.
Source: http://www.imo.org/en/OurWork/TechnicalCooperation/Pages/WomenInMaritime.aspx

The 2016 amendments to the 2006 Maritime Labor Convention include a reference to the ICS (International Chamber of Shipping)/ITF (International Transport Workers' Federation) Guidance on eliminating shipboard harassment and bullying. "The operationalization of the guidance and its practical implementation at the national level can help change shipboard cultures and develop a working environment in which all seafarers are treated with dignity and respect. Effective policies and timely response to complaints relating to harassment and bullying would render the industry more attractive to potential seafarers" (ILO, 2019, page 5). The IMO fosters the view that both government and industry should provide men and women equal access to and opportunity for maritime training, jobs and employment. The Organization recommends facilities suitable for women on board ships. Under the 2010 Manila Amendments to the International Convention on Standards of Training, Certification and Watch-keeping for Seafarers (STCW), resolution 14 regulates the promotion of female participation in the maritime industry (IMO, 2012).

The research on gender differences in maritime education and industry, especially onboard ships, is still rare in spite of its importance. Existing papers have raised the issue of the need to overcome gender segregation (Kitada, 2013; Belcher et al., 2003; Zhao, 1998). The leading institution in this field is the WMU, where numerous Master's and PhD theses have been written (Tifuh, 2014; Aggrey, 2000). The purpose of the study was to make an initial assessment of the women's attitudes towards working and living in a new and unusual environment at two maritime education institutions: the Nikola Vaptsarov Naval Academy (NVNA) and the Faculty of Maritime Studies, University of Split (FMS). NVNA and FMS are important stakeholders in the process of evolution of the equal treatment of men and women in maritime education and industry. Since 2009, women at NVNA have been eligible for admittance at courses *Navigation, Ship Power Plants and Electrical Engineering*. In 2011, the NVNA Academic Council decided to abolish quotas for male and female candidates. This act aimed to eliminate the restrictions on the training of women on an equal footing with men. At the FMS, there have never been any men/women admission quotas, nor any kind of limitation for the admission of women. This paper exposes the change of the process of admittance and graduation of women in the NVNA and the FMS.

2. RESEARCH METHODS

To gain a clear understanding of the intentions of women candidates for work on board merchant ships, a survey was conducted at the NVNA in the framework of several campaigns. To make their proposals to the applicants more persuasive, they conducted the survey in cooperation with the studying department, which is entirely responsible for conducting the admission campaign, using the interview method.

349 female applicants were interviewed in 2009 – 2013. Perspective students of all specialties were asked the following questions:

1. Do you intend to apply for study in any of the specialties: *Navigation, Ship Engineers or Electrical Engineers*?

2. If you are admitted to one of the three specialties and successfully graduate, do you plan to work on a merchant ship?

3. Would you consent to working with a male team?

4. Do you believe that physically and mentally you can take 4-5 months away from home?

5. Do you believe you can handle being managed by a male team?

The candidates had to choose one of the two possible answers - negative (*No*) or positive (*Yes*).

Apart from NVNA's questionnaire on the attitudes of female applicants about these 5 questions, similar data have been requested at both the NVNA and the FMS in 2012-2018.

3. RESULTS

Figure 2 presents results of the questionnaire used to examine the attitudes of 349 female applicants at the NVNA in 2009-2013.

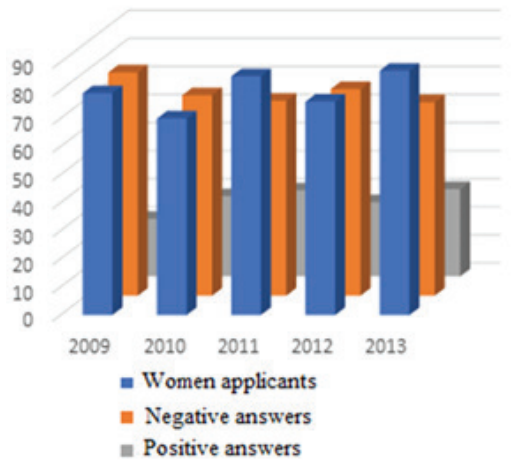


Figure 2.
Results of the survey of women applicants' attitudes in 2009-2013.

The results fluctuated between 70% and 90% in the period studied. In 2013 an average of 79.5% of respondents gave negative answer (No) to the 5 questions in the questionnaire.

Figure 3a shows female interest in seafaring professions at the NVNA.

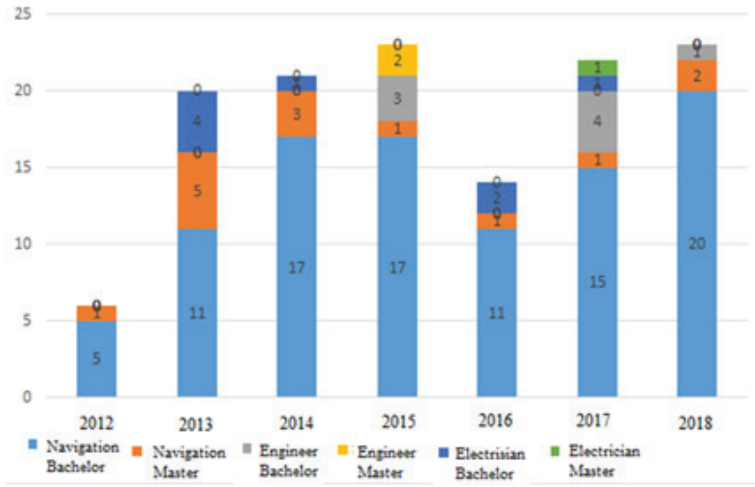


Figure 3a.
Number of female applicants to various studies at the NVNA in 2012-2018.

There is a growing interest of female applicants in all studies (from 6 female applicants in 2012 to 23 female applicants in 2018), but especially in Navigation (from 5 female applicants in 2012 to 20 female applicants in 2018).

Figure 3b shows female interest in seafaring professions at the FMS.

Figure 3b.
Number of female applicants to various studies at the FMS from 2012 to 2018 (NS Nautical Studies, ME Marine Engineering, MEEIT Marine Electrical Engineering and Information Technologies, B – Bachelor, M – Master).

The interest of female applicants for Nautical Studies has decreased from 29 female applicants for Nautical Studies Bachelor's degree (NS B) in 2012 to only 10 female applicants in 2018. The interest of female applicants in Marine Electrical Engineering and Information Technologies has increased from three female applicants in 2012 to 13 female applicants in 2018. The number of women applicants to Marine Engineering Studies has fluctuated between four (minimum in 2012) and nine candidates (maximum in 2015).

Figure 4a shows the number of female graduates at the NVNA.

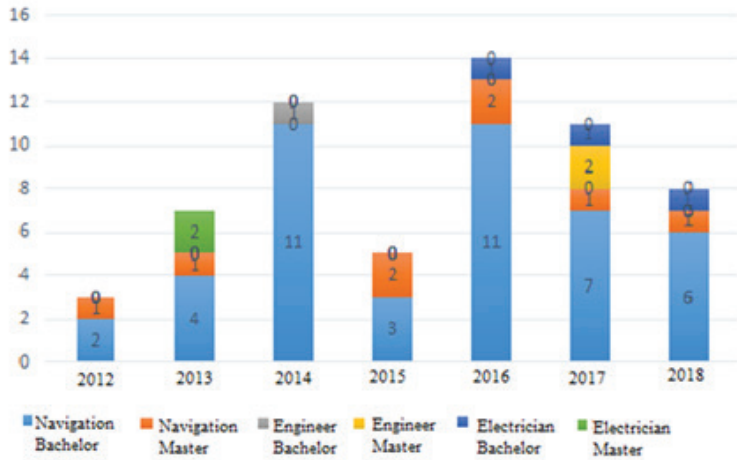


Figure 4a.
Number of female graduates at various NVNA courses from 2012 to 2018.

The number of female graduates has fluctuated between three graduates (minimum) in 2012 and 14 graduates (maximum) in 2016. By far the greatest number of women graduated in Navigation (between 2 female graduates (minimum) in 2012 to 11 female graduates (maximum) in 2014 and 2016).

Figure 4b shows the number of female graduates at the FMS.

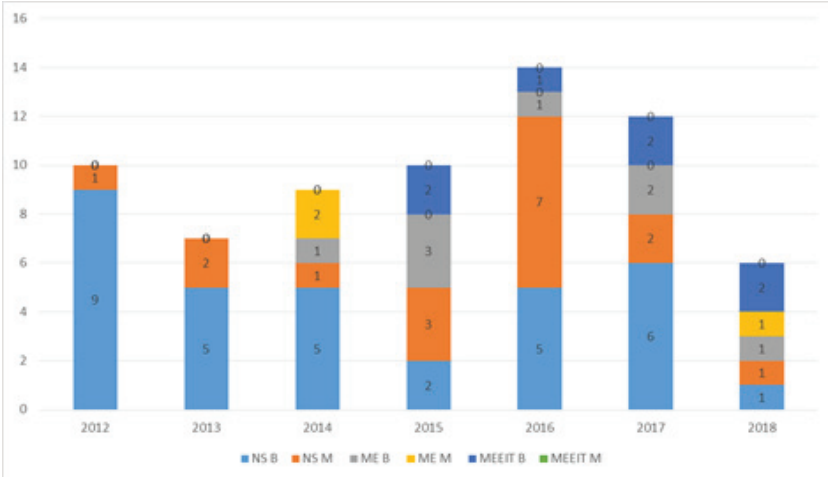


Figure 4b.
Number of female graduates at various courses at the FMS in 2012-2018 (NS Nautical Studies, ME Marine Engineering, MEEIT Marine Electrical Engineering and Information Technologies, B – Bachelor, M – Master).

The number of female graduates is considerably smaller than the number of women enrolled in the observed period: 9 female graduates for NS B in 2012 and only 1 in 2018; between 0 and 3 women graduated in ME B and between 0 and 2 in MEEIT B.

4. DISCUSSION

This paper explains the change in the process of admittance and graduation of women at the NVNA and the FMS. Women have been eligible for admittance at the courses *Navigation, Ship Power Plants and Electrical Engineering* at the NVNA since 2009, and the NVNA Academic Council decided to abolish the quotas for male and female candidates in 2011. At the FMS, there have never been any male/female admission quotas, nor any kind of limitation for female enrollment.

Figure 2 presents the results of the questionnaire used to establish the attitudes of 349 female applicants at the NVNA in 2009-2013. There is a tendency for a slow but lasting reduction of the negative (No) answers compared to the number of students, and a gradual increase in the specialties of interest. This tendency reflects the gradual change in female applicants' attitudes on the role of women in the maritime sector.

Figure 3a shows women's persistent interest in seafaring professions at the NVNA. Allowing female enrollment at the so-called regulated specialties - Navigation, Ship Engineer and Electrician - at the NVNA in 2011 has increased the interest of female applicants from 6 female applicants in 2012 to 23 female applicants in 2018. There is a growing interest of female applicants especially for the Navigation specialty (from 5 female applicants in 2012 to 20 female applicants in 2018), probably due to the idea that the captain's profession is more prestigious and perhaps more appropriate for women. This statistic does not include the number of interrupted studies.

Figure 3b. shows women's interest in seafaring professions at the FMS. The interest of female applicants for Nautical Studies has decreased from 29 in 2012 to 10 in 2018, while the interest of female applicants for Marine Electrical Engineering and Information Technologies has increased from 3 female applicants in 2012 to 13 female applicants in 2018. The number of female applicants to Marine Engineering Studies has fluctuated between 4 and 9 candidates in the observed period. The steady interest in Marine Engineering Studies stems from the high demand for engine officers and IT experts on the maritime and global labor market in general and easy conversion to on-shore jobs

Figure 4a. shows the number of female graduates. The number has fluctuated between 3 graduates (minimum) in 2012 and 14 graduates (maximum) in 2016. By far the greatest number of women at the NVNA graduated in Navigation (between 2 in 2012 and 11 in 2014 and 2016).

Five of 12 female graduates at the NVNA are active deck officers, engineers and electricians. The reasons are various and include:

1. female awareness of difficulties of life on board including fear of sexual comments, sexual abuse and any unwanted physical contact on board;
2. negative attitude of some recruitment companies to women onboard – they openly refuse to hire women on merchant ships.

Equal education and the promotion of equal employment opportunities, including in leadership roles, will ensure that the best possible candidate gets the job (MacNeil and Ghosh, 2017). Dragomir and Utureanu (2018) are of the opinion that shipping companies should update their human resources policies by making them gender-friendly and ensuring that policies on gender equality and cultural awareness are communicated on board their ships, in the on-shore headquarters of the company, to various stakeholders and to the community through their websites and the social media.

According to the Ministry of Labor and Social Policy of the Republic of Bulgaria, there were 86 registered recruitments of maritime specialists (MLSP, 2019). 21 of these are most active in the labor market for seafarers in commercial shipping. According to the Croatian Ship Manning Association, there are 23 crewing agencies active in Croatia (CROSMA, 2020), and according to the Ministry of the Sea, Transport and Infrastructure of the Republic of Croatia (MSTI, 2020) there are 41 crewing agencies, 8 employers and 6 shipping companies that are also registered for recruitment activities. The statistics show that the number of women is low compared with the number of men employed in such companies.

Figure 4b shows the number of female graduates at the FMS. The number of female graduates is much smaller compared to the number of women admitted in the observed period: 9 female graduates in NS B in 2012 and only 1 in 2018; between 0 and 3 female graduates in ME B and between 0 and 2 in MEEIT B. The percentage of women who graduated/were admitted is also smaller at the FMS than at the NVNA. At the FMS, the drop off rate is high as a large percentage of students enroll at the FMS only to receive students' grants.

The Bachelor Studies last for 4 years and Master Studies for 1.5 years at the NVNA, while the Bachelor Studies last for 3 years and Master Studies for 2 years at the FMS. During the period 2012-2018, 129 women enrolled at and 60 graduated from the three study programs at both levels at the NVNA. In that same period, 281 women enrolled at and 68 graduated from the three study programs (excluding women admitted and graduated from two other study programs – Maritime Management Studies and Maritime Yacht and Marina Technologies Studies) at both

levels at the FMS. The number of graduates does not include the 82 women admitted to the NVNA during the last 4 years and 112 women admitted to the FMS during the last 3 years. These numbers are high and there is a potential for these female students to change the image of the industry both in Bulgaria and Croatia upon successful graduation, but also worldwide. The growing number of female candidates for Navigation, Ship Engineer and Electrician creates a competitive environment on a completely new basis - the ability of women to work on an equal footing with men in a previously purely male profession.

Maritime education in Bulgaria dates back to 1881. Towards the end of the 20th century, the trainees were men. Worldwide changes over the last three decades have changed the perception of shipping traditions. Since the second half of the 20th century there have been examples of female captains, mechanics and electrical engineers in the Bulgarian merchant fleet. But they are exceptions rather than a rule. The reasons why women have not been part of a ship's crew are essentially physiological and emotional. Attempts and efforts to achieve gender equality have enabled women to look at male professions and declare a desire to seek realization by breaking the rules. In Croatia, the oldest naval academy originates from 1866. The FMS was inaugurated in 1959.

Maritime education and training is crucial for shaping future gender and culture-sensitive seafarers. MET institutions are expected to play multifaceted roles in the education and training of maritime students. Four important roles include:

1. serving as a training ground for future men and women who are expected to be equipped with technical knowledge, skills and attitude as part of the formulaic triad of competencies;
2. raising future seafarers with sensitive minds and character, more aware of life at sea and having them understand and be adaptive to diverse cultural orientations;
3. developing a mindset that erases gender biases and rises above cultural differences;
4. raising gender and cultural awareness by integrating such ideals in their curriculum and instruction (GECAMET, 2018).

The recruitment process starts with education and training. It is necessary to motivate women to pursue career paths in the maritime and ocean fields as early as possible in their education (Doumbia-Henry, 2019). According to Cars and Österman (2015), increasing the number of female students will not close the gender gap in the maritime industry on its own. Gender issues must be well-defined, operationalized and included in educational policy and curricula-making at individual, structural, as well as at the symbolic level. Horck (2010a) advises educational institutions to publish a university policy on the gender perspective and diversity management in general. It should be made in written form and posted in a public place to be understood and remembered by staff and students. According to Dragomir et al. (2018) the MET curriculum should include specific courses on female leadership, gender equality and cultural communication to develop leadership skills in women. Horck (2010b) also recommends maritime education and training institutions to offer courses on cultural, as well as courses on pedagogical (andragogical) awareness to students when women start to take up studies in maritime subjects.

Violeta Bulc, EU Commissioner for Transport (Safety4sea, 2018), claims that an increasing number of organizations are showing interest in addressing and providing solutions to gender equality in shipping by mentoring, coaching and/or training women. A new Leadership in the Public Sector course is being developed by the United Nations Institute for Training and Research (UNITAR) to support the United Nations Sustainable Development Goal of achieving gender equality and empowering all women and girls (SDG5).

MacNeil and Ghosh (2017) recommend international organizations to conduct further research/studies to identify up-to-date statistical information on women in the maritime industry. Future research on this topic will highlight the employment rate of women in the sector and outline the problems faced by both sides in the process.

5. CONCLUSION

The Bachelor Studies last for 4 years and Master Studies for 1.5 years at the NVNA, while the Bachelor Studies last for 3 years and Master Studies for 2 years at the FMS. During the period 2012-2018, 129 women enrolled at and 60 graduated from the three study programs at both levels at the NVNA. In that same period, 281 women enrolled at and 68 graduated from the three study programs (excluding women admitted and graduated from two other study programs – Maritime Management Studies and Maritime Yacht and Marina Technologies Studies) at both levels at the FMS. The number of graduates does not include the 82 women admitted to the NVNA during the last 4 years and 112 women admitted to the FMS during the last 3 years. These numbers are high and there is a potential for these female students to change the image of the industry both in Bulgaria and Croatia upon successful graduation, but also worldwide. The growing number of female candidates for Navigation, Ship Engineer and Electrician creates a competitive environment on a completely new basis - the ability of women to work on an equal footing with men in a previously purely male profession.

REFERENCES

Aggrey H., 2000. Women in Maritime Industry: A Review of Female Participation and their Role in Maritime Education and Training in the 21st Century, Master thesis, World MaritimeUniversity, Sweden.

Belcher P., Sampson H., Thomas M., Zhao M., 2003. Women Seafarers. Global Employment Policies and Practice. 1st ed., Geneva, International Labour Office.

Cars, M.B. & Österman, C., 2015. Mind the Gap! Maritime Education for Gender-Equal Career Advancement. WMU Studies in Maritime Affairs, pp.143–153. Available at: http://dx.doi.org/10.1007/978-3-662-45385-8_11.

CROSMA, 2020. Croatian Ship Manning Association. Available at: https://www.crosma.hr/en/, accessed on: 03 February 2020.

Doumbia-Henry, C., 2019. Foreword for JOMA December 2019—empowering women in the maritime community: the way ahead. WMU Journal of Maritime Affairs, 18(4), pp.521–524. Available at: http://dx.doi.org/10.1007/s13437-019-00187-7.

Dragomir, C. & Utureanu S. L., 2018. Gender in Maritime Transport - A Scientific Literature Overview. Ovidius University Annals, Economic Sciences Series, 18(1), pp.158-163.

Dragomir, C. et al., 2018. Women Leaders in Shipping as Role Models for Women Seafarers. TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation, 12(2), pp.279–284. Available at: http://dx.doi.org/10.12716/1001.12.02.07.

GECAMET, 2018. Gender Equality and Cultural Awareness in Maritime Education and Training, IAMU 2017 Research Project (No. 20170305), Constanta Maritime University.

Horck, J., 2010a. The gender perspective in maritime education and training. WMU Journal of Maritime Affairs, 9(1), pp.93–119. Available at: http://dx.doi.org/10.1007/bf03195168.

Horck J., 2010b. Meeting Diversities in Maritime Education, a blend from World Maritime University. Doctoral thesis, World Maritime University, Sweden.

ILO, 2020. Declaration concerning the aims and purposes of the International Labor Organization (DECLARATION OF PHILADELPHIA). Available at: https://www.ilo.org/wcmsp5/groups/public/---asia/---ro-bangkok/---ilo-islamabad/documents/policy/wcms_142941.pdf, accessed on: 06 May 2020.

ILO, 2019. Sectoral Meeting on the Recruitment and Retention of Seafarers and the Promotion of Opportunities for Women Seafarers. Available at: https://www.ilo.org/sector/activities/sectoral-meetings/WCMS_647753/lang--en/index.htm, accessed on: 03 February 2019.

ILO, 2007. ABC of women workers' rights and gender equality. 2nd Ed., Geneva: International Labor Office.

IMO, 2020. Available at: http://www.imo.org/en/OurWork/Technical Cooperation/Pages/WomenInMaritime.aspx, accessed on: 23 January 2019.

IMO, 2012. A study towards development of a Strategy for women seafarers, submitted by the Republic of Korea. Integration of Women in the Maritime Sector, (TC 62/8/1). Available at: http://docs.imo.org/Search.aspx?keywords=%22women%20seafarers%22, accessed on: 03 February 2019.

IMO, 1988. Strategy for the integration of women in the maritime sector. Available at: http://www.imo.org/en/OurWork/TechnicalCooperation/Pages/WomenInMaritime.aspx , accessed on: 03 February 2019.

ITF, 2019. Women Seafarers, Available at: https://www.itfseafarers.org/ITI-women-seafarers.cfm, accessed on: 13 March 2019.

Kitada, M., 2013. Code of behaviour at sea: women seafarers' shipboard identity management. WMU Journal of Maritime Affairs, 12(2), pp.213–227. Available at: http://dx.doi.org/10.1007/s13437-013-0044-7.

Romero Lares, M.C., 2017. A Case Study on Gender Equality and Women´s Empowerment Policies Developed by the World Maritime University for the Maritime Transport Sector. TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation, 11(4), pp.583–587. Available at: http://dx.doi.org/10.12716/1001.11.04.02.

MacNeil, A. & Ghosh, S., 2016. Gender imbalance in the maritime industry: impediments, initiatives and recommendations. Australian Journal of Maritime & Ocean Affairs, 9(1), pp.42–55. Available at: http://dx.doi.org/10.1080/18366503.2016.1271262.

MLSP, 2019. Ministry of Labor and Social Policy of the Republic of Bulgaria, Employment Agency. Available at: https://www.az.government.bg/intermediaries/intermediary_activity/marine/ ?page=1, accessed on: 13 March 2019.

MSTI, 2020. Ministry of the Sea, Transport and Infrastructure of the Republic of Croatia, 2020. Available at: https://mmpi.gov.hr/more-86/pomorci-112/zaposljavanje/1278, accessed on: 06 February 2020.

Safety4sea, 2018. Available at: https://safety4sea.com/women-maritime-encourage-participation/,accessed on: 06 May 2020.

Safety4sea, 2020. Available at: https://safety4sea.com/ilo-recommendations-to-ensure-equal-opportunities-for-seafarers/, accessed on: 06 May 2020.

Tifuh, A.N., 2014. Women merchant mariners: empowering West African women, World Maritime University Dissertations. 482. Available at: http://commons.wmu.se/all_dissertations/482, accessed on: 23 January 2019.

UNITED NATIONS, 2015. The World's Women 2015: Trends and Statistics. New York: United Nations, Department of Economic and Social Affairs, Statistics Division.

WISTA, 2020. Available at: https://wistainternational.com/, accessed on: 06 May 2020.

Zhao M., 1998. Women Seafarers in the EC: A Preliminary Report Based on German and UK Case Studies, 1st ed., Cardiff, Seafarers International Research Center.

Professional Titles for Women Seafarers in the Croatian and Montenegrin Media

Milena Dževerdanović Pejović

This paper aims to present a comparative view of the English and Croatian female maritime ranks aboard ship in the language of media. Regarding the English language, male/masculine forms have also been normative and gender-neutral; in other words, they refer to both genders (pilot, lawyer, captain). However, changes in the society and "embarkation" of women on board masculine professions have been reflected in language changes as well. The female professional titles are derived from the masculine forms. Social changes and gender awareness politics simultaneously took place in both countries, resulting in the rise of women seafarer number on board ships.

This paper presents a review of the comparative analysis of Montenegrin and Croatian texts. The results show that Croatian media use the female titles more frequently and regularly, while in Montenegrin texts their use is somewhat sporadic. The reasons for this are also found in the ethnical picture of the two countries. Montenegrin society still rests on patriarchal values and the authors of the texts prefer using masculine forms as gender-neutral. What is more, the Republic of Croatia accessed the European Union in 2013, and it was undoubtedly required to implement institutional regulations relating to minimizing gender discrimination in the society and public discourse. Finally, it was concluded that linguists and language planners have to differentiate between justified and non-justified use of female forms as they can assume the pejorative meaning.

KEY WORDS
~ Gendered discourse
~ Professional titles
~ Media discourse
~ Women seafarers

University of Montenegro, Faculty of Maritime Studies, Kotor, Montenegro
e-mail: milenadz@ac.me

doi: 10.7225/toms.v09.n02.017

1. INTRODUCTION

In modern times, when women have fought for equal status in male-dominated professions, it is also necessary to designate the corresponding female titles. Naming female titles has become a current issue of modern linguistics, politics, media, and diplomacy.

The traditional solution that has been applied so far is the use of masculine grammatical gender as an unmarked category, i.e. women were "identified" through men. Therefore, as far as language regulations are concerned, the usage of masculine forms for men in linguistics was an unmarked choice, a language norm. On the other side, women were marked, and in a way, they were identified "whether through man, father, husband, lover" (Perović, 2006). The use of masculine pronouns to refer to men's and women's professions and the use of the "neutral" generic pronouns ("he") to refer to both men and women, have become implicit and taken for granted in the English language. Linguists have argued since the rise of the feminist movement in the 1970s and 1980s that language has been mainly created for men.

Knowing that women in seafaring have started to board ships and advance in the hierarchy of licensed crew members, the language has to adapt to this new social and cultural changes. In the academic world, it is well known that publishers advise authors to avoid language which might be discriminatory or gender-sensitive, such as "he" for general use.

This new non-linguistic ambient, which was triggered by feminist theories from the last decades of the 20th century, had an impact on the seafaring language. The author of this paper has come to grip with a very delicate subject, but the attitude taken here is not a feminist one. On the contrary, the aim is to point to the necessity of harmonizing social and language trends.

The language material explored in the Montenegrin and Croatian languages, includes many forms for emerging masculine and feminine professions. However, the names for ranks used in a discourse of military forces and shipping mainly use the masculine form – in the linguistic terms, an unmarked and neutral one. However, the tendency is not only regional, it is still present in other patriarchal and traditional countries.

Finally, it was established that the language used in both media encourages female forms rather than the generic use of the masculine forms for both genders. It seems that "much of the media nowadays are concerned to appear non-sexist and to promote the interests of women" (Sunderland, 2004).

2. LANGUAGE AND GENDER

Gender issues in the twenty-first century are a part of globalised politics. "They are all part of a much larger movement: the movement to create a world in which principles of partnership, rather than domination and submission, are the primary ones" (Eisler, 2005, p. 24).

Are there different communicative patterns and differences between men and women in everyday and professional setting? For sure, a whole set of contextual factors define the speech styles of men and women (Weatherall, 2001).

Empirical research about gender and language is marked by a whole set of polarized concepts ascribed to men (rational, assertive, authoritative) and women (talkative, emotional, affectionate). The assumptions about ways of talking, tone of voice, sense of humour, small talk and the fundamental constituents of the feminine, as opposed to masculine ways of speaking, have been the subject of analysis of many linguists. According to Hofstede (1998, p. 10), this male-female power syndrome is expressed in some countries to a greater or lesser extent, and are by-and-large masculine (Japan, Germany, the United States) or feminine (Nordic countries).

These premises, based on research into public language, and which are of relevance to the topic of our paper, have shifted into research into specialized languages within different workplaces, particularly those traditionally occupied by men. Stereotypes about masculine and feminine language terms should not be regarded as opposite poles of the same continuum. Masculine language is not rational or neutral, nor is feminine discourse emotional and uncontrolled. Holmes carried out research on workplaces in New Zealand, and one of the conclusions relevant to the analysis in this article was that both women and men exploit different methods of discourse according to the types of interaction and context; however, slight discrimination against women pervades. This calls for social transformation (Holmes, 2006).

There is no doubt that gender issues require a sociolinguistic perspective, and the rise of new disciplines and human resource management has permeated various approaches. The rise of women to leading positions and, what is more, in "hyper-masculine work cultures" (Maaranen and Tienari, 2020) has come into focus more than ever before, particularly from the point of questioning women's roles in adapting to new positions.

Having the above in mind, women are sometimes in doubt as to which style of behaviour to adopt. In some cases, they are urged to choose assertive or more masculine styles of discourse in the public sphere, but when they do so, they are perceived as aggressive and confrontational (Coates, 2013, p. 202). On the other side, traditional views, rooted in myth and fairy tales, state that a woman succeeds when she is silent and obedient. This is well illustrated by the fairy tale of "The Seven Swans", when a sister saves her seven brothers from a spell by sewing shirts for them and staying speechless. Otherwise, if she had uttered anything, she would have failed in her intention (Lakoff, 2003, p. 162).

3. WOMEN IN SEAFARING

In the modern education system, women are trained in the same navigation and engineering courses as men. They are assigned many different jobs on board ships. Still, one may assume that professional equality of men and women on board is yet to come. The figures are higher than they used to be, but data about female captains and chief officers are difficult to obtain. According to the data available on the website of the International Maritime Organization (IMO), continuous gender-related programmes and campaigns are aimed at empowering women in the maritime sector and making women more representative of the seafaring sector. As posted on the IMO website, only 2% of seafarers are women (IMO, 2019). IMO has been actively contributing to supporting women in the maritime industry and encouraging women to "turn the current tide". One of the programmes, called "Women in Maritime", invites women to share their experiences on board and make their stories visible to other women. History's long tradition of men's domination

at sea needs constant activities and efforts in order to achieve gender equality and mitigate the discrimination against women in the maritime sector.

Further figures showing women's employment on board are rather discouraging. Data states that women choose to sail on cruise ships rather than on merchant ships, which are still regarded as a male-dominated arena. Women are underrepresented in the seafaring sector and make up only 18 % of the workforce (International Labour Office, 2003). The International Transport Workers' Federation has also supported the participation of women. It has established female support through maritime trade unions, with the aim to promote women's rights and maternity policies, and to set processes in place to deal with sexual harassment. Despite all these efforts, it seems that gender policies to a great extent differ from company to company and lack a national institutional legislation framework.

4. TWO SIDES OF THE COIN

The attitude held in this paper is that a lot has been achieved in the field of women's independence and empowerment, especially in male-dominated professions.

As noticed by Savić (2011), when we refer to a "woman pilot", "woman lieutenant", "woman colonel", or "woman general", the use of the feminine forms is an idiomatic feature of the language, but what is more important, it is a reflection of the new era in the social hierarchy.

In order to adapt the new social changes to language changes, the issue of naming female occupational titles is becoming challenging for linguists, researchers, editors, publishers, and journalists. Inconsistencies in this domain are evident. However, as regarded by the social and linguistic ambiance of the Republic of Croatia and the Republic of Montenegro, there are two sides to the coin. On the one side, women find that using female titles will contribute to their better positioning in the society and professional life. Other women think that the use of the feminine forms rather than masculine ones is not in accordance with the language. They find that the use of feminine words might be an expression of political will rather than actual language needs.

In addition, it must be mentioned that the social media have raised women's profile. Websites that carry testimonies of maritime women on board and in professional organizations, and maritime blogs (Nautilus International, Gender at sea blog spot, Women in Maritime) have also provided practical support for women seafarers.

Subtle manipulations with female occupational forms are more prominent on the intertextual level. Thus, in media reporting, authors may inconsistently use feminine and masculine forms throughout the narrative, depending on the rhetorical effect they wish to achieve. Mijušković (2013) observes that when the authors of media texts wish to obtain formality of discourse, they use masculine forms (as with English "judge": Montenegrin "sudija", Croatian: "sudac"), but if the female referent is blamed for some activity, she becomes in English a "female judge" (Montenegrin: "sudinica", Croatian: "sutkinja"). The use of female forms particularly bears pejorative connotation in the news about women at the highest diplomatic positions whose professional integrity is for some reason under question (English: "female minister" – Montenegrin: "ministarka" or Croatian: "ministrica"; English: "female ambassador" – Montenegrin: "ambasadorka", Croatian: "ambasadorica", and English: "female director" – Montenegrin and Croatian: "direktorica". The more the privacy of the female is scrutinized, the more female occupational titles are used.

In the article about reasons why the ship is referred to as "she" (Dževerdanović-Pejović, 2017), it is noted that under-informed men on ships have called women captains "Sir" since the 1980s because they did not know that "Ma'am" was the appropriate word to use. The word "lady" was archaic and referred to class status rather than to professional occupation. Knowing the centuries-long tradition of using the feminine pronoun "she" to refer to a woman, women also find it is about time to change the discriminatory "she" into "it". Calling the ship "she" is the act of attributing female qualities perceived as weaker to the ship. Such a linguistic view opposes the new position of women on board, after centuries-long isolation from the shipping world.

A fundamental top-down change was Lloyds List changing this naming practice, from calling ships "she" to using "it" (Hibberd and Woolcock, 2002).

There is no doubt that language is constitutive and reflective of social changes (Holmes, 2006) and that it plays a significant role in gender roles, particularly in masculine-dominated work cultures.

5. METHODOLOGY AND THEORETICAL FOUNDATIONS

Theoretical foundations outlined in this paper rely on the work of linguists Savić (2011), Šehović (2003), Kuzmanović-Jovanović (2013), Perović (2006, 2009), Sunderland (2004) and Lakoff (2003), and other relevant institutional documents dealing with gender policy issues. Gender-based knowledge is the starting basis for the media interpretation of female vocations in the maritime setting. The corpus is based on the 20, 300-word Montenegrin and Croatian online reports about women seafarers.

There are considerably fewer examples from the Montenegrin texts (8,400 words) because the Republic of Montenegro has a smaller fleet, and Montenegrin seafarers focus on the foreign maritime market. On the other hand, Croatia has

a larger fleet and considerably more seafarers, with about 154 ships in the Croatian merchant fleet (The Economic Value of the Croatian Shipping Industry, 2018). For this reason, the examples from the Croatian language were readily accessible for linguistic analysis.

The focus of the research was on the formation and actual use of female titles to designate jobs aboard ships. Target words were selected according to their frequency in the relevant national regulation books.

In order to provide a qualitative analysis of the results, the author relied on the relevant official sources from the Montenegrin and Croatian resources (Government Rulebooks and Regulations, Offices for Gender Equality, official dictionaries).

6. THE COMPARATIVE VIEW

As regards the internet articles about women in seafaring, the authors of the texts present these women in a sensationalist fashion in the headlines. The discursive function of headlines is to attract the readers' interest and catch their attention. The headlines in our corpus are usually accompanied by appealing images of women standing at the wheel of the ship.

Some representative examples from our corpus are Women taking over the helm ("Žene prezimaju kormilo"), Croatian daughter-in-law entered into history of navigation ("Hrvatska snaha ušla u povijest pomorstva), Croatian officers on board one of the most luxurious cruise ships ("Hrvatske časnice na jednom od najluksuznijih kruzera"), Montenegro: Humanity and brevity in a woman's manner ("Crna Gora: Čojstvo i junaštvo na ženski način").

The following example is taken from a Croatian portal and tells a story about the Croatian female third officer on board:

1. It is challenging to set limits on board, whether you give orders or set limits so that people listen to you and everything works well.

("Na brodu je dosta teško naći tu granicu, hoćete li zapovijedati ili naći neku granicu po kojoj vas i ljudi slušaju i sve štima.")

The female officer says that male colleagues treat her with respect, and the very presence of a woman on board brings a homely atmosphere.

2. She behaves very well and does her job well. There is peace on the bridge – no questions or objections.

("Zna se ponašati i vrlo dobro se nosi sa svojim poslom. Na mostu je mir. Nema pogovora, nema prigovora.")

The above examples show that women tend to fit into a male-dominated atmosphere on board. While working with their male mates, they chose to be regarded as people, not women, and even hid their feminine appearances while at work (Kitada 2013). We found this situation in our corpus:

3. I am not sure how to answer this question. For sure, while I am on board and in uniform, I consider myself a female officer in the same way that I look at my colleagues, whether they are males or females. Gender is not what defines an officer, but his knowledge and competencies in carrying out tasks and duties.

("Nisam sigurna kako da odgovorim na ovo pitanje. Zasigurno dok sam na brodu, kad sam u uniformi, ja sebe smatram časnicom, isto kao što smatram i ostale kolege, bilo muške ili ženske. Spol nije ono što definira časnika, već njegovo znanje i vještina u izvršavanju zadataka, odgovornosti i obaveza.")

The following examples prove that in the Croatian texts about women seafarers, all authors use female forms consistently. Apparently, women cope well with the male-dominated atmosphere aboard ships:

4. She has never been affected by the stories: "Baby, the sea is not for women". She strongly wishes to become a female captain of the ship.

("Nisu je pokolebale priče: "Mala, nije more za žene"; uporna je u svom naumu. Želi postati kapetanica broda.")

5. A lovely female seafarer will soon embark, and she will keep good memories of both ship captains.

("Simpatična pomorkinja uskoro će ponovno na brod, a u izvrsnom sjećanju ostala su joj obojica zapovjednika broda.")

The linguistic situation between the Montenegrin and Croatian seafarers aboard ships is similar. Most female titles are derived from the masculine, and use the suffixes –ica , – ka, and –inja. However, language and cultural distinctions have to be made between the term "kapetanica" (female captain) in the Croatian and Montenegrin languages. Namely, in the Montenegrin language, the traditional etymological meaning of the "female captain" ("kapetanica") in the coastal region of the Republic of Montenegro (the Boka Bay) was that of the "captain's wife". It had a pejorative connotation and referred to a captain's wife waiting for the return of her husband (Dževerdanović, 2017). Likewise, this meaning in the Montenegrin language seems to have been imprinted in the modern language. For this reason, some Montenegrin female captains prefer to use a gender-neutral masculine form rather than the female one ("kapetanica"). The same refers to the "female minister" (Montenegrin: "ministarka"), which is an old-fashioned style that implies a minister's wife.

Regarding written material about the female seafarers in Montenegrin online journals, the usage of masculine generic forms is more common. It is interesting to note that women themselves use the masculine forms in the text although the author uses female forms in the headline: "Female cadets from Montenegro learn to become officers on the famous sailing ship *Sea Cloud*" ("Kadetkinje iz Crne Gore uče za oficire na čuvenom jedrenjaku *Sea Cloud*.")

6. I started 17 years ago as a sailor on board "Sea Cloud". Afterwards, I sailed on board other school training ships, sailing

ships, then on cruise ships. I returned to "Sea Cloud" as a First Officer.

("Počela sam prije 17 godina kao mornar na brodu "Sea Cloud". Nakon toga sam prešla na druge školske brodove – jedrenjake, pa na klasične putničke brodove. Vratila sam se na ovu kompaniju gdje sam prvi oficir")

There are examples of the random usage of the masculine and feminine occupational titles in the narrative, when the journalists unsystematically choose between female and masculine forms.

7. A female lieutenant of the corvette, the First Officer in the Navy of the Republic of Montenegro, was on board ship from 05th to 13th August.

("Na brodu od 5. do 13. avgusta, bila je ukrcana i poručnica korvete, prvi oficir u Mornarici Vojske Crne Gore.")

Many Montenegrin officers and seafarers opted to board cruise ships due to attractive salaries and comfort that the cruise ship offers. It is interesting to note that feminine titles are consistently used for the jobs traditionally performed by women.

8. In the beginning, she worked as an assistant waitress, and after a few months, she changed her workplace and became a hostess in the restaurant. Snežana works as a cabin stewardess.

("Ona je radila kao pomoćna konobarica, da bi već nakon par mjeseci, promijenila radno mjesto i postala hostesa u restoranu. Snežana radi kao cabin stewardess").

6.1. Montenegrin and Croatian Rulebooks

The use of gender-sensitive language in media is partly reinforced by the global policy aimed at making women more visible in the media and public space. Many portals and publications are aimed at raising media and public awareness about the equality of women (Ured za ravnopravnost spolova - Žene i mediji, 2020).

As previously said, both languages employ derivational suffixes to form female nouns for certain professions, which were primarily reserved for men. Since the breakup of the former Yugoslavia, there have been two main choices that the countries in question have made. The language creators designed their independent paths in the creation of the standard languages. The most salient division was between Eastern and Western variant – the former inclined toward Turkish and Arabic language, the latter toward Latin and German words (Greenberg, 2004, p. 53).

In this light, some suffixes and borrowings from the Eastern and Western variants overlap. The most distinctive difference is, therefore, between the Eastern variant, as in –ica, –ka, –inja in the Montenegrin language (female minister -"ministarka", female doctor -"doktorica", female professor - "profesorica") and Western variant –ica in the Croatian language (female officer -"časnica", female captain -"kapetanica"). Sometimes, the suffixes –ica, and –ka are used interchangeably in the Montenegrin language such as (female psychologist - "psihološk-inja", "psiholog-ica").

After an insight into the rulebooks for seafarers of the Republic of Croatia (Pravilnik o zvanjima i svjedodžbama o osposobljenosti pomoraca, 2013), and the Republic of Montenegro (Pravilnik o zvanjima i uslovima za sticanje zvanja i uslovima za sticanje zvanja i izdavanje ovlašćenja, 2015), it was established that both documents use masculine generic forms for female and male seafaring ranks. Neither of the texts has an official statement, usually placed at the end of the documents, that the generic use of the masculine pronoun "he" throughout the text, or the use of masculine nouns is not an act of gender discrimination. This statement should be included in the documents of public discourse, or more precisely, in the administration discourse (Čaušević and Zlotrg, 2011). Also, it is recommended that in legal acts and regulations, both genders should be used at the beginning of the text while the rest of the text should employ masculine forms - "Where decisions on job assignments or other decisions on the rights and obligations of civil servants are adopted, the title of a post shall be used in the masculine and feminine gender-" (Act on Gender Equality, 2003).

In this light, the most representative examples for maritime professions in the Republic of Croatia, referring to all the three departments on board ships are: captain/master ("zapovjednik"), officer ("časnik"), seafarer ("pomorac"), crew member ("član posade"), chief engineer ("upravitelj stroja"), engineer ("časnik stroja"), cadet ("vježbenik"), ship's electrician ("brodski električar"), radio operator ("radio officer"), helmsman ("kormilar"), seaman ("mornar"), fitter ("brodski mehaničar"), oiler ("mazač").

In the Montenegrin language, masculine forms refer to both genders and are very similar to the mentioned Croatian terms: captain ("kapetan", "zapovjednik"), officer ("oficir"), seafarer ("pomorac"), crew member ("član posade"), chief engineer ("upravitelj mašine"), inžinjer ("engineer"), cadet ("kadet"), ship electrician ("brodski električar"), radio operater ("radio officer"), kormilar ("helmsman"), seaman ("mornar"), fitter ("brodski mehaničar"), oiler ("mazač").

In order to promote the idea of gender equality in the language, which should equally treat masculine and feminine forms in naming professional titles, the following table proposes the comparative view of female titles in the Montenegrin and Croatian languages extensively employed in the language of media and public discourse. References were made to the Montenegrin online dictionary (2010), Hrvatski jezični portal, and National classification of professions of the Republic of Croatia (2010).

Table 1.
A comparative view of the feminine ranks in the Montenegrin and Croatian language.

Montenegro	Croatia	English translation
Kapetanica/zapovjednica	Kapetanica/zapovjednica	Female captain
Oficirka	Časnica	Female officer
*Pomorac	*Pomorkinja	Female seafarer
Članica posade	Članica posade	Female crew member
Kadetkinja	Vježbenica	Female cadet
Upravljačica mašine	Upraviteljica stroja	Female chief engineer
Brodska inženjerka	Brodostrojarka	Female engineer
Brodska električarka	Brodska električarka	Female ship engineer
Radiooperaterka	Radiooperatorka	Female radiooperator
Kormilarka	Kormilarka	Female helmsman
Mornarka	Mornarka	Female seaman
Brodska mehaničarka	Brodska mehaničarka	Female fitter
Mazačica	Mazačica	Female oiler

The above female forms are derived from the masculine forms by suffixation. They are found in the official grammar although none of them occur in the official maritime acts.

It is evident that the Montenegrin word "pomorac" ("male seafarer") does not have an appropriate feminine form despite the existing derivative suffixes like –ica and –kinja, used to form other female words ("profesorica" for a "female professor").

An example of the pejorative meaning of the word is a "female oiler" ("mazačica"). Linguist Šehović (Šehović, 2003) warns that suffixes are not marked categories, and speakers choose which suffixes to use and whether their meaning is pejorative or mocking. Moreover, one must be aware that using female forms in some cases may contribute to gender discrimination.

Another question arises: Does ethnological heritage limit the use of certain forms? Do the Croatian and Montenegrin languages hesitantly use female derivative forms of some words that may imply unladylike behaviour? This question is heavily related to the qualitative approach, including ethnographic observations in the exploration of specialist discourse (Basturkmen, 2010), meaning that within a discourse of a specific fieldwork, we must take into account the cultural and mental backgrounds as parts of the ethnographic image. This was considered in further text.

6.2. Exceptions

As noted by Čaušević and Zlotrg (2011), one must be careful when choosing between the masculine and feminine forms. Savić (2011) recommended that in designating female occupations some past habits must be changed, and that the formation of female forms must be consistent with and adapted to gender-sensitive issues. She particularly insists that using the feminine form instead of gender-neutral or masculine forms may produce the pejorative effect.

Some words found during the reading of the corpus did not have a semantic feminine equivalent as their use might imply a negative or sexual connotation. One such is "seadog" ("morski vuk"). It would definitely be inappropriate to use the female term "seabitch" ("morska vučica"). Likewise, we did not find an equivalent female pair in the Montenegrin and Croatian languages for the masculine forms of the Croatian "mornar" ("sailorman"), or the Montenegrin "čamdžija" ("boatman").

The following interesting questions also arise: How, then, to name the female seafarer with a decades-long career at sea? Both the Montenegrin and Croatian languages have terms for a brave woman or "sea wolf" ("vučica") or lioness ("lafica"). The phrase "female sea wolf" ("morska vučica") was found in the Croatian media texts, but not in the Montenegrin ones.

9. Nothing is accidental, and at the same time, all is the result of accidental choices and circumstances, says our sea wolf, a life companion of the yachtsman S.F with whom she started adventure from the Pula Port.

(Ništa nije slučajno, a istovremeno sve je splet slučajnih izbora i okolnosti, veli naša "morska vučica", životna družica poznatog jedriličara S. F. sa kojim je u avanturu krenula baš iz pulske luke).

However, the search of our corpus confirmed that the use of "female sea wolf" in Montenegrin connotes attractive women and, thus, has an aesthetic or fashion-related meaning. It may refer to bikini women posing on the luxurious yachts rather than to women from the seafaring profession. It might have a sexist meaning again; therefore, in this case, it is the socially unexpected behaviour that bans the use of certain language phrases.

Unlike the Republic of Croatia, which entered the European Union, the Republic of Montenegro has become a candidate for membership. Many national programmes and projects are in progress, and the drafting of gender-related acts is in the focus of the current Montenegrin national policy.

The above stated means that institutional framework and legislation must take into account women's empowerment and the mitigation of gender discrimination, particularly at workplaces. This goal can be obtained if the societies stop to see women as a marked category, that is, whether linguistically or socially dependent on men, and encourage the concept of the masculine category as primary (Burr, 2003).

Dedication to real equality of the genders at all levels and in all social domains, especially of women in terms of their maternity rights and equal treatment in a professional setting, is a part of the Gender Equality Strategy (2018). The Council of Europe will, therefore, strive to encourage women's visibility in participation in all aspects of public and private life. This particularly relates to raising the importance of women's equal participation in education, decision-making policies, and choice of career. This is particularly important in countries with dominant patriarchal roles and gender stereotypes, as women are regarded as housewives and are discriminated in their professional roles by motherhood. Particular attention should be paid to addressing sexist language and eliminating sexism in the media and public discourse.

In that sense, it can be said that the more regular occurrence of female forms in the Croatian media discourse can partly be explained by the fact that the language policy of the Republic of Croatia, with the accession of this country to the European Union, has adopted new standards of women's affirmation in all spheres of the society.

7. CONCLUSION

The comparative view of the use of feminine forms and representation of women in Montenegrin and Croatian media, shows that there is a similar linguistic ambience in both countries, and that language of media reporting, rather than of the official documents, more consistently applies derivative forms for female gender. Language changes reflect social changes which have made the roles of women more visible. Professional networks and establishment of many "women in maritime" organisations worldwide, also bolstered female representatives in the public discourse in the analysed corpora of the two countries.

It can be concluded that the Republic of Croatia has a somewhat more regular language forms for the female maritime professions in public discourse and a higher language sensibility compared to other ex-Yugoslav states (Šehović, 2003). For example, the word for "seaman" has a female equivalent in the Croatian language ("pomorkinja"), derived from the masculine form, which is not the case in Montenegrin.

As regards language planning in both countries, it has been suggested that both language rules and language intuition should be used in the designation of professional occupations. In this light, female maritime professions are derived from the masculine forms in the official regulations for seafarers in both countries. In addition, in both languages, the use of the feminine forms in some examples could acquire a negative connotation ("female server", and "female oiler").

The commonly-held attitude is that women still represent a novelty on board ship. Women are regarded as wives, daughters or sisters, and are generally considered to be in some kind of relationship with men. Examples for this include the pejorative connotation for the female captain ("kapetanica"), implying a captain's wife in analogy with a female minister implying a minister's wife.

Given the lack of research material, particularly on the part of the Montenegrin corpus, we may still expect that this empirical study will be complemented with more extensive comparative research in the future.

Having in mind the view of language as a social category reflecting the world we live in, it is worth noting how social changes are reflected on the language. On a modern ship, which is still seen as a male-dominated world or man's world, it is worth exploring the pace at which the female ranks transit from being bad luck to being equal with male mates on board.

In conclusion, the view taken in this paper supports the attitude that we must be careful when choosing between the dichotomy pairs, i.e., masculine and feminine roles. Whenever we are in doubt whether to use female or masculine forms, we should take into account language intuition and make the women's role transparent and recognized.

REFERENCES

Act on Gender Equality, 2003. Narodne novine, 116, pp.4229-4232. Available at: http://www.ilo.org/dyn/natlex/natlex4.detail?p_lang=&p_isn=64728.

Basturkmen, H., 2010. Developing Courses in English for Specific Purposes. Available at: http://dx.doi.org/10.1057/9780230290518.

Burr, E., 2003. French. Gender and language politics in France. IMPACT: Studies in Language and Society, pp.119–139. Available at: http://dx.doi.org/10.1075/impact.11.09bur.

Čaušević J., Zlotrg S., 2011. Priručnik za prevladavanje diskriminacije u obrazovanju, medijima i pravnim dokumentima, Sarajevo: NIK Grafit.

Coates, J., 2013. Women, Men, and Language: A Sociolinguistic Account of Gender Differences in Language, London and New York: Routledge.

Dževerdanović-Pejović, M., 2017. Linguistic Facts as a Reflection of Changes in Seafaring: Is a ship still a "she"? The Mariner's Mirror, 103(3), pp.313–322. Available at: http://dx.doi.org/10.1080/00253359.2017.1340427.

Eisler, R., 2005. The Economics of the Enlightened Use of Power. Enlightened Power: How Women are Transforming the Practice of Leadership, pp. 21-39, San Francisco: Jossey-Bass.

Gender at sea blog. Nautilus International. Available at: https://www.nautilusint.org/en/.

Gender Equality Strategy 2018-23, 2018. Council of Europe. Available at: https://rm.coe.int/prems-093618-gbr-gender-equality-strategy-2023-web-a5/16808b47e1, accessed on: 11 April 2020.

Greenberg, R., 2004. Language and Identity in the Balkans, Oxford: Oxford University Press.

Hibberd A., Woolcock N., 2002. Lloyd's List sinks the tradition of calling ships 'she', The Telegraph. Available at: https://www.telegraph.co.uk/news/uknews/1388373/Lloyds-List-sinks-the-tradition-of-calling-ships-she.html.

Hofstede, G., Arrindell, W., 1998. Masculinity and Femininity: The Taboo Dimension of National Culture, London: Sage Publications.

Holmes, J., 2006. Gendered Talk at Work: Constructing Social Identity through Workplace Interaction, USA: Blackwell Publishing.

Hrvatski jezični portal, 2020. Available at: http://hjp.znanje.hr/index.php?show=search_by_id&id=ellkXBI%3D, accessed on: 12 March 2020.

International Labour Office, 2003. Woman Seafarer: Global employment policies and practice, Geneva: ILO.

International Maritime Organization, 2019. Women in Maritime. London: International Maritime Organization, available at: http://www.imo.org/en/OurWork/TechnicalCooperation/Pages/WomenInMaritime.aspx.

Kitada, M., 2013. Code of behaviour at sea: women seafarers' shipboard identity management. WMU Journal of Maritime Affairs, 12(2), pp.213–227. Available at: http://dx.doi.org/10.1007/s13437-013-0044-7.

Kuzmanović Jovanović, A., 2013. Rodno osetljiv jezik u sektoru bezbednosti, Beograd: Beogradski centar za bezbedonosnu politiku.

Lakoff, R., Language, Gender, and Politics: Putting "Women" and "Power" in the Same Sentence. The Handbook of Language and Gender, pp.160–178. Available at: http://dx.doi.org/10.1002/9780470756942.ch7.

Maaranen, A. & Tienari, J., 2020. Social media and hyper-masculine work cultures. Gender, Work & Organization. Available at: http://dx.doi.org/10.1111/gwao.12450.

Mijušković, S., 2013. Registar zvanja, zanimanja i titula žena, Podgorica: Ministarstvo za ljudska i manjinska prava.

National Classification of professions of the Republic of Croatia, 2010. Narodne novine 03(103), 09(75).

Perović, S., 2006. On je rekla: Upotreba rodno-senzitivnog jezika, Podgorica: Kancelarija za ravnopravnost polova Vlade Republike Crne Gore.

Perović, S., 2009. Jezik u akciji, Podgorica: CID.

Pravilnik o zvanjima i svjedodžbama o osposobljenosti pomoraca, 2013. Narodne novine 13(130)

Pravilnik o zvanjima i uslovima za sticanje zvanja i izdavanje ovlašćenja za članove posade pomorskih brodova, 2013. Službeni list Crne Gore, 2013(55).

Savić, S., 2011. Predlog za upotrebu rodno osetljivog jezika u vojsci: činovi žena. Bezbednost Zapadnog Balkana, 19, pp. 46–56.

Savić, S., 2011. Žene u avijaciji: Gracije ili borbene avijatičarke? Rod i bezbednost 3. Available at: http://www.bezbednost.org/upload/document/bilten_rod_i_bezbednost_3.pdf.

Šehović, A., 2003. Upotreba mocionih sufiksa (u nomina agentis et professionis) u savremenom razgovornom bosanskom jeziku, Pismo, 1(1), pp. 73-92.

Sunderland, J., 2004. Gendered Discourse, New York: Palgrave Macmillan.

The Economic Value of the Croatian Shipping Industry, 2018. Oxford Economics, London, UK. Available at: http://csamarenostrum.hr/userfiles/files/Croatian%20Shipping%20Presentation.pdf.

The Montenegrin Dictionary, 2010. Podgorica: Ministry of Education of the Government of the Republic of Montenegro.

Ured za ravnopravnost spolova Vlade Republike Hrvatske: Žene i mediji. Available at: https://ravnopravnost.gov.hr/istaknute-teme-i-projekti-11/zene-i-mediji/3267.

Weatherall, A., 2005. Gender, Language and Discourse. Available at: http://dx.doi.org/10.4324/9780203988817.

The Security Council and the Repression of Maritime Piracy: The Case of Somalia

Safwan Maqsood

Maritime piracy in the Somali territorial waters has been the focus of attention of international society for at least twelve years, and indeed the crime of piracy threatens international peace and security in a region through which half of the world's crude oil passes. In the three-decade absence of a Somali State, intervention by the Security Council is required to suppress such crimes and ensure freedom of maritime navigation. The Council resolutions based on Chapter VII of the UN Charter call for the Member States of the United Nations to arrest and bring to trial those accused of piracy before national courts. It is necessary for the States that are involved in anti-Somali piracy efforts to incorporate the principle of universal jurisdiction into their national laws and adopt new laws criminalizing modern piracy, which is outside the traditional notion of piracy stipulated in the United Nations Convention on the Law of the Sea 1982.

KEY WORDS
~ Maritime piracy
~ Armed robbery
~ Ransom

University of Sharjah, United Arab Emirates
e-mail: skhalil@sharjah.ac.ae

doi: 10.7225/toms.v09.n02.018

1. INTRODUCTION

The freedom of international maritime has always been one of the most important concerns of the international community because waterways and high seas are the routes through which most global trade passes. The primary hazard faced by ships is unrelated to the sea itself, but is related to the maritime piracy committed by groups with the only aim of stealing cargo or even ships themselves. Nowadays, the international community has shown rare solidarity against this crime by prosecuting perpetrators, destroying their ships and places of gathering, and describing pirates as enemies of humanity. Because this crime threatens international peace and security, the International Law of the Sea was established as a legal framework in the United Nations Convention on the Law of the Sea of 1982.

Traditionally, maritime piracy was practised in specific regions of the world, especially in the Caribbean and the Gulf of Malacca in East Asia, but in the past decade this piracy has emerged strongly in West and East Africa, specifically the Gulfs of Guinea and Aden. Directly or indirectly, it has caused global economic losses. From the Gulf of Aden alone these have reached tens of billions of US dollars. For example, half of the global supply of crude oil passes through this area, in addition to ships carrying various cargoes.[1]

In Somalia, marine piracy and armed robbery have been concentrated in the Somali Territorial Sea, and it affects most

1. *According to reports issued by the United Nations Office on Drugs and Crime, losses resulting from piracy in the Gulf of Aden reached more than 18 billion USD in 2006-2013. Moreover, the total sums paid as ransom for the kidnapped vessels was over 413 million USD (2005–2013), at a rate of USD four million per vessel. See : Drobenko, La piraterie saisie par le droit, 21 Neptunes revue (2015) 3; available at: https://cdmo.univ-nantes.fr/neptunus-e-revue/annees-2015/*

of the commercial ships passing through the Gulf of Aden. The problem here is that the Somali Interim Government announced that it was unable to exercise criminal jurisdiction to pursue and prosecute the perpetrators of these crimes despite this jurisdiction being in accord with both its constitution and international law. The status of Somalia as a failed State has prompted the UN Security Council to ask Members of the UN and even regional organisations such as European Union and African Union to pursue pirates in both the Somali Territorial Sea and on the mainland, and to place them before their national court or before the courts of another country.[2]

The importance of the current Somali case is that, despite international efforts to suppress and eradicate piracy, it has been suppressed, but not eliminated, as the Somali Government announced. Since March 2017 until the time of writing, no ship hijacking or ransom demands have been reported. However, they may recur at any moment once the current coercive measures are relaxed and international military forces are withdrawn. For this reason, it is important to ask whether the existence of a failed State leads to the spread of crimes such as maritime piracy, and whether the presence of piracy and armed robbery in this failed State justifies the intervention of other States seeking to suppress these crimes and prosecute their perpetrators.

2. CAUSES OF PIRACY IN SOMALIA: A RECENT PHENOMENON

According to the international law, States exercise jurisdiction within their national borders. Accordingly, criminal jurisdiction is exercised by national authorities. The most prominent of these is their personal jurisdiction over all their lands, territorial seas, and airspace, no matter how high. Any act that constitutes a criminal offence under the State's national law obliges them to pursue and prosecute perpetrators before national courts, and they alone have the right to establish and implement rulings on their territories.[3] Alongside the countries such as the Democratic Republic of the Congo and Haiti, Somalia is called a failed State. Such a State cannot provide the right to protection and security for its citizens, execute penal law throughout its borders or confront the perpetrators of crimes. In Somalia, this failure is due to the collapse of the political regime in 1991, after the escape of the former President Mohamed Siad Barre,[4] and the disintegration of the national army, police, and security forces. This dramatic event prompted individuals to establish armed militias not subject to the law, and control over cities and rural areas was ceded to civil warlords.[5] The Somali State thus fragmented virtually, if not legally, into two parts: Somaliland, and Puntland in Northern Somalia.[6] Local authorities and institutions were set up in both regions to manage the affairs of cities and regions, and to control security, but the south suffers from armed conflicts that started in 1992 and are ongoing. Armed militias were established which have weakened the State's authority and powers under the Constitution. In addition, there has been a clear and public spread of terrorist groups.[7]

Since its independence from Britain in 1960, and until the 1980s, there were no known piracy incidents in the Somali Territorial Sea.[8] The first incident was in 1989, at the beginning of the collapse of the political regime and the rupturing of the State. In that year, an armed opposition movement called the Somali National Front became active in the north, in what is known today as Puntland. Backed by Ethiopia, the group held four commercial ships legally sailing across the Somali Territorial Sea and an Italian tanker called *Kwanda*. The kidnappers claimed to have two motives: to reveal to the world the weakness of the Somali government through its inability to secure protection for foreign ships and to show that the Somali National Front was the most appropriate protection for shipping. Consequently, permission to enter the Somali Territorial Sea should be sought from the opposition movement and not the government. Scholars of international law consider that the Somali National Front borrowed this illegal practice from activities carried out by the Polisario (the Front in the Western Sahara), when it forced fishing

2. *Twenty-one countries responded to this call, often through the deployment of warships, including African countries (Kenya, the Seychelles, Tanzania and Mauritius), Arabian countries (Oman, the United Arab Emirates, Yemen and Saudi Arabia), Asian countries (China, South Korea, India, Taiwan and Japan), European countries (the Netherlands, Belgium, France, Germany, the United Kingdom, Russia and Italy), and the United States. Mainiatas, La Piraterie en Afrique, 23 Neptunes revue (2017) 2 ; available at: https://cdmo.univ-nantes.fr/neptunus-e-revue/annees-2017/*
3. *Silva, Somalia: State Failure, Piracy, and the Challenge to International Law, 50 Virginia Journal of International Law (2010), 554.*
4. *President Mohamed Siad Barre took control of Somalia in 1969 and ruled by fomenting disunity among the various clans, and by promoting the Darod clan. He was deposed from power by the General Mohammad Farah Aideed*
5. *Martin, La Répression des Actes de Piraterie Maritime : Développements Récents en Matière de Poursuites et Détention des Pirates Somaliens' LVI Annuaire Français de Doit International (2010) 517; available at : https:// persee.fr/docAsPDF/afdi_0066-3085_2010_num_56_1_4623.pdf*
6. *Garrod, The Emergence of Universal jurisdiction in Response to Somali Piracy: An Empirically Informed Critique of International Law's Paradigmatic Universal Jurisdiction, 18 Chines Journal of International Law (2019) 576; available at : https://academic.oup.com/chinesejil/article-abstract/18/3/551/5625568?redirectedFrom=fulltext*
7. *Farah, Maritime Trade and Piracy in the Gulf of Aden and the Indian Ocean (1994-2017), April Journal of Transportation Security (2018) 2; available at : https://www.springer.com/journal/12198*
8. *The author limits of the, maritime zones according to UNCLOS1982 as following: -The territorial sea extends to a limit of 12 nautical miles from the baseline of a coastal State. -The contiguous zone from the outer edge of the territorial sea to a maximum 24 nautical miles from the baseline. -The exclusive economic zone (EEZ) is the largest sea area, which cannot exceed 200 nautical miles from the base line.- The high seas are characterized by the principles of free use for all States. For more read the UNCLOS 1982.*

vessels to seek permission from itself and not the Moroccan authorities. Unfortunately, what happened in Somalia after the forced departure of Siad Barre and other regime members, and less than a year after the 1989 Somali incident, was the contrary to what the Front itself declared when it hijacked the ships. Neither the Front nor other opposition movements that emerged later made any effort to control the Somali Territorial Sea. Thus, an area of 120,000 km^2 lacked control and authority.[9]

This lack of control on land and at sea created lawlessness in Somalia, and led to the outbreak of piracy discussed here. Perhaps the most prominent of the acts of piracy concern illegal fishing by ships belonging to European, Asian, and African countries without any government control or licencing. Even today, ships from Japan, France, Spain, Pakistan, Taiwan, South Korea, and Sri Lanka practise illegal fishing in the Somali Territorial Sea despite the Security Council resolutions, the latest of which from December 2019, condemning these actions.[10] Moreover, since the late 1990s, other crimes under international law have also become widespread, i.e. the burial and disposal of nuclear waste and contaminants in the Somali Territorial Sea, human trafficking, and trading in Yemeni Qat. The latter has found a large market in this region and on the coast in particular.[11] Regarding maritime piracy and armed robbery, in the period 1990–1998, the International Maritime Bureau did not record any piracy incidents in the Somali Territorial Sea, but after 1998 the office began receiving information about ship hijacking, especially in the territorial sea opposite the Puntland region.[12]

It would seem that, when seeking the reasons for the emergence of piracy in Somalia, the fall of the Somali government and the rule of lawlessness since 1991 stand at the forefront. However, scholars of international law retain this is not the only justification. If we take Nigeria as an example, we can see it has a strong federal government and is a member of the Organization of the Petroleum Exporting Countries. Nevertheless, it suffers from pirate groups having emerged there and spread widely. These peoples including the pirates believed that the misallocation of national wealth, especially oil, among various regions in Nigeria led to widespread poverty, specifically in the south. When ships loaded with goods and products pass the Nigerian coasts and the poor see them, this prompts them to seize the ships or at least hijack them for ransom.[13] The same is true for Somalia. Millions of Somalis suffer from poverty and lack of work opportunities, and this has led some to resort to violating the law by committing crimes for money, such as seizing ships inside the Somali Territorial Sea in order to gain the ransom.[14] However, alongside the factors of the fall of the Siad Barre regime and poverty, the importance of other factors must not be diminished. One is the widespread access to weapons within the civilian population of Somalia, caused by the disintegration of the army, police, and security forces. Another is that, since the British and Italian colonisation of the country ended, many tribal conflicts erupted which pushed people to arm themselves. For this reason, the Somali society is considered to be one of the most armed in all Africa.[15] A third factor is the series of wars that broke out with its neighbour Ethiopia.[16] Finally, we must mention the lack of technical systems on merchant ships to protect against intruders, or even armed security personnel, meaning that the ships are easier to board.[17] The Somali pirates are classified as the best equipped and best organised compared to pirate groups in other regions like Malaga Bay, Guinea Bay, or the Caribbean islands. The pirates in Somalia carry automatic weapons and shoulder-held missiles, and use speedboats to move towards their targets.[18] Considering all of these factors, piracy and armed robbery has become an almost inevitable result in the Somali case.

3. SECURITY COUNCIL RESOLUTIONS: AUTHORISING INTERNATIONAL INTERVENTION IN SOMALIA

The International Law of the Sea laid out in the 1982 Convention allows the States to intervene to combat maritime piracy on the high seas or in an exclusive economic zone. Under Article 105 of the United Nations Convention on the Law of the Sea 1982, the States can exercise or not this repression without entailing any international responsibility, especially

9. *Amirelle, La piraterie maritime en Afrique contemporain, 116 Revue de Politique Africaine (2009) 105 ; available at : https://pdfs.semanticscholar.org/d769/8025ec*
10. *The Security Council stated in its Resolution (Expressing serious concern over reports of illegal, unreported and unregulated fishing (IUU) in Somalia's Exclusive Economic Zone (EEZ), recognizing that IUU fishing can contribute to destabilization among coastal communities, and noting the complex relationship between IUU fishing and piracy,) . See: S/RES/2500/2019, adopted in 4 December ,2019, p. 3 ; available at : www.un.org*
11. *Edem, Lutte contre la piraterie maritime par des gardes armes à bord des navires: Conflit de compétences entre Etats de pavillon et Etats côtiers-La nécessite de mécanismes de coopération' 21 Neptunes revue 2015) 2 ; available at: https://cdmo.univ-nantes.fr/neptunus-e-revue/annees-2015/*
12. *Drobenko, La piraterie saisie par le droit, 21 Neptunes revue (2015) 3; available at: https://cdmo.univ-nantes.fr/neptunus-e-revue/annees-2015/*
13. *Flagel, A., Le renouveau de la piraterie internationale, these present a l'universite de la Nouvelle- Caledonie, le 28 fevrier 2013, 343p , 170*
14. *Piette, The Fight against Maritime Piracy under French Law, 3 Montesquieu Law Review (2015) 2. And for more detailes see: Farah, Supra note 8, at 8.*
15. *Flagel, A., Le renouveau de la piraterie internationale, thèse présenté a l'université de la Nouvelle- Calédonie, le 28 février 2013, p.166. : Hoesslin, Von, La nébuleuse pirate en Somalie, (2012) 56 Diplomatie 42 ; available at: https://www.diplomatie.gouv.fr/fr/conseils-aux-voyageurs/informations-pratiques/risques/piraterie-maritime/*
16. *Amirelle, Supra note 9, at 105.*
17. *See article 9 of the Revise Code of Conduct concerning the Repression of Piracy, Armed Robbery, against Ships, and illicit maritime activity in the Western Indian Ocean and the Gulf of Aden Area, in 17 January 2017, p. 70.*
18. *Treves, Piracy, Law of the Sea, and Use of Force: Developments off the Coast of Somalia, 20 European Journal of International Law (2009) 400.*

since the Convention does not criminalise piracy or include measures for international criminal cooperation and legal assistance to extradite persons accused or convicted of piracy.[19] In the Somali Case, unlawful acts are committed in the Somali Territorial Sea, and the interference of countries is considered a violation of the sovereignty of a Member State of the UN, even if it is actually described as a failed State. However, sovereignty is a well-established concept in Customary International Law and, therefore, is still enjoyed even by failed States. What is committed in the Somali Territorial Sea differs from what the 1982 Convention refers to, as in the Convention piracy is implied in its traditional sense.[20]

In the Somali Case, foreign ships and crews are detained, and the owning company or flag State of the ship is given a ransom demand for money in exchange for their release. The aim of the detention is, therefore, not the pillaging of the cargo or ship's resources. As a result, we are facing a new form of maritime piracy that differs greatly from what prevailed for centuries. In our opinion, this new form is not described as maritime terrorism[21] despite the fact that the Security Council Resolution No. 1838 of 2008 describes it as such.[22] In view of the seriousness of these acts committed in Somalia and their serious impact on the security of maritime navigation and international trade routes, the intervention of the Security Council was necessary to limit attacks against commercial vessels.

Consequently, between May 2008 and December 2019, the Council issued more than thirty binding resolutions based on Chapter VII of the UN Charter, describing the situation in the Somali Territorial Sea as a threat to international peace and security. This means that the Council can delegate a State to take action to suppress these crimes, including the use of armed force.[23] Some scholars perceive that the Council intervened in this way, and issued more resolutions related to similar global issues, due to the steady rise of piracy and the serious threat to the freedom of navigation and shipping, both of which negatively affect giant international financial institutions and the global economy.[24]

These Resolutions, since May 2008, consider that any foreign military intervention to suppress piracy and armed robbery requires the explicit and written consent of the SIG in order to carry out these measures. The Somali Interim Government sent a list of countries that will pursue and prosecute pirates in its regional sea to the Secretary-General of the UN.[25] Moreover, Council Resolutions allow regional organisations to intervene to crack down on illegal acts. In this light, NATO and the EU launched two operations, *Ocean Shield and Atlanta*, to repress piracy in the Gulf of Aden, and both operations are ongoing in the Somali Territorial Sea twelve years after their launch.[26] With regard to the list prepared by the Somali Interim Government, the Council Resolutions on the Somali Case were based on Chapter VII of the UN Charter. This means that the commitment to cooperate with the Council to carry out repressive measures is obligatory for all Member States of the UN, and not to the specific group included in the Somali Interim Government list. Because piracy qualifies as a threat to International Peace and Security, the list prepared by the Somali Government for a limited number of Countries was a matter of consideration. For example, when the Council established the International Criminal Tribunal for Rwanda in 1995, it obligated all States to cooperate fully, and any breaches were considered to jeopardise international peace and security.[27] In the Somali case, if we assume that a country excluded from the Somali Interim Government list discovered a pirate group destined to target a foreign cargo ship in the Somali Territorial Sea, would it stand by and allow the pirates to commit the crime? Would such a problem be a violation of the Council's Resolution on Somalia? On the other hand, the United Nations Convention on the Law of the Sea 1982, especially Articles 100–107 consider that the State's exercise of its full competence to repress piracy

19. *Garrod, supra note 6 at 574.*
20. *For the Anglo-Saxon Scholars, the Classical Piracy defined as Attack against all nations indiscriminately and affect the interest of maritime trade throughout the world and by this crime we are all inquired, and individuals in turn can find their personal rights violated. Read: Bantekas, I, Supra note 2, at 156.*
21. *Maritime terrorism is define as (any act of unlawful violence directed against ships, individuals, goods, or property that they carry, or against maritime targets with the aim of direct or indirect influence on the government of a particular country or any other body to achieve political goals). This crime shares with piracy that they threaten the security of the International Community as a whole, and they constitute international Crimes that threaten the safety of Marine Ships and freedom of Navigation. In addition, both require the use of violence against ships, people and the money they carry. While Piracy differs from Maritime Terrorism in that the Second is not required to be committed on high seas, it can be committed in the Territorial Sea of the State, unlike Piracy in its classical sense, which stipulates its commission on high Seas and the Exclusive Economic Zone. The development of means of using Maritime Terrorism is the opposite of Piracy, which is still using traditional methods. In addition, Piracy is accomplish by fulfilling two conditions, the means used and the target, which is the attacking ship and the assaulted ship. While in maritime terrorism, it may be committee from inside the assaulted ship, that is, by its crew or passengers. The goal of maritime terrorism is vital and strategic, unlike Piracy, whose aim is to plunder or hijack the ship to obtain the funds it carries. Finally, Maritime terrorism aims to cause the largest possible number of losses to the attacked ship, while piracy aims to reduce losses and achieve more profit. See: Eudeline' Le Terrorisme Maritime, Une Nouvelle Forme de Guerre, 2 Outre –Terre Revue (2010) 87 s; available at : https://www.cairn.info/revue-outre-terre1-2010-2-page-83.htm*
22. *Farah, Hamza, Supra note 8, at 12. See also: Guilfoyle, Supra note 2, at 146.*
23. *The Security Council adopted between May 2008 and December 2019 the following Resolutions: 1814-1816-1838-1844-1846-1851-1897-1918-1950-1976-2015-2020-2077-2125-2184-2246-2316-2383-2442-2500.*
24. *Warnir, R., The Prosecution of Pirates in National Courts, 2014, 22.*
25. *Martin, Supra note 7, at 506.*
26. *Maniatis, Approche Juridique de la Piraterie, 21 Neptunes revue (2016) 5. In the same meaning, read Lorca, Harmonization of National Criminal Laws on Maritime Piracy: A Regulatory Proposal for the Crime of Piracy and its Penalties, 23 European Journal of Criminal Research' (2016) 117.*
27. *Guilfoyle, Supra note 2, at 152.*

is optional, not mandatory. In other words, the country whose warship sees a cargo ship being attacked by a group of pirates has a choice between interfering to prevent piracy or not.

In addition, the UNSC resolutions related to the Somali Case allow the delegated State to intervene by pursuing suspects of piracy, not only in the Somali Territorial Sea, but also on the Somali mainland.[28] This is a dangerous and negative development with respect to the principle of State sovereignty and territorial integrity. In this paper, we argue that the degree of seriousness of the Council's own Resolutions does not change by limiting maritime and land intervention to Somalia only, or by stipulating that the Somali Case is an exception and, therefore, does not create an International Customary Law. Rather, the emergence of an International Customary Law does not currently arise through a Security Council Resolution or a UN General Assembly Recommendation; instead, it arises from the frequency of an action over an uninterrupted period of time.[29] Accordingly, we believe that the Council's assertion of the specificity of the Somali case is unacceptable. Every legal issue has international and even internal importance and, therefore, it can be used as a rule or an international legal principle at any time.[30]

4. PROSECUTION OF SOMALI PIRATES: DELAYED NATIONAL JUSTICE

It is customary for the Somali Coast Guard forces to do their duty to prosecute the perpetrators of maritime piracy in the Somali Territorial Sea and bring them to trial before the Somali Criminal Courts. The latter, in turn, issue criminal rulings that vary between ruling on innocence, incarceration, imprisonment, or even all the way to execution in some cases, in accordance with the applicable Penal Code and provisions in the Somali penal institutions. However, since this scenario has not been implemented for three decades, the Security Council has intervened and, as indicated above, issued a series of resolutions calling on United Nations' Members States to suppress piracy and armed robbery in the Somali Territorial Sea and to prosecute those suspected of piracy who are Somali citizens.[31]

These resolutions evolved to move from demanding prosecution to requiring states to prosecute pirates before their courts or before the courts of another country, in accordance with either their national laws or the international law in application of universal jurisdiction. Above all, we must consider the position of the Somali legal system with regard to the crime of piracy committed in its territorial waters. This is especially significant given that the United Nations always affirms that its priority is to apply the Somali law against the perpetrators of piracy and armed robbery. In other words, we may question why the Somali Penal Code and other Somali laws, if any, are not applied, and whether there is any justification for the Security Council, with its Resolutions, to call for the application of comprehensive jurisdiction by other countries.

In this regard, we can say first that the Somali criminal law in force (Penal Code, Criminal Procedure Law) is based on four contradictory legal sources: Italian law, Anglo-Saxon law, Islamic law, and Somalia's prevailing tribal customs.[32] With regard to the Somali Penal Code promulgated in 1962, it was derived, if not quoted, in the majority of its provisions from the Italian Penal Code, while the Code of Criminal Procedures is derived from Anglo-Saxon law. These two laws are still in force in all parts of Somalia, even in the regions that announced their official (Somaliland) or administrative secession (Puntland).[33]

The main criticism of the Somali Penal Code is that it does not refer to the crime of maritime piracy in its texts despite Somalia's being a maritime nation with more than 3.000 km of coasts, and piracy being a historical and ancient crime. For many, the lack of stipulation in the Penal Code is due to two reasons. First, there was no commitment in the period before the collapse of the State in 1991 and, thus, no call for an amendment to the law from its promulgation until the fall of the political regime. Second, to punish piracy crimes, the Somali judiciary could have employed provisions on kidnapping crimes according to Articles 485–486 of the Penal Code. These two texts relate to the crimes of kidnapping persons in exchange for a financial ransom whether committed on land, sea or air, as the text does not specify the place of commission. The punishment stipulated in the law ranges between eight to eighteen years in prison, depending on any aggravated circumstances or exemptions, which might affect the punishment accordingly.[34]

Other difficulties related to the implementation of the Somali Penal Code relate to the first source of criminalization in the Code, which is Islamic Sharia. According to this Sharia, maritime piracy is the crime of brigandry (hiraba). Under this law,

28. *The number of Council Resolutions that allowed States to intervene on the Somali mainland to pursue suspected pirates reached 7; available at: https://un.org*
29. *In all UN Resolutions related the Somalia, we found the following text (…Affirms that the authorizations renewed in this resolution apply only with respect to the situation in Somalia and shall not affect the rights, obligations, or responsibilities of Member States under International Law. Including any rights or obligations under The Convention with respect to any other situation, and underscores in particular that this resolution shall not be considered as establishing customary International Law,).See The Security Council Resolution N. 1897, in 30 November 2009, p.4.*
30. *Garrod, supra note 6, at 575.*
31. *Warnir, Supra note 21, at 21.*
32. *See the Report of the Secretary General on the modalities for the establishment of specialized Somali anti-piracy Courts, S/2011/30, p. 40.*
33. *See: The Somali Penal Code, N 5, in 16 December 1962, and the Somali Code of Criminal Procedures N. 1, in June 1963.*
34. *Shnider, Universal Jurisdiction over Operation of a Pirate Ship: The Legality of the Evolving Piracy Definition in Regional Prosecutions, 38 North California Journal of International Law and Commercial Regulation (2013) 522 ; available at : https://www https://scholarship.law.unc.edu/ncilj/vol38/iss2/3/*

a cruel punishment equivalent to torture was imposed: cutting off the left leg and the right hand and, in case of recidivism, the right leg and the left hand. These penalties contradict the modern criminal policy of reforming and rehabilitating convicts wherever their crimes are and, therefore, it is not realistic for use in the Somali Penal Code.

To overcome these difficulties, the United Nations Office on Drugs and Crime (UNODC) has provided substantial and generous support to local governments in the Puntland and Somaliland regions to establish effective judicial institutions and train judicial, legal, and technical personnel. Its support included both material assistance and participation in the legislation of laws punishing piracy in these regions. Here, we note the success of the programme's efforts in Somaliland, where in 2012 a local law was legislated to combat maritime piracy.[35]

With regard to the Somaliland Law to Combat Maritime Piracy, it is classified as a special criminal law. According to Article 12, it is part of the Penal Code in force and this is the Law of 1962; however, no Penal Code was issued in Somaliland, and the Somali Penal Code of 1962 is still in force alongside the Somali Penal Procedures Law. This means that all criticism of the Somali Law remains the same, with the exception that in adapting the act of piracy and punishment, the new law identified the action committed as maritime piracy and set its punishment as 5–20 years in prison.[36]

Moreover, the new law limits criminal jurisdiction to the Somaliland Courts for all the piracy crimes committed in the Territorial Sea of Somaliland despite the non-demarcation of the maritime boundaries between the Republic of Somalia, a signatory to the 1982 Convention, and Somaliland unless the crime is subject to the jurisdiction of another country or criminal jurisdiction under the Common International Law and the intention is universal jurisdiction. It appears that, with the influence of the UNODC, the legislator of the law aimed to immediately address piracy in the Somaliland waters as much as possible.[37]

Despite the issuance of a somewhat recent law compared to the laws in force in Somalia, it is unfortunate that this law has not to date been widely applied, mainly because of the weakness of the judicial institutions in Somaliland. This is in addition to the fact that influential bodies benefit from the practice of maritime piracy and, thus, do not allow the prosecution of pirates before local courts. To demonstrate this apparent weakness, in August 2019, the Somaliland authorities released 19 convicted pirates who had been moved from the Seychelles to Somaliland, based on a Memorandum of Understanding, to spend their sentences in Somaliland.[38] However, the latter released them. This was qualified as a violation of Somaliland's obligation to the Seychelles and the international community to imprison the convicted persons within two prisons constructed with funds from the United Nations, which also trained their cadres in previous years. In the light of the above-mentioned difficulties in applying the Somali law before the Somali courts, it became imperative for the Security Council to find a legal solution that achieves justice.

5. CONCLUSION

Currently, the UN Security Council still plays a decisive role in the international campaign against the Somali piracy. This achievement is considered result from unanimity of the five permanent members of the Security Council and their satisfaction with the gravity of this crime and its impact on their commercial interests and national security. The Security Council has adopted more than forty resolutions in the past twelve years, including those that promote procedures related to the re-establishment of judicial institutions (i.e. the courts) in Somalia. These institutions were wholly damaged in the war, along with the legislative reform of the criminal laws in Somalia enacted six decades ago.*

Unfortunately, however, the Council has failed in its efforts on behalf of the Somalian judicial institutions. On the positive side, the Council called all the member States of the UN to integrate the principle of universal jurisdiction into their national criminal laws in order to prosecute piracy before national courts, due to the incapability of carrying out the United Nations Convention on the Law of the Sea 1982 upon the Somali situation. However, the application of universal jurisdiction by these countries faces a problem related to the difference in the sanctions imposed by the Courts: in the northern countries five years in prison is the maximum, while in the southern countries piracy incurs death penalty.

35. *The Somali Land law combatting the Piracy, N 52, in September 2012, also See : The Report of the Secretary-General on the situation with respect to piracy and armed robbery at sea off the coast of Somalia, S/2013/623, in 21 October 2013, p. 5.*
36. *The main provision is the Article 5 of the Law against the Piracy which stated that 1) An act of piracy at a ship or aircraft owned by Somaliland shall come under the jurisdiction of the Republic of Somaliland courts unless the ship or aircraft was, at the time of the commission of the offence, situated in the territorial waters of another country or that act is assigned, under international law, to another jurisdiction; 2) Notwithstanding the provisions of any other law and regardless of the nationality of the accused persons, the courts of Somaliland shall have jurisdiction to try any offences of piracy committed within the Somaliland sea or outside the Somaliland sea if committed in an area not falling within the sea of any other country when the Somaliland Coastal Forces detains the accused persons).*
37. *Lorca, Supra note 23, at 118.*
38. *It should be mentioned that the Security Council recognized in its resolutions the weakness of the Somali criminal laws, even the inability of the Somali Courts for pursuit and prosecution of the pirates. For more details read the following Resolutions: S/RES/1918(2010)-S/RES/1897(2009)-S/RES/1950(2010)-S/RES/1976(2011)-S/RES/2125(2013), S/RES/2246(2015)-S/RES/2500(2019).*

* *The resolutions mentioned to re-establish the judicial institutions in Somali are: N. 2500-N 2383 -N 2246 –N 2184 – N 2125 – N 2077 – N 2015 – N 1976.*

REFERENCES

Amirell, S.E. & Ndzesop, I., 2009. La piraterie maritime en Afrique contemporaine. Politique africaine, 116(4), p.97. Available at: http://dx.doi.org/10.3917/polaf.116.0097.

Bantekas, I., 2003. International Criminal Law. Available at: http://dx.doi.org/10.4324/9781843145295.

Drobenko, B., 2015. La piraterie saisie par le droit, Neptunes revue, 21, pp. 1-9.

Edem, S., 2015. Lutte contre la piraterie maritime par des gardes armes à bord des navires : Conflit de compétences entre Etats de pavillon et Etats côtiers - La nécessite de mécanismes de coopération. Neptunes revue, 3, pp. 1-10.

Eudeline, H., 2010. Le terrorisme maritime, une nouvelle forme de guerre. Outre-Terre, n° 25-26(2), p.83. Available at: http://dx.doi.org/10.3917/oute.025.0083.

Farrah, H., 2018. Maritime Trade and Piracy in the Gulf of Aden and the Indian Ocean (1994-2017). Journal of Transportation Security, pp. 1-19.

Garrod, M., 2019. The Emergence of "Universal Jurisdiction" in Response to Somali Piracy: An Empirically Informed Critique of International Law's "Paradigmatic" Universal Jurisdiction Crime. Chinese Journal of International Law, 18(3), pp.551–643. Available at: http://dx.doi.org/10.1093/chinesejil/jmz025.

Gaurier, D., 2000. Le crime contre l'humanité est-il une notion nouvelle ? Le pirate, ennemi du genre humain. Annuaire de Droit Maritime et Océanique, XVIII, pp.173-192.

Guilfoyle, D., 2016. Counter- Piracy Law Enforcement and Human Rights. International and Comparative Law Quarterly 59, pp.141-169.

López Lorca, B., 2016. Harmonisation of National Criminal Laws on Maritime Piracy: a Regulatory Proposal for the Crime of Piracy and its Penalties. European Journal on Criminal Policy and Research, 23(2), pp.115–132. Available at: http://dx.doi.org/10.1007/s10610-016-9325-y.

Maniatis, A., 2016. Approche Juridique de la Piraterie, Neptunes revue, 22(1).

Maniatis, A., 2017. La Piraterie en Afrique, Neptunes revue, 23, pp.1-6.

Martin, J.-C., 2010. La répression des actes de piraterie maritime : développements de poursuites et détention des pirates somaliens. Annuaire français de droit international, 56(1), pp.497–527. Available at: http://dx.doi.org/10.3406/afdi.2010.4623.

Piette, G., 2015. The Fight against Maritime Piracy under French Law. Montesquieu Law Review, 3, pp. 2-10.

Shnider, S., 2013. Universal Jurisdiction over Operation of a Pirate Ship: The Legality of the Evolving Piracy Definition in Regional Prosecutions. North California Journal of International Law and Commercial Regulation, 38(2), pp. 474-569.

Silva, M., 2010. Somalia: State Failure, Piracy, and the Challenge to International Law. Virginia Journal of International Law, 50, pp. 553-578.

Treves, T., 2009. Piracy, Law of the Sea, and Use of Force: Developments off the Coast of Somalia. European Journal of International Law, 20(2), pp.399–414. Available at: http://dx.doi.org/10.1093/ejil/chp027.

Warnir, R., 2014. The Prosecution of Pirates in National Courts. Abu Dhabi. ECSSR.

Somalian laws

Law on Combatting Piracy (Somaliland). N .52, in 2012.

Penal Code (Somalia Republic) N. 5, in 16 December 1962.

Procedures Criminal Code (Somalia Republic) N1, in 13 June 1963.

Conventions

United Nations Convention on the Law of the Sea 1982.

Convention for the Suppression of Unlawful acts against the safety of maritime navigation 1988.

United Nations Reports

The Report of the Secretary-General on the modalities for the establishment of specialized Somali anti-piracy courts. S/2011/360, on 15 June 2011.

The Report of the Secretary-General on the situation with respect to piracy and armed robbery at sea off the coast of Somalia, S/2013/623, on 21 October 2013.

The Revise Code of Conduct concerning the Repression of Piracy, Armed Robbery, against Ships, and illicit maritime activity in the Western Indian Ocean and the Gulf of Aden Area, on 17 January 2017.

Security Council Resolutions

S/RES/1816, on 26 May 2008.

S/RES/1831, on 19 August 2008.

S/RES/1838, on 7 October 2008.

S/RES/1844, on 20 November 2008.

S/RES/1846, on 2 December 2008.

S/RES/1851, on 16 December 2008.

S/RES/1872, on 26 May 2009.

S/RES/1897, on 30 November 2009.

S/RES/1916, on 19 March 2010.

S/RES/1918, on 23 April 2010.

S/RES/1950, on 23 November2010.

S/RES/1976, on 11 April 2011.

S/RES/2010, on 30 September 2011.

S/RES/2015, on 24 October 2011.

S/RES/2142, on 5 March 2014.

S/RES/2158, on 29 May 2014.

S/RES/2221, on 26 May 2015.

S/RES/2232, on 28 July 2015.

S/RES/2275, on 24 March 2016.

S/RES/2289, on 27 May 2016.

S/RES/2297, on 7 July 2016.

S/RES/2444, on 14 November 2018.

S/RES/2500, on 4 December 2019.

The Need for Legal Regulation of Blockchain and Smart Contracts in the Shipping Industry

Marko Perkušić[a], Šime Jozipović[b], Damir Piplica[a]

The paper analyzes the potential impact of blockchain technology and smart contracts on the shipping industry. As the shipping industry represents a complex system of various actions that have to be controlled and registered, blockchain technology could serve as a tool to allow the streamlining of numerous processes, whilst at the same time taking the human factor out of multiple elements where trust between involved parties is an issue. The authors therefore first present how blockchain technology works and what smart contracts are, in order to give an insight into their applicability in the shipping sector. After a general overview of the technological and legal characteristics of blockchain technology and smart contracts, the authors present examples of relevant subjects, relations, and contracts in the shipping industry. Based on the charter party, a key contract in the shipping industry, the authors present the existing problems which could potentially be solved using blockchain technology. Besides the benefits of blockchain technologies, the authors furthermore point out the existing deficiencies that still make blockchain technology hard to apply in legal relations within the shipping industry. Based on these insights, the authors highlight the current developments in this area and present the existing and expected regulatory reforms of blockchain solutions and smart contracts within the European Union.

KEY WORDS
~ Blockchain
~ Smart contracts
~ Shipping industry
~ Shipping contracts
~ Charter party

a. University of Split, Department of Forensic Science, Split, Croatia
e-mail: maperku@gmail.com
b. , University of Split, Faculty of Economies, Bussiness and Tourism, Split, Croatia
e-mail: sime.jozipovic@efst.hr

doi: 10.7225/toms.v09.n02.019

1. INTRODUCTION

When someone mentions blockchain or smart contracts, most people will immediately think of virtual currencies like bitcoin, Litecoin, or ether. This is because both blockchain technology and smart contracts, as we know them today, originated from virtual currencies. In fact, the success of cryptocurrency like Bitcoin is one of the main arguments that advocates of blockchain point out when discussing the potential impact of this technology. However, blockchain and smart contracts are slowly starting to be used in other areas, such as insurance, construction, stock markets[1], and of the course shipping industry.[2] Because of its complexity and its essential

1. *Perkušić, M. (2019): Legal Issues of Electronic Payment, Doctoral Dissertation, University of Rijeka, Faculty of Law, p. 399.*
2. *Some authors look at blockchain as a purpose technology that will be able to increase productivity, while others see blockchain as a technology that will change industrial organization. Blossey, G., Eisenhardt, J., Hahn, G. J. (2019): Blockchain Technology in Supply Chain Management: An Application Perspective, Proceedings of the 52nd Hawaii International Conference on System Sciences|2019, URI: https://hdl.handle.net/10125/60124 ISBN: 978-0-9981331-2-6 (CCBY-NC-ND4.0) p. 6886. ; Tapscott, D., Tapscott, A. (2017): "How blockchain will change organizations," MIT Sloan Management Review, vol. 58, no. 2, pp. 10–13. ; Babich, V., Hilary, G. (2018): "Distributed ledgers and operations: What operations management researchers should know about blockchain technology," SSRN Electronic Journal.*

value to the global market,[3] the shipping industry is being placed in the very center of the adaptation of blockchain and smart contracts into their way of functioning.[4] Numerous companies, countries, and academic institutions are working to implement blockchain technology. However, despite those efforts, the shipping industry has still proven to be resilient to the new technical and technological advancements. Various studies[5] have shown that the reason for this is primarily linked to the nature of business between legal entities in the shipping industry[6], while other authors have highlighted the need for regulation as a prerequisite for the growth of this field[7]. For this reason we are going to analyze the inner workings of blockchain and smart contracts, where they can be used (or are already being used) in the shipping industry (especially between legal entities) and identify the existing regulations that could apply to blockchain and smart contracts in the shipping industry. Based on the above conducted analysis, we then intend to determine whether there is a need for special regulation of blockchain and smart contracts in the shipping industry, which could help in their general application in order to reduce costs, save time, and generally increase the trust in the entire process[8].

2. BLOCKCHAIN OVERVIEW

As has been already mentioned above, blockchain technology originates from virtual currencies, bitcoin cryptocurrency to be exact,[9] and as such has been analyzed many times.[10] That is why we are only going to point out the main features of blockchain, as well as its segmentation into public and permissioned blockchain which is important in establishing the way in which a blockchain could fulfill all the requirements of the shipping industry.

Before defining blockchain we have to emphasize that there is not a general definition of blockchain that is widely accepted. There is rather a wide range of definitions in which authors are looking at blockchain from different aspects. Having that fact and the subject of our paper in mind, we deem that blockchain can be defined as "a distributed database, which is shared among and agreed upon a peer-to-peer network. It consists of a linked sequence of blocks, holding timestamped transactions that are secured by cryptography and verified by the network community. Once an element is appended to the blockchain, it cannot be altered, turning a blockchain into an immutable record of past activity".[11] From that definition we can conclude that the main characteristics of blockchain are:

- It is a distributed database (data is not saved in one place, rather it is dispersed through a network of interconnected computers),
- It is shared among and agreed upon by peer-to-peer network (peers make a peer-to-peer network and they are equal participants who enable a network to function for all participants without the need for central coordination, and they do so by allowing their computers to perform the tasks the network requires),

3. *United Nations Conference on Trade and Development (UNCTAD) and the International Maritime Organization (IMO) have estimated that „in 2016 approximately 90% of world trade was transported by sea". Di Gregorio, R., Skjærset Nustad, S. (2017): Blockchain adoption in the shipping industry, A study of adoption likelihood and scenario-based opportunities and risks for IT service providers, Copenhagen Business School, Number of STUs: 272,322, p. 5.*
4. *It is stated that "blockchain implementation in the world of global trade could shake up traditional processes through automation and decentralization". Clott, C., Hartman, B., Beidler, B. (2020): Maritime Supply Chains, Chapter 10 - Sustainable blockchain technology in the maritime shipping industry, Elsevier Inc., p. 211.*
5. *Acciaro, M., Ferrari, C., Lam, J. S. L., Macario, R., Roumboutsos, A., Sys, C., et al. (2018): Are the innovation processes in seaport terminal operations successful? Maritime Policy & Management, 45, p. 787–802. ; Vanelslander, T., Sys, C., Carlan, V. (2016): Innovation among seaport operators: A QCA approach for determining success conditions, International Journal of Transport Economics, 43, p. 291–314. ; Arduino, G., Aronietis, R., Crozet, Y., Frouws, K., Ferrari, C., et al. (2013): How to turn an innovative concept into a success? An application to seaport-related innovation, Research in Transportation Economics, Volume 42, Issue 1, June 2013., p. 97-107.*
6. *Bavassano, G., Ferrari, C., Tei, A. (2020): Blockchain: How shipping industry is dealing with the ultimate technological leap, Research in Transportation Business & Management 34, 100428, available at: www.elsevier.com/locate/rtbm, accessed: 8. September 2020.*
7. *Pečarić M. , Peronja I., Mostarac M. (2020)*: Application of "blockchain" and "smart contract" tehnology in international payments – the case of reimbursement banks, /Scientific Journal of Maritime Research/ 34 (2020) 166-177 , Faculty of Maritime Studies Rijeka, p. 176 f.*
8. *As an example of current situation we can point out that "inter-firm information sharing systems are outdated and manual processes still prevail in the majority of its supply chain. This results in a lack of coordination among industry actors, poses security risks and an increased workload for authorities, reduces trust between parties doing business in the industry, and ultimately reduces the overall efficiency of business processes". Di Gregorio, R., Skjærset Nustad, S. (2017): op. cit. p. 6.; Jensen, T., Bjørn-Andersen, N., Vatrapu, R. (2014): Avocados crossing borders. Proceedings of the 5th ACM international conference on Collaboration across boundaries: culture, distance & technology - CABS '14.*
9. *Satoshi Nakamoto (creator of bitcoin) defines a bitcoin as "a chain of digital signatures recorded by a distributed time-stamp server in a cryptographically secured ledger called the Block Chain". Pflaum, I., Hateley, E. (2014): A bit of a problem: National and extraterritorial regulation of virtual currency in the age of financial disintermediation, Georgetown Journal of International Law, vol. 45, p. 1174. ; Nakamoto, S. (2008): Bitcoin: A Peer-to-Peer Electronic Cash System, available at: https://bitcoin.org/bitcoin.pdf, accessed: 8. September 2020., p. 1.*
10. *See Kiviat, T. I. (2015): Beyond Bitcoin: Issues In Regulating Blockchain Transactions, 65 Duke Law Journal; Kütük-Markendorf, M. E. (2016): Rechtliche Einordnung von Internetwährungen im deutschen Rechtssystem am Beispiel von Bitcoin, PL Academic Research; Blocher, W. (2016): The next big thing: Blockchain – Bitcoin – Smart Contracts, 71. Deutsche Juristentag – Anwaltsblatt 8-9. ; Ryan, P. (2017): Smart Contract Relations in e-Commerce: Legal Implications of Exchanges Conducted on the Blockchain, Technology Innovation Management Review, Volume 7, Issue 10. ; Bouidani, M. M. (2019): Design and Implementation of Blockchain Shipping Application, A Thesis Submitted in Partial Fulfilment of the Requirements for Degree of Master of Applied Science in the Department of Electrical and Computer Engineering, University of Victoria.*
11. *Seebacher, S., Schüritz, R. (2017): Blockchain Technology as an Enabler of Service Systems: A Structured Literature Review. Lecture Notes in Business Information Processing Exploring Services Science, p. 14.*

- It consists of a linked sequence of blocks (records in blockchain are stored through blocks which contain data and are connected with one another through a cryptographic authentication called hashing which then forms a blockchain),
- It uses timestamps (data points that show when each block was connected in a chronological order and it is tamper-proof),
- It is secured by cryptography (a system that links blocks together and enables secure transmission and exchange of digital data in a decentralized manner),
- It is verified by the network community (no centralized authority exists but all verification is conducted by peers),
- It cannot be altered (to alter the existing data on a blockchain one would have to do it retroactively and need to alter all subsequent blocks. To be able to do this one would have to have the consensus of the network majority).

As we have already mentioned, blockchain is divided into public and permissioned blockchain. The main characteristic of a public blockchain (which most of cryptocurrencies are using) is that anyone can use the protocol and be a part of a peer-to-peer network. This openness makes the network transparent and decentralized. A permissioned blockchain is very similar to a public one. The main difference is, however, that it is not open, which means that if someone wants to join the network he or she needs permission, therefore only an agreed set of readers and writers have the authorization to interact with the blockchain.[12] There is a further division of permissioned blockchain into consortium blockchain and private blockchain.[13] The difference is that in a consortium blockchain there is a consortium of parties that has a common interest in some ledger,[14] while private blockchain is used by a private company for internal use.[15] In recent years permissioned blockchain is becoming more and more popular, especially between entities that have a certain degree of trust between each other and do not want their data (like contacts in digital form) to be saved on a public network, even though there are ways to keep certain information private on the public blockchain.[16] Because of that certain degree of trust between the entities that use permissioned blockchain, consensus mechanisms are much easier to use in permissioned blockchain and, due to this fact, it is cheaper and faster than public blockchain. However, if entities do not trust each other, only a public blockchain can completely protect them in a way they know that nobody could have modified the stored data. The above mentioned segmentation of blockchain, as well as its definition and main characteristics, will be important when we come to the part of this paper where we establish in which aspects of the shipping industry blockchain could be generally used and what form of blockchain would be most suitable for it.

3. SMART CONTRACTS OVERVIEW

The idea of a smart contract was created by Nick Szabo in 1994 when he defined a smart contract as a "computerized transaction protocol that executes the terms of a contract".[17] However, the first smart contract system was created in 2014 on the Ethereum platform, using Ehter cryptocurrency and functions with public blockchain technology.

Even though it is called a smart contract, from a legal point of view, we believe that smart contracts are not primarily contracts or forms of a contract, but usually a way to implement or execute a contract.[18] Therefore, smart contracts can be defined as a way of executing predefined criteria and conditions on which two or more parties agree to in order for them to execute themselves independently using computer code located on the blockchain network.[19] The basic configuration of smart contracts consists of four phases:

1. The conclusion a contract whose terms and conditions are then being translated into a code;
2. The chain of events where the obligations defined in the contract begin to be fulfilled;
3. The If-this-then-that phase where the code activates the transfer of value, if terms and conditions are met;
4. The settlement where contractual obligations have been fulfilled and saved on the blockchain.[20]

There are many positive aspects of smart contracts that are often highlighted in academic literature. For example, their ability

12. *Harshvardhan (2018): Improving shipping contracts with the use of emerging technologies, Master of Engineering in Supply Chain Management at the Massachusetts Institute of Technology, p. 24.*
13. *Buterin, V. (2015): "Crypto Renaissance Salon - On Public and Private Blockchains", retrieved from https://blog.ethereum.org/20l5/08/07/on-public-and-private-blockchains; Harshvardhan (2018): op. cit. p. 24.*
14. *Similar division of blockchain is also made where blockchain is divided on public blockchain, fully private blockchain, and federated or consortium blockchain for which it is highlighted that it is mostly used in banking sector. Jain, P. (2018): Improving the process of container shipping using blockchain, Master of Applied Science in Supply Chain Management at the Massachusetts Institute of Technology, p. 15-16.*
15. *Buterin, V. (2015): "Crypto Renaissance Salon - On Public and Private Blockchains", retrieved from https://blog.ethereum.org/20l5/08/07/on-public-and-private-blockchains; Harshvardhan (2018): op. cit. p. 24.*
16. *For example by using zk-SNARK Technique (Zero-Knowledge Succinct Non-Interactive Argument of Knowledge). Harshvardhan (2018): op. cit. p. 25.*
17. *Szabo, N. (1994): Smart Contracts, retrived from: http://www.fon.hum.uva.nl/rob/Courses/InformationInSpeech/CDROM/Literature/LOTwinterschool2006/szabo.best.vwh.net/smart.contracts.html; Gans, J. S. (2019): The fine print in smart contracts, NBER Working Paper Series, Working Paper 25443, available at: http://www.nber.org/papers/w25443, p. 2.*
18. *Perkušić, M, Jozipović, Š., Mamut, J. (2020): Mogućnosti korištenja i pravnog uređenja tzv. pametnih ugovora u Republici Hrvatskoj, Slakoper, Z., Tot, I. (ur.), Hrvatsko obvezno pravo u poredbeno-pravnom kontekstu: Petnaest godina Zakona o obveznom odnosima, Ekonomski fakultet Sveučilišta u Zagrebu, Zagreb, p. 8.*
19. *Perkušić, M, Jozipović, Š., Mamut, J. (2020): op. cit. p. 8.*
20. *See similar Pilavci, E. E. (2019): The Regulation of Smart Contracts: Law, Governance and Practice, İSTANBUL BİLGİ ÜNİVERSİTESİ LİSANSÜSTÜ PROGRAMLAR ENSTİTÜSÜ BİLİŞİM VE TEKNOLOJİ HUKUKU YÜKSEK LİSANS PROGRAMI, p. 8.-*

to increase contractibility and facilitate exchange of anything of value (money, shares, service, etc.) without conflict and in an algorithmically automated way.[21] Smart contracts are often being compared with conventional contracts, even though they are not perfectly comparable. As key benefits of smart contracts it is for example pointed out that they: (1) reduce risks as they are saved on an inalterable blockchain, (2) cut down administration and service costs as automation substitutes the need for a mediator or a central broker, and (3) improve the efficiency of business processes by cutting out intermediaries from the process[22] Although there are many benefits of smart contracts, later in this paper we show how they are used (or are attempted to be used) in the shipping industry, and we analyze the problems that emerge in their application in practice.

4. PROBLEMS OF THE SHIPPING INDUSTRY

Although the business of moving cargo from point A to point B on the surface might seem as a rather simple endeavour, the modern shipping industry is a complex amalgamation of various activities, businesses entities, and often diverging interests of involved parties. As an example we can use the tanker shipping market and the contracts related to this area. In a typical movement of liquid bulk cargo[23] from one port to another, multiple legal entities are involved, namely:

- The Consignor (supplier) – is engaged in exporting the commodity which he has produced or purchased from a producer;
- The Consignee (receiver) – is the importer of the commodity;
- Port terminals – act as facilitators of loading and unloading operations aboard a ship;
- Port authorities – navigate ships within their waters and are responsible for their safe navigation;
- Traders – find demand-supply gaps and trade with that commodity to make a profit;
- Charterers – handle logistics for movement of commodity for traders and are often part of the same organization as the traders;
- Ship-owner – (in this context) can be a group of companies or individuals that make sure that a ship always has a cargo to move;
- Brokers – are intermediaries between charterers and ship-owners, and
- Port agents – are local representatives of charterers and ship-owners that help with the logistics and communication at each port.[24]

It is clear that various agreements occur between all these legal entities, but as the most important contract for this paper we can single out the *Charter Party* which is a contract between ship-owner and charterer for the transport of commodity on the sea.[25] Based on the example of the Charter party, we can show how the whole system generally works and we can point out shortcomings of the system. The whole process starts with the trader who finds a demand-supply gap through which he can profit from the margin. After finding that gap the trader makes a deal with the consignor (supplier) and the consignee (receiver), and then he gives a task to the charterer to arrange the shipping of that commodity. The charterer contacts his brokers and gives them the data on the cargo that needs to be transported. Brokers then look for an available ship that can transport that cargo. After finding a suitable ship, brokers connect those parties which then start to negotiate the terms and conditions of the carriage. If they can agree on terms and conditions of the contract, they then sign the contract, physically or via email.[26] After the contract is concluded, the ship transports the cargo to the agreed port and meets its obligations from the contract. If the terms and conditions of a contract have all been met by the ship-owner, the charterer makes the transfer of funds and so the contract is fulfilled from both parties.[27]

As we can see from the example of the tanker shipping market and Charter party, the process of moving cargo from point A to point B requires a lot of intermediaries, paperwork,

21. *Chong, L. W., He, Z. (2019): Blockchain Disruption and Smart Contracts, The Review of Finanial Studies I v 32 n 5, p. 1762.*
22. *Zheng, Z., Xie, S., Dai, H., Chen, W., Chen, X., Weng, J., Irman, M. (2019): An Overview on Smart Contracts: Challenges, Advances and Platforms, Journal Pre-proof, To appear in : Future Generation Computer Systems, PII: S0167-739X(19)31628-0, DOI: http://doi.org/10.1016/j.future.2019.12.2019., p. 2.*
23. *Bulk shipping is transport of bulk commodities that represent large parcels of semi-manufactured goods and raw materials (coal, grain, oil, etc.). Similar to bulk shipping, there are liner shipping and specialized shipping. Liner shipping represents transport of small parcels of semi-manufactured and manufactured goods (general cargo), while specialized shipping represents transport of large consignments of goods which are difficult to handle (cars, trucks, liquefied natural gas, etc.). Di Gregorio, R., Skjærset Nustad, S. (2017): op. cit. p. 13-14. ; Stopford, M. (2009): Maritime economics, London: Routledge.*
24. *Harshvardhan (2018): op. cit. p. 9-10.*
25. *Harshvardhan (2018): op. cit. p. 11.*
26. *Directive 2000/31/EC of the European Parliament and of the Council of 8th June 2000 on certain legal aspects of information society services, in particular electronic commerce, in the Internal Market ('Directive on electronic commerce'), Official Journal L 178 , 17/07/2000 P. 0001 – 0016, in Article 9, Paragraph 1, states that Member States shall ensure that their legal system allows contracts to be concluded by electronic means and that the legal requirements applicable to the contractual process neither create obstacles for the use of electronic contracts nor result in such contracts being deprived of legal effectiveness and validity on account of their having been made by electronic means. Paragraph 2 of the same Article states that Paragraph 1 shall not apply to all or certain contracts that fall into the categories that Paragraph 2 then explains. Charter Party does not fall into the categories that are explained further in Paragraph 2, and because of that there are no obstacle for Charter Party to be concluded in electronic form on the territory of the European Union.*
27. *For more detail about Charter Party and how it works in practice see Harshvardhan (2018): op. cit. p. 11-14.*

time and money. As the main problems we can emphasize:

- Waste of time while all these legal entities find each other;
- Exhaustive and slow negotiations about terms and conditions of the contract;
- High costs for intermediaries;
- Extensive documentation that maintains a trail between several contracting parties who communicate on multiple channels;
- Poor document management (some documents, such as the Bill of Lading,[28] still need to be delivered in the original to the cargo receivers, which in the past has frequently caused delays in cases where the original of the Bill of Lading was not received on time),
- Constant need to be online in order to find clients and monitor market trends, and
- Slow international fund transfers that take several day to arrive.[29]

5. USE OF BLOCKCHAIN AND SMART CONTRACTS IN THE SHIPPING INDUSTRY

5.1. Aspects of the Shipping Industry Where Blockchain and Smart Contracts Could Generally Apply

Because the above mentioned problems in the shipping industry are widespread in various segments of the industry, many stakeholders (companies, countries, ports, and government authorities) are trying to find solutions through the implementation of modern technologies. This search for a new way to tackle the numerous issues of maritime transport have accelerated since blockchain and smart contracts entered the market. Today a majority of innovative solutions and new approaches are based on these technologies.

In 2015 Israel's Wave Company started trying to implement blockchain in solving the problems of inconsistent Electronic Data Interchange and lack of trust, while in 2016 Hong Kong's Chain of Things started researching the sharing of IoT (Internet of Things)[30] information (through blockchain), collected with the sensors on ships and containers to relevant parties.[31] However, the big breakthrough of blockchain solutions in the shipping industry came in 2017, when shipping giant Maersk and his partners (IBM, Schneider Electronic, etc.)[32] announced that they have a blockchain solution for digitizing global trade.[33] By using the earlier described advantages of blockchain, Maersk Group deem it can cut the costs of administration and processing of physical documents[34], stop fraud, especially in undeveloped markets, as well as cyber-attacks.[35] After Maersk Group, other important actors in the shipping industry (such as Hyundai Merchant Marine, Samsung SDM, Mitsui OSK Lines, etc.) started to look for their own blockchain solutions. As a result of such great interest there are solutions, based on blockchain and smart contracts, for:

- More efficient inter-firm information sharing system;[36]
- Simplifying paper process;
- Combating cargo fraud;
- Improving container utilization efficiency, and
- Saving precipitation cost of funds.[37]

Most of the above solutions are primarily based on blockchain, but there are also aspects of the shipping industry where smart contracts can have a very important role. For example, blockchain based smart contracts could be used to:

- Track the Bill of Lading and automate fund transfers[38];
- Execute a Charter Party agreement;
- Initiate a fund transfer between a ship owner and a charterer, and
- Calculate hire and demurrages based on a pre-defined formula.[39]

Another interesting approach to implementation of blockchain solutions in the shipping industry is made by Hong Kong based startup 300Cubits. Most of the other companies avoid bringing cryptocurrencies into the shipping industry

28. *Bill of Ladding is a legal document (record of the traded goods) issued by a carrier (or their agent) to a shipper to acknowledge receipt of cargo for shipment. It contains details about the type, quantity, and destination of the cargo.*
29. *See Harshvardhan (2018): op. cit. p. 15-17.*
30. *For a more detailed description of sharing of IoT information through blockchain see Si, H., Sun, C., Li, Y., Qiao, H., Shi, L. (2019): IoT information sharing security mechanism based on blockchain technology, Future Generation Computer Systems 101 p. 1028-1040., journal homepage: www.elsevier.com/locate/fgcs.*
31. *Shi, H., Wang, X. (2018): Research on the Development Path of Blockchain in Shipping Industry, APCIM & ICTTE, Beijing, China, Association for Computing Machinery. ACM ISBN 978-1-4503-6604-5/18/11…$15.00 https://doi.org/10.1145/3321619.3321671, p. 244-245.*
32. *In the Case M.8742 - IBM / MAERSK / GTD JV, European Commission has concluded that the notified operation (between Maersk, IBM and GTD JV) falls within the scope of the Merger Regulation and it declared it compatible with the internal market. Available at: https://ec.europa.eu/competition/mergers/cases/decisions/m8742_181_3.pdf?fbclid=IwAR1Mq-o4g-wRytQ_OL-EBCsfuowI9fKmviiBMhuRq66m4_Jz2OFi5pahE38, accessed: 25. September 2020.*
33. *They released TradeLens platform that offers "real-time access to shipping data and shipping documents, including IoT and sensor data". Irannezhad, E. (2018): Is blockchain a solution for logistics and freight transportation problems? Transportation Research Procedia 00 (2018) 000-000, World Conference on Transport Research – WCTR 2019 Mumbai 26-31 May 2019, p. 3.*
34. *It is estimated that from overall physical transportation costs, 1/5th goes on administration and processing of physical documents.*
35. *Di Gregorio, R., Skjærset Nustad, S. (2017): op. cit. p. 25-26.*
36. *Jensen, T., Bjørn-Andersen, N. & Vatrapu, R. (2014): Avocados crossing borders. Proceedings of the 5th ACM international conference on Collaboration across boundaries: culture, distance & technology - CABS '14.*
37. *Shi, H., Wang, X. (2018): op. cit. p. 245.*
38. *By using smart contracts fund transfers could be automated, without intermediaries and with reduced costs. Papathanasiou A., Cole R., Murray, P. (2020): The (non-)application of blockchain technology in the Greek shipping industry, European Management Journal, doi: https:// doi.org/10.1016/j.emj.2020.04.007.*
39. *Harshvardhan (2018): op. cit. p. 30.*

because of the extra complications that could emerge by using unregulated virtual value, but 300Cubits is trying to launch its own cryptocurrency (based on blockchain) for the shipping industry that would be used as deposit during the booking process, whereby the shipper would lose his deposit if he should fail to show up with the cargo, and the container line would lose its deposit if it failed to load the cargo according to the agreement.[40]

5.2. Difficulties in Applying Blockchain and Smart Contracts in the Shipping Industry

Although there are many ways of using blockchain and smart contracts in the shipping industry, the fact is that none of the mentioned solutions are widely accepted and used in the shipping industry. There are many reasons why the existing solutions are not widely accepted, but as the main factors we can emphasize the following:

- Blockchain applications are still not so easy to use and cheap enough to force changes in the existing system;
- In order to function properly, blockchain based solutions require wider usage, which in turn means that different stakeholders would need to join a broad consortiu[41] and, as we have already mentioned, blockchain based solutions are still not at that level of cost-effectiveness to force the creation of such consortium;
- There are still many economic and technology promotion barriers which need to be fully resolved before the general acceptance of blockchain based solutions in the shipping industry.[42]

6. THE ROLE OF THE INTERNATIONAL MARITIME ORGANIZATION (IMO)

The International Maritime Organization (IMO) is a specialized agency of the United Nations and it is in charge of the safety, security, and environmental performance (prevention of marine and atmospheric pollution) of international shipping, which transports more than 80 per cent of global trade.[43] The main purpose of IMO is to create a fair and effective regulatory framework (through conventions) for the shipping industry that can be universally adopted and implemented.[44] Conventions for which the IMO is responsible can be classified into four categories:

- maritime safety
- prevention of marine pollution
- liability and compensation (especially in relation to damage caused by pollution), and
- other conventions that deal with e.g. tonnage measurement, unlawful acts against shipping and salvage, etc.[45]

From the above we can conclude that IMO measures cover a lot of aspects of international shipping, but the process of contracting between legal entities, as well as the new technologies in the shipping industry, are largely governed by free-market practices and the conventions of the IMO do not delve significantly into that area. That is why we do not see the IMO as an institution that would take the lead in the regulation of blockchain and smart contracts. Therefore, we deem that it is necessary to look somewhere else for the solution that could help in the general application of blockchain and smart contract in the shipping industry.

7. REGULATION OF BLOCKCHAIN AND SMART CONTRACTS IN THE EUROPEAN UNION (EU)

Around one third of the world's merchant fleet is controlled out of Europe. Europe is thus one of the leading maritime centers of the world (it has 329 key seaports on its coastline).[46] The European Union has realized the importance of maritime trade, which, amongst other things, constitutes over 75% of its external trade and about 1/3 of its internal trade.[47] It is therefore not surprising that the EU has put in place an extensive legislative framework for safety, environmental protection and quality shipping, which covers the entire shipping chain. An essential aspect of the modernization of shipping regulation and administration is the process of digitalization and administrative simplification - the so-called European Maritime Single Window environment[48].

The European Parliament and the Council adopted Directive 2010/65/EU on reporting formalities for ships arriving in and/or departing from ports of the Member States on October 20th 2010. It created an environment that allows for the digital and centralized submission of information. The Maritime Single Window involves a rather large number of authorities, including transport, customs, border control, safety, security, health

40. *Di Gregorio, R., Skjærset Nustad, S. (2017): op. cit. p. 28.*
41. *See Harshvardhan (2018): op. cit. p. 74.*
42. *For more details about economic and technology promotion barriers see Shi, H., Wang, X. (2018): op. cit. p. 246-247.*
43. *See http://www.imo.org/en/About/Pages/Default.aspx, accessed: 22. September 2020.*
44. *See http://www.imo.org/en/About/Pages/Default.aspx, accessed: 22. September 2020.*
45. *See http://www.imo.org/en/About/Conventions/Pages/Home.aspx, accessed: 22. September 2020.*
46. *See https://ec.europa.eu/transport/modes/maritime/maritime-transport_en, accessed: 28. September 2020.*
47. *See https://ec.europa.eu/transport/modes/maritime/maritime-transport_en, accessed: 28. September 2020.*
48. *https://ec.europa.eu/transport/modes/maritime/digital-services/e-maritime_en, accessed: 28. September 2020.*

and environment[49]. However, it currently however does not allow for a fully harmonized application. Therefore, the Valletta Declaration was endorsed by the Council of the EU on 08 June, 2017[50], highlighting the need for a fully harmonized interface and a standardized maximum data set, including the information necessary for the management of port and port terminals. All the presented measures make it clear that the European Union has put a significant focus on the modernization and digitalization of the shipping industry in general.

However, besides the general regulation of the digitalization process in the shipping industry, the European Union has also taken significant steps in the regulation of virtual currencies. Through the European directive on the prevention of money laundering and terrorist financing, the term „virtual currency" was defined.[51] A "virtual currency" is a means of exchange accepted by natural or legal persons which can be transferred, stored, and traded electronically and that is not issued or guaranteed by a central bank or a public authority.[52] As such virtual currency is of relevance in the context of shipping regulation in cases where shipping contracts are structured based on block-chain or smart contract solutions that use virtual currency as a means of exchange or insurance. However, the mentioned directive does not regulate blockchain or smart contracts itself.

This is not due to the European Union not being aware of the potential of block-chain technology, but rather a consequence of the early stage and an uncertain direction this technology might take in the future. The European Commission considers blockchain to be a new technology that makes it possible for large groups of people or organizations, regardless of trust amongst them, to collectively agree on and permanently record information without the need of a third-party authority.[53] As such, the Commission realizes the potential value of this technology and it has approached the technological developments regarding blockchain and smart contracts through the creation of a broad EC blockchain strategy containing the creation of a European blockchain partnership[54], as well as the promotion of legal certainty and establishment of interoperability standards.[55] Amongst other factors, the European Commission and other European bodies have established numerous expert groups and units like the Digital Innovation and Blockchain unit that is managing the Startup Europe and Innovation Radar initiative.[56] In combination with the already mentioned efforts to modernize the shipping industry and establish an EU wide framework in this field, it can be expected that the European Union will be at the forefront of the regulation and implementation of blockchain integration in the shipping sector.

8. CONCLUSION

Although the current attempts to implement blockchain and smart contracts in the shipping industry look promising, the analysis has shown that there are still many obstacles to overcome before blockchain and smart contracts can fully replace the existing system in the shipping industry. Many legal entities in the shipping industry are accustomed to the current system and, even though it has a lot of flaws, the complexity of shipping contractual relations makes it hard to substitute it with anything that has not previously been examined and stress tested. Therefore any new system will have to be impeccable in order to force the diverse stakeholders to join it. It is especially important to note that the previously defined stakeholders will have vastly different interest in the technology. As presented above on the example of a charter party regarding a tanker shipping operation, multiple intermediaries are involved in the entire process. It is clear that it is rather unlikely that those intermediaries have an interest in the creation of a system that would make their role obsolete or at least significantly less relevant. Therefore those subjects will either offer the most intense pushback to the technology or in time attempt to adapt their business model to the new system. Port authorities will usually be much more focused on the above mentioned public law dimension of digitalization as they work closely with numerous agencies and government organizations. Modernization for those authorities will therefore primarily be focused on the above described streamlining of procedures and the information transfer. The various other stakeholders involved in the process have, however, a strong primary interest in the civil law dimension of modernization, namely the creation of safe and effective smart contracts based on blockchain technology.

Based on this assessment the next logical question relates to the structure of a blockchain shipping contract or blockchain

49. *In detail on the national application of the Maritim Single Window see: EUROPEAN COMMISSION DIRECTORATE-GENERAL FOR MOBILITY AND TRANSPORT Directorate D - Logistics, maritime & land transport and passenger rights D.1 - Maritime transport & logistics National Single Window Guidelines, from April 17th 2015, available under https://ec.europa.eu/transport/sites/transport/files/modes/maritime/doc/2015-06-11-nswguidelines-final.pdf.*
50. *Declaration of the European Ministers responsible for the Integrated Maritime Policy on Blue Growth - Valletta Declaration - 8037/17 KS/lo 1 GIP 1B.*
51. *Directive (EU) 2018/843 of the European Parliament and of the Council of 30 May 2018 amending Directive (EU) 2015/849 on the prevention of the use of the financial system for the purposes of money laundering or terrorist financing, and amending Directives 2009/138/EC and 2013/36/EU (Text with EEA relevance) PE/72/2017/REV/1, OJ L 156, 19.6.2018, p. 43–74.*
52. *Directive (EU) 2018/843, Article 1, (2) d nr. 18 Amendments to Directive (EU) 2015/849.*
53. *https://ec.europa.eu/digital-single-market/en/blockchain-technologies, accessed: 28. September 2020.*
54. *https://ec.europa.eu/digital-single-market/en/news/european-countries-join-blockchain-partnership, accessed: 28. September 2020.*
55. *https://ec.europa.eu/digital-single-market/en/blockchain-technologies, accessed: 28. September 2020.*
56. *https://ec.europa.eu/digital-single-market/en/content/digital-innovation-and-blockchain-unit-f3, accessed: 28. September 2020.*

shipping system in general. Two options come to mind, a consortium based approach and an open approach. An open approach could benefit from integration with various external stakeholders. By using datasets from public authorities that could be made available under special legal agreements and entered directly into the blockchain, the system could receive numerous external data entry points from reliable sources. This system would however require a close collaboration with multiple public authorities. Furthermore, this would raise issues relating to data protection, while the responsibility for entry errors would also have to be assigned. Due to the involved risks and challenges, it is therefore to be expected that, despite the above mentioned efforts of the EU to embrace blockchain technology, the private sector will be at the forefront of these developments.

The lack of data entry points related to generally trusted, responsible, and liquid subjects in the form of public authorities, however, will require that stakeholders in a blockchain system to have at least a basic level of trust amongst each other, in order to ensure a common interest in the general functionality of the system. This will certainly lead to the focusing on consortium based blockchain solutions. These solutions might be still related to information that is also delivered to public authorities or other bodies. However, the responsibility for data entry is most likely to be assigned to the private subjects that are issuing or controlling certain data.

Therefore, it is our opinion that the future of blockchain technology in the shipping sector will be based on a broad consortium based approach for the general use of the new system based on blockchain and smart contracts. Blockchain technology is developing quickly and it is rapidly becoming more practical, cheaper, faster, and more convenient to adopt. If we add artificial intelligence solutions, such as Natural Language Processing (NLP), into our considerations, we are certain that new consortium based blockchain systems will be ready within a reasonable timeframe to replace the current traditional systems. In this regard it is important to point out that early adaptations of such systems will certainly require complex and wide reaching traditional consortium contracts, in order to establish a basic level of trust, necessary for the system to function properly in the first place. Starting from consortium based solutions, however, it could in the future be possible that other stakeholders, especially the EU and its member states, enter this field, both through regulation, as well as through an active involvement in the systems.

From the above considerations we can conclude that at this point in time there is still no need for legal regulation of blockchain and smart contracts in the shipping industry. This is because it is currently unclear how the new system will be designed before it can fully replace the existing organization of the shipping industry. The very minimum of information for adequate regulation would be to know which entities will be involved in the system, what their rights and obligations will be, and how a verification system will be designed. While we have some indicators, showing that stakeholders will be the main driving forces behind the technologies, this is not enough to present an entire legal framework. Furthermore, the roles of all participants will strongly depend on the technical feasibility of certain solutions and the specific arrangements between the involved parties. Therefore it is still too early to identify the necessary facts to create a quality regulatory framework, whereby it is better to wait for the system to evolve, rather than to act prematurely by overregulating this field, thereby preventing its development.

REFERENCES

Acciaro, M. et al., 2018. Are the innovation processes in seaport terminal operations successful? Maritime Policy & Management, 45(6), pp.787–802. Available at: http://dx.doi.org/10.1080/03088839.2018.1466062.

Arduino, G. et al., 2013. How to turn an innovative concept into a success? An application to seaport-related innovation. Research in Transportation Economics, 42(1), pp.97–107. Available at: http://dx.doi.org/10.1016/j.retrec.2012.11.002.

Babich, V. & Hilary, G., 2018. What Operations Management Researchers Should Know About Blockchain Technology. SSRN Electronic Journal. Available at: http://dx.doi.org/10.2139/ssrn.3131250.

Bavassano, G., Ferrari, C. & Tei, A., 2020. Blockchain: How shipping industry is dealing with the ultimate technological leap. Research in Transportation Business & Management, 34, p.100428. Available at: http://dx.doi.org/10.1016/j.rtbm.2020.100428.

Blocher, W., 2016. The next big thing: Blockchain – Bitcoin – Smart Contracts, 71. Deutsche Juristentag – Anwaltsblatt 8-9.

Blossey, G., Eisenhardt, J. & Hahn, G., 2019. Blockchain Technology in Supply Chain Management: An Application Perspective. Proceedings of the 52nd Hawaii International Conference on System Sciences. Available at: http://dx.doi.org/10.24251/hicss.2019.824.

Bouidani, M.M., 2019. Design and Implementation of Blockchain Shipping Application, A Thesis Submitted in Partial Fulfilment of the Requirements for Degree of Master of Applied Science in the Department of Electrical and Computer Engineering, University of Victoria.

Buterin, V., 2015. Crypto Renaissance Salon - On Public and Private Blockchains. Available at: https://blog.ethereum.org/20l5/08/07/on-public-and-private-blockchains.

Clott, C., Hartman, B. & Beidler, B., 2020. Sustainable blockchain technology in the maritime shipping industry. Maritime Supply Chains, pp.207–228. Available at: http://dx.doi.org/10.1016/b978-0-12-818421-9.00011-2.

Cong, L.W. & He, Z., 2019. Blockchain Disruption and Smart Contracts. The Review of Financial Studies, 32(5), pp.1754–1797. Available at: http://dx.doi.org/10.1093/rfs/hhz007.

Di Gregorio, R., Skjærset Nustad, S., 2017. Blockchain adoption in the shipping industry, A study of adoption likelihood and scenario-based opportunities and risks for IT service providers, Copenhagen Business School, Number of STUs: 272,322.

European Commission – Blockchain Technologies, 2020. Available at: https://ec.europa.eu/digital-single-market/en/blockchain-technologies.

European Commission – Digital Innovation and Blockchain (Unit F.3), 2020. Available at: https://ec.europa.eu/digital-single-market/en/content/digital-innovation-and-blockchain-unit-f3.

European Commission – European Countries Join Blockchain Partnership, 2020. Available at: https://ec.europa.eu/digital-single-market/en/news/european-countries-join-blockchain-partnership.

European Commission – Maritime Transport, 2020. Available at: https://ec.europa.eu/transport/modes/maritime/maritime-transport_en.

European Commission – Mobility and Transport, 2020. Available at: https://ec.europa.eu/transport/modes/maritime/digital-services/e-maritime_en.

European Commission – National Single Window Guidelines, 2020. Available at: https://ec.europa.eu/transport/sites/transport/files/modes/maritime/doc/2015-06-11-nswguidelines-final.pdf.

European Commission, 2018. Available at: https://ec.europa.eu/competition/mergers/cases/decisions/m8742_181_3.pdf?fbclid=IwAR1Mq-o4g-wRytQ_OL-EBCsfuowl9fKmviiBMhuRq66m4_Jz2OFi5pahE38.

Gans, J., 2019. The Fine Print in Smart Contracts. Available at: http://dx.doi.org/10.3386/w25443.

Harshvardhan, 2018. Improving shipping contracts with the use of emerging technologies, Master of Engineering in Supply Chain Management at the Massachusetts Institute of Technology.

IMO Conventions, 2020. Available at: http://www.imo.org/en/About/Conventions/Pages/Home.aspx.

IMO, 2020. Available at: http://www.imo.org/en/About/Pages/Default.aspx.

Irannezhad, E., 2020. Is blockchain a solution for logistics and freight transportation problems? Transportation Research Procedia, 48, pp.290–306. Available at: http://dx.doi.org/10.1016/j.trpro.2020.08.023.

Jain, P., 2018. Improving the process of container shipping using blockchain, Master of Applied Science in Supply Chain Management at the Massachusetts Institute of Technology.

Jensen, T., Bjørn-Andersen, N. & Vatrapu, R., 2014. Avocados crossing borders. Proceedings of the 5th ACM international conference on Collaboration across boundaries: culture, distance & technology - CABS'14. Available at: http://dx.doi.org/10.1145/2631488.2631500.

Kiviat, T.I., 2015. Beyond Bitcoin: Issues In Regulating Blockchain Transactions, 65 Duke Law Journal.

Kütük-Markendorf, M.E., 2016. Rechtliche Einordnung von Internetwährungen im deutschen Rechtssystem am Beispiel von Bitcoin. Available at: http://dx.doi.org/10.3726/b10492.

Nakamoto, S., 2008. Bitcoin: A Peer-to-Peer Electronic Cash System. Available at: https://bitcoin.org/bitcoin.pdf.

Papathanasiou, A., Cole, R. & Murray, P., 2020. The (non-)application of blockchain technology in the Greek shipping industry. European Management Journal. Available at: http://dx.doi.org/10.1016/j.emj.2020.04.007.

Pečarić, M., Peronja, I. & Mostarac, M., 2020. Application of "blockchain" and "smart contract" tehnology in international payments – the case of reimbursement banks. Pomorstvo, 34(1), pp.166–177. Available at: http://dx.doi.org/10.31217/p.34.1.18.

Perkušić, M, Jozipović, Š., Mamut, J., 2020. Mogućnosti korištenja i pravnog uređenja tzv. pametnih ugovora u Republici Hrvatskoj, Hrvatsko obvezno pravo u poredbenopravnom kontekstu: Petnaest godina Zakona o obveznom odnosima, Ekonomski fakultet Sveučilišta u Zagrebu, Zagreb.

Perkušić, M., 2019. Legal Issues of Electronic Payment, Doctoral Dissertation, University of Rijeka, Faculty of Law.

Pflaum, I., Hateley, E., 2014. A bit of a problem: National and extraterritorial regulation of virtual currency in the age of financial disintermediation, Georgetown Journal of International Law, vol. 45.

Pilavci, E. E., 2019. The Regulation of Smart Contracts: Law, Governance and Practice, İSTANBUL BİLGİ ÜNİVERSİTESİ LİSANSÜSTÜ PROGRAMLAR ENSTİTÜSÜ BİLİŞİM VE TEKNOLOJİ HUKUKU YÜKSEK LİSANS PROGRAMI.

Ryan, P., 2017. Smart Contract Relations in e-Commerce: Legal Implications of Exchanges Conducted on the Blockchain. Technology Innovation Management Review, 7(10), pp.14–21. Available at: http://dx.doi.org/10.22215/timreview/1110.

Seebacher, S. & Schüritz, R., 2017. Blockchain Technology as an Enabler of Service Systems: A Structured Literature Review. Exploring Services Science, pp.12–23. Available at: http://dx.doi.org/10.1007/978-3-319-56925-3_2.

Shi, H. & Wang, X., 2018. Research on the Development Path of Blockchain in Shipping Industry. Proceedings of the Asia-Pacific Conference on Intelligent Medical 2018 & International Conference on Transportation and Traffic Engineering 2018 on - APCIM & ICTTE 2018. Available at: http://dx.doi.org/10.1145/3321619.3321671.

Si, H. et al., 2019. IoT information sharing security mechanism based on blockchain technology. Future Generation Computer Systems, 101, pp.1028–1040. Available at: http://dx.doi.org/10.1016/j.future.2019.07.036.

Stopford, M., 2009. Maritime Economics. Available at: http://dx.doi.org/10.4324/9780203891742.

Szabo, N., 1994. Smart Contracts, retrived from: http://www.fon.hum.uva.nl/rob/Courses/InformationInSpeech/CDROM/Literature/LOTwinterschool2006/szabo.best.vwh.net/smart.contracts.html.

Tapscott, D., Tapscott, A., 2017. How blockchain will change organizations, MIT Sloan Management Review, 58(2).

Vanelslander, T., Sys, C., Carlan, V., 2016. Innovation among seaport operators: A QCA approach for determining success conditions, International Journal of Transport Economics, 43.

Zheng, Z., Xie, S., Dai, H., Chen, W., Chen, X., Weng, J., Irman, M., (2019): An Overview on Smart Contracts: Challenges, Advances and Platforms, Journal Pre-proof, To appear in : Future Generation Computer Systems, PII: S0167-739X(19)31628-0.

Application of Satellite Imagery and Water Indices to the Hydrography of the Cetina RiverBasin (Middle Adriatic)

Tea Duplančić Leder[a], Nenad Leder[b], Martina Baučić[a]

The paper gives a brief description of the remote sensing method used for the identification and extraction of water surfaces. Landsat 8 and Sentinel 2 satellite imagery was used to separate land from bodies of water in the complex karst area surrounding the Croatian Cetina River, flowing into the Adriatic Sea. Water indexing methods are presented in detail. The most frequently used water indices were selected: NDWI, MNDWI, AWEI_nsh, AWEI_sh, WRI and LSWI, and their results compared. The combination of satellite imagery and calculated water indices is concluded to be very useful for the identification and mapping of the area and banks of lakes, riverine zones, river mouths and the coastline in the coastal zone. Landsat 8 satellite imagery is slightly inferior to Sentinel 2 due to lower image resolution. The best results were obtained with the NDWI water index and the worst with LSWI.

KEY WORDS
~ Water index
~ Sentinel 2
~ Landsat 8
~ Riverine zone
~ Coastal zone

a. University of Split, Faculty of Civil Engineering, Architecture and Geodesy
e-mail: tleder@gradst.hr
b. University of Split, Faculty of Maritime Studies, Split, Croatia
e-mail: nleder@pfst.hr

doi: 10.7225/toms.v09.n02.020

1. INTRODUCTION

Hydrography is the branch of applied sciences which deals with the measurement and description of the physical features of oceans, seas, coastal areas, lakes and rivers, as well as with the prediction of their change over time, for the primary purpose of safety of navigation and in support of all other marine activities, including economic development, security and defense, scientific research, and environmental protection (International Hydrographic Organization, 2020).

Hydrography underpins many other activities associated with bodies of water, including coastal zone management and marine science. One of the most important tasks of hydrography in coastal zone management is to determine the coastline of coastal and riverine zones.

Water is a significant resource and an important factor of the land cover. Its changes have a considerable effect on the climate and environment of a particular area. A variety of factors cause changes in bodies of water, including climate change that has resulted in drought, erosion, floods and various types of water pollution. Remote sensing surface water distribution monitoring has a number of advantages, such as low cost, high frequency of data acquisition, wide coverage and low interference of surface conditions. The method is used in water resource assessment, hydrography, coastal zone management and environmental impact studies.

Since the beginnings of implementation of remote sensing water extraction technique almost forty years ago (Work and Gilmer, 1976), numerous studies have focused on algorithms for extracting water development.

The paper briefly presents remote sensing methods used for water surface identification and extraction. Six commonly

used water indexing methods or algorithms based on algebraic operations in two or more spectral channels have been compared, applied to the Cetina River basin. Landsat 8 and Sentinel 2 satellite missions have been selected as the sources of data used in this study, which has proven optimal for this purpose in the cost-benefit analysis.

The main goal of this paper is to evaluate the potential of the application of satellite remote sensing and water indices to differentiate land from bodies of water in the karst area of the Cetina River, with special emphasis on the area of Cetina River inflow into the sea.

2. MATERIALS AND METHODS

2.1. Study Area

The Cetina River belongs to the Adriatic basin. It springs in the northwestern part of the Dinara Mountain at the altitude of 385 m and is 105 km long. From its spring, the river flows through the karst area of the Sinj Field, southward through a canyon and finally into the Adriatic Sea in the town of Omiš. The catchment partly lies in the mountains and partially in what is morphologically a karst field (Figure 1). The Cetina River catchment covers the area of approximately 4,145 km2 (Kadić et al., 2019), divided in two parts by the Dinara Mountain. The eastern part of the catchment (two thirds of the catchment or approx. 2,614 km2), referred to as the "indirect" catchment, is mainly situated in Bosnia and Herzegovina, with a continental climate. The western part has the surface of approx. 1,531 km2 (one third of the catchment). It is the "direct" or topographic catchment, almost entirely situated in the Republic of Croatia, with climate under the strong influence of the Adriatic Sea (Mediterranean climate) (Figure 1). The length of the river from the Glavaš spring to the mouth on the Adriatic Sea in Omiš is 104 km. The entire catchment is situated in karst terrain consisting of very thick layers of limestone and dolomites, with intensive karstification and complex hydrogeological conditions. Cetina is a karst river, its waters circulating between fields through underground karst channels. The entire area is a typical karst terrain.

The Cetina River basin can be divided into two morphological parts: the mountainous area and karst fields. The relationships of these relief units define the movement of surface and groundwater within the basin. Surface flows are mainly found in karst fields and composite or complex structure valleys consisting of canyons, valley expansions and culverts, with the communication of water between the fields taking place underground.

The Cetina River flow regimen reaches its maximum during autumn, the second highest level in the spring, and minimum in the summer. There are several hydroelectric power plants on the river: Peruća, Orlovac, Buško blato, Đale, Zakučac and Kraljevac that have a strong effect on the natural hydrological regimen of the river and the overall area. Peruća Lake (coordinates 43°49'N 16°36'E, surface approximately 15 km^2, maximum depth 65 m) is an artificial lake in karst terrain and the hub of the Cetina River power system (hydroelectric power plants Peruća, Đale and Zakučac). Cetina River flows into the Adriatic Sea near the town of Omiš (43°26'36"N; 16°41'35"E) (Figure 2).

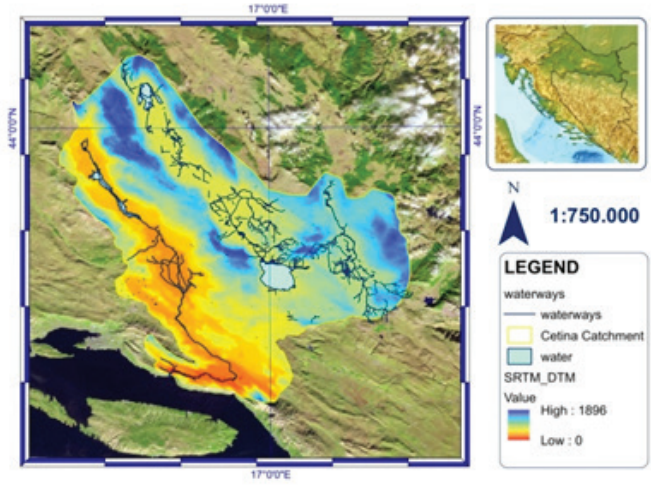


Figure 1.
Cetina River catchment area.

The area examined in this study has the surface of 2,750 km^2 and is situated between 43°24'04,84" N latitude and 16°23'11,75" E longitude up to 43°59'21,35" N latitude and 16°54'10,59" E longitude. It is located within the yellow rectangle in Figure 2 and includes the topographic catchment of the Cetina River (Figure 2). The whole area was tested with six water indices; the results are for better insights presented in two characteristic larger areas: (a) Peruća Lake (purple) and (b) the mouth of the Cetina River (purple) (Figure 2). Both areas examined have still water (lake and sea) and permanent watercourses (river). Likewise, both larger areas are mostly mountains, with some lowlands. The first area for which the results are presented is the northern part of the Peruća Lake shown in Figure 2, top right. The second area is the mouth of the Cetina River shown in Figure 2, bottom right.

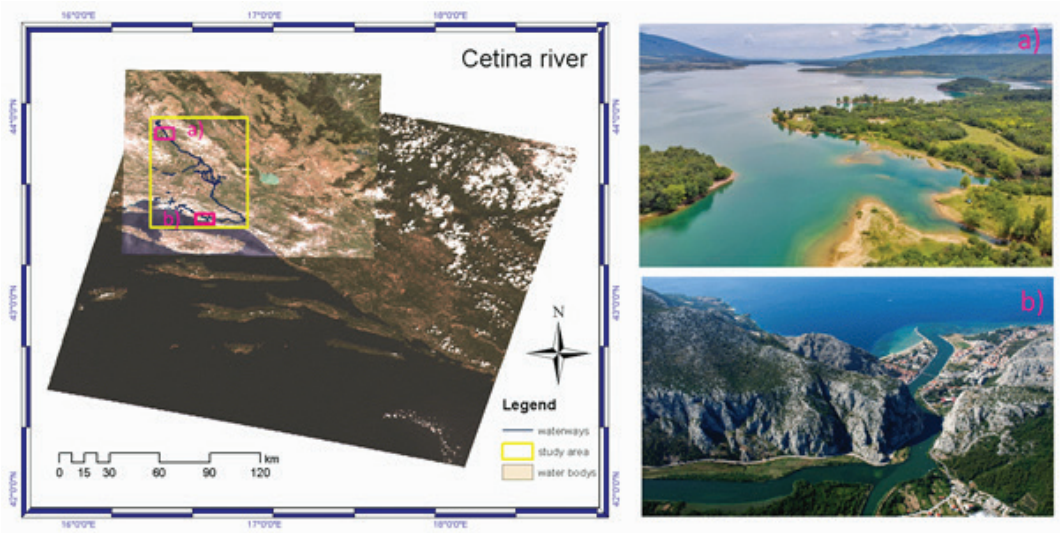


Figure 2.
Area examined (yellow) and two larger areas: (a) Peruća Lake (purple) and (b) the Cetina River mouth (purple) as caught on Landsat 8 and Sentinel 2A satellite images.

2.2. Materials

Satellite mission data were used to detect and extract water (sea) surfaces using the water index calculation method.

The cost-benefit analysis for this study indicated two free satellite missions, Landsat 8 and Sentinel 2, as optimal data sources. Satellite images from early September 2018 were used, taken in similar weather conditions around 10 am (Table 1).

Landsat 8 (launched in early 2013) is the latest of NASA's (National Aeronautics and Space Administration) longest-running multispectral satellite observation mission series. The mission has 9 sensors in the Operational Land Imager (OLI) visible and infrared spectrum range with 15 m panchromatic spatial resolution, and 30 m multispectral channel spatial resolution, and 2 Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) sensors in the thermal infrared range with 100 m spatial resolution (Figure 3). The data can be obtained free of charge at USGS (United States Geological Survey) explorer (https://earthexplorer.usgs.gov/).

Free ESA (European Space Agency) satellite Sentinel 2 observation mission (Sentinel-2A and Sentinel-2B, launched 2015 and 2017) is part of the Copernicus satellite program (Sentinel 1-10). The mission is complementary to the previous SPOT mission. It is a multispectral 13 channel mission in the visible, near infrared and shortwave infrared part of the spectrum (Figure 3). Spatial resolution is 10 m, 20 m and 60 m, temporal resolution is 5 days, and the width range is 290 km. Sentinel data can be obtained free of charge from the Copernicus Open Access Hub (https://scihub.copernicus.eu/), while the atmospheric condition scene correction can be conducted using the SEN2COR open application.

September was selected for satellite imagery as electromagnetic radiation from the Sun is still strong at this time of the year and the reflection is strong. Temperatures are high but not excessive, and pressure, humidity and atmospheric correction are not very high. This period is also characterized by the lack of sudden temperature changes and sudden chlorophyll booms that affect water color. As for the coastal areas, since there are not as many swimmers or vessels as in the summer, there is no water turbidity or water color change.

Table 1.
Satellite images used in the study.

Sensor	Date	Time (UTC)	Temp.°C	Pressure hPa	Humidity %	Source
Landsat 8	06-09-2018	9h 35min	27.7	1012.3	42.18	USGS explorer
Sentinel 2A	10-09-2018	9h 50min	28.0	1020.2	30.56	Copernicus Open Access Hub

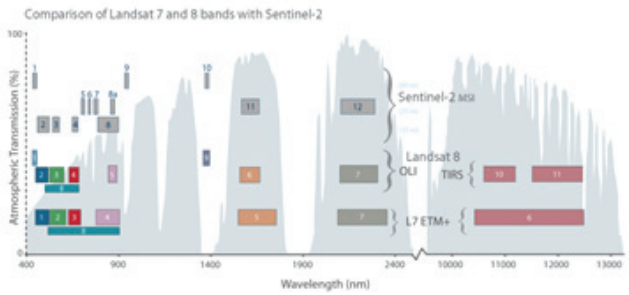


Figure 3.
Comparison of bands, wavelengths and spatial resolution of Landsat 7 and Landsat 8 with the Sentinel 2 satellite mission (according Wulder, et al., 2019).

2.3. Methodology

There are many methods for automated identification of bodies of water by satellite remote sensing scene. Such methods are divided into active satellite mission methods, which use the radar portion of electromagnetic radiation (Guerreonero Robinson, et al., 2013) and passive satellite mission methods, the most commonly used methods of which are divided into three categories (Jiang et al., 2014):

1. The spectral channel method identifies water surfaces by finding thresholds in one or more spectral channels. It is simple to apply, but shadows are frequently incorrectly classified due to topography, urban areas or other background irregularities (Rundquist et al., 1987);
2. The classification method applies supervised or unsupervised machine-learning algorithms to the extraction of bodies of water from multispectral scenes (Otukei and Blaschke, 2010);
    a. Supervised classification usually uses maximum-likelihood classifiers, decision trees, artificial neural networks or support vector machines method;
    b. Unsupervised classification uses K-means or iterative self-organizing data analysis (ISODATA) (Otukei and Blaschke, 2010; Lu and Weng, 2007).

    This method achieves good results, but necessitates prior knowledge of the terrain or existing reference data for the selected samples, aggravating the use of this method on poorly known terrain (Frazier and Page, 2000);
3. The water index method combines different algebraic operations over two or more spectral channels to accentuate the discrepancy between bodies of water and land (Jiang et al., 2012; Lu et al., 2011). The principles used by the method are similar to those of the Normalized Difference Vegetation Index (NDVI) (Townshend and Justice, 1986). The following indices are most commonly used to identify bodies of water:
    a. Normalized Difference Water Index - NDWI (McFeeters, 1996);
    b. Modified Normalized Difference Water Index – MNDWI (Xu, 2006; Du et al., 2016);
    c. Automated water extraction index – AWEI (Feyisa et al., 2014);
    d. Water Ratio Index - WRI (Shen and Li, 2010); and
    e. Land surface water index LSWI (Xiao et al., 2002).

In this paper, water index calculation methods have been used and applied to unsupervised classification, enabling the automation of the entire process. Many authors have lately attempted to improve the results and test the quality of different water indices (Feyisa et al., 2014; Baiocchi et al., 2012; Maglione et al., 2014; Elsahabi et al., 2016; Mukherjee and Samuel, 2016; Sarp and Ozcelik, 2016; Kaplan and Avdan, 2017a) on individual satellite sensors. Some authors have compared multiple indices across multiple sensors, e. g. Kwang (2018) compared the accuracy of 4 water indices on 2 sensors, Zou et al., (2017) compared 9 indices across 3 sensors, and El Kafrawy et al., (2017) 3 indices and 2 remote sensing methods on 2 multispectral sensors.

2.3.1. Normalized Difference Water Index

The oldest water index, the Normalized Difference Water Index – NDWI, was proposed by McFeeters for mapping and highlighting the characteristics of bodies of water by remote sensing (McFeeters, 1996) using the near infrared (NIR) and green channels to calculate the water index.

Mathematically, the Normalized Difference Water Index according to McFeeters is expressed as:

$$NDWI = (Green - NIR) / (Green + NIR) \quad (1)$$

The algorithm reduces non-water features such as vegetation and soil by suppressing the low NIR reflectance of water features, while simultaneously maximizing the reflectance of water at green wavelengths. As threshold value is 0, positive values correspond to bodies of water and negative values to other bodies. Although the NDWI has the ability to detect turbid waters (McFeeters, 1996), its main disadvantage is the inability to distinguish between built-up areas and bodies of water, making it difficult to extract water (Xu, 2006).

2.3.2. Modified normalized water index

Xu (2006) modified the McFeeters index by replacing the near-infrared (NIR) with the shortwave (SWIR) channel, thereby improving the extraction of water features especially from built-up areas, reducing and eliminating noise present in the NDWI model.

MNDWI is mathematically expressed as:

$$MNDWI = (Green - SWIR) / (Green + SWIR) \quad (2)$$

2.3.3. Automated Water Extraction Index

Automated Water Extraction Index - AWEI was proposed by Feyis et al. (2014) to improve the extraction of bodies of water in areas containing shadows or dark parts, while simultaneously offering a stable threshold value for distinguishing water from other surface objects. The algorithm aims to maximize the enhancement of water features by adding different coefficients (Feyis et al., 2014). Two automated water extraction indices were developed, one of which removes shadow pixels, while the other removes non-water pixels, such as dark built-up surfaces in urban areas (Feyis et al., 2014). AWEI indices can be used in different environmental conditions.

Mathematically, AWEI indexes are presented as:

$$AWEI_{nsh} = 4 \times (Green - SWIR1) - (0.25 \times NIR + 2.75 \times SWIR2) \quad (3)$$

$$AWEI_{sh} = Blue + 2.5 \times Green - 1.5 \times (NIR + SWIR1) - 0.25 \times SWIR2 \quad (4)$$

Index using: (1) $AWEI_{sh}$ provides the best water surface extraction where dark shadows and other characteristics such as snow, ice or high albedo built-up areas are present; (2) $AWEI_{nsh}$ enables optimal separation of bodies of water from other surfaces; (3) $AWEI_{sh}$ and $AWEI_{nsh}$ are the best at distinguishing water from high albedo surfaces and shady/dark surfaces; (4) in areas without shadows, dark city backgrounds and low albedo areas, the use of AWE_{sh} or $AWEI_{nsh}$ (Feyis et al., 2014) is recommended.

2.3.4. Water Ratio Index

Water Ratio Index - WRI was proposed (Shen and Li, 2010) as the ratio between total spectral reflectance of the Red and Green channels versus total near-infrared (NIR) and shortwave infrared (SWIR) spectral reflectance.

WRI is mathematically expressed as:

$$WRI = (Green + Red) / (NIR + SWIR) \quad (5)$$

2.3.5. Land surface water index

Land surface water index - LSWI was proposed (Xiao et al., 2002) as the ratio between the difference between near infrared (NIR) and shortwave infrared (SWIR) channels and the sum of near infrared (NIR) and shortwave infrared (SWIR) channels.

Mathematically, LSWI can be expressed as:

$$LSWI = (NIR - SWIR1) / (NIR + SWIR1) \quad (6)$$

2.4. Computation Procedure

The first stage of scene processing was preprocessing, or atmospheric correction, which eliminates potential absorption and dispersion of electromagnetic waves in the atmosphere. Atmospheric correction of Landsat scenes was performed in NASA's Atmospheric Correction Parameter Calculator (https://atmcorr.gsfc.nasa.gov), with coordinates, altitudes, and meteorological data on temperature, pressure, and humidity used as correction parameters. The Sentinel Application Platform (SNAP; http://step.esa.int/) calculates the atmospheric correction of Sentinel 2 scenes based on pressure parameters and quantity of ozone.

Following preprocessing, the area examined was cut in both scenes to facilitate computation, after which water indices were calculated for the area in question.

Having calculated water indices, unsupervised classifications were made for the area examined, whereby pixel elements were divided into classes based on their natural association in spectral space. Unlike supervised classification, the first step does not require any knowledge of the space being classified, which is suitable for identification of water surfaces in unfamiliar areas.

Unsupervised classification process was performed in two stages: grouping (into classes) followed by class recognition. Classification was performed using ArcGIS and the ISODATA mathematical algorithm classification, whereby the first 5 classes in the area examined were obtained and subsequently reclassified into two basic classes: water and non-water (land). This method of unsupervised classification and reclassification produces better results than simple classification into 2 classes.

After performing the classification, the overall accuracy of output classification for six selected indices of the two scenes was established. Classification accuracy was established using vector data control points obtained from topographic maps and hydrographic survey sheets, by which they were formed from the confusion matrix and the overall accuracy and Kappa coefficient for each test classification were calculated (Ayyanna et al., 2018; FAO, 2016; Mohd Hasmadi et al., 2009; Pontus et al., 2014; Rwanga and Ndambuki, 2017).

3. RESULTS

Values of water indices for the area examined were calculated and are shown more extensively in two sample areas: (1) the northern part of Peruća Lake (Figure 4) and (2) the mouth of the Cetina River, where the river flows into the sea (Figure 5). Google Earth satellite images (up) and Google Street with roads and settlement names (down) are shown on the left side of Figures 4 and 5 for the purpose of comparison of water index results with the actual situation on site. The percentages of land and water surface areas obtained by different indices in the areas examined were calculated (Figure 4) and overall accuracy, as well

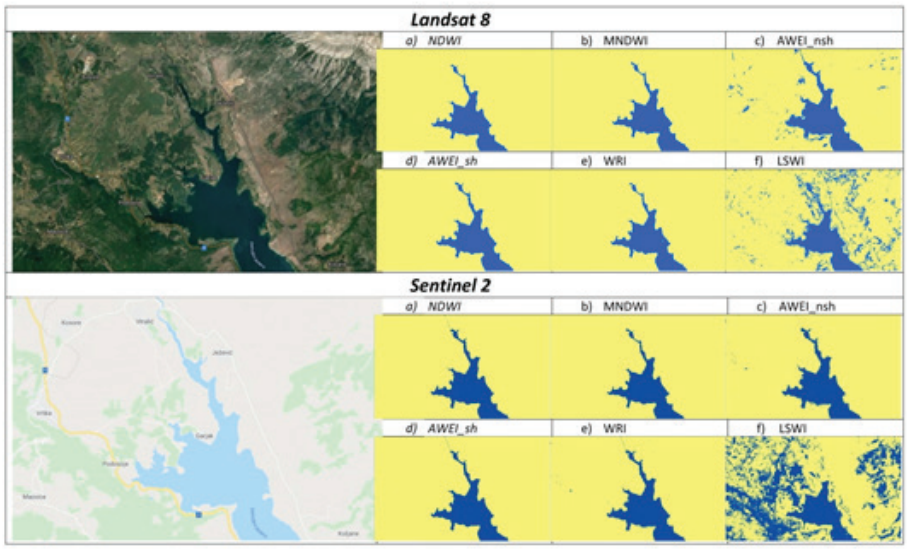


Figure 4.
Values of water indices calculated for the area of Peruća Lake:
a) NDWI; b) MNDWI; c) AWEI_nsh, d) AWEI_sh e) WRI and f) LSWI.

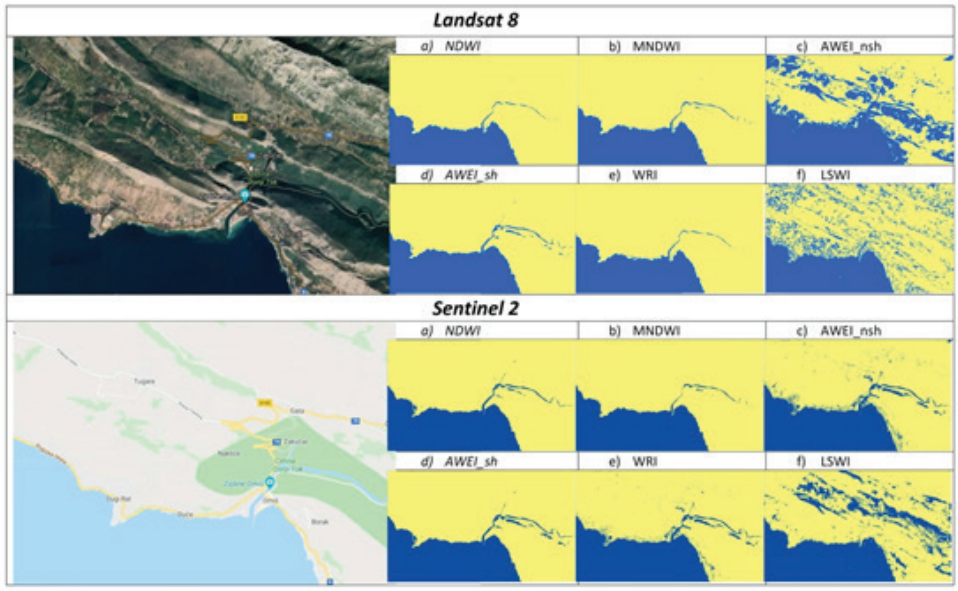


Figure 5.
Values of water indices calculated for the area of the mouth of Cetina River:
a) NDWI; b) MNDWI; c) AWEI_nsh, d) AWEI_sh e) WRI and f) LSWI.

Table 2.
Overall accuracy of previous research results (%).

Authors	Satellite	NDWI	MNDWI	AWEI_sh	AWEI_nsh	WRI	LSWI
Zhou et al., 2017	**L8**	95.7	94.6	95.3	95.4	-	94.1
	S2	95.6	95.1	95.5	94.8	-	94.4
Kwang et al., 2018	**L8**	99.8	99.6	98.8	98.6	-	-
	S2	99.4	99.9	99.6	98.6	-	-

Table 3.
Kappa coefficients of water indices obtained by ISODAT classifications from previous research.

Authors	Satellite	NDWI	MNDWI	AWEI_sh	AWEI_nsh	WRI	LSWI
Zhou et al., 2017	**L8**	0.915	0.891	0.907	0.909	-	0.881
	S2	0.913	0.897	0.910	0.897	-	0.887
Kwang et al., 2018	**L8**	0.997	0.987	0.969	0.964	-	-
	S2	0.985	0.997	0.991	0.962	-	-

as the Kappa coefficient for the classification of Landsat 8 (Table 3) and Sentinel 2 (Table 4) satellite images obtained. Furthermore, the results thus obtained were compared with those of previous water resource surveys published in scientific papers (Tables 2 and 3).

The values of water indices calculated for the Peruća Lake area are presented in Figure 4. The conclusion is that satellite images can be used to identify lake surfaces and banks, although image quality depends on the type of satellite.

Figure 5 shows the values of water indices calculated for the mouth of Cetina River, indicating that both the river and the bank, as well as its mouth in the vicinity of the town of Omiš, are perfectly discernible from satellite images. Furthermore, it is important to emphasize that the coastline near the mouth of the Cetina River is also identified very well.

The results obtained with the Landsat 8 satellite images are slightly inferior to those from the Sentinel 2 due to lower image resolution preventing the recognition of narrow watercourses and small reservoirs. An example of this situation is visible in the middle of the upper part of Figure 4 and in the middle right of Figure 5.

In spite of low air humidity, the LSWI Index responds to vegetation moisture and built-up areas. The results obtained using Sentinel 2 were inferior to those obtained from Landsat 8 due to the range of NIR and SWIR1 channels. AWEI_nsh also produced poor results in areas under vegetation, built-up areas

Figure 6.
Vector polygons of the area examined used as reference values for water index comparison.

and on roads. The WRI index gives satisfactory results but shows noise in the built-up area (settlement Vrlika, middle left in Figure 4, and in Figure 5 one in a series of settlements along the coastline and the road).

The first step in water index testing was the calculation of the percentage of pixels in each class (Tables 4 and 5), and the percentage of area covered by each class. In the next stage, all bodies of water (rivers, lakes, reservoirs, sea) or water surface polygons in the area examined were vectorized from the topographic maps using the scale 1:25 000 (Figure 6), with polygons used as reference values for evaluation of classification accuracy. Land covers 89.829% and water 10.171% of the total area examined. The percentage of classified areas was determined based on 500 and 2500 control points in the area examined. 500 points are concluded to have given satisfactory results for a small number of classes. After that, vector polygon surfaces were compared with the percentage of area belonging to each class. The final assessment of classification accuracy of each individual water index involved the calculation of overall accuracy and of the Kappa classification coefficient (Tables 4 and 5).

The mean accuracy of water index calculation for Landsat 8 images based on 500 control points is 95.48, while the mean accuracy for Sentinel 2 images is 96.70. When AWEI_sh and LSWI indices which give inferior results are omitted, mean accuracy value for Landsat 8 is 99.86 and 99.69 for Sentinel 2. The mean of the Kappa coefficient for Landsat 8 is 0.920 and 0.988 for the four indices giving better results, while the mean value of the Kappa coefficient for Sentinel 2 is 0.929 and 0.988 with better indices.

Table 4.
The values of land and water polygon percentages obtained using different indices; overall accuracy and Kappa coefficient of classification for the Landsat 8 image.

Landsat 8		**NDWI**	**MNDWI**	**AWEI_sh**	**AWEI_nsh**	**WRI**	**LSWI**
vector	Land (%)	90.201	90.171	81.219	89.946	90.225	74.998
	Water (%)	9.799	9.829	18.781	10.054	9.775	25.002
500	Land (%)	90.2	90.2	81.2	90.0	90.2	75.0
	Water (%)	9.8	9.8	18.8	10.0	9.8	25.0
2500	Land (%)	90.20	90.16	81.20	89.60	90.24	75.00
	Water (%)	9.80	9.84	18.80	10.40	9.76	25.00
	Accuracy	99.87	99.90	90.16	99.84	99.84	83.25
	Kappa	0.989	0.989	0.846	0.988	0.988	0.772

Table 5.
The values of land and water polygon percentages obtained using different indices; overall accuracy and Kappa coefficient of classification for the Sentinel 2 image.

Sentinel 2		**NDWI**	**MNDWI**	**AWEI_sh**	**AWEI_nsh**	**WRI**	**LSWI**
vector	Land (%)	90.053	90.292	88.950	90.044	89.266	74.484
	Water (%)	9.947	9.708	11.049	9.956	10.734	25.516
500	Land (%)	90.0	90.2	89.0	90.0	89.2	74.4
	Water (%)	10.0	9.8	11.0	10.0	10.8	25.6
2500	Land (%)	90.02	90.19	89.12	89.92	89.22	74.44
	Water (%)	9.98	9.81	10.88	10.08	10.78	25.56
	Accuracy	99.96	99.77	98.74	99.95	99.09	82.68
	Kappa	0.989	0.989	0.863	0.988	0.988	0.758

The mean accuracy of water index calculation for Landsat 8 images based on 500 control points is 95.48, while the mean accuracy for Sentinel 2 images is 96.70. When AWEI_sh and LSWI indices which give inferior results are omitted, mean accuracy value for Landsat 8 is 99.86 and 99.69 for Sentinel 2. The mean of the Kappa coefficient for Landsat 8 is 0.920 and 0.988 for the four indices giving better results, while the mean value of the Kappa coefficient for Sentinel 2 is 0.929 and 0.988 with better indices.

4. DISCUSSION

We have recently witnessed sudden changes in water surfaces in the Croatian coastal area, manifested in the drying or flooding of certain areas. Many authors are trying to identify the optimum water index as an automated method of water area mapping.

Croatian authors have seldom tried to map water surfaces by remote sensing methods (e.g. Duplančić Leder and Leder, 2019), but the quality of the results obtained has never evaluated. For water surface extraction purposes, the water index method chooses the appropriate satellite image created in optimal atmospheric conditions. For the Cetina River basin, optimal satellite images are taken after the bora wind, when the air is free of clouds and moisture, and clear and well-defined transition between land and water is discernible.

At this particular time of the year, the waters of the Cetina River and Peruća Lake are clear, and the sea is transparent and blue, suitable for water index application. Smaller watercourses, especially reservoirs, have turbidity issues, and their brown color reduces both the reflection of electromagnetic energy and the possibility of water index application.

This study used the free data of Sentinel 2 and Landsat 8 satellite missions. Satellite images were taken in September 2018, four days apart (Landsat on September 6, Sentinel on September 10), in almost identical meteorological conditions, allowing the comparison of the results obtained. At 10 am on September 6, temperature was 27.7 °C, air pressure 1012.3 hPa, and humidity 42%, whereas on September 10, temperature was 28.0 °C, air pressure 1020.2 hPa, and humidity 30% (Table 1). The selected satellite images had optimal reflectance and water color for this study. Before calculating the water index of the images, atmospheric correction with meteorological data was performed.

Both images give similar and satisfactory results for all water indices. The classification accuracy of four water indices - NDWI, MNDWI, AWEI_nsh and WRI - was over 99%, with water index AWEI_sh having the classification accuracy of over 90% and LSWI a slightly poorer classification accuracy of over 80%. The accuracy of classification results can thus be concluded to be satisfactory, and considered high. Comparing the two satellite missions, slightly better results have been obtained with Sentinel 2 due to its better spatial resolution. If the results of this analysis are compared with the results obtained by other authors, the results can be concluded to be satisfactory, indicating that accuracy and the Kappa coefficient have been calculated at a large number of control points.

For example, using an unknown number of control points, Kwang et al. (2018) obtained the mean water index accuracy of 99.20 and the mean Kappa coefficient of 0.979 for Landsat 8, and the mean accuracy of 99.37, and the mean Kappa coefficient of 0.984 (Tables 2 and 3) for Sentinel 2. Using 60 control points, Zhou et al. (2017) obtained the mean accuracy of 95.02, and mean Kappa coefficient of 0.901 for Landsat 8, and the mean accuracy of 95.08, and the mean Kappa coefficient of 0.901 for Sentinel 2 (Tables 2 and 3). Yang et al. (2017) examined Sentinel 2 images and NDWI and MNDWI indices in urban and coastal areas. The mean water index accuracy in urban areas was 97.92, and 98.88 in the coastal area. The Kappa coefficient was 0.645 in urban areas, and 0.839 in the coastal area. These results are similar to those obtained for the examined Cetina River area.

Problems in connection with water index based methods occur in the extraction of small bodies of water, particularly from Landsat images, due to their low spatial resolution. Better results can be obtained from higher resolution commercial satellite missions (WW2, RapidEye…), aerophotogrametric or LIDAR images (Zhou et al., 2017). The limitations of commercial missions are the existence of only near infrared (NIR) channels with visible channels. Most indices give poorer results in built-up areas and especially in cities characterized by a lot of noise, attempted to be avoided by combining the water index method with other methods or by combining different parameters (Figure 4; mountainous part of Peruća Lake with Vrlika settlement on the left; Figure 5 shows the mouth of the Cetina River with the town of Omiš on the right side of the image). A particularly serious problem was encountered in the mountainous areas where low sun elevation creates long shadows and numerous side effects, which combined with low temperature, ice and poorer reflection have proven problematic for some of the indices (Figures 5 c and 5 f). The conditions for the extraction of water surfaces are considered to be favorable when the angle of elevation of the Sun is above 40 degrees (Kaplan and Avdan, 2017b). The angle of the Sun in the Landsat 8 image was 49.63 degrees and 40.45 degrees in the Sentinel 2 image.

The results of this study are slightly better in case of extraction of coastal than fresh water (Figure 5). Reflection over sea can be concluded to be better due to the different composition of salt water and lower quantity of dissolved substances (higher transparency). Very similar results were obtained by other authors in their studies (e.g. Yang et al., 2017).

The MNDWI index is suitable for the identification of flooded areas in cities, while AWEI indices are intended for areas

in full shadow and areas covered with ice. The LSWI index is suitable for the identification of moisture content and as such is not well suited for the purposes of this study (Zhou et al., 2017).

5. CONCLUSION

In recent years, the International Hydrographic Organization (IHO) has changed the basic purpose of its activity. Namely, its primary goal is no longer limited to the safety of navigation, but has come to include a number of other activities relating to the physical features of oceans, seas, coastal areas, rivers and lakes. One of the most important tasks of hydrography, applied to coastal zone management, is to identify the coastline, coastal and riverine zones.

Since standard hydrographic survey methods are prohibitively expensive and time consuming, this paper used the satellite remote sensing technique and the water index calculation method to distinguish land from bodies of water in the complex karst area of the Croatian Cetina River, flowing into the sea in the vicinity of the town of Omiš. In this area, spatial and temporal changes of water and land are frequent, and there is a need for fast and efficient mapping of these changes.

Landsat 8 (NASA) and Sentinel 2 (ESA) satellite missions were used to obtain satellite images, while NDWI, MNDWI, AWEI, WRI and LSWI indices were used to extract water (sea) and land surfaces.

From the hydrographic point of view, the studied Cetina River area can be divided into three units: Peruća Lake, Cetina River and the mouth of the river on the Adriatic Sea (coastal area). The combination of satellite imagery and calculated water indices can be concluded to be well suited to the identification and mapping (smaller scale maps) of the area and banks of lakes, riverine zones, the river mouth area and the coast in the coastal zone. Furthermore, satellite image quality depends on satellite type.

The results obtained using Landsat 8 satellite images are slightly inferior to those obtained using Sentinel 2 due to lower image resolution. This study has shown the NDWI index as the most appropriate for the identification of bodies of water. The poorest results were obtained with the AWEI_sh and LSWI indices, providing that the LSWI index is primarily used for moisture extraction, rather than for water surfaces, while AWEI_sh is intended for mapping bodies of water in shaded areas (high mountains), built-up areas and roads. Likewise, it is evident that classification results are slightly better for marine than freshwater areas extraction. The poorest results were obtained in urban areas, especially when the AWEI_sh and LSWI indices, which give inferior results, were used.

ACKNOWLEDGMENTS

The presented research is partially supported by the KK.01.1.1.02.0027 project co-financed by the State Budget of the Republic of Croatia and by the European Union from the European Fund for Regional Development within the Operational Program "Competitiveness and Cohesion".

REFERENCES

Ayy anna, A. et al., 2018. Accuracy Assessment of Supervised and Unsupervised Classification using Landsat-8 Imagery of D-7 Shahapur Branch Canal of UKP Command Area Karnataka. International Journal of Current Microbiology and Applied Sciences, 7(07), pp.205–216. Available at: http://dx.doi.org/10.20546/ijcmas.2018.707.025.

Baiocchi, V., Brigante, R., Domenici, D., Radicioni, F., 2012. Coastline Detection Using High Resolution Multispectral Satellite Images, FIG Working Week 2012 - Rome, Italy, 1-15.

Du, Y. et al., 2016. Water Bodies' Mapping from Sentinel-2 Imagery with Modified Normalized Difference Water Index at 10-m Spatial Resolution Produced by Sharpening the SWIR Band. Remote Sensing, 8(4), p.354. Available at: http://dx.doi.org/10.3390/rs8040354.

Duplančić Leder, T., Leder, N., 2019. A comparison of algorithms for coastline mapping using satellite methods (in Croatian), Hrvatske vode, 110(27), pp.295-304.

El Kafrawy, S. et al., 2017. Performance Evaluation of Shoreline Extraction Methods Based on Remote Sensing Data. Journal of Geography, Environment and Earth Science International, 11(4), pp.1–18. Available at: http://dx.doi.org/10.9734/jgeesi/2017/36233.

Elsahabi, M., Negm, A. & Hamid M.H. El Tahan, A., 2016. Performances Evaluation of Surface Water Areas Extraction Techniques Using Landsat ETM+ Data: Case Study Aswan High Dam Lake (AHDL). Procedia Technology, 22, pp.1205–1212. Available at: http://dx.doi.org/10.1016/j.protcy.2016.02.001.

Feyisa, G.L. et al., 2014. Automated Water Extraction Index: A new technique for surface water mapping using Landsat imagery. Remote Sensing of Environment, 140, pp.23–35. Available at: http://dx.doi.org/10.1016/j.rse.2013.08.029.

FAO, 2016. Map Accuracy Assessment and Area Estimation: A Practical Guide, Food and Agriculture Organization (FAO) of the United Nations, Rome.

Frazier, P.S., & Page, K.J., 2000. Body of water detection and delineation with Landsat TM data, Photogramm. Eng. Remote Sens., 66, pp.1461–1468.

Guerreonero Robinson, D.A., Bijker & Tolpekin, V.A., 2013. Shoreline detection using TerraSAR-X Quad polarization mode, International Hydrographic Review, November, pp. 15-25.

International Hydrographic Organization, 2020. Definition-of-hydrography, Available at: https://iho.int/en/importance-of-hydrography, accessed on: 20 July 2020.

Jiang, H. et al., 2014. An Automated Method for Extracting Rivers and Lakes from Landsat Imagery. Remote Sensing, 6(6), pp.5067–5089. Available at: http://dx.doi.org/10.3390/rs6065067.

Jiang, Z. et al., 2011. Water body delineation using index composition and HIS transformation. International Journal of Remote Sensing, 33(11), pp.3402–3421. Available at:
http://dx.doi.org/10.1080/01431161.2011.614967.

Kadić, A. et al., 2019. Hydrological functioning of three karst springs located in the Cetina River catchment in Croatia, Geophysical Research Abstracts, EGU General Assembly, 2019.

Kaplan, G. & Avdan, U., 2017a. Object-based water body extraction model using Sentinel-2 satellite imagery. European Journal of Remote Sensing, 50(1), pp.137–143. Available at:
http://dx.doi.org/10.1080/22797254.2017.1297540.

Kaplan, G. & Avdan, U., 2017b. Water extraction technique in mountainous areas from satellite images. Journal of Applied Remote Sensing, 11(04), p.1. Available at:
http://dx.doi.org/10.1117/1.jrs.11.046002.

Kwang, C., Jnr, E.M.O. & Amoah, A.S., 2017. Comparing of Landsat 8 and Sentinel 2A using Water Extraction Indexes over Volta River. Journal of Geography and Geology, 10(1), p.1. Available at:
http://dx.doi.org/10.5539/jgg.v10n1p1.

Lu, D. & Weng, Q., 2007. A survey of image classification methods and techniques for improving classification performance. International Journal of Remote Sensing, 28(5), pp.823–870. Available at:
http://dx.doi.org/10.1080/01431160600746456.

Lu, S. et al., 2011. Water body mapping method with HJ-1A/B satellite imagery. International Journal of Applied Earth Observation and Geoinformation, 13(3), pp.428–434. Available at:
http://dx.doi.org/10.1016/j.jag.2010.09.006.

Maglione, P., Parente, C. & Vallario, A., 2014. Coastline extraction using high resolution WorldView-2 satellite imagery. European Journal of Remote Sensing, 47(1), pp.685–699. Available at:
http://dx.doi.org/10.5721/eujrs20144739.

McFeeters, S.K., 1996. The use of the Normalized Difference Water Index (NDWI) in the delineation of open water features. International Journal of Remote Sensing, 17(7), pp.1425–1432. Available at:
http://dx.doi.org/10.1080/01431169608948714.

Mohd Hasmadi, I., Pakhriazad, H.Z., Shahrin, M.F., 2009. Evaluating supervised and unsupervised techniques for land cover mapping using remote sensing data, Malaysian Journal of Society and Space, 5(1), pp.1-10.

Mukherjee, N. & Samuel, C., 2016. Assessment of the Temporal Variations of Surface Water Bodies in and around Chennai using Landsat Imagery. Indian Journal of Science and Technology, 9(18). Available at:
http://dx.doi.org/10.17485/ijst/2016/v9i18/92089.

Otukei, J.R. & Blaschke, T., 2010. Land cover change assessment using decision trees, support vector machines and maximum likelihood classification algorithms. International Journal of Applied Earth Observation and Geoinformation, 12, pp.S27–S31. Available at:
http://dx.doi.org/10.1016/j.jag.2009.11.002.

Olofsson, P. et al., 2014. Good practices for estimating area and assessing accuracy of land change. Remote Sensing of Environment, 148, pp.42–57. Available at:
http://dx.doi.org/10.1016/j.rse.2014.02.015.

Rundquist, D.C. et al., 1987. The relationship between summer-season rainfall events and lake-surface area, JAWRA Journal of the American Water Resources Association, 23(3), pp.493–508. Available at:
http://dx.doi.org/10.1111/j.1752-1688.1987.tb00828.x.

Rwanga, S.S. & Ndambuki, J.M., 2017. Accuracy Assessment of Land Use/Land Cover Classification Using Remote Sensing and GIS. International Journal of Geosciences, 08(04), pp.611–622. Available at:
http://dx.doi.org/10.4236/ijg.2017.84033.

Sarp, G. & Ozcelik, M., 2017. Water body extraction and change detection using time series: A case study of Lake Burdur, Turkey. Journal of Taibah University for Science, 11(3), pp.381–391. Available at:
http://dx.doi.org/10.1016/j.jtusci.2016.04.005.

Shen, L. & Li, C., 2010. Water body extraction from Landsat ETM+; imagery using adaboost algorithm. 2010 18th International Conference on Geoinformatics. Available at:
http://dx.doi.org/10.1109/geoinformatics.2010.5567762.

Townshend, J.R., Justice, C., 1986. Analysis of the dynamics of African vegetation using the normalized difference vegetation index. International Journal of Remote Sensing, 7(11), pp.1435–1445. Available at:
http://dx.doi.org/10.1080/01431168608948946.

Work, E. A. Jr, Gilmer, D. S., 1976. Utilization of Satellite Data for Inventorying Prairie Ponds and Lakes, Photogrammetric Engineering and Remote Sensing, 42(5), pp. 685–694.

Wulder, M.A. et al., 2019. Current status of Landsat program, science, and applications. Remote Sensing of Environment, 225, pp.127–147. Available at:
http://dx.doi.org/10.1016/j.rse.2019.02.015.

Xiao, X. et al., 2002. Landscape-scale characterization of cropland in China using Vegetation and Landsat TM images. International Journal of Remote Sensing, 23(18), pp.3579–3594. Available at:
http://dx.doi.org/10.1080/01431160110106069.

Xu, H., 2006. Modification of normalised difference water index (NDWI) to enhance open water features in remotely sensed imagery. International Journal of Remote Sensing, 27(14), pp.3025–3033. Available at:
http://dx.doi.org/10.1080/01431160600589179.

Yang, X. et al., 2017. Mapping of Urban Surface Water Bodies from Sentinel-2 MSI Imagery at 10 m Resolution via NDWI-Based Image Sharpening. Remote Sensing, 9(6), p.596. Available at:
http://dx.doi.org/10.3390/rs9060596.

Zhou, Y. et al., 2017. Open Surface Water Mapping Algorithms: A Comparison of Water-Related Spectral Indices and Sensors. Water, 9(4), p.256. Available at:
http://dx.doi.org/10.3390/w9040256.

CONTRIBUTION

Crew Change and Other Present Issues
Pjesme / Poems
Guidelines

Crew Change and Other Present Issues

The Covid-19 pandemic has thrown the world into disarray. And the international shipping industry is no exception. Manning levels have been reduced as crew become hard to change and be refreshed; hours of rest are being ignored and replaced with non-paid hours of work and compliance performance; systems crucial for the safe operation of the world's shipping fleet are being disregarded on a daily basis through superficial remote inspections. This is of course about crew change, but also much more than that. Our industry has adapted and had to make-do given the unprecedented nature of the present Covid-19 crisis. As the worker representatives who engage every day to improve these systems and standards for the benefit of all seafarers, we in ITF understood the reasons ship owners, manning companies, port states, flag states and others requested flexibility in the application of international rules. However, the extreme interpretations of the regulations and short cuts taken by some in the industry, with the blessing of some flag states in particular, have gone too far, for too long. Of greatest concern is that these short cuts risk becoming permanent. International rules, regulations, standards, conventions and agreements are how the public, governments and seafarers can have faith in the healthy and safe operation of this critical industry. Every international rule that has been created and adopted was for a reason; be an accident; a drowning; a spill; a grounding; a death. These rules are not an added extra, or 'nice to have'. They are the basis on which seafarers agree to go to work, and countries agree to admit ships into their waters and marine environments. This report highlights the extremes that these rules are being pushed by some players in the international shipping industry; why such short cuts are dangerous to seafarers' health and safety, human life and the marine environment; and why we need to return to proper implementation and enforcement of these rules by flag states and port state control authorities for the benefit of everyone. We urge you to consider the findings of this report. If you are a flag or port state – reflect on your responsibilities. If you are a seafaring or maritime union – draw on this knowledge to push for real enforcement in your jurisdictions. If you are media – hear our warnings and report them to the world as we do not raise such a serious alarm lightly.

The ITF have decades of experience in the international shipping industry, particularly in the development and enforcement of conventions and standards which prevent harm to people and the planet. It is our obligation as seafarers' representatives to compile this report because what we are witnessing right now causes us extreme worry. We cannot in good conscience be complacent and allow seafarers' safety and security to be put at risk. We hope that by drawing focus to the impending disasters within our industry that international attention will force pause and reflection, so that we avert unnecessary harm to the world's two million seafarers, the public, and our marine environment.

The international rules that govern the international maritime industry are made up of regulations, standards, conventions and agreements. These rules, agreed by International Maritime Organisation (IMO) Member States, are how the public, governments and seafarers themselves can have faith in the healthy and safe operation of this critical, and potentially dangerous, industry. Governments created the rules – governments need to enforce the rules. We are very concerned that during the present Covid-19 pandemic, government regulators in flag and port states have chosen to suspend the application and enforcement of these critical rules. Each breach of each rule adds undue risk to the international shipping industry, and undermines the international rules system that delivers these regulations to us. Companies will ask themselves, 'if we can ignore this rule, why not this other? Or all of them? The consequences could be calamitous for the people who work in this industry, the public and our marine environment.

It is particularly concerning to us that employer compliance with the IMO, which regulates safety and security of life at sea, is exempted. It is understandable that in the early days of the outbreak, all parts of the industry needed to agree practical, temporary measures to allow flexibility in the application of various international regulations. However, inconsistent interpretations across regulators, flag states, port states, classification societies, ship owners and companies has made a mockery of what should be universal rules for the safe operation of a global industry and the welfare of its global workforce. Safe ship operations seem to have been forgotten or deprioritised, thereby endangering the safety of maritime workers and the marine environment. We say that enough is enough: over six months has passed since the outbreak of this pandemic. Too many corners have been cut for too long. Contravention of critical maritime regulations is no longer acceptable to seafarers' representatives and should not be acceptable to shipowners, port state regulators, or flag states.

Governments, particularly through their Port State Controls, and the maritime industry more broadly, need to ensure the effective and consistent enforcement of safety and security-related IMO regulations with immediate effect. The regulations were developed and amended for the safety of maritime workers and the marine environment, and therefore cannot simply disappear. The international regulations that have been adopted and implemented are now being undermined, out of expedience, not out of necessity. These practices are setting a dangerous precedent and, if allowed to continue, will put maritime workers' safety in jeopardy. The main areas of concern that are being undermined under IMO regulations are:

- Threat to the safety of lives and ships at sea;
- Threat to the marine and coastal environment;
- Seafarers loss of employment opportunities and income; Reduction to manning levels;
- Additional responsibilities are being required of the seafarers beyond their normal duties;
- Increased physical and mental pressure and fatigue;
- Limited access to port facilities and the consequences on ship operations and social issues;
- The plight of seafarers' families;
- Reduced attractiveness to pursue a career at sea when international and national legislation that has been adopted for the protection of seafarers can so easily and over a sustained period of time be set aside; The ITF Maritime Safety Committee believe that if governments want vital cargo to continue to flow in and out of their ports, they have a legal and moral obligation to fulfil their commitment to the international maritime regulations that they have created and endorsed for the safety and security of maritime workers and the marine environment. Anything less risks undermining the international rules system that safe and efficient global trade relies on.

- Minimum safe manning of a ship is made up of both the overall number of crew on board, as well as minimum numbers at required skill levels, for the particular size and type of vessel. In practice, however, Minimum Safe Manning levels have become determined by the ship owner, rather than the regulator. This is because flag states almost always approve the manning levels for ships put forward by shipowners – however low. The practice of flag states 'rubber-stamping' ship owners' manning levels without due regard to safety has concerned the ITF for many years, but has become unacceptably dangerous in recent months as shipowners have pushed for lower and lower manning levels in the face of the crew change crisis. To ensure global trade continues uninterrupted (and the income they gain from registering ships), some flag states have advised companies to contact the relevant flag state administrations (registries) and advise of any difficulties in recruiting adequate crew numbers. In most cases, the administrations are providing exemptions to these companies for manning numbers well-below what would have been considered safe pre-pandemic. This has resulted in many companies now declaring reduced minimum manning on their ships with the approval of the flag state that their ship is registered to. These companies save money in wages and recruitment, but the risk for the crew, cargo and the environment increase substantially. This corner-cutting increases pressure on seafarers, harming their mental and physical wellbeing, their lives. Reduced minimum manning intensifies stress onboard and contributes to fatigue because it spreads the same workload across a smaller number of seafarers. In what we know from what seafarers report, inadequate manning extends seafarers' hours of work when they are already stretched. Minimum safe manning

is, by design, meant to ensure minimum safety standards can be met onboard. Anything below minimum safe manning is unsafe and puts lives, ships and the environment at risk.

- Few ships employ seafarers above the minimum safe manning numbers. Those ships that do can ensure the ship is able to safely sail and operate in almost any situation. Ships that operate with the minimum will be at great danger should some of the crew become unwell or injured, or the seafaring conditions deteriorate. It has often been alleged that human error is the cause of a maritime incident or accident without mentioning the responsibility and complacency of shipowners and flag state administrations who agree to insufficient manning of the ship, as a contributing factor for the alleged human error. An overworked, tired and fatigued seafarer is more likely to make mistakes than a seafarer who is fresh, well-rested and supported by an adequate number of skilled crewmates. It is a contradiction that governments and companies publicly display indignation following major incidents that negatively affect their coastlines, the wider environment and costs lives, while condoning the practices which prejudice safety and produce inadvisable risk in the first place.

We say: **enough is enough** – seafarers are already under increased pressure and suffering from fatigue due to extended employment agreements, extended working hours, additional tasks normally performed by inspectors and dockworkers, and the uncertainty over when they will be able to return home to their loved ones. Unsafe manning presents an unacceptable threat to the safety and security of the crew, the ship and the environment and requires immediate action. The ITF is also concerned about the lack of familiarisation procedures taking place for new sign-on crew due to reduced manning, as well as the premature promotion of seafarers to cover certain positions. Both issues have emerged as consequences of the pandemic and governments' willingness to set aside international regulations to keep trade moving at all cost.

WHEN CRISIS MANAGEMENT BECOMES CRISIS EXPLOITATION, WE MUST SPEAK UP

Branko Berlan

ITF Accredited Representative to the International Maritime Organisation

ART

MŔTVO MÔRE

Ive Marković Kora

THE SWELL

trans. by Mirna Čudić Žgela

Pùne
malinkunìje
ne hãjuć
za životôn
túјodu se
niz konõl
bòta
za bòton.

Kôjo se
krãju
ko mãteri
zbìje
po se uspìnje
uz rêde
uz gròte
a môre je
potéže
niza škrãpe
kroz gandõjè
nôse
meju bòte.

Filled with
melancholy
oblivious of life
rolling
down the channel
the breakers
follow
one another.

Some
reach the shore
hugging it as if it were
a mother' bosom.
Going up
the rocks,
along the caves
the sea
dragging it
down the reefs
through the cracks
back
among the breakers.

RJEČNIK

mŕtvo môre	uzburkano more (poslije oluje)
malinkunìja	melankonija
túdoju se	kotrljati se, valjati se
konõl	more između kopna i otoka
bòta	udar vala
hãjuć	mariti
krôj	kopno
rêd	živac kamen
gròta	izborani kamen
škrãpa	ižlijebljeni kamen
gandôj	rupa u živom kamenu pokraj mora
nôse	nazad

VÌŠTA

Ive Marković Kora

VISION / VIEW

trans. by Mirna Čudić Žgela

Molôjte mi
rîči
pînku dûšê
Škòja.
Ma, jê svè u srìći
debèlega portafòja!?

Nè,
ne môjte me
kùdit
nîsôn
pròtivu tèga.
Nekà je
Brõč
bòji,
nekà bùde
svèga.

Sômo,
sômo pènson
zõč
zõč smo
pozabìli
da je jedôn
Brõč.

Svè je
ništò drùgo
i blîdi vìšta
od nãšega škòja
ostãlo je mãlo
a bŕž
i nìšta.

Leave me
words,
leave me
bits of the Island's soul.
Does happiness really lie
in a full wallet?

No,
do not
scold me
I have nothing
against it.
I want Brač
to be prosperous:
let there be
an abundance
of everything.

Only,
only I wonder
why
why we have
forgotten
that Brač
is unique,
that there is noother island
like Brač.

All the rest
is
something else
and the vision
of our island
fades
little has remained
perhaps
nothing.

RJEČNIK

molôjte	pustite
pînka	komadić
škôj	otok
portafòj	novčanik
pènsot	mislit
zõč	zašto
pozabìt	zaboravit
vìšta	pogled
bŕž	možda
jê	je li

About ToMS: Ethics, Conflict of Interest, License and Guides for Authors

The Journal is published in English as an open access journal, and as a classic paper journal (limited edition).

ToMS aims at presenting the best maritime research primarily, but not exclusively, from Southeast Europe, particularly the Mediterranean area. Papers will be double-blind reviewed by 3 reviewers. With the intention of providing an international perspective at least one of the reviewers will be from abroad. ToMS also promotes scientific collaboration with students and has a section entitled Students' ToMS. These articles also undergo strict peer reviews. Furthermore, the Journal publishes short reviews on significant papers, books and workshops in the fields of maritime science.

Our interest lies in general fields of maritime science (transport, engineering, maritime law, maritime economy) and the psychosocial and legal aspects of long-term work aboard.

1. PUBLICATION ETHICS

Ethical Policies of ToMS

Plagiarism is arguably the most complicated ethical issue. Our policies define plagiarism as "taking material from another's work and submitting it as one's own." ToMS *holds authors — not the Publisher or its editors and reviewers — responsible* for ensuring that all the ideas and findings included in a manuscript are attributed to the proper source. We also refer to our role as steward of what constitutes ethical conduct. Ethical misconduct is the reason for our commitment to continue to strive to educate all the parties in the publishing process how to handle this matter. As a member of Crossref, ToMS has a powerful weapon – iThenticate system, which is not perfect.

"Even if there were reliable and sensitive plagiarism detection software, many issues would remain to be addressed.

For example, how much copying is legitimate? Clearly, the reuse of large amounts of others' text constitutes plagiarism. But what should one think about copying short passages from the author's own earlier work, such as commonly occurs in the Methods section? In the Nature article it is suggested that some journals set a quantitative limit whereby the amount of text that can be reused is limited to about 30 percent. This may be utilitarian, but it seems curious and arbitrary that 25 percent of copied text might be deemed acceptable whereas 30 percent might not. Indeed, two authors who copied the same number of words could find themselves on opposite sides of that border if one author simply was more verbose and thus diluted their plagiarized content below the threshold! No, this is not a simple issue at all." [cited from: http://newsletter.aspb.org/ethics.cfm]

Expectations for Publishing in ToMS

Faculty of Maritime Studies expects authors submitting to and publishing in its journals to adhere to ethical standards to ensure that the work they submit to or publish in the journal is free of scientific misconduct. Authors must:

- Take credit only for work that they have produced.
- Properly cite the work of others as well as their own related work.
- Submit only original work to the journal.
- Determine whether the disclosure of content requires the prior consent of other parties and, if so, obtain that consent prior to submission.
- Maintain access to original research results; primary data should remain in the laboratory and should be preserved for a minimum of five years or for as long as there may be reasonable need to refer to them. All authors of articles submitted for

publication assume full responsibility, within the limits of their professional competence, for the accuracy of their paper. Instances of possible scientific misconduct related to papers submitted to or published in the ToMS will be addressed by following the procedure outlined below.

2. CONFLICT OF INTEREST

The authors, reviewers and other participant are obligated to clearly state possible conflict of interest. Editor-in-chief, senior editor and/or executive editors board decide on actions based on conflict of interest (COI).

Editors' Duty

Disclosure and Conflicts of Interest: The editor cannot use unpublished materials, disclosed in submitted manuscript for his/her own research, without prior written consent of the author(s).

If author(s) of submitted paper is a member of editorial board or editor-in-chief, the submission, review and decision process is carried by the highest ranking editor who is not the author.

Reviewers' Duty

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

3. MALPRACTICE

Procedure for addressing allegations of scientific misconduct or other ethical violations

Scientific misconduct in publishing includes but is not limited to:

- Data manipulation;
- Data falsification;
- Fraud: fabricating a report of research or suppressing or altering data;
- Duplicate publication;
- Plagiarism and
- Self-plagiarism.

Procedure for handling allegations of misconduct

- All allegations of scientific misconduct or ethical violation will be referred to the editor for research integrity or to the editor-in-chief. All allegations should be made in writing.
- Editor for research integrity will report the case in the meeting of the Editorial board and recommend the actions in 30 days.
- Except redraw of the paper, punishment could be inclusion in the black list of the journal and prohibition of further publishing in ToMS.

Submission declaration

Submission of an article implies that the work described has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis or as an electronic preprint), that it is not under consideration for publication elsewhere, that its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere including electronically in the same form, in English or in any other language, without the written consent of the copyright-holder.

4. OPEN ACCESS LICENSE

Articles are freely available to both subscribers and the wider public with permitted reuse.

All articles published Open Access will be immediately and permanently free for everyone to read and download. Permitted reuse is defined by Creative Commons Attribution (CC BY) license, which: lets others distribute and copy the article, to create extracts, abstracts, and other revised versions, adaptations or derivative works of or from an article (such as a translation), to include in a collective work (such as an anthology), to text or data mine the article, even for commercial purposes, as long as they credit the author(s), do not represent the author as endorsing their adaptation of the article, and do not modify the article in such a way as to damage the author's honor or reputation.

For further details see the Creative Commons website.

5. PUBLICATION ETHICS AND MALPRACTICE STATEMENT

Unethical behavior is unacceptable and Transactions on Maritime Science does not tolerate plagiarism in any form. Authors who submit articles affirm that manuscript contents are original. Furthermore, authors' submission also implies that the manuscript has not been published previously in any language, either fully or partly, and is not currently submitted for publication elsewhere. Editors, authors, and reviewers, within the Transactions on Maritime Science are to be fully committed to good publication practice and accept the responsibility for fulfilling the following duties and responsibilities, as set by the COPE Code of Conduct for Journal Editors (http://publicationethics.org/resources/guidelines).

5.1. Duties of the Authors

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

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

Multiple, Redundant, or Concurrent Publications: Authors should not concurrently submit the same manuscript for publishing to other journals, or conference proceedings. It is also expected that the author(s) will not publish redundant manuscripts, or manuscripts describing the sameresearch in several publishing venues, after the initial manuscript has been accepted for publication.

Acknowledgement of Sources: Author(s) should acknowledge all sources of data used in the research and cite publications that have influenced their research.

Authorship of the Paper: Authorship should be limited only to those who have made a significant contribution to conceiving, designing, executing and/or interpreting the submitted study. All those who have significantly contributed to the study should be listed as co-authors. The corresponding author should also ensure that all the authors and co-authors have seen and approved the final submitted version of the manuscript and their inclusion as co-authors.

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

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

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

5.2. Duties of Reviewers

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

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

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

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

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

5.3. Duties of the Editor

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

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

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

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

Disclosure and Conflicts of Interest: The editor cannot use unpublished materials, disclosed in submitted manuscript for his/her own research, without prior written consent of the author(s).

6. GUIDELINES FOR AUTHORS

The Journal is published in English as an open access journal, and as a classic paper journal (limited edition).

ToMS aims at presenting the best maritime research primarily, but not exclusively, from Southeast Europe, particularly the Mediterranean area. Papers will be double-blind reviewed by 3 reviewers. With the intention of providing an international perspective at least one of the reviewers will be from abroad. ToMS also promotes scientific collaboration with students and has a section entitled Students'ToMS. These articles also undergo strict peer reviews. Furthermore, the Journal publishes short reviews on significant papers, books and workshops in the fields of maritime science.

Our interest lies in general fields of maritime science (transport, engineering, maritime law, maritime economy) and the psychosocial and legal aspects of long-term work aboard.

6.1. Before you Begin

6.1.1. Ethics in publishing

For information on Ethics in publishing and Ethical guidelines for journal publication see Publication Ethics

6.1.2. Conflict of interest

All authors are requested to disclose any actual or potential conflict of interest including any financial, personal or other relationships with other people or organizations within three years of beginning the submitted work that could inappropriately influence, or be perceived to influence, their work.

6.1.3. Submission declaration

Submission of an article implies that the work described has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis or as an electronic preprint), that it is not under consideration for publication elsewhere, that its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere including electronically in the same form, in English or in any other language, without the written consent of the copyright-holder.

6.1.4. Changes to authorship

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

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

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

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

Note that:

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

After the accepted manuscript is published in an online issue:

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

6.1.5. Copyright

Upon acceptance of an article, authors will be asked to complete an 'Exclusive License Agreement'. Permitted reuse of open access articles is determined by the Journal Open Source License (CC-BY).

6.1.6. Role of the funding source

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

6.1.7. Open access

Articles are freely available to both subscribers and the wider public with permitted reuse. All articles published Open Access will be immediately and permanently free for everyone to read and download. Permitted reuse is defined by following Creative Commons user license:

Creative Commons Attribution (CC BY): lets others distribute and copy the article, to create extracts, abstracts, and other revised versions, adaptations or derivative works of or from an article (such as a translation), to include in a collective work (such as an anthology), to text or data mine the article, even for commercial purposes, as long as they credit the author(s), do not represent the author as endorsing their adaptation of the article, and do not modify the article in such a way as to damage the author's honor or reputation. For further details see the Creative Commons website.

6.2. Guidelines for Authors: Manuscript Preparation and Submission

6.2.1. Organization of the manuscript

First (title) page

The first page should carry:

a. the paper title;

b. full names (first name, middle – name initials, if applicable), and last names of all authors;

c. names of the department(s) and institution(s) to which the work should be attributed. If authors belong to several different institutions, superscript digits should be used to relate the authors' names to respective institutions. Identical number(s) in superscripts should follow the authors names and precede the institution names;

d. the name, mailing address and e-mail of the corresponding authors;

e. source(s) of research support in the form of financial support, grants, equipment or all of these.

Last page

The last page should carry:

a. ethical approval, if required;

b. authors' declarations on their contributions to the work described in the manuscript, their potential competing interests, and any other disclosures. Authors should disclose any commercial affiliations as well as consultancies, stock or equity interests, which could be considered a conflict of interest. The details of such disclosures will be kept confidential but ToMS urges the authors to make general statements in the Acknowledgement section of the manuscript.

c. a list of abbreviations used in the paper (if necessary);

Other pages

Each manuscript should follow this sequence:

- title page;
- abstract;
- text (Introduction, Methods, Results, Conclusions/ Discussion);
- acknowledgments;
- references;
- tables (each table complete with title and footnotes on a separate page);
- figures and figure legends, and the last page.

6.2.2. Text organization and style

6.2.2.1. Abstract

The second page should contain the Abstract. ToMS requires that the authors prepare a structured abstract of not more than 250 words. The abstract should include (at least) four sections: Aims, Methods, Results, and Conclusion, not necessarily separated.

Aim. State explicitly and specifically the purpose of the study.

Methods. Concisely and systematically list the basic procedures, selection of study participants or laboratory/ experimental/simulation setup, methods of observation (if applicable) and analysis.

Results. List your primary results without any introduction. Only essential statistical significances should be added in brackets. Draw no conclusions as yet: they belong in to the next section.

Conclusion. List your conclusions in a short, clear and simple manner. State only those conclusions that stem directly from the results shown in the paper. Rather than summarizing the data, conclude from them.

6.2.2.2. Main text

Do not use any styles or automatic formatting. All superscripts or subscripts, symbols and math relations should be written in MathType or Equation editor.

Introduction

The author should briefly introduce the problem, particularly emphasizing the level of knowledge about the problem at the beginning of the investigation. Continue logically, and end with a short description of the aim of the study, the hypothesis and specific protocol objectives. Finish the section stating in one sentence the main result of the study.

Results

Key rules for writing the Results section are:

a. the text should be understandable without referring to the respective tables and figures, and vice versa;

b. however, the text should not simply repeat the data contained in the tables and figures; and

c. the text and data in tables and figures should be related to the statements in the text by means of reference marks.

Thus, it is best to describe the main findings in the text, and refer the reader to the tables and figures, implying that details are shown there. The formulations such as "It is shown in Table 1 that the outcome of Group A was better than that of Group B" should be replaced by "The outcome of Group A was better than that of Group B (Table 1)."

The need for brevity should not clash with the requirement that all results should be clearly presented.

Discussion/Conclusions

The discussion section should include interpretation of study findings in the context of other studies reported in the literature. This section has three main functions:

a. assessment of the results for their validity with respect to the hypothesis, relevance of methods, and significance of differences observed;

b. comparison with the other findings presented in the relevant literature; and

c. assessment of the outcome's significance for further research.

Do not recapitulate your results, discuss them!

6.2.2.3. Tables

Information on significance and other statistical data should preferably be given in the tables and figures. Tables should not contain only statistical test results. Statistical significances should be shown along with the data in the text, as well as in tables and figures.

Tables should bear Arabic numerals. Each table should be put on a separate page. Each table should be self-explanatory, with an adequate title (clearly suggesting the contents), and logical presentation of data. The title should preferably include

the main results shown in the table. Use tables in order to present the exact values of the data that cannot be summarized in a few sentences in the text.

Avoid repetitive words in the columns: these should be abbreviated, and their explanations given in the footnotes. Present data either in a table or a figure.

Each column heading for numerical data given should include the unit of measurement applied to all the data under the heading. Choose suitable SI units.

Place explanatory matter in footnotes, not in the heading.

Explain in footnotes all nonstandard abbreviations that are used in each table.

6.2.2.4. Figures

Figures should be numbered in sequence with Arabic numerals. Legends to figures should be listed on a separate page, in consecutive order. Minimum resolution for all types of graphics is 300 dpi and 600 dpi is recommended. The legend of a figure should contain the following information:

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

Use simple symbols, like closed and open circles, triangles and squares. Different types of connecting lines can be used. The meanings of symbols and lines should be defined in the legend.

Each axis should be labeled with a description of the variable it represents.

Only the first letter of the first word should be capitalized. The labeling should be parallel with the respective axis. All units should be expressed in SI units and parenthesized. Make liberal use of scale markings.

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

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

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

6.2.2.5. Authorship statement

All contributing authors must fill out and sign these statements and submit them to the Editorial Office. Accepted manuscripts will not be published until signed statements from all authors have been received.

6.2.2.6. Acknowledgments

Technical help, critical reviews of the manuscript and financial or other sponsorship may be acknowledged. Do not acknowledge paid services, e.g. professional translations into English.

6.2.2.7. References

References cited in the manuscript are listed in a separate section immediately following the text. The authors should verify all references. Usage of DOIs is mandatory.

Examples of citation in text:

It is well known fact (Strang and Nquyen, 1997; Antoniou, 2006) that FT is not an appropriate tool for analyzing nonstationary signals since it loses information about time domain.

First group of authors (Vetterli and Gall, 1989) proposed Multiresolution Signal Analysis (MRA) technique or pyramidal algorithm. Second group (Crochiere et al., 1975; Crochiere and Sambur, 1977) proposed subband coding algorithm. Legal acts are cited as in example: The Constitution of the Republic of Croatia (Constitution of the Republic of Croatia, 2010) is the main legal source for this subject matter, as well as any other subject matter relating to the Croatian legal system. References from the Web are cited in the text as (Author(s) last name, year of origin if known (year of accessed in other cases). If the author is unknown, such as in case of company web page, instead of author's name, title of the web page is used.

Examples for reference section:

Journals

Petrinović, R., Wolff, V. S., Mandić, N. and Plančić, B., (2013), International Convention on the Removal of Wrecks, 2007. – a New Contribution to the Safety of Navigation and Marine Environment Protection, Transaction on Maritime Science, 2(1), pp. 49-55., https://doi.org/10.7225/toms.v02.n01.007

Pennec, E. and Mallat, S., (2005), Sparse Geometric Image Representations with Bandelets, IEEE Transactions on Image Processing, 14(4), pp. 423 – 438., https://doi.org/10.1109/TIP.2005.843753

Web links

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

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

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

Books

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

Chapter in book

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

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

Conference proceedings

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

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

Regulations, standards or legal acts:

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

6.2.2.8. Supplementary materials

Supplementary materials are optional. Authors can submit different types of materials which will be available on-line.

6.2.2.9. Language

Authors may use standard British or American spelling, but they must be consistent. The Editors retain the customary right to style and, if necessary, shorten texts accepted for publication.

This does not mean that we prefer short articles – actually, we do not limit their size - but rather a resection of the obviously redundant material.

The past tense is recommended in the Results Section.

Avoid using Latin terms; if necessary, they should be added in parentheses after the English terms. Real names rather than "levels" or "values" should refer to parameters with concrete units (e.g. concentration).

6.2.2.10. Abbreviations

Only standard abbreviations and symbols may be used without definition and may be used in the title or the page-heading title.

Non-standard abbreviations should not be used in the title or page-heading title. They must be explained in the text in the following way: the term should be written in full when it appears in the text for the first time, followed by the abbreviation in parentheses; from then on, only abbreviation is used in the text. This applies separately to the Abstract and the rest of the text.

6.2.3. Submission of manuscripts

Paper submission via ToMS web page Open Journal System.
www.toms.com.hr